


Review

The Invasive *Ailanthus altissima*: A Biology, Ecology, and Control Review

Jordi Soler * and Jordi Izquierdo 

Department of Agri-Food Engineering and Biotechnology, Universitat Politècnica de Catalunya,
08860 Castelldefels, Spain; jordi.izquierdo@upc.edu

* Correspondence: soleraaa@hotmail.com; Tel.: +34-689460905

Abstract: Tree of Heaven (*Ailanthus altissima* (Mill.) Swingle) is a tree native to China which has invaded disturbed areas in many regions worldwide. Its presence endangers natural ecosystems by displacing native species, modifying habitats, changing community structures, and affecting ecosystem processes. Its invasive nature is enhanced by its high ability to reproduce both vegetatively through root regrowth and sexually through seeds. Seeds, which are wind dispersed, are the main mechanism by which this species reaches new habitats. When they germinate and develop the root system, roots emit new shoots that contribute to a rapid increase in the tree density and the subsequent expansion of the population nearby. The contradictory results about the ecological requirements for seeds to germinate and their degree of dormancy and longevity indicate the complexity and difficulty of understanding the mechanisms that govern the biology and adaptability of this plant. The management of this weed aims at its eradication, with programs based on herbicide applications carried out by injecting the active ingredient directly to the trunk. But, not many active ingredients have shown total control, so new ones should be tested in order to increase the range of available herbicides. During the last few decades, some biological agents have been identified, but their efficacy in controlling the tree and their safety for the local flora have not yet been determined. A correct management strategy should take into account all these aspects in order to contain the expansion of this species and, ultimately, allow its eradication.

Keywords: Tree of Heaven; biological invasion; germination requirements; biological control; chemical control; management



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1. Introduction

Tree of Heaven (*Ailanthus altissima* (Mill.) Swingle) is one of the most invasive weeds in temperate climates of the world [1]. It is a dioecious species that belongs to the family Simaroubaceae and to the genus *Ailanthus*, which comprises up to 15 different species, as found in the extensive review by Kowarik [2]. Adults can reach a height of up to 27 m and 1 m diameter at breast height [3]. The leaves are sparse and pinnaticomposite and they can be glabrous or pubescent, with leaf length measuring up to 90 cm [4]. The cotyledons are rounded and with epigeal germination [5]. Male flowers contain 10 stamens, while female flowers have 10 non-functional stamens and a pistil with 5–6 free carpels. The fruits are winged and elongated up to 5 cm in length, samara type, and grouped in leafy and hanging clusters [4]. The blooming period in Mediterranean latitudes occurs during May and July [6]. The diameter at breast height is a good indicator of the amount of seed production [7], with a female adult tree producing up to 300,000 seeds per year [8].

Seeds are mainly dispersed by wind [9], but they can remain in the canopy throughout the winter [5]. The species has a root system with high potential to expand by producing new shoots that contribute to its vegetative dispersion. Most of the roots are found in the first 46 cm of soil [3], with roots sprouts found up to 27 m from the parent tree [10]. More information about the biology of this species can be found in [11].

A. altissima is present in all continents except Antarctica and prefers areas with high human disturbance [2]. The initial ornamental use of this tree in many gardens and backyards favored its spread; however, because of its invasive traits, ornamental uses have decreased, and the origin of new infestations nowadays lies with existing natural populations [11]. Infestations seem to be dependent on the level of disturbance of the invaded area [12], as a positive correlation is found between the presence of *A. altissima* along different parts of the Danube river and areas with dense human population [13]. Additionally, it is not affected by urban pollution [14]. It adapts well to a wide range of soils and prefers warm climes [3], although it is able to establish itself in many different climatic conditions [11]. It is well established in the Mediterranean basin, in which many eradication programs have been carried out [15].

As an invasive plant, *A. altissima* has all the detrimental ecological effects on local ecosystems that have been described for these types of species elsewhere [16,17]. However, it has several particular traits that contribute to generating further damage. The rapid entry into flowering (fourth year), the huge amount of seed production, the wind dispersal, and the vegetative reproduction favor its expansion and enhance its persistency [7]. Its ecological preference for altered and degraded ecosystems and its well-developed root system make this species frequent in communication corridors such as railways, freeways, or walkways [2], in which it damages constructions and pavements and reduces visibility [18], in rural areas along fencerows, woodland edges, or forest openings [2], and in heritage areas such as archaeological monuments, degrading them [19–22]. But, apart from physical damage, this species has allelopathic effects. Ailanthone, a quassinoid compound, has exhibited pre- and postemergence herbicidal activity against other species [11]. It can be found in different parts of the tree and negatively affects the growth of different native species [23], allowing an increase in the presence of other non-native species [24]. Assays with concentrated extracts of ailanthone have shown different effects towards different weeds [25], with dicots being the more affected species [26]. Perhaps this fact may explain why the removal of *A. altissima* in natural areas does not allow native plants to recover until two years later [27]. The modification of bacterial colonies from soil and retardations in the growth of plants under *A. altissima* canopies have also been reported [28].

2. Seed Dormancy

Although *A. altissima* was classified as a species having seeds with non-dormant embryos [29], some years later, dormancy was described [30,31]. The environmental requirements for *A. altissima* seeds to germinate have been shown to be greatly variable according to the bibliography, which suggests that several intrinsic factors, such as embryo immaturity or the presence of inhibitors, must have some influence on the level of dormancy of the seeds [32]. Additionally, the level of dormancy of seeds seems to also be related to the environmental conditions suffered by the parent plant, as great variability was found among the germination rates of seeds collected at the same time from different individuals [7]. In fact, the seeds have to break both the physiological dormancy produced by the presence of inhibiting hormones and the mechanical barrier of the coat that contains the embryo [33].

In order to break the dormancy of *A. altissima* seeds, different methods have been tested. Gibberellic acid [34,35], cold stratification [3,33,36–41], wet or dry stratifications [42,43], and sulfuric acid or boiling water [33] have been applied to the seeds over different periods of time. From the results reported, cold stratification seems to give the highest germination rates. A summary of these methods and the results obtained can be found in Table 1.

Table 1. Summary of germination requirements of *Ailanthus altissima* seeds according to different authors. * \approx the number is an approximation from a graphic.

| Seed Harvest Date | Germination Place | Pre-Treatment | Light/Dark (h) | Temperature (°C) | Seeds per Treatment | Germination (%) | Author |
|-------------------|-------------------|---|-------------------------------------|------------------|---------------------|--|--------|
| March | Growth chamber | No | 12/12 | 20.5 | 100 | 67 to 97 | [44] |
| September | | | | | 150 | 50 to 90 | |
| November | Greenhouse | No | Natural sunlight | 21–24 | 10 | 66.1 | [45] |
| December | Greenhouse | No | Natural sunlight | Ambient | 25 | 90.67 to 91.38 | [46] |
| October | Laboratory | Seeds floating on water up to 5 months | Fluorescent lights | 22–25 | 50 | 94.4 | [47] |
| | | Seeds in leaf litter under forest canopy up to 5 months + 4 °C for 5 weeks in moist sand | Fluorescent lights | 22–25 | 50 | 78.9 | |
| January | Greenhouse | No | Natural sunlight | 15–20 | 250 | 52.7 | [48] |
| | Greenhouse | Floating seeds in water for 3 days 10 days 20 days | Natural sunlight | 15–20 | 250 | 86.8 | |
| | | | | | | 58.8 | |
| | | | | | | 32.4 | |
| | Greenhouse | Submerged seeds in water for 3 days 10 days 20 days | Natural sunlight | 15–20 | 250 | 67.7 35.3 30.7 | |
| Not defined | Field | Yes | Sunlight limited at 100, 65, 35, 7% | 12.9–46.9 | 96 | * \approx 80 | [49] |
| Not defined | Greenhouse | 0–1.5 °C (no time defined) + water soaked for 48 h + 3–5 °C moist vermiculite for 3 months + Bare soil or low leaf litter or high leaf litter | 12/12 | 20–30 | 45 | \approx 70 \approx 80 \approx 50 | [50] |
| October | Growth chamber | Stratification for 8 weeks | Not defined | 25 | 20 | 60.2 | [51] |
| October | Growth chamber | Stratification for 8 weeks | Not defined | 25 | 20 | 58.3 | [52] |
| | Growth chamber | Gibberellic acid 40 ppm | Light/dark | 30 | | good | [34] |
| Not defined | Growth chamber | Stored from 2 to 4 years + 4 °C for one month + Gibberellic acid 500 ppm | Dark | 40 °C for 24 h | Not defined | good | [35] |

Table 1. Cont.

| Seed Harvest Date | Germination Place | Pre-Treatment | Light/Dark (h) | Temperature (°C) | Seeds per Treatment | Germination (%) | Author |
|-------------------|-------------------|--|---|------------------|---------------------------------------|-----------------------|----------------------|
| October | Greenhouse | Seeds incubated under field conditions for 1 to 5 years at: soil depth = 10 cm | Natural sunlight | 26.5 | 30–50 | 1.9 to 81 | [38] |
| | | soil depth = 0 cm | | | | 79.4 to 83 | |
| | Greenhouse | 1–4 °C for 88 days | Natural sunlight | 25/20 | 50 | 87 | |
| | Greenhouse | Stored 5 years in lab conditions | Natural sunlight | Not defined | 50 | 83.5 | |
| Late summer | Greenhouse | 1.7 °C for 28 days | Natural sunlight | Ambient | depending on source: 40, 43, or 64 | 0 to 78.1 | [7] |
| December | Laboratory | Seeds incubated under litter and duff layers in field conditions | 12/12 Fluorescent lights | 18-20 | 100 | 28 and 79 | [32] |
| December | Field | 1 year with cold moist sand | High flux of sunlight Low flux of sunlight | Ambient | 50 | ≈ 25 ≈ 21 | [43] |
| | | 3 months with cold moist sand | High flux of sunlight Low flux of sunlight | | | ≈ 15 ≈ 8 | |
| October | Growth chamber | 2 months at 17–20 °C | 16/8 | 15 20 30 | 80 | ≈ 55 ≈ 25 ≈ 18 | [37] |
| | Growth chamber | Stored 1 year (no treatment) Stored 2 years (no treatment) Stored 3 years (no treatment) | 16/8 | 20 | 100 | 12 19 20 | |
| | Field | no | Natural sunlight | Ambient | 792 | ≈25 | |
| Dispersal season | Growth chamber | 4 °C more than 1 year | 16/8 | 24/16 | 125 | 50.8 | [41] |
| Fall | Growth chamber | 4 °C during winter | Not defined | Not defined | Not defined | 87 | [36] |
| | Field | | Natural sunlight | Ambient | 100 80 | ≈ 6 to 9 ≈ 6 to 13 | |

Table 1. Cont.

| Seed Harvest Date | Germination Place | Pre-Treatment | Light/Dark (h) | Temperature (°C) | Seeds per Treatment | Germination (%) | Author |
|-------------------|-------------------|---|----------------|-------------------------|----------------------|--|--------|
| October | Growth chamber | No | 12/12 | 15/6 20/10 30/20 | 25 | 0 71 87 | [39] |
| | | | 24 Dark | 15/6 20/10 30/20 | | 0 75 84 | |
| | | | 12/12 | 15/6 20/10 30/20 | | 19 51 82 | |
| | Growth chamber | 4 °C for one month | 24 Dark | 15/6 20/10 30/20 | | 7 37 89 | |
| | | | | | | | |
| | | | | | | | |
| October | Growth chamber | Moist at 5 °C for 12 days Dry at 5 °C for 12 days Moist at 25 °C for 12 days Dry at 25 °C for 12 days Control 5 °C for 4 days 5 °C for 12 days | Dark | 20(16 h)/ 30(8 h) | 30 | 95 76 84 75 70 77 96 | [42] |
| November | Growth chamber | 4 °C for 1 month | Dark | 25 25/30 30 40 | 100 naked embryos | 40 73 94 51 | [40] |
| Not defined | Growth chamber | Control Sulfuric acid 95% for 10 min Sulfuric acid 50% for 10 min Hot water 95 °C for 15 min 3 °C for 10 days 3 °C for 15 days 3 °C for 20 days | Not defined | 20 | 100 | 26 20 60 40 29 32 52 | [33] |

3. Seed Germination

3.1. Temperature Requirements

The variability of the results found makes setting an optimal temperature for seed germination difficult. In growth chambers under constant temperature, the highest germination rates were obtained at 15 °C and the lowest at 30 °C [37]. Simulating different heat treatments, as forest fires would do, germination decreased with increasing heat temperatures [41]. However, with an alternating temperature regime of 15/6 °C, seeds germinated almost four times less than at an alternating higher temperature of 30/20 °C [39]. If the coat of the seed is removed, the best germinating temperatures for naked embryos were found by alternating 25/30 °C or by a constant 30 °C [40]. In growth chambers at 20.5 °C, germination reached 90 and 97% depending on the place the seeds were collected [44]. At a constant 20 °C, germination rates ranged from 44.4 to 26.2% depending on the intensity of the chamber flux light [43]. In greenhouse conditions with natural light and a temperature ranging between 21 and 24 °C, germination rates were 66.1% [45] or 90.7% and 91.4% depending on the natural stands from which the seeds were collected [46]. A pre-treatment with gibberellic acid showed 30 °C as the optimal temperature [34].

3.2. Light Requirement for Germination and Growth

Although *A. altissima* is considered to be a shade intolerant species [3], it can germinate and grow under a natural forest canopy with low light conditions [53] or be competitive in a closed-canopy forest [54]. Simulating different leaf litter layers over *A. altissima* seeds in the greenhouse, no differences in germination were found, meaning that a lack of direct light it is not the main condition for its germination [50]. Furthermore, measurements of leaf water potential found no differences between trees growing under high irradiance conditions with shaded ones. However, it seems that germination rates are affected by light exposure, because the average time needed for seedlings to emerge was longer when the flux of natural light was reduced, for example by using plastic nets to mimic shadow conditions [49] or positioning under a dense forest canopy [43]. The inhibition effect of the coat was also deduced from the study of [40], in which they found that naked embryos in dark conditions, which do not promote the germination of the seeds, were able to achieve a germination rate of 94%.

Additionally, longer photoperiods allowed seedlings to more quickly develop their vascular system than seedlings growing in completely dark conditions, although the increment was non-significant [55].

3.3. Water Requirements for Germination and Growth

In laboratory conditions and using Polyethylene glycol (PEG) to simulate different water stress conditions, the germination rate of *A. altissima* seeds decreased when reducing the water potential. Germination significantly decreased when water potential decreased from −2 to −4 bar, with almost no germination found at −6 bar and none at all at −8 bar [51,52]. Similar decreasing trends when lowering the water potential were observed by [56], although *A. altissima* seedlings supported better water stress than *Phytolacca americana* and *Robinia pseudoacacia* [57].

Greenhouse experiments on the effect of water availability on plant growth showed that decreasing irrigation regimes (1, 0.25, 0.1, and 0.05 L per week) reduced the leaf and root area of the plants, although the results were not statistically different [58]. With a similar water regime experiment (0.3 and 0.03 L per week) a positive correlation between drought and growth was found, with seedlings having a more reduced growth, height, and dry weight at low water availability [45]. The differences between both studies probably lie in the fact that the first experiment lasted two years while the second lasted only one, suggesting that plants have mechanisms to adapt to a water-scarce environment. In adult plants, the ability of this species to cope with drought may also be related to its ability to take water mainly from deeper soil layers (more than 75 cm) than from the first 25 cm of

soil layers [59]. Other authors pointed out that *A. altissima* was more efficient in terms of root-to-leaf water transport capacity than native species [60].

Water exposure seems to affect seed germination. Some studies report increases in the germination rate of seeds exposed to 3 days of water (floating or submerged) compared to 20 days [48], although the opposite trend was found, with no descending rate observed for seeds floating for 5 months [47].

4. Seed Longevity

For species that are reproduced by seeds, the longevity of the seeds is a key factor for determining the persistency of the species in the habitat. *A. altissima* seeds have very low level of predation [12,44] and although some authors found that the longevity of the *A. altissima* seed bank was not significant [8], or not enough to form a long-term seed bank [2,43], more recent studies have shown that the viability of stored seeds can be as long as three [37], five [38], or nine years [7].

5. Seedlings Survival

The survival of *A. altissima* seedlings depends primarily on soil water availability and the competition with the native flora [14]. If the native flora has a very dense canopy, seedlings will hardly survive in such a shady environment, but if the level of disturbance of the canopy forest is significant, more light will reach the understory, more seeds will germinate, and more seedlings will survive [37,43]. Shade and cold conditions act as limiting factors for seedlings' establishment [11].

6. Dispersion

The main aim of any biological dispersal process is to allow the reproductive structures of the plant to reach long distances from the mother plant [48]. The distance is more related to the height of the plant than to the seed mass [54]. In the case of *A. altissima*, long distances from the seed source are mainly achieved by means of the wind [9,47,61] and secondarily by water [3] or animals such as birds or ants [54]. Wind is the primary source of dispersion as the fruit is a samara well-adapted to wind dispersal [3] and fruits may reach distances up to 200 m from the mother plant [62]. The final distance will depend on the wind speed and the orography, because some studies have found shorter distances [12,63,64]. Water is a secondary source of dispersion. Samaras are also adapted to float on water [48,65,66] and can be scattered downstream [47,54,67]. Seeds can remain viable in water for a long time (94.4% germinability after five months) [47].

7. Vegetative Reproduction

Asexual reproduction is an important trait to consider for this species, as new shoots from roots act as a dispersion mechanism [11]. The absence of a taproot is common [3] and a root system that has an asymmetrical shape, adapted to the soil characteristics [2]. New shoots can appear from stumps or roots, and the shapes of leaves vary if they appear from root sprouts (from unifoliate to pentafoliate or others) or seedlings (trifoliate) [5]. When aerial parts suffer damage or die, new shoots from the root system appear [3].

8. Management

Different strategies such as chemical, mechanical, and biological or a combination of them have been applied for the management of *A. altissima* trees in natural ecosystems. Many of these strategies showed a good efficacy; however, it is important to point out that due to the high capacity of the plant to resprout from the root system as explained before, any action on well-established individuals will need long-term supervision to check the efficacy of the measurement [2,68,69], particularly when female trees are present.

8.1. Mechanical

Mechanical control can be performed by hand or with any tool, but it is only effective against seedlings, because once the root system is established, cutting or breaking the roots will promote resprouting [5], and successive cuts will increase the number of shoots [11]. Mechanical control on established trees showed very weak control of the populations. For example, when comparing mechanical versus chemical, it was found a mortality of 21.3% by manual cutting versus near total control with different herbicides [70]. Other authors have demonstrated that herbicides such as glyphosate, imazapyr, picloram, triclopyr, or 2,4-D had better control than mechanical methods alone [21,71,72]. When comparing cutting versus herbicide application over the cut stump with glyphosate, imazapyr, or triclopyr, trees without herbicide produced more resprouts than trees with herbicide [73]. Similar results were obtained, with a mortality of 52% by only cutting compared to near 90%, when herbicides were applied over the cut stump [74]. A combination of mechanical actuations plus chemical control seems to be the best procedure rather than chemical control alone [68,71].

8.2. Chemical

Herbicides are the most popular method to manage *A. altissima* populations [75]. Systemic herbicides are the most efficient particularly when applied at the end of the growing season because they are transported to the root system via the phloem with the descending movement of the sap [69].

The application of the herbicides on the trees is performed by means of different techniques: stem injection, basal bark, or cut stump. Stem injection is performed by making holes with a drill into the trunk and filling each hole with herbicide, by the E-Z-ject Lance system (injecting into the trunk solid capsules containing herbicide) or by hack-and-squirt which is spraying into cuts performed with a hack along the stem. Basal bark consists of spraying herbicides into the lower part of an uncut trunk. Cut stump consists of spraying or injecting the herbicide on the cut surface of the trunk.

Herbicides have been applied diluted and undiluted, with different results. The best results with the stem injection technique were observed using undiluted glyphosate and making holes [76]. However, undiluted triclopyr applied by hack-and-squirt showed no total effectiveness over the trees [73]. The E-Z-ject Lance system has been tested with triclopyr and imazapyr [77,78], and glyphosate [71,78,79] with varied efficacy.

The efficacy of basal bark applications depended on the diameter of the tree. Diluted triclopyr showed good control in most cases [70,74,77,79], but diluted mixtures of triclopyr + fluroxypyr, aminopyralid + fluroxypyr or glyphosate alone did not show total mortality when applied to trees with bigger diameters [21].

For cut stump applications, mortality seems to depend on the concentration of the active ingredient. Spraying diluted active ingredients alone (i.e., triclopyr or glyphosate) or mixed (i.e., triclopyr + fluroxypyr, aminopyralid + fluroxypyr or glyphosate) did not achieve total mortality of the trees [21,73], while the same active ingredients undiluted reached total control [76]. Another case is granular herbicides like Metsulfuron methyl, where undiluted applications are not possible, which had a great mortality but not all trees died [74].

8.3. Biological

Although *A. altissima* tissues contain chemical compounds that likely act as a natural defense against pests [2], during the last decades many different organisms have been identified as biological agents of *A. altissima* trees, some of them with high specificity. These natural enemies are arthropods and fungus and most of them have been reported in Chinese ecosystems, although lately they have also been reported in the places where *A. altissima* has been introduced, probably due to accidental introductions [80]. Mites have been reported to attack leaves, with the genus *Aculus* spp. being the most mentioned ones [81–84]. Coleoptera such as *Eucryptorrhynchus brandti* and *Eucryptorrhynchus chinensis*

have shown good specificity over *A. altissima* in China [80]. These coleoptera also showed good specificity in quarantine trials, preferring this tree over others when feeding at the larval stage and for oviposition [75,85,86] making them a good option for biological control. In Italy, the orange whitefly (*Leurocanthus spiniferus*) has been reported on *A. altissima* for the first time, but this insect cannot be considered a biological agent because the trees tolerated the infestation [87].

Some generalist insects have a range of hosts that include *A. altissima* leaves in their diet, such as the butterflies *Atteva punctella* and *Samia cynthia*, whose host range includes trees from the genus *Simarouba* [80,88] and the beetle *Maladera castanea* [3]. Regarding biological control, *A. altissima* acts as a host for the invasive pest *Lycorma delicatula* in North America [89].

Fungus has an important role in *A. altissima* biocontrol. Some *Verticillium*, *Alternaria*, and *Cercospora* species have shown good results as biocontrol agents [80]. The *Verticillium* species are the most important and they have been identified in many countries like the USA [3,90–95], Austria [96], Italy [97], and Spain [98]. Common symptoms of trees affected by *Verticillium* are premature defoliation, yellowish vascular discoloration, and final mortality [91]. Different strains of *Verticillium* may act depending on the climate, with *V. dahliae* being the most common in warm areas and *V. nonalfae* in cooler regions [96]. Trees can be infected during winter and show the first symptoms the next growing season. Under laboratory conditions, *V. nonalfae* was transmitted by *E. brandti*, which carried the propagules of the fungi externally and internally [99].

9. Challenges

A. altissima has a very extensive bibliography involving many other topics such as medicinal properties or phytosanitary activity of some of its components. All this information has not been cited in this review because it is not relative to the invasive aspect of this weed in natural ecosystems. However, from the information reviewed, it appears that there is a need for further study of the behavior of this prolific species. Understanding the mechanisms of seed dormancy, determining the ecological requirements for seeds to germinate, or finding the best herbicide combination to control this weed are some of the aspects that are not well known. Additionally, some challenges derived from its control still have to be addressed. The use of herbicides may provoke soil/water contamination for drift or root exudates. When managing its populations, the vegetal residues of the trees generated should be properly treated to avoid the negative effects of their allelopathic compounds, by converting the residues into mulching in a secure way. The biological control with the fungus *Verticillium* in the invaded areas faces the challenge of the possible effect on native flora. As this tree has been shown to have growth limitations when living in closed-canopy forests, it would be interesting to determine the best planting density of native species in order to deter its establishment. New research studies are needed in order to properly develop successfully management programs aimed to eradicate this weed from our natural systems.

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References

1. Weber, E.; Gut, D. Assessing the risk of potentially invasive plant species in central Europe. *J. Nat. Conserv.* **2004**, *12*, 171–179. [CrossRef]

2. Kowarik, I.; Säumel, I. Biological Flora of Central Europe: *Ailanthus altissima* (Mill.) Swingle. *Perspect. Plant Ecol. Evol. Syst.* **2007**, *8*, 207–237. [[CrossRef](#)]
3. Miller, J.H. *Ailanthus altissima* (Mill.) Swingle. *Ailanthus. Silv. N. Am.* **1990**, *2*, 101–104.
4. Sánchez-Cuxart, A.; Llistosella, J. *Guia il·lustrada per a Conèixer els Arbres*; Publicacions i Edicions de la Universitat Barcelona: Barcelona, Spain, 2015.
5. Hu, S.Y. *Ailanthus. Arnoldia* **1979**, *39*, 29–50.
6. Sanz e Lorza, M.; Dana Sánchez, E.D.; Sobrino Vesperinas, E. *Atlas de las Plantas Alóctonas Invasoras en España*; Dirección General para la Biodiversidad: Madrid, Spain, 2004.
7. Wickert, K.L.; O’Neal, E.S.; Davis, D.D.; Asson, M.T. Seed production, viability, and reproductive limits of the invasive *Ailanthus altissima* (Tree-of-Heaven) within invaded environments. *Forests* **2017**, *8*, 226. [[CrossRef](#)]
8. Evans, C.W.; Moorhead, D.J.; Barger, C.T.; Douce, G.K. *Invasive Plant Responses to Silvicultural Practices in the South*; the University of Georgia Bugwood Network: Tifton, GA, USA, 2006.
9. Bossard, C.C.; Randall, M.J.; Hoshovsky, C.M. *Invasive Plants of California’s Wildlands*; Univ of California Press: California, UK, 1957.
10. Howard, J.L. *Ailanthus altissima*. In *Fire Effects Information System*; US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer): Fort Collins, CO, USA, 2004.
11. Sladonja, B.; Sušek, M.; Guillermic, J. Review on invasive Tree of Heaven (*Ailanthus altissima* (Mill.) Swingle) conflicting values: Assessment of its ecosystem services and potential biological threat. *Environ. Manag.* **2015**, *56*, 1009–1034. [[CrossRef](#)] [[PubMed](#)]
12. Martin, P.; Canham, C. Dispersal and recruitment limitation in native versus exotic tree species: Life-history strategies and Janzen-Connell effects. *Oikos* **2010**, *119*, 807–824. [[CrossRef](#)]
13. Wagner, S.G.K.; Moser, D.G.K.; Franz Essl, F. Urban rivers as dispersal corridors: Which factors are important for the spread of alien woody species along the Danube? *Sustainability* **2020**, *12*, 2185. [[CrossRef](#)]
14. Feret, P.O. *Ailanthus*: Variation, cultivation, and frustration. *J. Arboric.* **1985**, *11*, 361–368. [[CrossRef](#)]
15. Brunel, S.; Brundu, G.; Fried, G. Eradication and control of Invasive Alien Plants in the Mediterranean Basin: Towards Better Coordination to Enhance Existing Initiatives. *Bull. OEPP/EPPO Bull.* **2013**, *43*, 290–308. [[CrossRef](#)]
16. Andersen, M.C.; Adams, H.; Hope, B.; Powell, M. Risk assessment for invasive species. *Risk Anal.* **2004**, *24*, 787–793. [[CrossRef](#)] [[PubMed](#)]
17. Vilà, M.; Ibáñez, I. Plant invasions in the landscape. *Landsc. Ecol.* **2011**, *26*, 461–472. [[CrossRef](#)]
18. Casella, F.; Vurro, M. *Ailanthus altissima* (Tree of heaven): Spread and harmfulness in a case-study urban area. *Arboric. J.* **2013**, *35*, 172–181. [[CrossRef](#)]
19. Celesti-Grapow, L.; Blasi, C. The role of alien and native weeds in the deterioration of archaeological remains in Italy. *Weed Technol.* **2004**, *18*, 1508–1513.
20. Trotta, G.; Savo, V.; Cicinelli, E.; Carboni, M.; Caneva, G. Colonization and damages of *Ailanthus altissima* (Mill.) Swingle on archaeological structures: Evidence from the Aurelian Walls in Rome (Italy). *Int. Biodeterior. Biodegrad.* **2020**, *153*, 105054. [[CrossRef](#)]
21. Fogliatto, S.; Milan, M.; Vidotto, F. Control of *Ailanthus altissima* using cut stump and basal bark herbicide applications in an eighteenth-century fortress. *Weed Res.* **2020**, *60*, 425–434. [[CrossRef](#)]
22. Celesti-Grapow, L.; Ricotta, C. Plant invasion as an emerging challenge for the conservation of heritage sites: The spread of ornamental trees on ancient monuments in Rome, Italy. *Biol. Invasions* **2021**, *23*, 1191–1206. [[CrossRef](#)]
23. Gómez-Aparicio, L.; Canham, C.D. Neighbourhood analyses of the allelopathic effects of the invasive Tree *Ailanthus altissima* in temperate forests. *J. Ecol.* **2008**, *96*, 447–458. [[CrossRef](#)]
24. Brooks, R.K.; Barney, J.N.; Salom, S. The Invasive Tree, *Ailanthus altissima*, impacts understory nativity, not seedbank nativity. *For. Ecol. Manag.* **2021**, *489*, 119025. [[CrossRef](#)]
25. Novak, M.; Novak, N.; Milinović, B. Differences in allelopathic effect of tree of heaven root extracts and isolated ailanthone on test-species. *J. Cent. Eur. Agric.* **2021**, *22*, 611–622. [[CrossRef](#)]
26. Heisey, R.M. Identification of an allelopathic compound from *Ailanthus altissima* (Simaroubaceae) and characterization of its herbicidal activity. *Am. J. Bot.* **1996**, *83*, 192–200. [[CrossRef](#)]
27. Terzi, M.; Fontaneto, D.; Casella, F. Effects of *Ailanthus altissima* invasion and removal on high-biodiversity Mediterranean grasslands. *Environ. Manag.* **2021**, *68*, 914–927. [[CrossRef](#)]
28. Medina-Villar, S. Impactos ecológicos de los árboles exóticos invasores en la estructura y funcionamiento de los ecosistemas fluviales y de ribera. *Ecosistemas* **2016**, *25*, 116–120. [[CrossRef](#)]
29. Barton, L.V. Experiments at boyce Thompson institute on germination and dormancy in seeds. *Sci. Hortic.* **1939**, *7*, 186–193.
30. Little, S. *Ailanthus altissima* Mill. Swingle: *Ailanthus*. In *Seeds of Woody Plants in the United States*; Schopmeyer, C.S., Ed.; Tech. Coord.; USDA Forest Service: Washington, DC, USA, 1973; pp. 201–202.
31. Dirr, M.A.; Heuser, C.W., Jr. *The Reference Manual of Woody Plant Propagation*; Varsity Press: Athens, GA, USA, 1987.
32. Redwood, M.E.; Matlack, G.R.; Huebner, C.D. Seed longevity and dormancy state in an invasive tree species: *Ailanthus altissima* (Simaroubaceae). *J. Torrey Bot. Soc.* **2019**, *146*, 79–86. [[CrossRef](#)]
33. Deltalab, B.; Naziri Moghaddam, N.; Khorrami Raad, M.; Kaviani, B. The effect of cold and acid scarification on seed germination of three green space tree species. *J. Ornament. Plants* **2023**, *13*, 85–97.

34. Jian, Z.; Shouhua, G.; Yu, S.; Yong-qi, Z.; Xiao-yan, Y.; Lin, Y. The operational seed germination conditions of *Ailanthus altissima*. *Acta Bot. Boreali-Occident. Sin.* **2007**, *5*, 1030–1034.
35. Bao, Z.; Nilsen, E.T. Interactions between seedlings of the invasive tree *Ailanthus altissima* and the native tree *Robinia pseudoacacia* under low nutrient conditions. *J. Plant Interact.* **2015**, *10*, 173–184. [\[CrossRef\]](#)
36. Facelli, J.M. Multiple indirect effects of plant litter affect the establishment of woody seedlings in old fields. *Ecology* **1994**, *75*, 1727–1735. [\[CrossRef\]](#)
37. Constan-Nava, S.; Bonet, A. Genetic Variability Modulates the effect of habitat type and environmental conditions on early invasion success of *Ailanthus altissima* in Mediterranean ecosystems. *Biol. Invasions* **2012**, *14*, 2379–2392. [\[CrossRef\]](#)
38. Rebbeck, J.; Jolliff, J. How long do seeds of the invasive tree, *Ailanthus altissima* remain viable? *For. Ecol. Manag.* **2018**, *429*, 175–179. [\[CrossRef\]](#)
39. Pepe, M.; Gratani, L.; Fabrini, G.; Arone, L. Seed germination traits of *Ailanthus altissima*, *Phytolacca americana* and *Robinia pseudoacacia* in response to different thermal and light requirements. *Plant Species Biol.* **2020**, *35*, 300–314. [\[CrossRef\]](#)
40. Kheloufi, A.; Mansouri, L.M.; Zerrouni, R.; Abdelhamid, O. Effect of temperature and salinity on germination and seedling establishment of *Ailanthus altissima* (Mill.) Swingle (*Simaroubaceae*). *Reforesta* **2020**, *9*, 44–53. [\[CrossRef\]](#)
41. Cruz, O.; Riveiro, S.F.; Arán, D.; Bernal, J.; Casal, M.; Reyes, O. Germinative behaviour of *Acacia dealbata* Link, *Ailanthus altissima* (Mill.) Swingle and *Robinia pseudoacacia* L. in relation to fire and exploration of the regenerative niche of native species for the control of invaders. *Glob. Ecol. Conserv.* **2021**, *31*, e01811. [\[CrossRef\]](#)
42. Graves, W.R. Stratification not required for Tree-of-Heaven seed germination. *Tree Plant. Notes* **1990**, *41*, 1012.
43. Kota, N.L.; Landenberger, R.E.; McGraw, J.B. Germination and early growth of *Ailanthus* and tulip poplar in three levels of forest disturbance. *Biol. Invasions* **2007**, *9*, 197–211. [\[CrossRef\]](#)
44. Cabra-Rivas, I.; Castro-Díez, P. Potential Germination success of exotic and native trees coexisting in central Spain riparian forests. *Int. J. Ecol.* **2016**, *2016*, 7614683.
45. Stevens, M.T.; Roush, C.D.; Chaney, L. Summer Drought Reduces the Growth of Invasive Tree-of-Heaven (*Ailanthus altissima*) seedlings. *Nat. Areas J.* **2018**, *38*, 230–236. [\[CrossRef\]](#)
46. Delgado, J.A.; Jimenez, M.D.; Gomez, A. Samara size versus dispersal and seedling establishment in *Ailanthus altissima* (Miller) Swingle. *J. Environ.* **2009**, *30*, 183–186.
47. Kaproth, M.; McGraw, J. Seed viability and dispersal of the wind-dispersed invasive *Ailanthus altissima* in aqueous environments. *For. Sci.* **2008**, *54*, 490–496.
48. Kowarik, I.; Säumel, I. Water dispersal as an additional pathway to invasions by the primarily wind-dispersed tree *Ailanthus altissima*. *Plant Ecol.* **2008**, *198*, 241–252. [\[CrossRef\]](#)
49. González-Muñoz, N.; Castro-Díez, P.; Fierro-Brunnenmeister, N. Establishment success of coexisting native and exotic trees under an experimental gradient of irradiance and soil moisture. *Environ. Manag.* **2011**, *48*, 764–773. [\[CrossRef\]](#) [\[PubMed\]](#)
50. Kostel-Hughes, F.; Young, T.P.; Wehr, J.D. Effects of leaf litter depth on the emergence and seedling growth of deciduous forest tree species in relation to seed size. *J. Torrey Bot. Soc.* **2005**, *132*, 50–61. [\[CrossRef\]](#)
51. Yigit, N.; Sevik, H.; Cetin, M.; Kaya, N. Determination of the Effect of Drought Stress on the Seed Germination in Some Plant Species. Doctoral Dissertation, InTech, London, UK, 2016.
52. Sevik, H.; Cetin, M. Effects of water stress on seed germination for select landscape plants. *Pol. J. Environ. Stud.* **2015**, *24*, 689–693. [\[CrossRef\]](#) [\[PubMed\]](#)
53. Knüsel, S.; De Boni, A.; Conedera, M.; Schleppi, P.; Thormann, J.J.; Frehner, M.; Wunder, J. Shade tolerance of *Ailanthus altissima* revisited: Novel insights from southern Switzerland. *Biol. Invasions* **2017**, *19*, 455–461. [\[CrossRef\]](#)
54. Thomson, F.J.; Moles, A.T.; Auld, T.D.; Kingsford, R.T. Seed dispersal distance is more strongly correlated with plant height than with seed mass. *J. Ecol.* **2011**, *99*, 1299–1307. [\[CrossRef\]](#)
55. Borger, G.A.; Kozlowski, T.T. Effects of photoperiod on early periderm and xylem development in *Fraxinus pennsylvanica*, *Robinia pseudoacacia* and *Ailanthus altissima* seedlings. *New Phytol.* **1972**, *71*, 703–708.
56. Song, L.; Wenwen, L.; Shufen, C. Effect of PEG on seed germination of *Ailanthus altissima*. *J. Ningxia Agric. Coll.* **2005**, *4*, 25–29.
57. Pepe, M.; Crescente, M.F.; Varone, L. Effect of Water Stress on Physiological and Morphological Leaf Traits: A Comparison among the Three Widely-Spread Invasive Alien Species *Ailanthus altissima*, *Phytolacca americana*, and *Robinia pseudoacacia*. *Plants* **2022**, *11*, 899. [\[CrossRef\]](#)
58. Trifilò, P.; Raimondo, F.; Nardini, A.; Lo Gullo, M.A.; and Salleo, S. Drought resistance of *Ailanthus altissima*: Root hydraulics and water relations. *Tree Physiol.* **2004**, *24*, 107–114. [\[CrossRef\]](#)
59. Granda, E.; Antunes, C.; Máguas, C.; Castro-Díez, P. Water use partitioning of native and non-native tree species in riparian ecosystems under contrasting climatic conditions. *Funct. Ecol.* **2022**, *36*, 2480–2492. [\[CrossRef\]](#)
60. Petruzzellis, F.; Nardini, A.; Savi, T.; Tonet, V.; Castello, M.; and Bacaro, G. Less safety for more efficiency: Water relations and hydraulics of the invasive tree *Ailanthus altissima* (Mill.) Swingle compared with native *Fraxinus ornus* L. *Tree Physiol.* **2019**, *39*, 76–87. [\[CrossRef\]](#) [\[PubMed\]](#)
61. Planchuelo, G.; Catalán, P.; Delgado, J.A. Gone with the wind and the stream: Dispersal in the invasive species *Ailanthus Altissima*. *Acta Oecologica* **2016**, *73*, 31–37. [\[CrossRef\]](#)
62. Kota, N.L. Comparative Seed Dispersal, Seedling Establishment and Growth of Exotic, Invasive *Ailanthus Altissima* (Mill.) Swingle and Native *Liriodendron tulipifera* (L.). Graduate Theses, West Virginia University, Morgantown, WV, USA, 2005.

63. Cho, C.W.; Lee, K.J. Seed dispersion and seedling spatial distribution of the tree of heaven in urban environments. *Korean J. Environ. Ecol.* **2002**, *16*, 87–93.
64. Landenberger, R.E.; Kota, N.L.; McGraw, J.B. Seed dispersal of the non-native invasive tree *Ailanthus altissima* into contrasting environments. *Plant Ecol.* **2007**, *192*, 55–70. [[CrossRef](#)]
65. Säumel, I.; Kowarik, I. Urban rivers as dispersal corridors for primarily wind-dispersed invasive tree species. *Landsc. Urban Plan.* **2010**, *94*, 244–249. [[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. Cabra-Rivas, I.; Alonso, A.; Castro-Díez, P. Does stream structure affect dispersal by water? A case study of the invasive tree *Ailanthus altissima* in Spain. *Manag. Biol. Invasions* **2014**, *5*, 179–186. [[CrossRef](#)]
68. Constan-Nava, S.; Bonet, A.; Pastor, E.; Lledó, J. Long-term control of the invasive tree *Ailanthus altissima*: Insights from Mediterranean protected forests. *For. Ecol. Manag.* **2010**, *260*, 1058–1064. [[CrossRef](#)]
69. EPPO. PM 9/29 *Ailanthus altissima*. OEPP/EPPO Bull. **2020**, *50*, 148–155. [[CrossRef](#)]
70. Burch, P.; Zedaker, S. Removing the invasive tree *Ailanthus altissima* and restoring natural cover. *J. Arboric.* **2003**, *29*, 18–24. [[CrossRef](#)]
71. Meloche, C.; Murphy, S.D. Managing Tree-of-Heaven (*Ailanthus altissima*) in Parks and Protected Areas: A Case Study of Rondeau Provincial Park (Ontario, Canada). *Environ. Manag.* **2006**, *37*, 764–772. [[CrossRef](#)]
72. Young, C.; Bell, J.; Morrison, L. Long-term treatment leads to reduction of tree-of-heaven (*Ailanthus altissima*) populations in the Buffalo National River. *Invasive Plant Sci. Manag.* **2020**, *13*, 276–281. [[CrossRef](#)]
73. DiTomaso, J.; Kyser, G. Control of *Ailanthus altissima* using stem herbicide application techniques. *Arboric. Urban For.* **2007**, *33*, 55–63. [[CrossRef](#)]
74. Johnson, J.M. An Evaluation of Application Timing and Herbicides to Control *Ailanthus altissima*. Master's Thesis, The Pennsylvania State University, The Graduate School College of Agricultural Sciences, University Park, PA, USA, 2011.
75. Kok, L.T.; Salom, S.M.; Yan, S.; Herrick, N.J.; McAvoy, T.J. Quarantine evaluation of *Eucryptorrhynchus brandti* (Harold) (Coleoptera: Curculionidae), a potential biological control agent of tree of heaven, *Ailanthus altissima* in Virginia, USA. In Proceedings of the XII International Symposium on Biological Control of Weeds, La Grande Motte, France, 22–27 April 2008.
76. Venegas, T.J.; Pérez, P.C. Análisis y optimización de técnicas de eliminación de especies vegetales invasoras en medios forestales de Andalucía. In Proceedings of the V Congreso Forestal Español, Ávila, Spain, 21–25 September 2009. S.E.C.F-Junta de Castilla y León, Ed..
77. Eck, W.; McGill, D. Testing the Efficacy of Triclopyr and Imazapir Using Two Application Methods for Controlling Tree-of-Heaven along a West Virginia Highway; e-Gen. Tech. Rep. SRS-101; U.S. Department of Agriculture, Forest Service, Southern Research Station: Asheville, NC, USA, 2007; pp. 163–168.
78. Lewis, K.; McCarthy, B. Nontarget Tree Mortality after Tree-of-Heaven (*Ailanthus altissima*) injection with Imazapyr. *North. J. Appl. For.* **2007**, *25*, 66–72. [[CrossRef](#)]
79. Bowker, D.; Stringer, J. Efficacy of herbicide treatments for controlling residual sprouting of tree-of-heaven. In Proceedings of the 17th Central Hardwood Forest Conference, Lexington, KY, USA, 5–7 April 2010; Fei, S., Lhotka, J., Stringer, J., Gottschalk, K., Miller, G., Eds.; Gen. Tech. Rep. NRS-P-78. U.S. Department of Agriculture, Forest Service, Northern Research Station: Newtown Square, PA, USA, 2011; pp. 128–133.
80. Ding, J.; Wu, Y.; Zheng, H.; Fu, W.; Reardon, R.; Liu, M. Assessing potential biological control of the invasive plant, tree-of-heaven, *Ailanthus altissima*. *Biocontrol Sci. Technol.* **2006**, *16*, 547–566. [[CrossRef](#)]
81. Marini, F.; Profeta, E.; Vidović, B.; Petanović, R.; de Lillo, E.; Weyl, P.; Hinz, H.L.; Moffat, C.E.; Bon, M.-C.; Cvrković, T.; et al. Field Assessment of the host range of *Aculus mosoniensis* (Acari: Eriophyidae), a biological control agent of the Tree of Heaven (*Ailanthus altissima*). *Insects* **2021**, *12*, 637. [[CrossRef](#)]
82. Skvarla, M.J.; Ochoa, R.; Ulsamer, A.; Amrine, J. The eriophyid mite *Aculops ailanthic* Lin, Jin, and Kuang, 1997 (Acariformes: Prostigmata: Eriophyidae) from tree of heaven in the United States new state records and morphological observations. *Acarologia* **2021**, *61*, 121–127. [[CrossRef](#)]
83. De Lillo, E.; Marini, F.; Cristofaro, M.; Valenzano, D.; Petanović, R.; Vidović, B.; Cvrković, T.; Bon, M.C. Integrative taxonomy and synonymization of *Aculus mosoniensis* (Acari: Eriophyidae), a potential biological control agent for Tree of Heaven (*Ailanthus altissima*). *Insects* **2022**, *13*, 489. [[CrossRef](#)]
84. Kashefi, J.; Vidović, B.; Guermache, F.; Cristofaro, C. Occurrence of *Aculus mosoniensis* (Ripka, 2014) (Acari; Prostigmata; Eriophyoidea) on Tree of heaven (*Ailanthus altissima* Mill.) is expanding across europe. first record in France confirmed by barcoding. *Phytoparasitica* **2022**, *50*, 391–398. [[CrossRef](#)]
85. Herrick, N.J.; McAvoy, T.J.; Zedaker, S.M.; Salom, S.M.; Kok, L.T. Site characteristics of *Leitneria floridana* (Leitneriaceae) as related to potential biological control of the invasive Tree-of-heaven, *Ailanthus altissima*. *Phytoneuron* **2011**, *27*, 1–10.
86. Herrick, N.J.; McAvoy, T.J.; Snyder, A.L.; Salom, S.M.; Kok, L.T. Host-range testing of *Eucryptorrhynchus brandti* (Coleoptera: Curculionidae), a candidate for biological control of Tree-of-heaven, *Ailanthus altissima*. *Environ. Entomol.* **2012**, *41*, 118–124. [[CrossRef](#)] [[PubMed](#)]
87. Bubici, G.; Prigigallo, M.I.; Garganese, F.; Nugnes, F.; Jansen, M.; Porcelli, F. First report of *Aleurocanthus spiniferus* on *Ailanthus altissima*: Profiling of the insect microbiome and micrnas. *Insects* **2020**, *11*, 161. [[CrossRef](#)] [[PubMed](#)]

88. Wilson, J.; Landry, J.-F.; Janzen, D.; Hallwachs, W.; Nazari, V.; Hajibabaei, M.; Hebert, P. D.-N. Identity of the *Ailanthus* webworm moth (Lepidoptera: Yponomeutidae), a complex of two species: Evidence from DNA barcoding, morphology and ecology. *ZooKeys* **2010**, *46*, 41–60. [\[CrossRef\]](#)
89. Kreitman, D.; Keena, M.A.; Nielsen, A.L.; Hamilton, G. Effects of temperature on development and survival of Nymphal *Lycorma delicatula* (Hemiptera: Fulgoridae). *Environ. Entomol.* **2021**, *50*, 183–191. [\[CrossRef\]](#)
90. Snyder, A.L.; Salom, S.M.; Kok, L.T. Survey of *Verticillium nonalfalfae* (Plectosphaerellaceae) on Tree-of-heaven in the southeastern United States. *Biocontrol Sci. Technol.* **2014**, *24*, 303–314. [\[CrossRef\]](#)
91. Rebbeck, J.; Malone, M.A.; Short, D.P.G.; Kasson, M.T.; O’Neal, E.S.; Davis, D.D. First report of *Verticillium* wilt caused by *Verticillium nonalfalfae* on Tree-of-Heaven (*Ailanthus altissima*) in Ohio. *Plant Dis.* **2013**, *97*, 999. [\[CrossRef\]](#) [\[PubMed\]](#)
92. O’Neal, S.E. Biological Control of *Ailanthus altissima*: Transmission, Formulation, and Risk Assessment of *Verticillium nonalfalfae*. Master’s Thesis, The Pennsylvania State University. The Graduate School College of Agricultural Sciences, University Park, PA, USA, 2014.
93. Kasson, M.T.; Short, D.P.; O’Neal, E.S.; Subbarao, K.V.; Davis, D.D. Comparative pathogenicity, biocontrol efficacy, and multilocus sequence typing of *Verticillium nonalfalfae* from the invasive *Ailanthus altissima* and other hosts. *Phytopathology* **2014**, *104*, 282–292. [\[CrossRef\]](#)
94. Kasson, M.T.; O’Neal, E.S.; Davis, D.D. Expanded Host Range Testing for *Verticillium nonalfalfae*: Potential Biocontrol Agent Against the Invasive *Ailanthus altissima*. *Plant Dis.* **2015**, *99*, 823–835. [\[CrossRef\]](#)
95. Brooks, R.K.; Wickert, K.; Baudoin, A.; Kasson, M.T.; Salom, S. Field-inoculated *Ailanthus altissima* stands reveal the biological control potential of *Verticillium nonalfalfae* in the mid-Atlantic region of the United States. *Biol. Control.* **2020**, *148*, 104298. [\[CrossRef\]](#)
96. Maschek, O.; Halmschlager, E. Natural distribution of *Verticillium* wilt on invasive *Ailanthus altissima* in eastern Austria and its potential for biocontrol. *For. Pathol.* **2017**, *47*, e12356. [\[CrossRef\]](#)
97. Pisuttu, C.; Marchica, A.; Bernardi, R.; Calzone, A.; Cotrozzi, L.; Nali, C.; Pellegrini, E.; Lorenzini, G. *Verticillium* wilt of *Ailanthus altissima* in Italy caused by *V. dahliae*: New outbreaks from Tuscany. *iForest* **2020**, *13*, 238–245.
98. Moragrega, C.; Carol, J.; Bisbe, E.; Fabregas, E.; Lorente, I. First report of *Verticillium* Wilt and mortality of *Ailanthus altissima* caused by *Verticillium dahliae* and *V. albo-atrum sensulato* in Spain. *Plant Dis.* **2021**, *105*, 3754. [\[CrossRef\]](#)
99. Snyder, A.L.; Salom, S.M.; Kok, L.T.; Griffin, G.J.; Davis, D.D. Assessing *Eucryptorrhynchus brandti* (Coleoptera: Curculionidae) as a potential carrier for *Verticillium nonalfalfae* (Phyllachorales). *Biocontrol Sci. Technol.* **2012**, *22*, 1005–1019. [\[CrossRef\]](#)

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