diversity

MDPI

Review

Assessment of the Potential of the Invasive Arboreal Plant *Ailanthus altissima* (Simaroubaceae) as an Economically Prospective Source of Natural Pesticides

Ekaterina Kozuharova [1,*], Ardalan Pasdaran [2], Abdel Rahman Al Tawaha [3], Teodora Todorova [4], Zheko Naychov [5] and Iliana Ionkova [1]

1 Department of Pharmacognosy, Faculty of Pharmacy, Medical University of Sofia, 2 Dunav Str., 1000 Sofia, Bulgaria
2 Medicinal Plants Processing Research Center, Shiraz University of Medical Sciences, Shiraz 73, Iran
3 Department of Biological Sciences, Al-Hussein Bin Talal University, Ma'an P.O. Box 20, Jordan
4 Institute of Biodiversity and Ecosystems Research, Bulgarian Academy of Sciences, 2 Gagarin Str., 1113 Sofia, Bulgaria
5 Department of Surgery, Obstetrics and Gynecology, Faculty of Medicine, Division of Cardiac Surgery, University Hospital Lozenetz, Sofia University St. Kliment Ohridski, 1407 Sofia, Bulgaria
* Correspondence: ina_kozuharova@yahoo.co.uk or ina@pharmfac.mu-sofia.bg

Abstract: The extensive use of pesticides may negatively affect human health. Additionally, it is one of the main reasons for the decline of pollinators and is thus a hazard for most crops and biodiversity as a whole. Good candidates for the replacement of pesticides with ones less toxic to humans and pollinators are natural products (bioactive compounds extracted from plants), even though it should be kept in mind that some of them can be toxic too. *Ailanthus altissima* (Mill.), swingle, known also as tree of heaven, (Simaroubaceae) is one of the most aggressive alien invasive plants. It demonstrates a high tolerance to various habitat conditions and a potent propagation ability. This plant has a prominent ability to suppress the seed development of local vegetation. The aim of this review study is to summarize the potential of this plant for use as a natural pesticide, starting with ethnobotanical information. The essential oils extracted from *A. altissima* with its main components α-curcumene α-gurjunene, γ-cadinene, α-humulene, β-caryophyllene, caryophyllene oxide, germacrene D, etc., have been reported to possess different activities such as insect repellent, insecticidal, and herbicidal activity. Additionally, polar extracts and particularly quassinoids, the phenolic constituents of *A. altissima* leaves, are potent phytotoxins and fumigants. The basic extraction protocols are also summarized.

Keywords: biopesticides; essential oils; quassinoids; invasive plants' management

check for updates

Citation: Kozuharova, E.; Pasdaran, A.; Al Tawaha, A.R.; Todorova, T.; Naychov, Z.; Ionkova, I. Assessment of the Potential of the Invasive Arboreal Plant *Ailanthus altissima* (Simaroubaceae) as an Economically Prospective Source of Natural Pesticides. *Diversity* **2022**, *14*, 680. https://doi.org/10.3390/d14080680

Academic Editor: Kevin Cianfaglione

Received: 8 July 2022
Accepted: 17 August 2022
Published: 19 August 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

Pesticides are a broad group of heterogeneous chemicals. They are toxic substances used to kill, prevent, or control pests such as insects and other animals, plants/weeds or fungi that harm crops, ornamental plants, stock, or, humans. In addition, they are considered to have public health benefits by increasing food productivity and decreasing food-borne and vector-borne diseases/infections caused by bacteria, fungi, or other pathogens [1,2]. All pesticides interfere with normal metabolic processes in the pest organism and are often classified according to the type of organism they are intended to control (e.g., herbicides; insecticide; fungicide; fumigant) [2]. However acute, high-dose pesticide exposures have been known for decades to cause clinically obvious and sometimes fatal poisoning. Moreover, the subclinical toxicity with a wide range of asymptomatic effects at levels of exposure too low to produce overt signs and symptoms should not be underestimated—they can cause cancer, cardiovascular dysfunctions, neurodegenerative disorders, etc. [1,3–9], and children are particularly at risk [1,8,10,11].

According to The Food and Agriculture Organization, "it is estimated that the value of pollination services to global food production is worth up to USD 600 billion annually" [12]. However, there is a great deal of evidence for pollinators' global decline [13–27]. One of the biggest issues besides habitat destruction, the loss of floral resources, and emerging diseases is the negative impact of pesticides, particularly neonicotinoids, with more than 19,000 scientific references addressing these environmental threats [19,20,28–35]. Herbicides and fungicides such as glyphosate, metolachlor, oxadiazon, prochloraz, propiconazole, etc., have been found to harm pollinators [29,32,36–41]. The essential elements of an effective pollinator conservation policy have been summarized and the approach is holistic and based on scientific knowledge [42,43].

To reduce the harm of the pesticides in use, it is necessary to find a way to replace them with ones less toxic to humans and pollinators. Good candidates for this are natural products—bioactive compounds obtained from plants. Of course, this should be approached with caution. It is well known that many poisons have a vegetal origin. It is important to discover the ones that have selective activity. This requires an approach in two steps. The first step is finding the pesticide activity of the natural products. The second step involves tests for safety.

Two groups of natural products deserve attention for their possible roles as biopesticides. Some plant essential oils (e.g., *Thymus serpyllum*, *Origanum majorama*, *Alpinia conchigera*, *Zingiber zerumbet*, *Curcuma zedoaria*, *Achillea vermicularis*, and *A. teretifolia*) repel insects and have contact and fumigant insecticidal actions against specific pests [44–46]. These actions are attributed to the compounds amphene, camphor, 1,8-cineole (eucalyptol), terpinen-4-ol, isoborneol, α-humulene, α-pinene, β-pinene, and (−)-α-bisabolol [44,46–48]. Additionally, essential oils are considered potential bio-herbicides, with different and selective herbicidal mechanisms in comparison to the synthetic herbicides [49–55] as they are active against germination and early radicle growth at different levels [55]. The high presence of oxygenated monoterpenes (β-pinene, limonene, *p*-cymene, carvone, carvacrol, etc.) is related to potent phytotoxic activity [55] as well as to the α-pinene and 1,8-cineole [47,51,56]. In addition, the active phenolic monoterpenoids carvacrol and thymol have been suggested as alternative pesticides, herbicides, and insecticides [52]. Many studies on the various quassinoids (isolated compounds) from different genera have revealed the promising pesticide potential of this class of compounds [57–59].

The search for a replacement of pesticides is worth being conducted among alien invasive plants firstly because they are inexpensive and abundant sources of bioactive compounds, and secondly because they obviously have the phytochemical equipment to suppress the local vegetation and resist pests. *Ailanthus altissima* (Mill.) Swingle, the tree of heaven (Simaroubaceae), is a hard to control alien, aggressive, and invasive woody plant species [60–70]. The plant is native to northern and central China and has turned into a noxious weed in Europe, America, Australia, and other parts of the world where it has been introduced. [61]. Particularly, *A. altissima* is considered the most invasive alien species in Europe together with *Ambrosia artemisiifolia* L. and *Robinia pseudacacia* L. [61], which negatively affects the local biodiversity [68,70]. The tree of heaven not only outcompetes the local plants but also suppresses their seed germination and seedling development [71]. Additionally, it is less attacked by herbivorous insects [61,62,66].

The aim of this review study is to summarize the potential of *A. altissima* for use in natural pesticides through the following methods: (1) by summarizing the ethnobotanical data for pesticide activity reports, (2) by identifying the groups of compounds with pesticide potential, and (3) by summarizing the extraction protocols for each of the compounds' groups in order to further enhance the optimal extraction protocols' designs.

2. Material and Methods

In 2019–2022, we accessed Google Scholar, Web of Science, and PubMed to identify publications with the search strings: "*Ailanthus altissima*", "ethnobotany", "traditional", "quassinoids", "essential oil(s)", "fumigant", "insect repellent", "juglone index", "phytotoxic", "insecticide", "insecticidal", "herbicide", "herbicidal", "fungicide", and "antifungal". No particular restriction was considered for the search strategy, such as publication language or publication year. The results of the search were publications primarily in the English language, and they covered the period from 1980 to 2021. Following the PRISMA 2000 guidelines, the records were assessed for eligibility and the inappropriate ones were excluded (namely, 160 studies were included in the review; the excluded ones were 35 studies that did not fit to the review topic and 2 that were not reliable).

We focused on the quassinoids and the essential oils for two reasons: firstly, these groups of compounds are known for their insect repellent, fumigant, fungicidal, and phytotoxic potential, and secondly, quassinoids are the most prevalent constituents in genus *Ailanthus* [72–78]. The aggressively invasive behavior of *A. altissima* suggests the promising potential of this plant for future pesticide formulations.

3. Results and Discussion

3.1. Ethnobotanical Data about Ailanthus altissima (Mill.) Swingle

Ethnobotanical information is usually focused on the medicinal properties of plants. Therefore, information regarding the pesticide potentials of plants is valuable but scarce. For invasive plant species, ethnobotanical records are collected in their native ranges of distribution. The local human populations in these regions have established traditions in the application of such plants. The bark of *Ailanthus altissima* (臭椿 chou chun) was initially recorded in Xin Xiu Ben Cao, a renowned traditional Chinese medicine monograph [79]. The information within this book relates that besides the many others therapeutic effects of *A. altissima,* the bark of the plant was used as an insecticide [79]. *A. altissima* plant materials were often used in ancient China against insect predators of stored grains [80]. The traditional use of *A. altissima* in Chinese medicine represents the starting point for scientific research seeking evidence of such pharmacological activities, and in this particular case, its potential pesticidal effects.

3.2. Chemical Constituents of Ailanthus altissima and Extraction Methods

A. altissima contains various secondary metabolites such as alkaloids, terpenoids, flavonoids, essential oil, etc., with a wide range of pharmacological effects such as anti-cancer, anti-inflammatory, anti-protozoal, etc. [79,81–93]. For instance, extracts of *A. altissima* stems containing ailanthone possess antiplasmodial activity against *Plasmodium falciparum P. berghei* [94,95]. An interesting new discovery is the antifungal effect of the alkaloid canthin-6-one isolated from *A. altissima* against *Fusarium oxysporum* f. sp. *cucumerinum* [96].

Here we focus on the quassinoids and essential oils as potential biopesticides since there is an indication that these groups of compounds have such effects [9–18].

3.3. Essential Oil of Ailanthus altissima: Composition and Extraction Overview

The qualitative and quantitative compositions of *A. altissima* essential oil vary considerably. This variability depends on the plant populations/ecological factors, the extractable parts, the ontogenesis stage, and the drying process. The main components are α-curcumene, α-gurjunene, γ-cadinene, α-humulene, β-caryophyllene, caryophyllene oxide, germacrene D, etc. [83,97–99].

The extraction methods are summarized here. The collection of the materials for *A. altissima* essential oil extraction may take place in the summer in Tunisia [97,98] or in September in Croatia [83]. The extraction of essential oil is a technological challenge as our own experience revealed (unpublished data). Basically, the essential oil of different plant parts (roots, stems, leaves/young and old plants, flowers, and ripe fruits, all cut into small pieces) is extracted by hydrodistillation for 3–4 h using a Clevenger-type apparatus [83,98] or a simple laboratory Quick-fit apparatus [97]. The identification of the components is performed by GC-FID and GC/MS analyses.

Additionally, the essential oil of *A. altissima* bark was extracted by the Soxhlet method with anhydrous diethyl ether until the distilled liquid became colorless. The solvent was evaporated under a vacuum in a rotary evaporator and the fumigant activity was tested against four major stored grain insects [100].

3.4. Quassinoids Extraction, Fractionation, and Isolation Overview

Quassinoids are all-chair cyclic and highly oxygenated derivatives of squalene. Biogenetically, they can be regarded as the degraded triterpenoids, which are isolated exclusively as bitter principles from plants of the Simaroubaceae family [101].

A. altissima is rich in quassinoids (Table 1, Figure 1) and the process of the identification of new quassinoids is still progressing [90]. The concentration of ailanthone, one of the main quassinoids, may range from 6.44 µg/mL to 825 µg/mL, depending on the source locality in China [102].

Table 1. List of isolated quassinoids from *A. altissima*.

	Compound	CAS Registry Number	Plant Material	Contents or Obtained Amount mg/g Dry Weight	Ref.
1	2-dihydroailanthone	not assigned	Bark	0.027	[103]
2	6α-tigloyloxychaparrin	75144-71-7	Root bark	0.003	[104]
3	6α-tigloyloxychaparrinone	69423-70-7	Seedling	0.017	[104]
4	11-acetylamarolide	29913-88-0	Bark, seed	0.018	[104]
5	12-dihydroisoailanthone	n. a	Bark	0.080	[103]
6	13,18-dehydroglaucarubinone	68703-94-6	Root bark	0.124	[104]
7	Ailanthone	981-15-7	Root, seed, leaves	0.003–0.05	[103,105]
8	Ailantinol A	176181-83-2	Aerial parts	0.007	[72]
9	Ailantinol B	177794-39-7	Stem bark	0.002	[72]
10	Ailantinol C	n. a	Stem bark	0.002	[73]
11	Ailantinol D	n. a	Stem bark	0.0005	[73]
12	Ailantinol E	n. a	Root bark	0.0004	[74]
13	Ailantinol F	n. a	Aerial parts	0.0004	[74]
14	Ailantinol G	n. a	Aerial parts	0.0007	[74]
15	Ailantinol H	n. a	Aerial parts	0.0002	[106]
16	Altissinol A	n. a	Bark	0.001	[104]
17	Altissinol B	n. a	Bark	0.003	[104]
18	Amarolide	29913-86-8	Bark, seed	0.001	[104]
19	Chaparrinone	22611-34-3	Root bark	0.002	[104]
20	Chaparrolide	33512-38-8	Bark	0.003	[104]
21	Δ^{13-18}-dehydroglaucarubolone	n. a	Seed	0.0002	[72,104]
22	Glaucarubin	1448-23-3	Stem bark	0.003	[104]
23	Glaucarubinone	1259-86-5	Seed	n. a	-
24	Glaucarubol	1448-22-2	Stem bark	n. a	-
25	Isoailanthone	n. a	Root bark	0.0002	[103]
26	Shinjudilactone	80180-30-9	Seed	0.003	[107]
27	Shinjuglycoside A	n. a	Seed	0.012	[108]
28	Shinjuglycoside B	n. a	Seed	0.044	[108]

Table 1. *Cont.*

	Compound	CAS Registry Number	Plant Material	Contents or Obtained Amount mg/g Dry Weight	Ref.
29	Shinjuglycoside C	n. a	Seed	0.005	[108]
30	Shinjuglycoside D	n. a	Seed	0.002	[108]
31	Shinjuglycoside E	112667-45-5	Root bark	0.0002	[109]
32	Shinjuglycoside F	112667-46-6	Root bark	0.00005	[109]
33	Shinjulactone A	89353-91-3	Seed	0.002	[105]
34	Shinjulactone B	80648-28-8	Aerial parts	0.001–0.004	[110]
35	Shinjulactone C	82470-74-4	Root bark	0.001	[107]
36	Shinjulactone F	n. a	Root bark	0.003	[111]
37	Shinjulactone G	n. a	Root bark	0.0003	[112]
38	Shinjulactone H	n. a	Root bark	0.001	[112]
39	Shinjulactone I	n. a	Root bark	0.0002	[111]
40	Shinjulactone J	n. a	Root bark	0.0001	[111]
41	Shinjulactone K	94451-22-6	Root bark	0.0005	[111]
42	Shinjulactone L	n. a	Root bark	0.0005	[113]
43	Shinjulactone M	n. a	Root bark	0.0005	[114]
44	Shinjulactone N	n. a	Root bark	0.0002	[114]
45	Shinjulactone O	n. a	Root bark	0.001	[115]
46	Chuglycoside A	n. a	Seed (samara)	0.003	[116]
47	Chuglycoside B	n. a	Seed (samara)	0.014	[116]
48	Chuglycoside C	n. a	Seed (samara)	0.024	[116]
49	Chuglycoside D	n. a	Seed (samara)	0.001	[116]
50	Chuglycoside E	n. a	Seed (samara)	0.145	[116]
51	Chuglycoside F	n. a	Seed (samara)	0.002	[116]
52	Chuglycoside G	n. a	Seed (samara)	0.001	[116]
53	Chuglycoside H	n. a	Seed (samara)	0.0005	[116]
54	Chuglycoside I	n. a	Seed (samara)	0.032	[116]
55	Chouchunlactone A	n. a	Root bark	0.0001	[90]
56	Chouchunlactone B	n. a	Root bark	0.0003	[90]
57	Chouchunlactone C	n. a	Root bark	0.0007	[90]
58	Chouchunlactone D	n. a	Root bark	0.0002	[90]
59	Chouchunlactone E	n. a	Root bark	0.0002	[90]

Different extraction and isolation procedures have been developed according to the chemical nature and class of the quassinoids. Many of the quassinoids are categorized as non-polar or low polar compounds. However, a significant number of polar quassinoids have been reported as well. The extraction approach is performed either using polar, semi-polar, or non-polar solvents. The polar group of solvents includes hot methanol, hot water, ethanol, or similar ones [72–74,103–105]. As example of a non-polar solvent that is used is hexane [106,107]. Generally, the procedures include the solvent partitioning and solid-phase fractionation. In most cases, during the solvent partitioning, quassinoids concentrate in the semi-polar solvent (e.g., dichloromethane, chloroform, and ethyl acetate) [105,108]. In the solid-phase extraction and isolation methods, various stationary phases such as silica gel or/and C-18, C-8 (reverse phase) are used [109,110]. A wide range of solvent mixtures have been used as mobile phases with varying polarities, although a rising polarity gradient was often considered for future separation. Methanol in ethyl acetate (with an increasing methanol percentage), methanol in chloroform, and methanol in acetone are some of the most popular eluents [57,114].

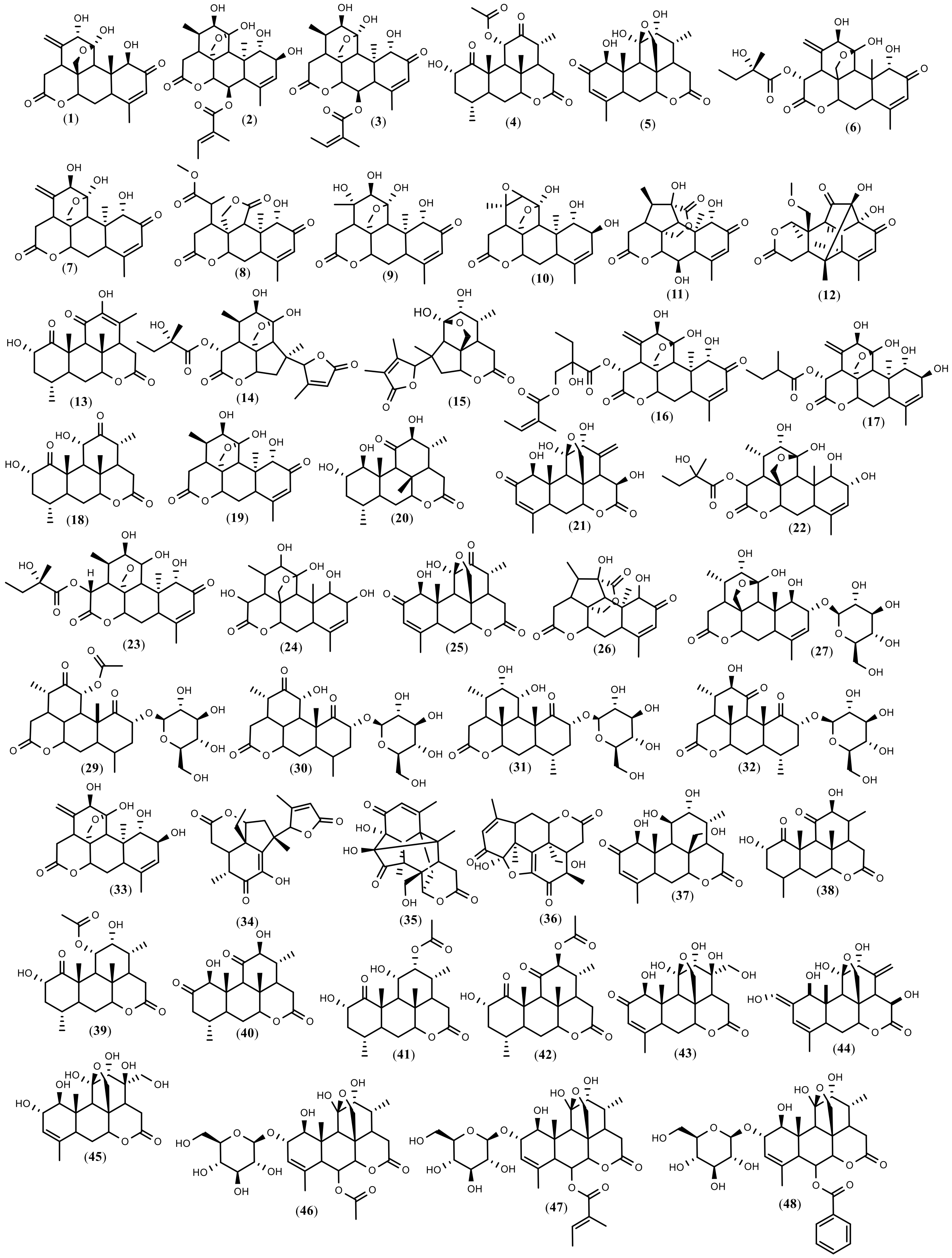

Figure 1. *Cont.*

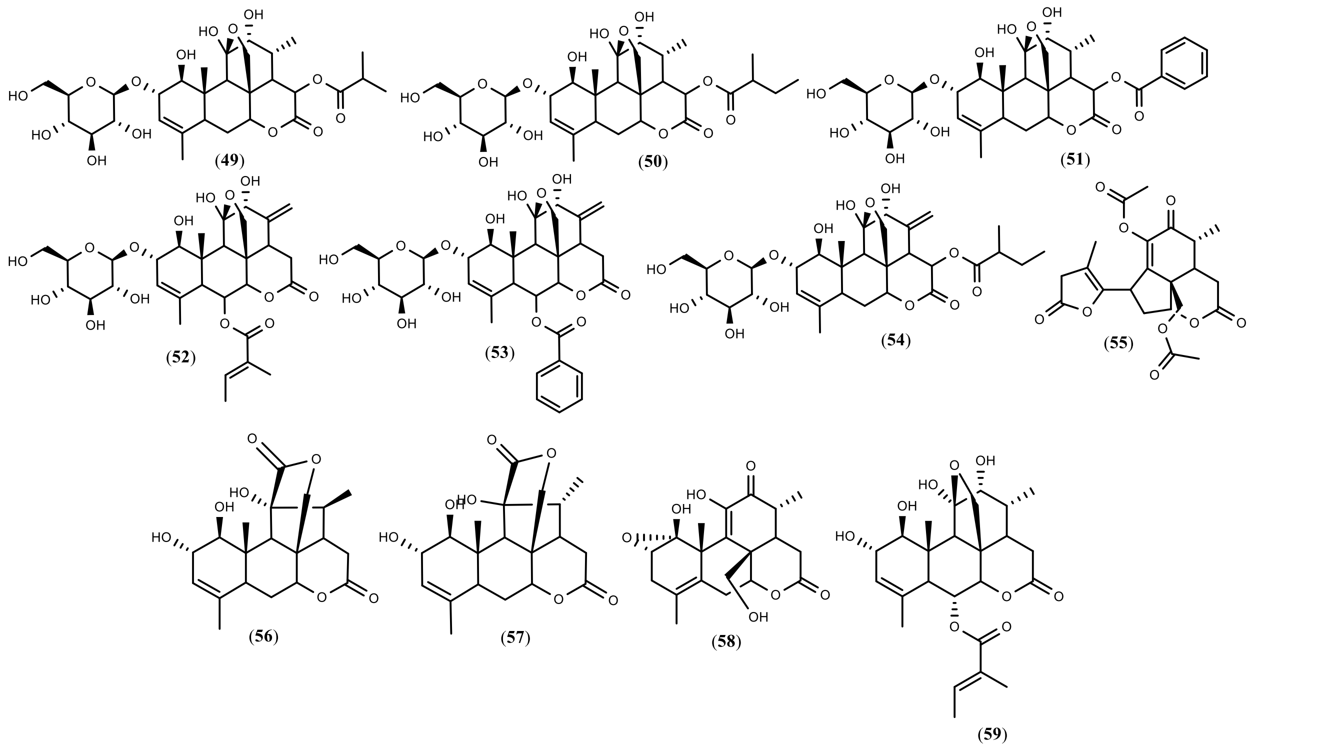

Figure 1. The structure of quassinoids isolated from *A. altissima*. The compound numbers correspond to the list in Table 1.

Many of the quassinoids could be formed as crystalline matters. Hence, quassinoids are purifiable phytochemicals [111–113].

For the phytotoxicity and larvicidal tests, fresh leaves were cut into pieces, soaked in methanol in a glass container, kept at room temperature (25 °C) for 72 h, were filtered, and then the methanol was evaporated [117]. For the fumigant and phytotoxicity bioassays of the quassinoids, the extracts are prepared as follows: the roots and leaves are extracted separately at room temperature—at a dose of 10% *w*/*v*—successively with solvents of increasing polarity [petroleum ether, chloroform, chloroform: methanol (9:1), methanol and water]. The aqueous leaf extract, more active in bioassays, is fractionated in H_2O:BuOH. The n-butanol extract, which shows activity in the preliminary bioassays, is dissolved in methanol and 2 g of this extract is fractionated by gel-permeation chromatography on a Sephadex LH-20 column, eluting with MeOH [57].

3.5. Biopesticide Potential of Ailanthus altissima and Tests' Design

3.5.1. Phytotoxicity Assay of *Ailanthus altissima*

Essential Oil Phytotoxicity

The essential oils of *A. altissima* negatively affect the seed germination and early-stage development of the seedlings of the target species. The effect is dose-dependent and is greater in the light than in the dark. In addition, the phytotoxic effect depends on the origin of the essential oil, as the oil extracted from flowers is the most phytotoxic [97,98]. The caryophyllene oxide, b-caryophyllene, germacrene D, and hexahydrofarnesyl acetone presented in the essential oil may be responsible for such a phytotoxic effect [98,118,119]. Additionally, the complete inhibition of the germination of target plants is achieved after the application of 400 to 600 µg/mL hydrodistilled leaf residues [97].

Phytotoxicity of Polar *Ailanthus altissima* Extracts

The juglone index [120] of *A. altissima* has been assessed as very high (0.80–1.40 depending on the extract concentration [121–123]. The plant produces allelopathic substances that inhibit the seed germination and seedling growth of competing species. They are located mostly in the bark and the roots, but also occur in the leaves, seeds, and wood. The inhibitor(s) can readily be extracted from *A. altissima* with methanol, but not dichloromethane, indicating the plant's polar characteristics. The experimental tests show "striking" postemergence effects, with a nearly complete mortality of all the receiver plant species [124].

The compounds of the methanolic extracts from *A. altissima's* fresh leaves and some sub-fractions have strong inhibitory effects on plant growth. Some fractions show a regulatory effect on plant by inhibiting the growth of radicles at higher concentrations and enhancing their growth at lower concentrations [117]. The compounds of the aqueous extracts from *A. altissima*'s fresh leaves and bark negatively influence the growth of the treated seedlings of *Sinapis alba* L. and *Brassica napus* L. regardless of the dilution [125]. The aqueous extracts of *A. altissima* leaves have a concentration-dependent herbicidal effect on *Medicago sativa* L. seed germination [126].

Ailanthone is highly phytotoxic, with concentrations of 0.7 mL/L causing 50% inhibition of radicle elongation in a standardized bioassay with garden cress (*Lepidium sativum* L.) seeds [127]. The quassinoids (from the root bark of *A. altissima*), e.g., ailanthone, ailanthinone, and ailanthinol; the alkaloids such as 1-methoxycanthin-6-one; and the phenolic constituents of the leaves are potent phytotoxins [57,97,128–132]. A significant pre-emergence herbicide activity is found for most of the bark dichloromethane extracts, which is directly correlated with the ailanthone concentration. A remarkable combined pre- and post-emergence herbicidal activity was found for a specific fraction. These results indicate that the bark of *A. altissima* is a potential source for the production of natural herbicides for use in agriculture [133]. Methanol bark extract with the main component ailanthone was tested for herbicidal effects under field conditions. The results show that it was quite efficient against the weeds but also caused serious injuries to the crops. Thus, a weakness of ailanthone is its non-selectivity, but a positive feature lies in its ephemeral effects. Ailanthone is easily degradable by soil microorganisms [126,134]. It is necessary to note, however, that ailanthone is an acute toxic triterpene and should be used with caution [135].

3.5.2. Antifungal Activity

The antifungal activity test results are contradictory and depend on the extraction methods and reagents. The methanol and ethanol *A. altissima* leaves' extracts have fungicidal activity only against *Cladosporium cladosporioides* of all the tested nine species belonging to *Fusarium*, *Penicillium*, *Aspergillus*, and *Giberella*—the toxic microfungi found in cereals used for livestock and human food. However, this activity is weaker compared to the *Juglans regia* leaves' extracts [136]. Ethanol, methanol, and aqueous extracts of *A. altissima* were tested against *Ceratocystis manginecans* (the causal agent of Mango Sudden Death) using a poisoned food technique and the treatments result in thin, collapsed/damaged hyphae compared to the control. Phytochemical profiling of the most effective extracts revealed that 9-octadecanoic acid and I-(+)- ascorbic acid 2, 6-hexadecanoate possibly contribute to the antifungal effect [137]. Both acetone and methanol from the leaves' extracts have activity against *Candida albicans*, which is higher than amphotericin B, a gold standard in antifungal therapy [87]. Although *C. albicans* is not a crop pathogen, the result shows that further antifungal activity is worth testing. The chloroform extract of *Ailanthus excelsa* stem bark shows fungistatic and fungicidal activity against *Aspergillus niger*, *A. fumigatus*, *Penicillium frequentence*, *P. notatum*, and *Botrytis cinerea* [138]. It is the quassinoids that have been found to have inhibitory activities against plant fungal pathogens [139].

3.5.3. Fumigant and Insect Repellent Activity

Essential Oil Fumigant and Insect Repellent Activity

The essential oil of *A. altissima* bark has a fumigant activity against some pest beetles. One possible application of *A. altissima* bark essential oil is for killing insects that damage stored foods or seeds, as it causes 99.3 and 81.9% mortality to *Oryzaephilus surinamensis* (Linnaeus) (Coleoptera: Silvanidae) and *Sitophilus oryzae* (Linnaeus) (Coleoptera: Curculionidae) with within 24 h, respectively [80,140,141]. In addition, Lü and his co-workers revealed that despite its weak fumigant activity against *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae) and *Liposcelis paeta* Pearman (Psocoptera: Liposcelididae) adults, it notably repels *T. castaneum* adults and *L. paeta* nymphaea [80,140,141]. Additionally, *A. altissima* bark oil possesses high fumigant activity against *Lasioderma serricorne* (Fabricius 1792) (Coleoptera: Anobiidae) adults with a mortality of 100% at 8 μL/L air within 48 h of exposure; thus, it is obviously a strong repellent of these pests [142]. (Z)-3-hexen-l-ol, which is one of the main components of the essential oil extracted from *A. altissima* stems [97], is known as a key herbivore-induced plant volatile. There is no doubting its role as an indirect defense and this compound is a good candidate for novel insect pest control strategies [143]. Additionally, caryophyllene and caryophyllene oxide, which are the main constituents of the essential oil of *A. altissima* leaves and samara [97], are attractive to green lacewings [144]. Green lacewing larvae are predators of many soft-bodied insect pests such as: aphids, thrips, whiteflies, leafhoppers, spider mites (especially red mites), and mealybugs, and consequently they participate in biological control [145]. Caryophyllene and caryophyllene oxide stimulate oviposition in green lacewings, which leads to increased larval predation against pest insects [144]. *A. altissima* contains compounds with strong acaricidal activity against the parasitic mites that cause skin disease, namely, *Psoroptes cuniculi* and *Sarcoptes scabiei* var. *cuniculi* [146]. It was also found to have activity towards nematodes of the *Meloidogyne* genus [147].

Polar Extracts' Fumigant and Insect-Repellent Activity

The methanol extracts of *A. altissima* fresh leaves are practically non-toxic to the mosquito *Aedes aegypti* larvae [117] and the leaves are even used for feeding silkworms [148]. However, the methanolic extract of *A. altissima* leaves causes the malformation and mortality of the larvae of the moth *Agrotis ipsilon*, (Lepidoptera: Noctuidae), which are known to cause considerable damage to crops by severing young plants at the ground level. Aqueus extracts of *A. altissima* leaves have oviposition-deterrence effects against *Spodoptera frugiperda* (Smith) (Noctuidae), causing delays in the time to pupation and emergence in addition to reduced larval and pupal biomasses [149,150]. This moth is considered a noxious pest because the larvae cause massive damage to various crops; consequently, insecticide sprays are employed against it [151]. In addition, 0.5, 1, and 2% ethanol (70%) extracts of *A. altissima* bark and leaves have strong antifeeding activity against and significant insecticidal effects on gypsy moth (*Lymantria dispar* (L.)) larvae—insects known as voracious defoliating pests of deciduous trees.

The diethyl ether extract of *A. altissima* possesses an extremely strong repellent effect and to a certain extent a contact-killing effect on *Oryzaephilus surinamensis* (Linnaeus), the saw-toothed grain beetle [152]. The ethanol extract of *A. altissima* leaves possess strong acaricidal activity (97.4%) against the spider mite, *Tetranychus urticae* (Koch), a plant-feeding mite generally considered to be a pest [153]. The extract has no direct toxic effect on the pest but reduces its fertility about threefold and suppresses the development of larvae from eggs. The maximum efficiency of the extract was observed after 7–10 days when a filial generation of the spider mites started developing [154].

Quassinoids extracted both from leaves and roots have insecticidal, antifeedant, and insect-growth-regulatory activity, and ailanthone, in particular, was found to be efficient against the aphid *Acyrtosiphon pisum* [57]. There is a high mortality rate of aphids, pests of peas, when treated with ailanthone [155]. Methanol extracts or active substances such as ailanthone, chaparinone, glaucarubinone, and 13 (18)-dehydroglaucarubinone obtained from *A. altissima* leaves can be recommended for the development of new botanical insecticides targeted against the phytophagous larvae of *Spodoptera littoralis*, a moth referred to as the African cotton leafworm [156]. At the same time, quassinoids seems to be nontoxic for bees as they are found in propolis [57,134,157–160]. In addition, *A. altissima* bark-based hexane and methanol extracts do not possess any genotoxic, mutagenic, or carcinogenic effects on *Saccharomyces cerevisiae*, which was used as a test object to evaluate the potential harm to human health [161].

4. Conclusions

The essential oil and other extracts from *A. altissima* are quite promising as natural herbicides. Additionally, the essential oil and other tree-of-heaven compounds have potent fumigant activity. The essential oil and other extracts from *A. altissima*—as natural products—are biodegradable and possibly less harmful to human health and to pollinators. Of course, one should keep in mind that even natural products may have some toxicity; for instance, carvacrol and thymol aside from their efficacy cannot be considered completely safe. Even though the hexane and methanol extracts of *A. altissima* do not possess in vitro any genotoxic, mutagenic, or carcinogenic effects, further well-designed tests for both the pesticidal efficiency and toxicity in humans and pollinators of the essential oils and quassinoids obtained from this plant are required.

Ideally, effective extraction protocols for industrial yield should be developed so that both essential oils and quassinoids from *A. altissima* can be obtained as natural pesticides. They can help to reduce the use of synthetic pesticides and thereby their negative effects on wild pollinators and honeybees. Additionally, the intensified harvesting of this aggressive invasive plant species might contribute to decreasing their populations and reducing their destructive impact on natural habitats.

Author Contributions: Conceptualization, E.K. and A.P.; methodology, A.P. and E.K.; validation, A.P., I.I., Z.N., A.R.A.T. and E.K.; formal analysis, A.P., Z.N. and E.K.; investigation, E.K. and A.P.; writing—original draft preparation, E.K. and A.P.; writing, review, and editing, E.K., A.P., T.T. and A.R.A.T.; visualization, A.P. and E.K.; supervision, E.K. and I.I.; project administration, T.T.; funding acquisition, T.T. All authors have read and agreed to the published version of the manuscript.

Funding: This work has been carried out in the framework of the National Science Program "Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters", approved by the Resolution of the Council of Ministers № 577/17 August 2018 and supported by the Ministry of Education and Science (MES) of Bulgaria (Agreement № Д01-279/03 December 2021).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets used or analyzed in the current study are available from the corresponding author on reasonable request. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Weiss, B.; Amler, S.; Amler, R.W. Pesticides. *Pediatrics* **2004**, *113* (Suppl. 4), 1030–1036. [CrossRef] [PubMed]
2. The Editors of Encyclopaedia Britannica. "Pesticide". *Encyclopedia Britannica*, 28 July 2022. Available online: https://www.britannica.com/technology/pesticide (accessed on 8 August 2022).
3. Alavanja, M.C.; Bonner, M.R. Pesticides and human cancers. *Cancer Investig.* **2005**, *23*, 700–711. [CrossRef]
4. Costa, L.G.; Giordano, G.; Guizzetti, M.; Vitalone, A. Neurotoxicity of pesticides: A brief review. *Front. Biosci.* **2008**, *13*, 1240–1249. [CrossRef]
5. Damalas, C.A.; Eleftherohorinos, I.G. Pesticide exposure, safety issues, and risk assessment indicators. *Int. J. Environ. Res. Public Health* **2011**, *8*, 1402–1419. [CrossRef] [PubMed]
6. Suratman, S.; Edwards, J.W.; Babina, K. Organophosphate pesticides exposure among farmworkers: Pathways and risk of adverse health effects. *Rev. Environ. Health* **2015**, *30*, 65–79. [CrossRef]
7. Li, Z.; Jennings, A. Worldwide regulations of standard values of pesticides for human health risk control: A Review. *Int. J. Environ. Res. Public Health* **2017**, *14*, 826. [CrossRef]
8. Kim, K.H.; Kabir, E.; Jahan, S.A. Exposure to pesticides and the associated human health effects. *Sci. Total Environ.* **2017**, *1*, 525–535. [CrossRef]
9. Landrigan, P.J. Pesticides and Human Reproduction. *JAMA Intern. Med.* **2018**, *178*, 26–27. [CrossRef]

10. Adeyemi, J.A.; Ukwenya, V.O.; Arowolo, O.K.; Olise, C.C. Pesticides-induced Cardiovascular Dysfunctions: Prevalence and Associated Mechanisms. *Curr. Hypertens. Rev.* **2021**, *17*, 27–34. [CrossRef]
11. Needleman, H.L.; Gunnoe, C.; Leviton, A.; Reed, R.; Peresie, H.; Maher, C.; Barrett, P. Deficits in psychologic and classroom performance of children with elevated dentine lead levels. *N. Engl. J. Med.* **1979**, *300*, 689–695. [CrossRef]
12. FAO. Pollinators Vital to Our Food Supply under Threat. 2021. Available online: http://www.fao.org/news/story/en/item/384726/icode/ (accessed on 25 July 2021).
13. Biesmeijer, J.C.; Roberts, S.P.M.; Reemer, M.; Ohlemüller, R.; Edwards, M.; Peeters, T.; Schaffers, A.P.; Potts, S.G.; Kleukers, R.; Thomas, C.D.; et al. Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science* **2006**, *313*, 351–354. [CrossRef]
14. Brown, M.J.; Paxton, R.J. The conservation of bees: A global perspective. *Apidologie* **2009**, *40*, 410–416. [CrossRef]
15. Potts, S.; Biesmeijer, K.; Bommarco, R.; Breeze, T.; Carvalheiro, L.; Franzén, M.; González-Varo, J.P.; Holzschuh, A.; Kleijn, D.; Klein, A.-M.; et al. *Status and Trends of European Pollinators. Key Findings of the STEP Project*; Pensoft Publishers: Sofia, Bulgaria, 2015; p. 72.
16. Potts, S.G.; Biesmeijer, J.C.; Kremen, C.; Neumann, P.; Schweiger, O.; Kunin, W.E. Global pollinator declines: Trends, impacts and drivers. *Trends Ecol. Evol.* **2010**, *25*, 345–353. [CrossRef]
17. Carvalheiro, L.G.; Kunin, W.E.; Keil, P.; Aguirre-Gutiérrez, J.; Ellis, W.N.; Fox, R.; Biesmeijer, J.C. Species richness declines and biotic homogenisation have slowed down for NW-European pollinators and plants. *Ecol. Lett.* **2013**, *16*, 870–878. [CrossRef]
18. Ollerton, J.; Erenler, H.; Edwards, M.; Crockett, R. Extinctions of aculeate pollinators in Britain and the role of large-scale agricultural changes. *Science* **2014**, *346*, 1360–1362. [CrossRef]
19. Goulson, D.; Nicholls, E.; Botías, C.; Rotheray, E.L. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. *Science* **2015**, *347*, 1255957. [CrossRef]
20. Goulson, D.; Frey, H.; Tzinieris, S.; Callaghan, C.; Kerr, J. Call to restrict neonicotinoids. *Science* **2018**, *360*, 973. [CrossRef]
21. Wright, G.A.; Softley, S.; Earnshaw, H. Low doses of neonicotinoid pesticides in food rewards impair short-term olfactory memory in foraging-age honeybees. *Sci. Rep.* **2015**, *5*, 15322. [CrossRef]
22. Stanley, D.A.; Smith, K.E.; Raine, N.E. Bumblebee learning and memory is impaired by chronic exposure to a neonicotinoid pesticide. *Sci. Rep.* **2015**, *5*, 16508. [CrossRef]
23. Stanley, D.A.; Garratt, M.P.; Wickens, J.B.; Wickens, V.J.; Potts, S.G.; Raine, N.E. Neonicotinoid pesticide exposure impairs crop pollination services provided by bumblebees. *Nature* **2015**, *528*, 548–550. [CrossRef]
24. Woodcock, B.A.; Isaac, N.J.; Bullock, J.M.; Roy, D.B.; Garthwaite, D.G.; Crowe, A.; Pywell, R.F. Impacts of neonicotinoid use on long-term population changes in wild bees in England. *Nat. Commun.* **2016**, *7*, 12459. [CrossRef] [PubMed]
25. Sánchez-Bayo, F.; Goulson, D.; Pennacchio, F.; Nazzi, F.; Goka, K.; Desneux, N. Are bee diseases linked to pesticides?—A brief review. *Environ. Int.* **2016**, *89*, 7–11. [CrossRef] [PubMed]
26. Ramos-Jiliberto, R.; de Espanés, P.M.; Vázquez, D.P. Pollinator declines and the stability of plant–pollinator networks. *Ecosphere* **2020**, *11*, e03069. [CrossRef]
27. Althaus, S.L.; Berenbaum, M.R.; Jordan, J.; Shalmon, D.A. No buzz for bees: Media coverage of pollinator decline. *Proc. Natl. Acad. Sci. USA* **2021**, *118*, e2002552117. [CrossRef]
28. Whitehorn, P.R.; O'connor, S.; Wackers, F.L.; Goulson, D. Neonicotinoid pesticide reduces bumble bee colony growth and queen production. *Science* **2012**, *336*, 351–352. [CrossRef]
29. Boily, M.; Sarrasin, B.; DeBlois, C.; Aras, P.; Chagnon, M. Acetylcholinesterase in honey bees (*Apis mellifera*) exposed to neonicotinoids, atrazine and glyphosate: Laboratory and field experiments. *Environ. Sci. Pollut. Res.* **2013**, *20*, 5603–5614. [CrossRef]
30. Goulson, D. An overview of the environmental risks posed by neonicotinoid insecticides. *J. Appl. Ecol.* **2013**, *50*, 977–987. [CrossRef]
31. Botías, C.; David, A.; Horwood, J.; Abdul-Sada, A.; Nicholls, E.; Hill, E.; Goulson, D. Neonicotinoid residues in wildflowers, a potential route of chronic exposure for bees. *Environ. Sci. Technol.* **2015**, *49*, 12731–12740. [CrossRef]
32. Main, A.R.; Hladik, M.L.; Webb, E.B.; Goyne, K.W.; Mengel, D. Beyond neonicotinoids–Wild pollinators are exposed to a range of pesticides while foraging in agroecosystems. *Sci. Total Environ.* **2020**, *742*, 140436. [CrossRef]
33. English, S.G.; Sandoval-Herrera, N.I.; Bishop, C.A.; Cartwright, M.; Maisonneuve, F.; Elliott, J.E.; Welch, K.C. Neonicotinoid pesticides exert metabolic effects on avian pollinators. *Sci. Rep.* **2021**, *11*, 2914. [CrossRef]
34. Chan, D.S.W.; Raine, N.E. Population decline in a ground-nesting solitary squash bee (*Eucera pruinosa*) following exposure to a neonicotinoid insecticide treated crop (*Cucurbita pepo*). *Sci. Rep.* **2021**, *11*, 4241. [CrossRef] [PubMed]
35. Bloom, E.H.; Wood, T.J.; Hung, K.L.J.; Ternest, J.J.; Ingwell, L.L.; Goodell, K.; Szendrei, Z. Synergism between local- and landscape-level pesticides reduces wild bee floral visitation in pollinator-dependent crops. *J. Appl. Ecol.* **2021**, *58*, 1187–1198. [CrossRef]
36. Aktar, M.W.; Sengupta, D.; Chowdhury, A. Impact of pesticides use in agriculture: Their benefits and hazards. *Interdiscip. Toxicol.* **2009**, *2*, 1–12. [CrossRef]
37. Abraham, J.; Benhotons, G.S.; Krampah, I.; Tagba, J.; Amissah, C.; Abraham, J.D. Commercially formulated glyphosate can kill non-target pollinator bees under laboratory conditions. *Entomol. Exp. Appl.* **2018**, *166*, 695–702. [CrossRef]

38. Vázquez, D.E.; Balbuena, M.S.; Chaves, F.; Gora, J.; Menzel, R.; Farina, W.M. Sleep in honey bees is affected by the herbicide glyphosate. *Sci. Rep.* **2020**, *10*, 10516. [CrossRef]
39. Vázquez, D.E.; Ilina, N.; Pagano, E.A.; Zavala, J.A.; Farina, W.M. Glyphosate affects the larval development of honey bees depending on the susceptibility of colonies. *PLoS ONE* **2018**, *13*, e0205074. [CrossRef]
40. Haas, J.; Nauen, R. Pesticide risk assessment at the molecular level using honey bee cytochrome P450 enzymes: A complementary approach. *Environ. Int.* **2021**, *147*, 106372. [CrossRef]
41. Battisti, L.; Potrich, M.; Sampaio, A.R.; de Castilhos Ghisi, N.; Costa-Maia, F.M.; Abati, R.; Sofia, S.H. Is glyphosate toxic to bees? A meta-analytical review. *Sci. Total Environ.* **2021**, *767*, 145397. [CrossRef]
42. Hipólito, J.; Coutinho, J.; Mahlmann, T.; Santana, T.B.R.; Magnusson, W.E. Legislation and pollination: Recommendations for policymakers and scientists. *Perspect. Ecol. Conserv.* **2021**, *19*, 1–9. [CrossRef]
43. Gemmill-Herren, B.; Garibaldi, L.A.; Kremen, C.; Ngo, H.T. Building effective policies to conserve pollinators: Translating knowledge into policy. *Curr. Opin. Insect. Sci.* **2021**, *46*, 64–71. [CrossRef]
44. Shaaya, E.; Ravid, U.; Paster, N.; Juven, B.; Zisman, U.; Pissarev, V. Fumigant toxicity of essential oils against four major stored-product insects. *J. Chem. Ecol.* **1991**, *17*, 499–504. [CrossRef]
45. Isman, M.B. Plant essential oils for pest and disease management. *J. Crop Prot.* **2000**, *19*, 603–608. [CrossRef]
46. Suthisut, D.; Fields, P.G.; Chandrapatya, A. Fumigant toxicity of essential oils from three Thai plants (Zingiberaceae) and their major compounds against *Sitophilus zeamais*, *Tribolium castaneum* and two parasitoids. *J. Stored Prod. Res.* **2011**, *47*, 222–230. [CrossRef]
47. Polatoğlu, K.; Karakoç, Ö.C.; Gören, N. Phytotoxic, DPPH scavenging, insecticidal activities and essential oil composition of *Achillea vermicularis*, *A. teretifolia* and proposed chemotypes of *A. biebersteinii* (Asteraceae). *Ind. Crops Prod.* **2013**, *51*, 35–45. [CrossRef]
48. de Elguea-Culebras, G.O.; Sánchez-Vioque, R.; Berruga, M.I.; Herraiz-Peñalver, D.; Santana-Méridas, O. Antifeedant effects of common terpenes from Mediterranean aromatic plants on *Leptinotarsa decemlineata*. *J. Plant Nutr. Soil Sci.* **2017**, *17*, 475–485. [CrossRef]
49. Dudai, N.; Poljakoff-Mayber, A.; Mayer, A.M.; Putievsky, E.; Lerner, H.R. Essential oils as allelochemicals and their potential use as bioherbicides. *J. Chem. Ecol.* **1999**, *25*, 1079–1089. [CrossRef]
50. Tworkoski, T. Herbicide effects of essential oils. *Weed Sci.* **2002**, *50*, 425–431. [CrossRef]
51. Angelini, L.G.; Carpanese, G.; Cioni, P.L.; Morelli, I.; Macchia, M.; Flamini, G. Essential oils from Mediterranean Lamiaceae as weed germination inhibitors. *J. Agric. Food Chem.* **2003**, *51*, 6158–6164. [CrossRef]
52. Kordali, S.; Cakir, A.; Ozer, H.; Cakmakci, R.; Kesdek, M.; Mete, E. Antifungal, phytotoxic and insecticidal properties of essential oil isolated from Turkish *Origanum acutidens* and its three components, carvacrol, thymol and p-cymene. *Bioresour. Technol.* **2008**, *99*, 8788–8795. [CrossRef]
53. Haig, T.J.; Haig, T.J.; Seal, A.N.; Pratley, J.E.; An, M.; Wu, H. Lavender as a source of novel plant compounds for the development of a natural herbicide. *J. Chem. Ecol.* **2009**, *35*, 1129–1136. [CrossRef]
54. Verdeguer, M.; Blázquez, M.A.; Boira, H. Phytotoxic effects of *Lantana camara*, *Eucalyptus camaldulensis* and *Eriocephalus africanus* essential oils in weeds of Mediterranean summer crops. *Biochem. Syst. Ecol.* **2009**, *37*, 362–369. [CrossRef]
55. De Almeida, L.F.R.; Frei, F.; Mancini, E.; De Martino, L.; De Feo, V. Phytotoxic activities of Mediterranean essential oils. *Molecules* **2010**, *15*, 4309–4323. [CrossRef]
56. Wright, C.; Chhetri, B.K.; Setzer, W.N. Chemical composition and phytotoxicity of the essential oil of *Encelia farinosa* growing in the Sonoran Desert. *Am. J. Essent. Oil. Nat. Prod.* **2013**, *1*, 18–22.
57. De Feo, V.; Mancini, E.; Voto, E.; Curini, M.; Digilio, M.C. Bioassay-oriented isolation of an insecticide from *Ailanthus altissima*. *J. Plant Interact.* **2009**, *4*, 119–123. [CrossRef]
58. He, C.; Wang, Y.; Yang, T.; Wang, H.; Liao, H.; Liang, D. Quassinoids with insecticidal activity against *diaphorina citri* kuwayama and neuroprotective activities from *Picrasma quassioides*. *J. Agric. Food Chem.* **2019**, *68*, 117–127. [CrossRef]
59. Fang, X.; Di, Y.T.; Zhang, Y.; Xu, Z.P.; Lu, Y.; Chen, Q.Q.; Zheng, Q.T.; Hao, X.J. Unprecedented quassinoids with promising biological activity from *Harrisonia perforata*. *Angew. Chem. Int. Ed.* **2015**, *54*, 5592–5595. [CrossRef]
60. Kowarik, I.; Säumel, I. Biological flora of central Europe: *Ailanthus altissima* (Mill.) swingle. *Perspect. Plant Ecol. Evol. Syst.* **2007**, *8*, 207–237. [CrossRef]
61. DAISIE. *Handbook of Alien Species in Europe*; Springer: Dordrecht, The Netherlands, 2009. [CrossRef]
62. Petrova, A.; Vladimirov, V.; Georgiev, V. *Invasive Alien Plant Species in Bulgaria*; Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences: Sofia, Bulgaria, 2012. (In Bulgarian)
63. Zahariev, D. Invasive plant species along the major rivers in Strandzha Natural Park. In Proceedings of the Seminar of Ecology—2014, Sofia, Bulgaria, 24–25 April 2014; pp. 148–158.
64. Monaco, A. *European Guidelines on Protected Areas and Invasive Alien Species*; Council of Europe: Rome, Italy, 2014.
65. 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]
66. Global Invasive Species Database. Species Profile: Ailanthus altissima. 2019. Available online: http://www.iucngisd.org/gisd/species.php?sc=319 (accessed on 25 July 2022).

67. Domina, G. Invasive Aliens in Italy: Enumeration, History, Biology and Their Impact. In *Invasive Alien Species: Observations and Issues from Around the World*; Pullaiah, T., Ielmini, M.R., Eds.; John Wiley & Sons Ltd.: Hoboken, NJ, USA, 2021; Volume 3, pp. 190–214. [CrossRef]
68. Demeter, A.; Saláta, D.; Tormáné Kovács, E.; Szirmai, O.; Trenyik, P.; Meinhardt, S.; Czóbel, S. Effects of the Invasive Tree Species *Ailanthus altissima* on the Floral Diversity and Soil Properties in the Pannonian Region. *Land* **2021**, *10*, 1155. [CrossRef]
69. Motti, R.; Zotti, M.; Bonanomi, G.; Cozzolino, A.; Stinca, A.; Migliozzi, A. Climatic and anthropogenic factors affect *Ailanthus altissima* invasion in a Mediterranean region. *Plant Ecol.* **2021**, *222*, 1347–1359. [CrossRef]
70. 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]
71. Pedersini, C.; Bergamin, M.; Aroulmoji, V.; Baldini, S.; Picchio, R.; Pesce, P.G.; Ballarin, L.; Murano, E. Herbicide Activity of Extracts from *Ailanthus altissima* (Simaroubaceae). *Nat. Prod. Commun.* **2011**, *6*, 593–596. [CrossRef]
72. Kubota, K.; Fukamiya, N.; Hamada, T.; Okano, M.; Tagahara, K.; Lee, K.H. Two new quassinoids, ailantinols A and B, and related compounds from *Ailanthus altissima*. *J. Nat. Prod.* **1996**, *59*, 683–686. [CrossRef]
73. Kubota, K.; Fukamiya, N.; Okano, M.; Tagahara, K.; Lee, K.H. Two new quassinoids, ailantinols C and D, from *Ailanthus altissima*. *Bull. Chem. Soc. Jpn.* **1996**, *69*, 3613–3617. [CrossRef]
74. Tamura, S.; Fukamiya, N.; Okano, M.; Koyama, J.; Koike, K.; Tokuda, H.; Nishino, H. Three new quassinoids, ailantinol E, F, and G, from *Ailanthus altissima*. *Chem. Pharm. Bull.* **2003**, *51*, 385–389. [CrossRef]
75. Takeya, K.; Kobata, H.; Ozeki, A.; Morita, H.; Itokawa, H. A new quassinoid from *Ailanthus vilmoriniana*. *J. Nat. Prod.* **1997**, *60*, 642–644. [CrossRef]
76. Joshi, B.C.; Pandey, A.; Sharma, R.P.; Khare, A. Quassinoids from *Ailanthus excelsa*. *Phytochemistry* **2003**, *62*, 579–584. [CrossRef]
77. Manimaran, V.; Suganthy, M.; Balasubramanian, A.; Kumar, P.P. Management of tea mosquito bug, *Helopeltis antonii* Signoret infesting *Ailanthus excelsa* Roxb. *J. Entomol. Zool. Stud.* **2019**, *7*, 620–623.
78. Karalija, E.; Dahija, S.; Parić, A.; Zeljković, S.Ć. Phytotoxic potential of selected essential oils against *Ailanthus altissima* (Mill.) Swingle, an invasive tree. *Sust. Chem. Pharm.* **2020**, *15*, 100219. [CrossRef]
79. Li, X.; Li, Y.; Ma, S.; Zhao, Q.; Wu, J.; Duan, L.; Wang, S. Traditional uses, phytochemistry, and pharmacology of *Ailanthus altissima* (Mill.) Swingle bark: A comprehensive review. *J. Ethnopharmacol.* **2021**, *275*, 114121. [CrossRef]
80. Lü, J.H.; He, Y.Q. Fumigant toxicity of *Ailanthus altissima* Swingle, *Atractylodes lancea* (Thunb.) DC. and *Elsholtzia stauntonii* Benth extracts on three major stored-grain insects. *Ind. Crops Prod.* **2010**, *32*, 681–683. [CrossRef]
81. Ohmoto, T.; Koike, K.; Sakamoto, Y. Studies on the constituents of *A. altissima* Swingle II. The alkaloid constituent. *Chem. Pharm. Bull.* **1981**, *29*, 390–395. [CrossRef]
82. Ohmoto, T.; Koike, K. Studies on the constituents of *A. altissima* Swingle III. The alkaloid constituents. *Chem. Pharm. Bull.* **1984**, *32*, 170–173. [CrossRef]
83. Mastelić, J.; Jerković, I. Volatile Constituents from the Leaves of Young and Old *Ailanthus altissima* (Mili.) Swingle Tree. *Croat. Chem. Acta* **2002**, *75*, 189–197.
84. Kozuharova, E.; Lebanova, H.; Getov, I.; Benbassat, N.; Kochmarov, V. *Ailanthus altissima* (Mill.) Swingle—A terrible invasive pest in Bulgaria or potential useful medicinal plant? *Bothalia* **2014**, *44*, 213–230.
85. Zhelev, I.; Georgiev, K.; Dimitrova-Dyulgerova, I. Carotenoid profile of *Ailanthus altissima* stem bark, in-vitro antioxidant and antineoplastic activities. *World J. Pharm. Res.* **2016**, *5*, 1816.
86. Cho, S.K.; Jeong, M.; Jang, D.S.; Choi, J.H. Anti-inflammatory Effects of Canthin-6-one Alkaloids from *Ailanthus altissima*. *Planta Med.* **2018**, *50*, 527–535. [CrossRef]
87. Poljuha, D.; Sladonja, B.; Šola, I.; Dudaš, S.; Bilić, J.; Rusak, G.; Eloff, J.N. Phenolic composition of leaf extracts of *Ailanthus altissima* (Simaroubaceae) with antibacterial and antifungal activity equivalent to standard antibiotics. *Nat. Prod. Commun.* **2017**, *12*, 1934578X1701201021. [CrossRef]
88. Du, Y.Q.; Yan, Z.Y.; Shi, S.C.; Hou, Z.L.; Huang, X.X.; Song, S.J. Benzoic acid derivatives from the root barks of *Ailanthus altissima*. *J. Asian Nat. Prod. Res.* **2021**, *23*, 103–109. [CrossRef]
89. Du, Y.Q.; Yan, Z.Y.; Chen, J.J.; Wang, X.B.; Huang, X.X.; Song, S.J. The identification of phenylpropanoids isolated from the root bark of *Ailanthus altissima* (Mill.) Swingle. *Nat. Prod. Res.* **2021**, *35*, 1139–1146. [CrossRef]
90. Du, Y.Q.; Bai, M.; Yu, X.Q.; Lv, T.M.; Lin, B.; Huang, X.X.; Song, S.J. Quassinoids from the Root Barks of *Ailanthus altissima*: Isolation, Configurational Assignment, and Cytotoxic Activities. *Chin. J. Chem.* **2021**, *39*, 879–886. [CrossRef]
91. Wang, C.M.; Li, H.F.; Wang, X.K.; Li, W.G.; Su, Q.; Xiao, X.; Zhang, C.H. *Ailanthus altissima*-derived ailanthone enhances gastric cancer cell apoptosis by inducing the repression of base excision repair by downregulating p23 Expression. *Int. J. Biol. Sci.* **2021**, *17*, 2811. [CrossRef] [PubMed]
92. Duan, Z.K.; Lin, B.; Du, Y.Q.; Li, C.; Yu, X.Q.; Xue, X.B.; Huang, X.X. Monoterpenoid coumarins and monoterpenoid phenylpropanoids from the root bark of *Ailanthus altissima*. *New J. Chem.* **2021**, *45*, 1100–1108. [CrossRef]
93. Caramelo, D.; Pedro, S.I.; Marques, H.; Simão, A.Y.; Rosado, T.; Barroca, C.; Gallardo, E. Insights into the Bioactivities and Chemical Analysis of *Ailanthus altissima* (Mill.) Swingle. *Appl. Sci.* **2021**, *11*, 11331. [CrossRef]
94. Bray, D.H.; Boardman, P.; ONeill, M.J.; Chan, K.L.; Phillipson, J.D.; Warhurst, D.C.; Suffness, M. Plants as a source of antimalarial drugs 5. Activities of *Ailanthus altissima* stem constituents and of some related quassinoids. *Phytother. Res.* **1987**, *1*, 22–24. [CrossRef]

95. Okunade, A.L.; Bikoff, R.E.; Casper, S.J.; Oksman, A.; Goldberg, D.E.; Lewis, W.H. Antiplasmodial activity of extracts and quassinoids isolated from seedlings of *Ailanthus altissima* (Simaroubaceae). *Phytother. Res.* **2003**, *17*, 675–677. [CrossRef]
96. Li, Y.; Zhao, M.; Zhang, Z. Quantitative proteomics reveals the antifungal effect of canthin-6-one isolated from *Ailanthus altissima* against *Fusarium oxysporum* f. sp. cucumerinum in vitro. *PLoS ONE* **2021**, *16*, e0250712. [CrossRef]
97. Albouchi, F.; Hassen, I.; Casabianca, H.; Hosni, K. Phytochemicals, antioxidant, antimicrobial and phytotoxic activities of *Ailanthus altissima* (Mill.) Swingle leaves. *S. Afr. J. Bot.* **2013**, *87*, 164–174. [CrossRef]
98. El Ayeb-Zakhama, A.; Ben Salem, S.; Sakka-Rouis, L.; Flamini, G.; Ben Jannet, H.; Harzallah-Skhiri, F. Chemical Composition and phytotoxic effects of essential oils obtained from *Ailanthus altissima* (Mill.) Swingle cultivated in Tunisia. *Chem. Biodivers.* **2014**, *11*, 1216–1227. [CrossRef]
99. Kozuharova, E.; Benbassat, N.; Berkov, S.; Ionkova, I. *Ailanthus altissima* and *Amorpha fruticosa*—Invasive arboreal alien plants as cheap sources of valuable essential oils. *Pharmacia* **2020**, *67*, 71. [CrossRef]
100. Lü, J.; Wu, S. Bioactivity of essential oil from *Ailanthus altissima* bark against 4 major stored-grain insects. *Afr. J. Microbiol. Res.* **2010**, *4*, 154–157. [CrossRef]
101. Zhou, L.; Wang, J.; Wang, K.; Xu, J.; Zhao, J.; Shan, T.; Luo, C. Secondary metabolites with antinematodal activity from higher plants. In *Studies in Natural Products Chemistry*; Elsevier: Amsterdam, The Netherlands, 2012; Volume 37, pp. 67–114. [CrossRef]
102. He, Q.; Xiao, H.; Li, J.; Liu, Y.; Jia, M.; Wang, F.; Zhang, Y.; Wang, W.; Wang, S. Fingerprint analysis and pharmacological evaluation of *Ailanthus altissima*. *Int. J. Mol. Med.* **2018**, *41*, 3024–3032. [CrossRef] [PubMed]
103. Wang, R.X.; Mao, X.X.; Zhou, J.; Zhang, M.L.; Wu, Y.B.; Huo, C.H.; Gu, Y.C. Antitumor activities of six quassinoids from *Ailanthus altissima*. *Chem. Nat. Compd.* **2017**, *53*, 28–32. [CrossRef]
104. Wang, Y.; Wang, W.J.; Su, C.; Zhang, D.M.; Xu, L.P.; He, R.R.; Ye, W.C. Cytotoxic quassinoids from *Ailanthus altissima*. *Bioorg. Med. Chem. Lett.* **2013**, *23*, 654–657. [CrossRef]
105. Naora, H.; Ishibashi, M.; Furuno, T.; Tsuyuki, T.; Murae, T.; Hirota, H.; Takahashi, T.; Itai, A.; Iitaka, Y. Structure determination of bitter principles in *Ailanthus altissima*. Structure of shinjulactone A and revised structure of ailanthone. *Bull. Chem. Soc. Jpn.* **1983**, *56*, 3694–3698. [CrossRef]
106. Tamura, S.; Fukamiya, N.; Okano, M.; Koike, K. A new quassinoid, ailantinol H from *Ailanthus altissima*. *Nat. Prod. Res.* **2006**, *20*, 1105–1109. [CrossRef]
107. Ishibashi, M.; Tsuyuki, T.; Murae, T.; Hirota, H.; Takahashi, T.; Itai, A.; Iitaka, Y. Constituents of the Root Bark of *Ailanthus altissima* S WINGLE. Isolation and X-Ray Crystal Structures of Shinjudilactone and Shinjulactone C and Conversion of Ailanthone into Shinjudilactone. *Bull. Chem. Soc. Jpn.* **1983**, *56*, 3683–3693. [CrossRef]
108. Yoshimura, S.; Ishibashi, M.; Tsuyuki, T.; Takahashi, T.; Matsushita, K. Constituents of seeds of *Ailanthus altissima* Swingle. Isolation and structures of shinjuglycosides A, B, C, and D. *Bull. Chem. Soc. Jpn.* **1984**, *57*, 2496–2501. [CrossRef]
109. Niimi, Y.; Tsuyuki, T.; Takahashi, T.; Matsushita, K. Bitter principles of *Ailanthus altissima* Swingle. Structure determination of shinjuglycosides E and F. *Chem. Pharm. Bull.* **1987**, *35*, 4302–4306. [CrossRef]
110. Furuno, T.; Ishibashi, M.; Naora, H.; Murae, T.; Hirota, H.; Tsuyuki, T.; Iitaka, Y. Structure determination of bitter principles of *Ailanthus altissima*. Structures of shinjulactones B, D, and E. *Bull. Chem. Soc. Jpn.* **1984**, *57*, 2484–2489. [CrossRef]
111. Ishibashi, M.; Yoshimura, S.; Tsuyuki, T.; Takahashi, T.; Itai, A.; Iitaka, Y. Structure determination of bitter principles of *Ailanthus altissima*. Structures of shinjulactones F, I, J, and K. *Bull. Chem. Soc. Jpn.* **1984**, *57*, 2885–2892. [CrossRef]
112. Ishibashi, M.; Yoshimura, S.; Tsuyuki, T.; Takahashi, T.; Matsushita, K. Shinjulactones G and H, new bitter principles of *Ailanthus altissima* Swingle. *Bull. Chem. Soc. Jpn.* **1984**, *57*, 2013–2014. [CrossRef]
113. Ishibashi, M.; Tsuyuki, T.; Takahashi, T. Structure determination of a new bitter principle, shinjulactone L, from *Ailanthus altissima*. *Bull. Chem. Soc. Jpn.* **1985**, *58*, 2723–2724. [CrossRef]
114. Niimi, Y.; Tsuyuki, T.; Takahashi, T.; Matsushita, K. Structure determination of shinjulactones M and N, new bitter principles from *Ailanthus altissima* Swingle. *Bull. Chem. Soc. Jpn.* **1986**, *59*, 1638–1640. [CrossRef]
115. Yang, X.L.; Yuan, Y.L.; Zhang, D.M.; Li, F.; Ye, W.C. Shinjulactone O, a new quassinoid from the root bark of *Ailanthus altissima*. *Nat. Prod. Res.* **2014**, *28*, 1432–1437. [CrossRef]
116. Tan, Q.W.; Ni, J.C.; Zheng, L.P.; Fang, P.H.; Shi, J.T.; Chen, Q.J. Anti-Tobacco mosaic virus quassinoids from *Ailanthus altissima* (Mill.) Swingle. *J. Agric. Food Chem.* **2018**, *66*, 7347–7357. [CrossRef]
117. Tsao, R.; Romanchuk, F.E.; Peterson, C.J.; Coats, J.R. Plant growth regulatory effect and insecticidal activity of extracts of tree of Heaven (*Ailanthus altissima* L.). *BMC Ecol.* **2002**, *2*, 1. Available online: https://bmcecol.biomedcentral.com/articles/10.1186/1472-6785-2-1 (accessed on 25 July 2022).
118. Quintana, N.; El Kassis, E.G.; Stermitz, F.R.; Vivanco, J.M. Phytotoxic compounds from roots of *Centaurea diffusa* Lam. *Plant Signal. Behav.* **2009**, *4*, 9–14. [CrossRef]
119. De Martino, L.; Formisano, C.; Mancini, E.; Feo, V.D.; Piozzi, F.; Rigano, D.; Senatore, F. Chemical composition and phytotoxic effects of essential oils from four Teucrium species. *Nat. Prod. Commun.* **2010**, *5*, 1969–1976. [CrossRef]
120. Szabó, L. Juglone index—A possibility for expressing allelopathic potential of plant taxa with various life strategies. *Acta Bot. Hung.* **1999**, *42*, 295–305.
121. Csiszár, Á. Allelopathic effects of invasive woody plant species in Hungary. *Acta Silv. Lignaria Hung.* **2009**, *5*, 9–17. Available online: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1066.4899&rep=rep1&type=pdf (accessed on 25 July 2022).

122. Csiszár, Á.; Korda, M.; Schmidt, D.; Šporčić, D.; Süle, P.; Teleki, B.; Tiborcz, V.; Zagyvai, G.; Bartha, D. Allelopathic potential of some invasive plant species occurring in Hungary. *Allelopath. J.* **2013**, *31*, 309–318.
123. Novak, N.; Novak, M.; Barić, K.; Šćepanović, M.; Ivić, D. Allelopathic potential of segetal and ruderal invasive alien plants. *J. Cent. Eur. Agric.* **2018**, *19*, 408–422. [CrossRef]
124. Heisy, R. Allelopathic and herbicidal effects of extracts from tree of heaven (*Ailanthus altissima*). *Am. J. Bot.* **1990**, *77*, 662–670. [CrossRef]
125. Bostan, C.; Borlea, F.; Mihoc, C.; Selesan, M. *Ailanthus altissima* species invasion on biodiversity caused by potential allelopathy. *J. Agric. Sci.* **2014**, *46*, 95–103. Available online: http://cormoran.portiledefier.ro/wp-content/uploads/2013/02/bostan_cristian_1.pdf (accessed on 25 July 2022).
126. Sladonja, B.; Pohulja, D.; Sušek, M.; Dudaš, S. Herbicidal effect of *Ailanthus altissima* leaves water extracts on *Medicago sativa* seeds germination. In *Book of Abstracts of the 3rd Conference with International Participation Conference VIVUS*; Biotechnical Centre Naklo: Naklo, Slovenia, 2014; pp. 476–481. Available online: http://civ.iptpo.hr/wp-content/uploads/publikacije/Znanstveni%20rad%20u%20zborniku%20skupa_VIVUS_2014.pdf (accessed on 25 July 2022).
127. 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]
128. Casinovi, C.G.; Ceccherelli, P.; Fardella, G.; Grandolini, G. Isolation and structure of a quassinoid from *Ailanthus glandulosa*. *Phytochemistry* **1983**, *22*, 2871–2873. [CrossRef]
129. Lin, L.-J.; Peiser, G.; Ying, B.-P.; Mathias, K.; Karasina, F.; Wang, Z.; Itatani, J.; Green, L.; Hwang, Y.-S. Identification of plant growth inhibitory principles in *Ailanthus altissima* and *Castela tortuosa*. *J. Agric. Food Chem.* **1995**, *43*, 1706–1711. [CrossRef]
130. De Feo, V.; De Martino, L.; Quaranta, E.; Pizza, C. Isolation of phytotoxic compounds from tree-of-heaven (*Ailanthus altissima* Swingle). *J. Agric. Food Chem.* **2003**, *51*, 1177–1180. [CrossRef]
131. De Feo, V.; Martino, L.D.; Santoro, A.; Leone, A.; Pizza, C.; Franceschelli, S.; Pascale, M. Antiproliferative effects of tree-of-heaven (*Ailanthus altissima* Swingle). *Phytother. Res.* **2005**, *19*, 226–230. [CrossRef]
132. Lebedev, V.G.; Krutovsky, K.V.; Shestibratov, K.A. Fell Upas Sits, the Hydra-Tree of Death†, or the Phytotoxicity of Trees. *Molecules* **2019**, *24*, 1636. [CrossRef] [PubMed]
133. Borchardt, J.R.; Wyse, D.L.; Sheaffer, C.C.; Kauppi, K.L.; Fulcher, R.G.; Ehlke, N.J.; Biesboer, D.D.; Bey, R.F. Antimicrobial activity of native and naturalized plants of Minnesota and Wisconsin. *J. Med. Plant Res.* **2008**, *2*, 98–110. [CrossRef]
134. Heisey, R.M.; Heisey, T.K. Herbicidal effects under field conditions of *Ailanthus altissima* bark extract, which contains ailanthone. *Plant Soil* **2003**, *256*, 85–99. [CrossRef]
135. Anonymous. National Center for Biotechnology Information. PubChem Database. Ailanthone, CID=72965; 2019. Available online: https://pubchem.ncbi.nlm.nih.gov/compound/Ailanthone (accessed on 1 January 2022).
136. Balkan, B.; Balkan, S.; Aydoğdu, H.; Özcan, Ö. Antifungal activities of *Ailanthus altissima* Swingle and *Juglans regia* L. leaves against some cereal fungi. *J. Appl. Environ. Biol. Sci.* **2014**, *8*, 76–79.
137. Jabeen, K.; Asad, S.; Zakria, M. Antifungal Evaluation and Phytochemical Identification of Selected Botanicals against *Ceratocystis manginecans* Causing Mango Sudden Death. *J. Plant Pathol. Microbiol.* **2018**, *9*, 465. [CrossRef]
138. Joshi, B.C.; Pandey, A.; Chaurasia, L.; Pal, M.; Sharma, R.P.; Khare, A. Antifungal activity of the stem bark of *Ailanthus excelsa*. *Fitoterapia* **2003**, *74*, 689–691. [CrossRef]
139. Chen, J.J.; Bai, W.; Lu, Y.B.; Feng, Z.Y.; Gao, K.; Yue, J.M. Quassinoids with Inhibitory Activities against Plant Fungal Pathogens from *Picrasma javanica*. *J. Nat. Prod.* **2021**, *84*, 2111–2120. [CrossRef]
140. Lü, J. The insecticidal activities of *Ailanthus altissima* extracts on several kinds of important stored-grain insects. *Grain Storage* **2007**, *36*, 17–20.
141. Lü, J.H.; Lu, Y.J.; Hu, Y.Y. Controlling effects of three plant essential oils on *Liposcelis paeta*. *J. Henan Agric. Sci.* **2006**, *5*, 18.
142. Lü, J.H.; Shi, Y.L. The bioactivitiy of essential oil from *Ailanthus altissima* Swingle (Sapindales: Simaroubaceae) bark on *Lasioderma serricorne* (Fabricius) (Coleoptera: Anobiidae). *Adv. Mater. Res.* **2012**, *365*, 428–432. [CrossRef]
143. Wei, J.; Kang, L. Roles of (Z)-3-hexenol in plant-insect interactions. *Plant Signal. Behav.* **2011**, *6*, 369–371. [CrossRef] [PubMed]
144. Flint, H.M.; Salter, S.S.; Walters, S. Caryophyllene: An attractant for the green lacewing. *Environ. Entomol.* **1979**, *8*, 1123–1125. [CrossRef]
145. Goulson, D. *The Garden Jungle: Or Gardening to Save the Planet*; Random House: New York, NY, USA, 2019; p. 261.
146. Gu, X.; Fang, C.; Yang, G.; Xie, Y.; Nong, X.; Zhu, J.; Wang, S.; Peng, X.; Yan, Q. Acaricidal properties of an *Ailanthus altissima* bark extract against *Psoroptes cuniculi* and *Sarcoptes scabiei* var. cuniculi in vitro. *Exp. Appl. Acarol.* **2014**, *62*, 225–232. [CrossRef]
147. Caboni, P.; Ntalli, N.G.; Aissani, N.; Cavoski, I.; Angioni, A. Nematicidal activity of (E, E)-2, 4-decadienal and (E)-2-decenal from *Ailanthus altissima* against Meloidogyne javanica. *J. Agric. Food Chem.* **2012**, *60*, 1146–1151. [CrossRef] [PubMed]
148. Lucchetti, L.; Zitti, S.; Taffetani, F. Ethnobotanical uses in the Ancona district (Marche region, Central Italy). *J. Ethnobiol. Ethnomed.* **2019**, *15*, 9. [CrossRef]
149. Wagner, R.L.; Card, J.A. *Ailanthus altissima* aqueous extract deters *Spodoptera frugiperda* oviposition. *Gt. Lakes Entomol.* **2020**, *53*, 11. Available online: https://scholar.valpo.edu/tgle/vol53/iss1/11 (accessed on 25 July 2022).
150. Wagner, L.R.; Leach, E.M.; Wallace, J.R. Leaf Extract from *Ailanthus altissima* negatively impacts life history aspects in *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *J. Kansas Entomol. Soc.* **2021**, *93*, 140–152. [CrossRef]

151. Souza, J.R.; Carvalho, G.A.; Moura, A.P.; Couto, M.H.; Maia, J.B. Impact of insecticides used to control *Spodoptera frugiperda* (JE Smith) in corn on survival, sex ratio, and reproduction of *Trichogramma pretiosum* Riley offspring. *Chil. J. Agric. Res.* **2013**, *73*, 122–127. [CrossRef]
152. Lu, J.-H.L.; Lu, Y.J.; Tan, Y.B.; Liu, J.J.; Zhong, J.F. The controlling effects of plant extracts on *Oryzaephilus surinamensis* (Linnaeus). *J. Henan Uni. Tech.* **2006**, *3*, 17–20.
153. Chermenskaya, T.D.; Stepanycheva, E.A.; Shchenikova, A.V.; Chakaeva, A.S. Insectoacaricidal and deterrent activities of extracts of Kyrgyzstan plants against three agricultural pests. *Ind. Crops Prod.* **2010**, *32*, 157–163. [CrossRef]
154. Stepanycheva, E.A.; Chermenskya, T.D.; Chakaeva, A.S. Effect of biologically active substances of *Ailanthus altissima* Mill. Swingle)(Simarubaceae) on spider mite *Tetranychus urticae* Koch (Akari: Tetranychidae). *Agric. Chem.* **2011**, *4*, 52–59. (In Russian)
155. Polonsky, J.; Bhatnagar, S.C.; Griffiths, D.C.; Pickett, J.A.; Woodcock, C.M. Activity of quassinoids as antifeedants against aphids. *J. Chem. Ecol.* **1989**, *15*, 993–998. [CrossRef]
156. Pavela, R.; Zabka, M.; Tylova, T.; Kresinova, Z. Insecticidal activity of compounds from *Ailanthus altissima* against *Spodoptera littoralis* larvae. *Pak. J. Agric. Sci.* **2014**, *51*, 101–112. Available online: https://pakjas.com.pk/papers/2248.pdf (accessed on 25 July 2022).
157. Fokt, H.; Pereira, A.; Ferreira, A.M.; Cunha, A.; Aguiar, C. How do bees prevent hive infections? The antimicrobial properties of propolis. *Curr. Res. Technol. Educ. Top. Appl. Microbiol. Microb. Biotechnol.* **2010**, *1*, 481–493.
158. Connolly, J.D.; Hill, R.A. Triterpenoids. *Nat. Prod. Rep.* **2011**, *28*, 1087–1117. [CrossRef]
159. Slave, J. Effects of Calcium hydroxide and Quassia extract on Honey bees (*Apis mellifera*). In Proceedings of the 18th International Conference on Organic Fruit-Growing, Hohenheim, Germany, 19–21 February 2018; Foerdergemeinschaft Oekologischer Obstbau e.V. (FOEKO): Weinsberg, Germany, 2018; pp. 247–248.
160. Yang, K.; Wen, X.; Ren, Y.; Wen, J. Control of *Eucryptorrhynchus scrobiculatus* (Coleoptera: Cuculionidae), a major pest of *Ailanthus altissima* (Sapindales: Simaroubaceae), using a modified square trap net. *J. Econ. Entomol.* **2018**, *111*, 1760–1767. [CrossRef]
161. Todorova, T.; Boyadzhiev, K.; Shkondrov, A.; Parvanova, P.; Dimitrova, M.; Ionkova, I.; Kozuharova, E.; Chankova, S. Screening of *Amorpha fruticosa* and *Ailanthus altissima* extracts for genotoxicity/antigenotoxicity, mutagenicity/antimutagenicity and carcinogenicity/anticarcinogenicity. *BioRisk* **2022**, *17*, 201–212. [CrossRef]