

IMPACT OF INVASIVE PLANT SPECIES ON ECOSYSTEMS, BIODIVERSITY LOSS AND THEIR POTENTIAL INDUSTRIAL APPLICATIONS

Maria Denisa Cocîrlea ¹, Simona Oancea ^{2,*}

^{1,2}Department of Agricultural Sciences and Food Engineering, Lucian Blaga University of Sibiu, Dr.
I. Ratiu Street, no. 7-9, 550012 Sibiu, Romania



Abstract

Invasive plant species may cause not only several health problems, but also economic and environmental negative impacts – a gradual decrease of biodiversity and decline of soil fertility, issues that have recently come into the attention of several organizations including the research ones, in order to limit the spread of such species. The control methods of invasive species are often effective on the short term and include the probability of ecosystem imbalance over time, so that an efficient and sustainable management method that could add value to products or improve some industrial processes are strongly required. This study describes the potential of alien plants to maintain the quality of human life through different types of valorization, such as pharmaceutical, agriculture or food industry applications, energy production, paper technology and natural dyeing of various materials. Invasive plant species represent a global problem, accelerated by the current level of pollution and the rapidly-evolving society. Knowledge of chemical composition of different plant parts of invasive species, their potential for developing new products and their health effects will contribute to an efficient control, mechanical, chemical or biological, and an integrated management.

Keywords: environmental stability, invasive species, life quality, products, sustainability.

1. INTRODUCTION

Invasive species causes serious economic problems (Adelino et al., 2021, Shahrtash and Brown, 2021, Starešinič et al., 2021) and imbalances in the ecosystems where these settle in (Starešinič et al., 2021), even in protected areas (Pathak et al., 2021, Bakacsy and Bagi, 2020) where a low number of classical control methods can be implemented (Ngondya et al., 2019). Unfortunately, most of the time interest is given to covering losses incurred, not to preventing them (Adelino et al., 2021).

These species can accidentally enter a new area (Montagnani et al., 2022) due to intensive tourism (Renault et al., 2021) or numerous roadsides (Gusev, 2019). Horticultural species spread easily with the help of birds and wind (Celesti-Grapow and Ricotta, 2021). Duan et al. (2022) supported the idea that the potential of an alien species to become invasive is influenced by the structure of the ecosystem or by the relations they alter between native species. In turn, invasive species change the way ecosystems look (Bagrikova and Skurlatova, 2021). Moreover, Guarino et al. (2021) claim that the degree of invasion that a habitat has, does not influence the number of alien species present there. Notwithstanding, the wood characteristics of an alien species can be influenced by the region

in which individuals grow, according to Bardak et al. (2017). Zhou et al. (2021) observed that foreign species which have more efficient methods of dispersal are more resistant to drastic environmental conditions. Thus, the success of *Ambrosia artemisiifolia* is maintained by its impressive number of seeds (Gusev, 2019). Even so, in different habitat types, the invasiveness of alien species is different (Wagner et al. 2021). Some invasive species are even sensitive to some habitat factors. For example, high humidity and low light levels may limit the spread of *A. artemisiifolia* (Gusev, 2019). Other advantages they have over the native species are possibly longer flowering period (Guarino et al., 2021),

Several authors have supported the idea of reducing the impact of these species by involving their biomass in various applications (Kozuharova et al., 2020, Kavčič et al., 2020, Marinas et al., 2021, Paul et al., 2021), including the pharmaceutical area (McGaw et al., 2022). Currently, there are few studies focusing on the biotechnological potential of invasive plants (Rai and Singh, 2020). The aim of the present study was to describe the impact of several invasive plants on environment and human health, to illustrate the available methods of control and potential industrial applications as sustainable mode of valorization of different parts of invasive plants.

2. METHODOLOGY

To obtain the information presented in this paper, several original articles and review articles, published since 2017 until now on the Clarivate and SCOPUS databases were analyzed; their content and characteristics (Figure 1, Figure 2) were transposed into graphs and tables.

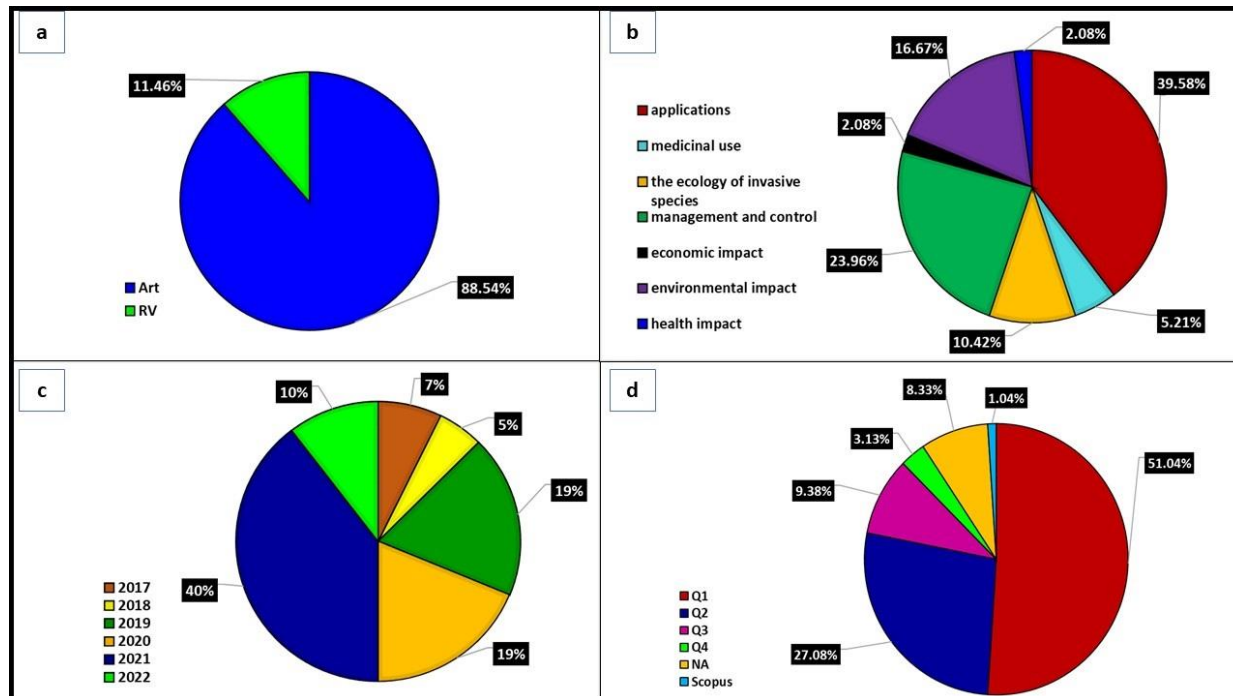


Figure 1. Relative abundance analysis of article characteristics: a –the type of article (Art – article; RV – review article); b – the field of study; c – the year of published papers; d – the type of journal (NA – no category quartile).

A number of 96 studies dealing with the impact of different alien species on the quality of the environment, the industrial applications in which their biomass can be used, the management applied methods and some general information, were selected for evaluation by using key terms

such as „invasive plant”, „invasive species”, „invasive herb”, „alien plant” along with the words „economy”, „industry”, „energy”, „sustainability”, „industrial”, „products”, „biodiversity”, „health”, „control” etc.

Figure 1 shows that original articles (88.54%) were mostly used for this study, 50% of the papers being published between 2021-2022. Most articles were published in journals of quartiles Q1 (51.04%) and Q2 (27.08%), only one being from a Scopus indexed journal. The majority of the selected articles assessed the topic of applications of invasive species (39.58%), and the fewest were focused on their health and economic impact (2.08%).

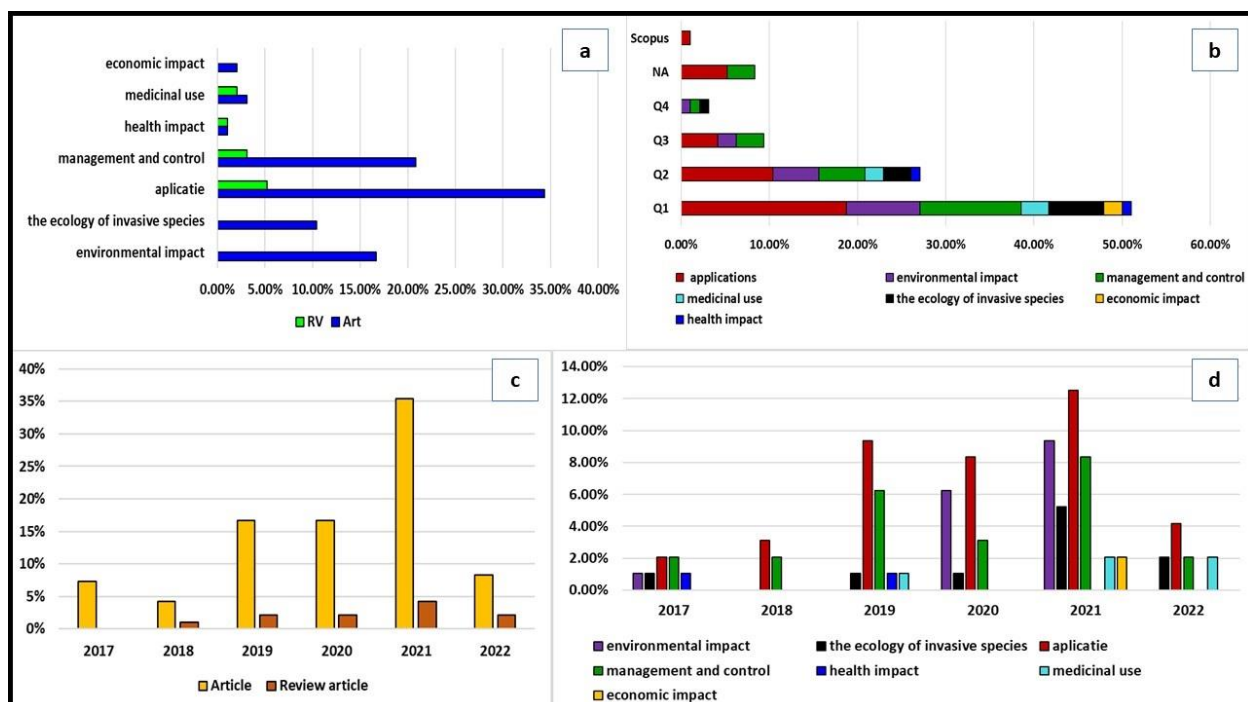


Figure 2. The distributions of: a – articles and review articles by the field to which these belong; b – study topics depending on the type of journal; c – articles and review articles by the year of publication; d – study topics depending on the year of publication.

As noticed in Figure 2, the most of the chosen original and review articles focused on applications of invasive plants (34.38%, respectively 5.21%) and on appropriate management and control measures (20.83%, respectively 3.13%). In almost all the presented categories of journals, there are articles on these two topics, but information about the health impact of these species is well represented in journals within quartiles Q1 and Q2. From 2017 there was no review article selected, but the majority of them were elected from 2021 (4.17%). For the selected period of publication, there are studies on the uses of invasive plant species, but from the perspective of their impact on human health, the most studies were published in 2017-2019. The articles about the economic impact were published mainly in 2021.

3. THE IMPACT OF INVASIVE PLANTS ON ENVIRONMENT AND HUMAN HEALTH

Most invasive plant species inhibits the growth and development of nearby plants through their allelopathic properties (Kalisz et al., 2020). The allelopathic compounds can also alter the microbial community of the soil, affecting those species associated with them (Qu et al., 2021). Some alien

plants have the ability to modify the pH of the soil, the nutrients level, the amount of accumulated phosphate or even the biomass of native plants (Teixeira et al., 2020, Demeter et al., 2021). The problems they cause are even greater as various pathogens or pests are introduced along with them, which put additional pressure on the development of autochthonous flora (Spence, 2020, Paul et al., 2021). Other species, such as *Ailanthus altissima* (Figure 3), can displace other plants by their shading (Demeter et al., 2021). Even so, there are cases when the invasion did not affect the seed bank of local species (Brooks et al., 2021).



Figure 3. Some representatives invasive plant species: 1 – *Amorpha fruticosa*, 2 – *Ailanthus altissima*, 3 - *Ambrosia artemisiifolia*, 4 – *Robinia pseudoacacia*, 5 – *Solidago canadensis*, 6 – *Rhus typhina*.

Not only plants populations are subjected to the pressure of these species, but also those of arthropods (Schirmel, 2020) or of carnivorous mammals (Hardesty-Moore et al., 2020).

The most affected species by the presence of alien plants are the endemic ones, from both terrestrial and aquatic environments (Gusev, 2021) and the riparian habitats are the most susceptible to their pressure (Castro Díez and Alonso Fernández, 2017). In this sense, some species can favor the erosion of the banks and bring pressure to the communities that grow there (Colleran et al., 2020). The accelerated degradation of their organic matter debris, as in the case of *S. canadensis* (Figure 3), cause imbalances in the feeding of organisms dependent on it (Dekanová et al., 2021). The same problem appear in the organisms whose diet includes certain amounts of native plant species matter, because of the induced decrease in their abundance (Pulscher et al., 2021). Sometimes, invasive plants can have a negative impact on water flows as in the case of *Acacia* sp. (Göswein et al, 2021) while in forests they slows down the natural regeneration (Dyderski and Jagodziński, 2020).

Invasive species do not encounter problems in growing in urban areas (Park et al., 2021, Dambiec et al., 2022), spreading easily through the inner rivers (Wagner et al., 2020), the anthropogenic pressure accentuating their spread (El-Barougy et al., 2021, Park et al., 2021, Zhang et al., 2022), and increased resistance to drought and temperature variation (Park et al., 2021).

Beyond these aspects, invasive species - especially woody ones, through their root system, represent a real threat to maintain the integrity of monuments and heritage areas (Celesti-Grapow and Ricotta, 2021).

Occasionally, alien plants are characterized by positive effects. For example, in mining areas, the presence of *Robinia pseudoacacia* (Figure 3) species showed the potential to improve soil quality (Shi et al., 2021).

Regarding the quality of human life, invasive plant species have a negative effect on health (Lake et al., 2017, Bakacsy and Bagi, 2020), a model that takes into account the impact of climate change on pollen allergy showing that the number of people with this sensitivity may double in the next twenty years in the case of *Ambrosia artemisiifolia* (Figure 3) (Lake et al., 2017). Some species, as for example *Solidago* sp., even causes contact allergies (Denisow-Pietrzyk et al., 2019). Rai and Singh (2020) highlighted the consequence of increasing the level of air pollutants, as alien species are not as efficient in their absorption: this can cause lung and cardiovascular problems. As a contradiction, in terms of medicinal properties, foreign species can be used for more purposes than native species (Yessoufou et al., 2021), but it is necessary to be taken into account their toxicological potential. *Ailanthus altissima* bark, for example caused hepatic and gastrointestinal dysfunction in certain high amounts, and even the death of involved mice (Liu et al., 2019), while *Gutenbergia cordifolia* affected the metabolism and the microbial community of the rumen (Ngondya et al., 2019).

4. METHODS OF INVASIVE PLANT CONTROL - CLASSICAL AND MODERN APPROACHES

In Romania, there is a serious shortage of data regarding the impact and means of control of invasive plant species (Sîrbu et al., 2021). In Figure 4, some management methods available for these alien plants, sorted by category, were listed.

As a biological control of invasive species, Shahrtash and Brown (2021) suggested that a microbiological approach could be promising, but this view should be further studied. This method was successful for individuals of *A. altissima* from the experiment of Dubach et al. (2021) who did not survive the infestations with fungus *Verticillium nonalfalae*, but this also affected an individual of *Quercus petraea*, suggesting that it could not be a completely safe method for the local flora. Another identified biological control measure was sheep grazing, which also has disadvantages on the health of the sheep and the quality of the products supplied from them (Zihare et al., 2019).

Bakacsy and Bagi (2020) observed that a successful short-term control method for clonal species as *Asclepias syriaca*, which can even be applied in protected areas, could be the herbicide treatment. Also in the temporary control of *Solidago* ssp., Glyphosate proved to be useful, but it was mentioned that this pesticide can negatively affect the environmental health (Świerszcz et al., 2017). In contrast, the chemical pesticide Indaziflam added in small amounts turned out to be effective in long-term remediation of invasive monocotyledonous species (Sebastian et al., 2017). Even though, there are cases when this method does not have a satisfactory effect, e.g. *Pyrus calleryana* (Coyle et al., 2021). The injection of herbicide into the stem can sometimes improve the treatment efficiency (Rebbeck et al., 2019).

A restriction method with a similar operating principle, but advantageous and effective for the difficult-to-control weeds as *Parthenium hysterophorus* is the synthesis and application of bioherbicides (Ojija et al., 2019).

Various articles have described the burn control as encouraging (Gornish et al., 2018, MacDonald et al., 2019, Rebbeck et al., 2019, Coyle et al., 2021), noting the requirement for continuous monitoring and repeated application of management measures to restore native biodiversity and prevent the reinvasion (Gornish et al., 2018, MacDonald et al., 2019). However, there are species whose seeds are resistant to seasonal wildfires, often their germination being only delayed (Moreschi et al., 2019), sometimes being faster than that of native species (MacDonald et al., 2019), so we can expect this method to be difficult to manage in their case.

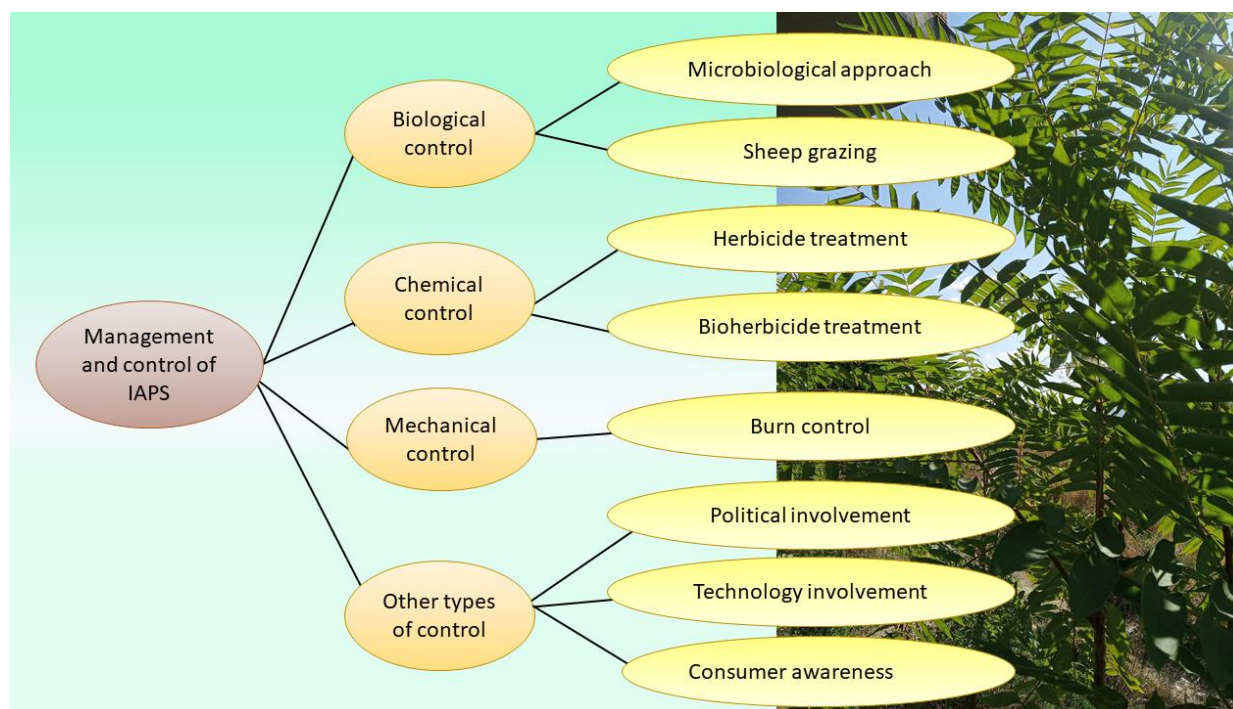


Figure 4. Types of control methods for invasive alien plant species (IAPS)

It was also proposed the dispersion limitation of these species by implementing a more critical management of ornamental horticulture and educating the consumer public about its aspects (Hulme et al., 2018), because it is a main context for the introduction of potentially invasive plants (Hulme et al., 2018, Arianoutsou et al., 2021, Beaury et al., 2021, Montagnani et al., 2022).

Takaya et al. (2022) attempted to improve the detection of non-arboreal invasive species distribution from satellite imagery, which had an average accuracy of 89% for *Solidago canadensis*, for monitoring purposes and then to choose appropriate management measures.

To better manage the invasive species situation, the European Union (EU) has implemented the Biodiversity Strategy (Zihare et al., 2019). Also, there are two important regulations with the same purpose: Regulation 1143/2014 (IAS Regulation) that was included in the EASIN computer system (Arianoutsou et al., 2021) and EU Regulation 2019/1262 which contains new added species to the list of invasive alien species of European Union concern (Celesti-Grapow and Ricotta, 2021), including *Ailanthus altissima*, *Salvinia molesta* and *Humulus scandens* (European Commission, 2019).

Technology can play an important role in restricting invasive species, control standards such as the Generic Impact Rating System (GISS) and Environmental Impact Classification for Foreign Taxa

(EICAT) being used to assess and compare the influence that these species have or could have on the environment, but first the problem of the literature deficit must be solved (Sohrabi et al., 2021) (Sohrabi et al., 2021).

5. POTENTIAL INDUSTRIAL APPLICATIONS OF INVASIVE PLANTS

Figure 5 illustrates the result of the relative abundance analysis considering different applications of invasive species that were identified in the selected studies. Most of the utilizations overlap the area of biopesticide production (26.47%), phytoremediation and other uses for environmental welfare (20.59%) and bioenergy production (17.65%), and the fewest exploitations were about obtaining various extracts and compounds (11.76%) or improving the quality of some materials, as thermoplastics (8.82%).

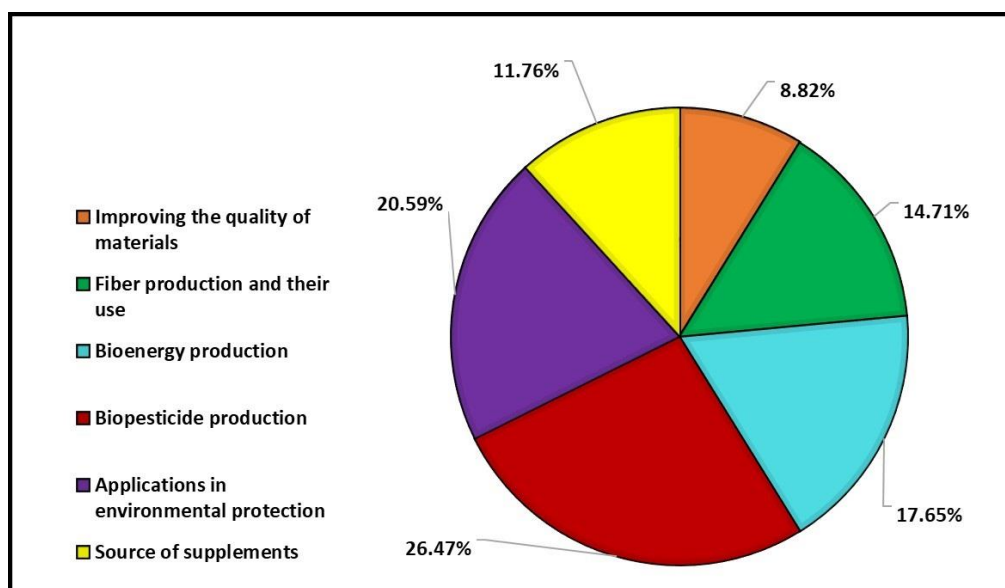


Figure 5. The spectrum of relative abundance of potential industrial applications

Bioenergy production

Agriculture favours the spread of invasive species and at the same time it is seriously affected by their impact. As a sustainable application for improving agricultural performance, Ahmed et al. (2020) used the raw material residues of the invasive species *Acacia cincinnata* for the production of biochar, bio-oil and biogas by pyrolysis. The same products, also qualitative, were obtained by Reza et al. (2019) from *Acacia holosericea*.

Invasive species can be a convenient biodiesel resource (Khan et al., 2021, Liu et al., 2019).

In terms of energy production, not only wood species can serve this purpose, Aref et al. (2017) obtaining a good quality coal from the biomass of *Rhazya stricta* and *Phragmites australis*.

Although they have a lower calorific value than what is available on the market, *Solidago* sp. pellets can be a good alternative energy source (Izydorzycykv et al., 2020), as well as the bark and wood of *A. altissima* and *R. pseudoacacia* (Kamperidou et al., 2018).

Applications in environmental protection

Several alien species, such as *Solidago canadensis* (Bielecka and Królak, 2019), have shown potential in phytoremediation of soils contaminated with heavy metals such as cadmium and lead

(Prabakaran et al., 2019). Other plants, such as *Solidago gigantea*, can serve as bioindicators of the degree of anthropogenic impact, the content of potentially toxic metals in the leaves being different in this respect (Dambiec et al., 2020). In order to reduce the amount of pollutants in the water, an attempt was made to produce adsorbents from invasive plants (Nguyen et al., 2022). *Eupatorium adenophrum spreng* was used as adsorbent, which works mainly through ion exchange, for removing copper from an aqueous solution (Fan et al., 2022) and *A. altissima* sawdust biosorbent for removing the Acid Yellow 29 present in the wastewater (Rahman et al., 2021). Almeida et al. (2021) obtained polyelectrolytes from the woody debris of *A. altissima* and *Acacia dealbata* and used them in a flocculation process of an effluent from olive oil mill.

Fiber production and their use

It was obtained from Goldenrods, Knotweeds and Black Locust papers with a quality suitable for their sale and even for printing (Starešinič et al., 2021, Karlovits et al., 2020). Natural dyes such as the one produced from the petals of *Impatiens glandulifera* can be used in obtaining colored paper (Klančnik, 2021). Other example for the use of cellulose fibers of species in this category refers to the production of dressings that also have antimicrobial and antioxidant properties (Marinas et al., 2021).

Source of supplements

Iyer et al., 2021 found that *Ulex europaeus* could be a good source of proteins which can reduce environmental problems related to animal husbandry. It was established that the recovered amount of protein could be influenced by the applied extraction method. (Iyer et al., 2022).

These species can also be important in the pharmaceutical industry, having applications in traditional medicine for treating asthma, epilepsy, bleeding (Li et al., 2021) or various sexually transmitted diseases (Maema et al., 2019). In this context, such plants could be seen as a valuable source of compounds with antimicrobial and antioxidant properties, e.g. *Acacia dealbata* (Paula et al., 2022) and *Solidago canadensis* (Elshafie et al., 2019). In addition, they could be used to treat pests of some crop plants (Elshafie et al., 2019). Thereby, leaves of Japanese toadflax contain a significant amount of carotenoids which can be exploited (Metličar et al., 2019). Also, some plant extracts could be used for inhibition of enzymes such as acetylcholinesterase or lipase (Paula et al., 2022).

Biopesticide production

It has been reported that the allelopathic properties of some invasive plant species such as *Nicotiana glauca* could be used to control other invasive species such as the coleopteran *Rhynchophorus ferrugineus* (Alghamdi, 2021). A good pesticidal effect on crop pests was shown by *Tephrosia vogelii* extract (Mkindi et al., 2017), while the essential oils of *S. canadensis* and *S. gigantea* showed insecticidal potential on *Culex quinquefasciatus*, *Spodoptera littoralis* and *Musca domestica* (Benelli et al., 2019). To control rice weevil, Bohinc et al., 2020 used plant matter from species such as *Rhus typhina* (Figure 3) or *Amorpha fruticosa* (Figure 3) in powder form, but this was not effective. The extract from *S. canadensis* also showed molluscicidal activity against *Pomacea canaliculata* (Shen et al., 2018).

Acetone leaf extracts of *Passiflora suberosa* and *Chromolaena odorata* showed a fungicidal effect on eight common pathogens, including *Pythium ultimum*, *Penicillium expansum* and *Rhizoctonia solani* (Meela et al., 2019). A virucidal effect was present at some samara compounds of *Ailanthus altissima*, inhibiting the multiplication of tobacco mosaic virus (Tan et al., 2020).

Aqueous extracts of *Solidago canadensis*, *Rhus typhina* and *Reynoutria japonica* have been used to develop textiles with increased resistance to UV radiation and low susceptibility to bacteria such as

Escherichia coli and *Staphylococcus aureus* in the formation of silver nanoparticles (Čuk et al., 2021). In addition, gold and silver-gold metallic nanoparticles were obtained from goldenrod extract, but gold nanoparticles were the only one which did not present toxicity at concentrations more than 50 µg/mL (Botha et al., 2019).

Table 1 shows several invasive plants with antimicrobial properties and some species of microorganisms whose development is inhibited by them.

Table 1. Antimicrobial activity of some invasive plant species identified in the bibliographic sources

Invasive plant species (Scientific name)	Common name	Microorganism type	Microorganism	References
<i>Solidago canadensis</i> L.	Canadian goldenrod	fungi	<i>Aspergillus niger</i> <i>Monilinia fructicola</i> <i>Penicillium expansum</i>	Elshafie et al., 2019 Čuk et al., 2021
		bacteria	<i>Bacillus megaterium</i> <i>Clavibacter michiganensis</i> <i>Pseudomonas fluorescens</i> <i>Staphylococcus aureus</i> <i>Escherichia coli</i>	
<i>Gleditsia triacanthos</i> L.	Honeylocust	fungi	<i>Candida albicans</i> <i>Candida parapsilosis</i>	Marinas et al., 2021
		bacteria	<i>Staphylococcus aureus</i> <i>Pseudomonas aeruginosa</i> <i>Enterobacter cloacae</i> <i>Acinetobacter baumannii</i> <i>Escherichia coli</i>	
<i>Ailanthus altissima</i> (Mill.) Swingle	Tree of Heaven	fungi	<i>Candida albicans</i>	Kozuharova et al., 2020
		viruses	Tobacco mosaic virus	Tan et al., 2020
<i>Amorpha fruticosa</i> L.	False indigo-bush	bacteria	<i>Staphylococcus aureus</i> <i>Sarcina lutea</i> <i>Bacillus cereus</i> <i>Pseudomonas aeruginosa</i> <i>Escherichia coli</i> <i>Bacillus subtilis</i>	Kozuharova et al., 2020
		fungi	<i>Candida albicans</i> <i>Candida sake</i> <i>Candida glabrata</i>	
<i>Acacia dealbata</i> Link.	Mimosa	bacteria	<i>Escherichia coli</i> <i>Staphylococcus aureus</i>	Paula et al., 2022
		fungi	<i>Candida albicans</i>	
<i>Reynoutria japonica</i> Houtt (syn. <i>Fallopia japonica</i> (Houtt.))	Japanese Knotweed	bacteria	<i>Staphylococcus aureus</i> <i>Escherichia coli</i>	Čuk et al., 2021
<i>Rhus typhina</i> L.	Staghorn sumac	bacteria	<i>Staphylococcus aureus</i> <i>Escherichia coli</i>	Čuk et al., 2021

Improving the quality of materials

Medved et al. (2020) have successfully used the woody debris of five invasive species (Table 1) to make wood-plastic composites. Zhao et al. (2021) utilised the biomass of *Phalaris arundinacea* and *Lonicera japonica* to reinforce the PHBV thermoplastic.

Regarding the improvement of the quality of construction materials, it was showed that the chips of different invasive species could be incorporated as a raw material in the production of bio-concrete with low carbon dioxide emissions (Göswein et al., 2021). Fouda et al. (2018) observed a good anti-corrosive activity of zinc in aqueous extract of *A. altissima*.

To summarize the information presented above, Table 1 illustrates different applications of invasive species, as well as the alien plants involved in them. In the future, further studies should be conducted on the toxicity of invasive species as well as on the pressure they exert on human health. The results of previous studies are encouraging, the quality of the products obtained based on them being satisfactory.

Table 2. Industrial applications for invasive plant species

Invasive species	Proposed Uses	References
<i>Acacia cincinnata</i>	Biochar production	Ahmed et al., 2020
<i>Reynoutria japonica</i> Houtt (syn. <i>Fallopia japonica</i> (Houtt.))	Papermaking	Starešinič et al., 2021 Karlovits et al., 2020
	Source of carotenoids	Metličar et al., 2019
	AgNP production	Čuk et al., 2021
<i>Fallopia sachalinensis</i> (F. Schmidt)	Papermaking	Starešinič et al., 2021
<i>Fallopia × bohemica</i> (Chrték & Chrtkova) J. Bailey	Source of carotenoids	Metličar et al., 2019
	Papermaking	Starešinič et al., 2021
<i>Robinia pseudoacacia</i> L.	Papermaking	Starešinič et al., 2021 Karlovits et al., 2020
	Wood-plastic composite production	Medved et al., 2020
	Pellets production	Kamperidou et al., 2018
<i>Solidago canadensis</i> L.	Papermaking	Starešinič et al., 2021 Karlovits et al., 2020
	AgNP, AuNP Au-AgNP production	Čuk et al., 2021 Botha et al., 2019
	Biopesticide production	Benelli et al., 2019 Shen et al., 2018
	Pellets production	Izydorzcyk et al., 2020
<i>Solidago gigantea</i> Aiton	Papermaking	Starešinič et al., 2021 Karlovits et al., 2020
	Biopesticide production	Benelli et al., 2019

<i>Ulex europaeus</i> L.	Alternate protein source	Iyer et al., 2021
<i>Nicotiana glauca</i> Graham	Biopesticide production	Alghamdi, 2021
<i>Gleditsia triacanthos</i> L.	Multi-functional wound dressings production	Marinas et al., 2021
	Wood-plastic composite production	Medved et al., 2020
<i>Rhazya stricta</i> Decne.	Charcoal production	Aref et al., 2017
<i>Phragmites australis</i> (Cav.) Trin. ex Steud.		
<i>Vachellia tortilis</i> (Forssk.) Galasso & Banfi (syn. <i>Acacia tortilis</i> (Forssk.) Hayne)		
<i>Tephrosia vogelii</i> Hook f.	Biopesticide production	Mkindi et al., 2017
<i>Acer negundo</i> L.	Wood-plastic composite production	Medved et al., 2020
<i>Aesculus hippocastanum</i> L.		
<i>Ailanthus altissima</i> (Mill.) Swingle	Polyelectrolytes (flocculants) obtaining	Almeida et al., 2021
	Wood-plastic composite production	Medved et al., 2020
	Biodiesel	Khan et al., 2021
	Zinc corrosion inhibitor production	Fouda et al., 2018
	Adsorbent production	Rahman et al., 2021
	Pellets production	Kamperidou et al., 2018
<i>Passiflora suberosa</i> L.	Biopesticide production	Meela et al., 2019
<i>Chromolaena odorata</i> (L.) R.M.King & H.Rob.		
<i>Impatiens glandulifera</i> Royle	Natural dye obtaining	Klančnik, 2021
<i>Rhus typhina</i> L.	AgNP production	Čuk et al., 2021
	Biofuel production	Liu et al., 2019
<i>Eupatorium adenophorum</i> Spreng.	Adsorbent production	Fan et al., 2022
<i>Phalaris arundinacea</i> L.	PHBV reinforcing agents obtaining	Zhao et al., 2021
<i>Lonicera japonica</i> Thunb.	PHBV reinforcing agents obtaining	Zhao et al., 2021
<i>Acacia dealbata</i> Link.	Polyelectrolytes (flocculants) obtaining	Almeida et al., 2021
<i>Sapindus mukorossi</i> Gaertn.	Biodiesel production	Khan et al., 2021
<i>Vernicia fordii</i> (Hemsl.) Airy		

Shaw.		
<i>Ricinus communis</i> L.		
<i>Toona sinensis</i> (Juss.) M.Roem		
<i>Linum usitatissimum</i> L.		
<i>Acacia holosericea</i> A. Cunn. ex G.Don	Bio-char, bio-oil and biogas production	Reza et al., 2019

4. CONCLUSIONS

To sum up, invasive plant species put a great pressure on the components of the ecosystems in which they spread, especially in protected and riparian areas. Sometimes, alien plants can have positive effects on the environment such as their potential accumulation of heavy metals from soil, which can contribute to the removal of such toxic substances. The majority of the management methods used until now were just temporary effective or adversely affected native species. Even so, technological and legislative involvement could increase the rate of control success for these species. The exploitation of invasive plants for various industrial uses could facilitate their control, while also bringing benefits through products resulting from their biomass, as several authors have considered. The majority of the studies used in this paper came from journals indexed in Web of Sciences/ Clarivate, published after 2019 and develops two main issues: the applications of alien plants and their implemented control measures. Most of the applications described in the selected studies concern the pesticidal properties of these species. The topic is broad and more studies are required in the future on the industrial potential valorization of invasive plants.

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