

Review

Dittrichia viscosa: Native-Non Native Invader

Barbara Sladonja ¹, Danijela Poljuha ^{1,*}, Marin Krapac ¹, Mirela Uzelac ¹ and Maja Mikulic-Petkovsek ²

¹ Institute of Agriculture and Tourism, Karla Huguesa 8, 52440 Poreč, Croatia; barbara@iptpo.hr (B.S.); marin@iptpo.hr (M.K.); mirela@iptpo.hr (M.U.)

² Department of Agronomy, Biotechnical Faculty, University of Ljubljana, Jamnikarjeva 101, SI-1000 Ljubljana, Slovenia; maja.mikulic-petkovsek@bf.uni-lj.si

* Correspondence: danijela@iptpo.hr; Tel.: +385-52-408-336

Abstract: *Dittrichia viscosa* (L.) Greuter is a shrub native to the Mediterranean, however, declared as a very invasive species in Australia and North America. Environmental (climatic) and socio-economic (land abandonment) changes can trigger different adaptive mechanisms and cause changes in species behavior, influencing invasion dynamics. Motivated by the recently noticed change of *D. viscosa* behavior in its native Mediterranean habitat, we discuss the invasion properties, its behavior in the native habitat and new areas, and its management options. We review the species' adverse effects and its positive ecosystem services in the Millennium Ecosystem Assessment framework. In this review, we provide information on the phytochemical properties of *D. viscosa* and highlight its potential use in ecological agriculture, phytopharmacy, and medicine. The presented data is useful for developing effective management of this contentious species, with emphasis on mitigating environmental and economic damages, especially in agriculture. The final aim is to achieve a balanced ecosystem, providing a high level of possible services (provisioning, regulating, cultural and supporting).

Keywords: contentious invasive species; invasive properties; ecosystem services; phytochemical properties; weed



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1. Introduction

Dittrichia viscosa (L.) Greuter, Stinkwort or False Yellowhead, is a perennial ruderal plant belonging to the Compositae family, native to the Mediterranean and Western Asia [1–3]. It is declared and listed on the Alert List of Environmental Weeds in Australia and North America [1]. It is abundant in anthropically altered areas [4]. In the Mediterranean, *D. viscosa* belongs to the vegetation of abandoned Mediterranean cultures, class of *INULETEA VISCOSAE* Trinajstić (1965) 1978; characteristic of the association *Helichryso italici-Dittrichietum viscosae* Trinajstić ex Di Pietro, Germani & Fortini 2017 [5], a pasture of immortelle and false yellowhead [3,6]. Owing to its high seed production and spreading, good adaptability, and resistance to adverse conditions, it is considered an important environmental weed [1,6]. Recently an unusual spread of *D. viscosa* was recorded in coastal Croatia (personal records), causing functional and economic problems (Figure 1). Although there are no published quantitative data showing the spread of *D. viscosa* in Croatia, according to GBIF database (which included six different datasets) [7] from 2009 to 2020 number of observations have increased supporting our observations (Figure 2).

In neighboring Slovenia, it is considered indigenous and widespread [8]. Habitat changes in the Mediterranean basin, as well as in Croatia, are commonly linked to environmental and socio-economic alterations, land abandonment, and loss of traditional agricultural areas [9]. Climate change is one of the most significant environmental threats to biodiversity and has a number of potential effects on weeds in both agricultural and native vegetation landscapes [10,11]. It is known that climate variations can influence the spreading of invasive plant species [12–14]. Hence, established non-native species could become invasive if climate change increases their competitive ability or spreading rate [15].



Figure 1. High abundance of *Dittrichia viscosa* on abandoned agriculture land in coastal Croatia.

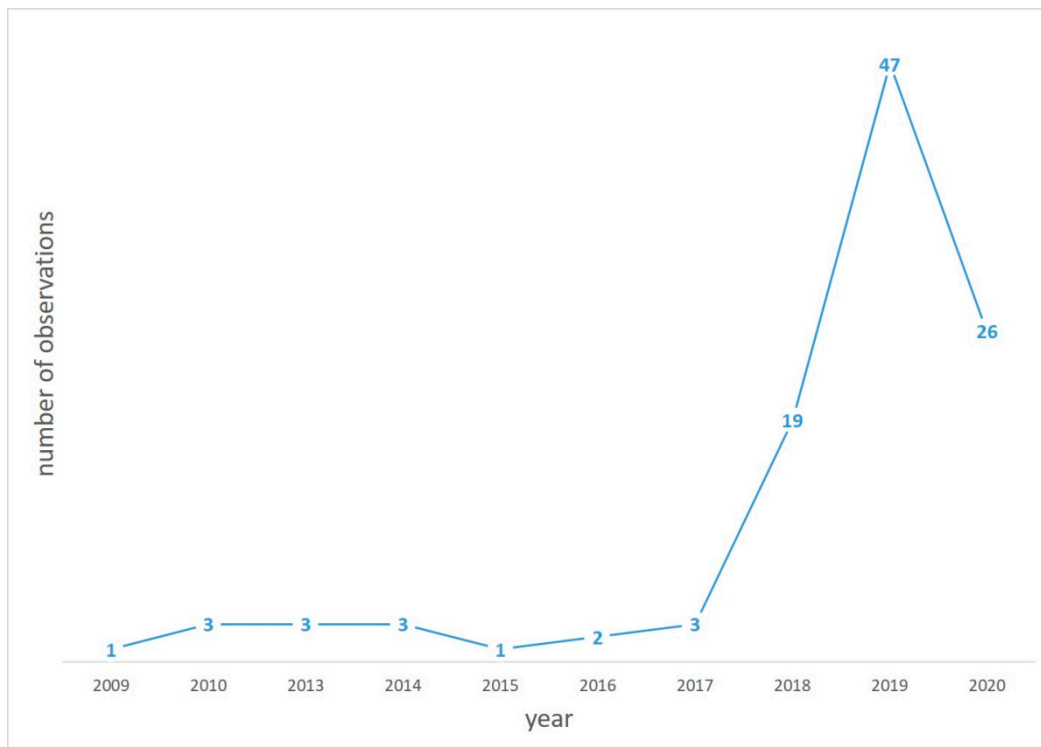


Figure 2. Number of observations of *D. viscosa* in the Republic of Croatia from 2009 to 2020.

However, to date, the characteristics that make species a successful invader or the ecosystem features that predispose it to invasion are still poorly understood [16,17]. Moreover, it is unclear which species or community attributes enhance invader success or explain spread dynamics [18]. Nevertheless, it has been shown that invasion success is dependent on unique interactions between the invader and the environment [19–22]. There are many hypotheses about why invasive species are successful. Some hypothesized mechanisms are reproductive ability, vegetative growth, predation, adaptation, and allelopathy [18]. These competitive mechanisms can provide substantial socio-economic, landscape, and ecological services, both in native and non-native species [23].

Generally, ecosystem services are defined as the output of natural systems from which humans can derive benefits. They have been categorized into four categories by the

Millennium Ecosystem Assessment [24]: cultural, provisioning, supporting, and regulating. This assessment has been created to qualitatively test the effects of singular species and give useful inputs for effective environmental management. *D. viscosa* is known to offer a large variety of ecosystem functions in the Mediterranean basin. It is an important species that can be used for phytoremediation, as a bio accumulator or bioindicator, as well as an additional tool in ecological agriculture [25–27]. For example, *D. viscosa* is a host plant for natural enemies (the parasitic complex of *Myopites stylata* and *Eupelmus urozonus*) of plant pests like olive fruit fly (*Bactrocera oleae* Gmel.) [28].

Provisioning of potentially useful compounds to humans is an important ecosystem service. Plant species can be a consolidated source of bioactive components, and many higher plants possess allopathic potential [29,30], which can be investigated and used for the development of commercial natural herbicides. Plant-derived natural products have also served as an important resource for medicinal compounds. *D. viscosa* contains several biologically active compounds: flavonoids, sesquiterpene lactones, sesquiterpene acids, and triterpenes [31].

The aims of this review are to: (i) review and summarize the current state of knowledge regarding *D. viscosa* invasiveness potential; (ii) provide an overview of *D. viscosa* ecosystem services; (iii) provide information for the effective management of the species in changing habitats and assess its contribution to the ecosystem.

2. *Dittrichia viscosa* Invasive Properties

It is difficult to identify factors associated with the degree of invasion by alien plants. It is certain that invasive species are more plastic in a variety of traits. Still, it remains extremely difficult to define a set of traits responsible for particular species invasiveness [32]. *D. viscosa* has the potential to be a serious environmental weed both in native and introduced areas.

2.1. *D. viscosa* in Native Areas

It shows a great pioneer character and, in recent years, has largely expanded its range in many Mediterranean countries, possibly due to increased human disturbances [33]. According to Wacquant [34] the species areal has been expanding in the Mediterranean for the previous 25 years. He described the capability of *D. viscosa* to colonize new habitats and threaten biodiversity, mostly due to its phenotypic plasticity [35]. It has been proven that climatic changes can drive the spread of thermophilic species, such as *D. viscosa*. Vesperinas et al. [12] correlated the expansion of these species with mean temperature increases.

According to different authors *D. viscosa* has a number of characteristics that makes it highly competitive in its native range:

2.1.1. Biology

Morphological and anatomical characteristics that make *D. viscosa* a good invader are: substantial roots even in small plants, dense canopy, presence of glandular hairs on leaves and stems, strong odor, the glandular hairs secrete lipids, polysaccharides, and proteins.

2.1.2. Reproduction, Regeneration, and Dispersal

D. viscosa is a prolific seed producer, but the longevity and viability of *D. viscosa* seeds are unknown [36]. *D. viscosa* tolerates salty soil with small amounts of available water and germination is favored by ground disturbance and fire. It can withstand soils with salinity of sea water level, approx. 30 g NaCl/L [37]. *Dittrichia viscosa* can be regenerated in several ways. One is by seeds which can be collected at the end of October, the second is through cuttings, and the third is the transplantation of whole plants. Although in nature germinates the following year without interventions, the germination rates in the pots are poor [36]. The impact of salinity on the germination rate of *D. viscosa* in Slovenia was studied by Grašič et al. [38]. The authors concluded that even though *D. viscosa* seed is

highly resistant to salinity, elevated salinity levels cannot be considered the main factor in determining its occurrence.

2.1.3. Allelopathy

D. viscosa is rich in secondary compounds such as flavonoids, sesquiterpenes and essential oils [36]. The allelopathic potential of the leaf exudates increases during the dry, hot, and sunny summer. Seasonal and geographic variations have also been found, but all inside native growing areas [39]. Dor and Hershenhorn [40] also revealed that *D. viscosa* produces sesquiterpene lactone, tayunin, which inhibits the growth of other nearby plants. Moreover, *D. viscosa* extracts can delay germination of other plants by reducing the frequency of dividing cells in the root [4,41].

2.1.4. Tolerance of a Broad Range of Environmental Conditions

Different authors [8,33,42] have described its high tolerance to salinity and unfavorable conditions. Al Hassan et al. [33] have evaluated the potential risk that *D. viscosa* represents for Mediterranean salt marsh vegetation, and it depended on its salt tolerance. They proved that *D. viscosa* prefers anthropically influenced or degraded communities and that the lower salinity makes it more competitive. *D. viscosa* can compromise some less tolerant species and general biodiversity. They also explain mechanisms responsible for stress tolerance in this species. *D. viscosa* is a ruderal plant, grows in abandoned fields, roadsides, walking trails, urban areas, and all modified and altered areas by anthropic activities [36,43,44].

2.1.5. Lack of Predators

2.2. *D. viscosa* in New Areas

De Laurentis et al. [39] recorded that the chemical composition and concentration of volatile constituents of *D. viscosa* from different areas in Italy were different. This indicates the possibility that, also in the introduced areas, the chemical composition could be different. Still, site-specific studies are needed to prove this assumption.

In the USA, California pest rating was performed according to plant's invasive characteristics and observed behavior on the site [45]. *D. viscosa* was rated as a species with high risk (score 3/3) to establish a widespread distribution, high risk for a host range, high risk for reproduction and dispersal, medium economic impact, and high environmental impact.

In Australia, where *D. viscosa* is considered a serious environmental weed marked for eradication flowering occurs between December and April. As in native areas, *D. viscosa* spreads by seed. Seed can also be spread during construction works or when attached to machinery. Germination is generally enhanced by fire or mechanical disturbance which creates bare ground. Under laboratory conditions, *D. viscosa* seeds undergo a deep dormancy, which is broken by a lack of light [46]. Generally, it is indicated as a drought-resistant and salt tolerant species [37,47], but it is occasionally found in Australia in swamps and along waterways [45]. There are no specific investigations on the invasive properties of *D. viscosa* in introduced areas and available information on which characteristics are climate or site-specific.

3. *Dittrichia viscosa* Ecosystem Services

Ecosystem services are the outputs of natural systems from which humans derive benefits [23]. Invasiveness can induce losses in ecosystem services. However, novel services are resulting from the characteristics of invasive species as well. The review of *D. viscosa* ecosystem services shows that it successfully meets many contemporary environmental and social needs. In its native range, *D. viscosa* provides several ecosystem services and functions, presented in Table 1.

These useful services have been arranged and grouped within the Millennium Ecosystem Assessment [24]. In the Table, all ecosystem services provided by *D. viscosa* have been investigated and summarized within four main groups. In general, provisional ecosystem services include food, fiber, genetic resources, pharmaceuticals and fresh water. Within this

group, *D. viscosa* provides several services. The most studied services of *D. viscosa* (Table 1) are medicinal services and weed and pest control. For example, leaf extracts of *D. viscosa* contain antifungal agents which inhibit the growth of dermatophytes and *Candida albicans*, a group of fungi that cause a skin disease in animals and humans [31]. Additionally, both leaf extracts and dry leaves proved to be effective herbicides for use in organic agriculture. The extracts decreased seed germination of several weed species: *Sinapis arvensis* L., *Amaranthus palmeri* S. Wats., and *Solanum nigrum* L. [40]. Leaf extracts can also be used for the preparation of natural nematicides. The root-knot nematode *Meloidogyne javanica* causes severe damage in vegetable crops in Israel, especially in organic vegetable production systems. The use of *D. viscosa* extracts reduced nematode infection on tomato plants [58]. Regulating ecosystem services such as pollination, climate regulation, air quality regulation, and supporting services are important but global and not specific to *D. viscosa*. Cultural ecosystem services are expressed through aesthetic value, ecotourism, preservation of traditional practices. *D. viscosa* is a plant known in Mediterranean traditional medicine and agricultural practices (Table 1).

Table 1. Ecosystem services, as defined by the Millennium Ecosystem Assessment [24], provided by *Dittrichia viscosa*.

Category	Example of Service Provided by <i>D. viscosa</i>	References
Provisioning	Medicinal	[31,48–53]
	Weed management	[4,8,54,55]
	Pest control	[40,56–60]
	Antifungal control	[31,61–64]
	Biomass production	[65]
Regulating	Bioindicator	[36,66,67]
	Bioaccumulator	[36,68–71]
	Phytoremediation	[36,43,55,72,73]
	Desertification control	[33,42,74]
Cultural	Traditional use	[34]
	Biogeographical component	[51,75,76]
Supporting	Primary production	[77,78]
	Nutrient cycling	[41,79]
	Soil formation	[80]

Invasive plant species represent a natural resource that can be freely collected without anthropogenic pressure on local resources in their natural habitats. The use of this resource can be a control method of invasive species and contributes to the ecological balance. Moreover, the collection of these species can produce economic and social benefits, especially in rural areas. Additional potential remains for *D. viscosa* in provisioning of useful phytochemicals. Certainly, in order to realize this potential, site-specific researches are needed.

4. Plant Chemistry as a Competitive Advantage and Potential Ecosystem Service

It is often assumed that alien plants can become invasive when they possess novel secondary metabolites compared to the native plants in the introduced range. High chemical diversity and phytochemical uniqueness in alien species could indicate biological invasion potential [30]. Moreover, data on chemical properties can provide a background for possible approaches to restrict and control invasive populations and are of considerable taxonomic interest. A study by Brahmi-Chendouh et al. [81] revealed the chemical com-

position of *D. viscosa* extracts, highlighting its diversity in polyphenolic constituents and the abundance of bioactive nutraceutical phytochemicals. Trimech et al. [82] described the metabolic profile of *D. viscosa* and the structures of the major polyphenolic constituents tentatively assigned based on their MS and UV–VIS spectra. Caffeic acid, also present in *D. viscosa* derivatives, plays an important role in the plants' defence against pathogens and insects [83,84]. They also participate in processes that promote herbicidal properties [85].

The search for new natural phytotoxins that can be applied in agriculture as target herbicides recently increased [86]. The allelopathic potential of *D. viscosa* can be found in its leaf leachate, which could be used in irrigation for sustainable weed management [55]. The high diversity of bioactive compounds in *D. viscosa* extracts highlights its significant potential for use in agriculture and pharmaceuticals.

5. Invasive Native-Non Native *D. viscosa*

Despite the broad scientific interest on the topic, the “invasive-native-non-native” terminology is still unresolved [33]. Some scientists identify native species with invasive characteristics as “expansive” or “super-dominant” [87]. Others distinguish invasive species from transformers, not harmful species, and weeds, which can be non-native species, but not necessarily [88]. In our case, *D. viscosa* is classified as a weed, a native species that often grows in the Mediterranean area in sites where it is not wanted and has detectable economic or environmental impacts [89]. It is also classified as a non-native invasive outside its range of origin. Invasiveness is a dynamic process influenced by changing environmental parameters [15,90]. Many studies relate invasiveness to biotic and abiotic conditions, but the underlying mechanisms are still unclear, i.e., which variables best correlate to the observed patterns of richness and abundance [91]. Human activities such as pollution and land-use change often result in rapid environmental shifts [92,93]. Moreover, climate change is considered one of the major causes of disturbances to ecological conditions and poses an additional challenge to our ability to manage invasiveness. Due to their adaptability to climate change disturbance, such as increased temperatures and CO₂ concentrations, invasive species have increased opportunities for a spread in a broad range of geographic conditions [94]. Under changing local conditions, any species, regardless of origin (native or non-native), can respond with novel ecological behaviors and assume invasive characteristics. There are several examples where native species are considered invasive; for instance, the fern *Pteridium aquilinum* (L.) Kuhn. and the shrub *Ulex europaeus* L. [95].

In this review, we are discussing an example of an expressed change in the species distribution pattern, noticed on a local scale in Croatia. Local changes provoked native *D. viscosa* behavior change, expressing its competitive characteristics and becoming an abundant weed in Croatian coastal areas (Figure 1). As in many places in the Mediterranean, complex socio-economic and environmental factors resulted in such changes. Rural depopulation and land abandonment are common in Croatia, but little is known about their impact on biodiversity and population dynamics. Although there are numerous case studies on the impacts of land abandonment in the Mediterranean basin [96], there are limited studies on these processes in Croatia [97]. Among the most significant processes of global environmental change [98], the termination of crop cultivation and livestock grazing, seen in rural areas, could be some of the main reasons behind recent increases in abundance of *D. viscosa* and other similar weeds in coastal Croatia. The invasive properties overviewed in this study are the background of evidence for spreading, which will develop under specific conditions. However, the data on its invasion dynamics remains scarce [36].

When given the opportunity, native species can move into new areas where they have a competitive advantage over indigenous ones [99]. They can exhibit aggressive characteristics—such as demographic explosions, biomass accumulation, high reproductive output, phenotypic plasticity, and novel reproductive strategies—becoming weeds [100,101]. Some weeds are particularly concerning and have been listed as a priority for agricultural management or legislation. *D. viscosa* is listed in the Alert List of Environmental Weeds of

Australia [2]. The list comprises 28 non-native plants that threaten biodiversity and cause other environmental and economic damage. These weeds have the potential to degrade Australia's ecosystems seriously. It is not clear how *D. viscosa* was introduced to Australia, but it may have been introduced by horticulturalists. Throughout Australia, weeds are spreading uncontrollably fast, and their management is consuming an enormous amount of resources. Particularly, considering their potential for negative effect, such as reducing agricultural production, damaging infrastructure, and can negatively influence human health or well-being [102].

6. Species Management

When *D. viscosa* is treated as weed it needs proper management measures, but it can also be used as a management mean for other weed removals. Effective management strategies require detailed assessments of both the positive aspects of species in an ecosystem and the negative impacts of their invasiveness [103]. The goal is to manage invasive species in a way that establishes balanced and controlled ecosystems, providing a high level of possible ecosystem services. This is especially valid for native habitats in which there are natural mechanisms of species control. In new habitats, though, these species deserve special attention in recognition of their costs and management models. In the case study of buffelgrass in Australia, Grice and the authors created broadscale strategic solutions for the management of this species. Many invasive species, *D. viscosa* including, are contentious species and management approaches could follow the same direction as Grice et al. [104] proposed. The results and observations presented in this review highlight the fragility of environmental balance, as well as the unexplored potential of *D. viscosa*. Systematic research on the invasion dynamics and ecosystem services provisioning of *D. viscosa*, as well as complex large scale strategies and actions, are needed to establish sustainable management plans.

Different authors [40,105] have proved that *D. viscosa* chemical properties can be useful in weed germination inhibition, and therefore used as a biological herbicide. They identified that allelopathic activity changed during the vegetation; extracts from leaves collected in spring were more active than those collected in autumn. *D. viscosa* could also be used as a secondary plant in biological control [1]. Moreover, this species has shown a significant potential in soil management, in particular in use for phytoremediation in mining-affected semiarid soils, since it is an efficient bioaccumulator of trace metals [33].

7. Conclusions

Motivated by observed changes in *Dittrichia viscosa* behavior, with a particularly noticeable negative impact on agriculture, in this review, we add and summarize valuable information to the existing knowledge on this species. Ecosystem disturbances and constant changes in environmental conditions can easily compromise the ecological balance. Climate change poses risks that vary greatly geographically. Phytochemicals present in the plant organs of *D. viscosa* make it a promising resource for use in organic agriculture and phytomedicine. The positive aspects of species in any ecosystem have to be weighed against the loss of other ecosystem services. Habitat-specific studies are essential to adopt goal-specific measures in the management of *D. viscosa*. Still, it is more likely to use the plant in the native environment as an ecosystem provider and try to control its spread and eradicate when possible in the new habitats. Additional studies on the possible uses of extracts from *D. viscosa* for the purpose of controlling weeds in agriculture and other uses of this species in soil management would also be beneficial.

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