Research Article

Notes on the occurrence of *Phytolacca americana* L. in crop fields and its potential agricultural impact

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Citation: Follak S, Schwarz M, Essl F (2022) Notes on the occurrence of *Phytolacca americana* L. in crop fields and its potential agricultural impact. *BioInvasions Records* 11(3): 620–630, https://doi.org/10.3391/bir.2022.11.3.04

Received: 6 October 2021
Accepted: 9 March 2022
Published: 31 May 2022

Handling editor: Vanessa Lozano
Thematic editor: Giuseppe Brundu

Abstract

Phytolacca americana is a large perennial invasive alien plant indigenous to the eastern United States. In Europe, it usually infests forest edges, open woodlands and other disturbed habitats. In this study, the occurrence of the species as a weed in crop fields in Austria was analysed based on distribution data collected from different sources. Moreover, *P. americana* was surveyed in a selected area in southern Austria (Styria) and its behaviour as weed was analysed by phytosociological relevés. The situation of the species in Austrian neighboring countries (the Czech Republic, Germany, Hungary, Italy, Slovakia, Slovenia, Switzerland) was also briefly investigated. The results show that *P. americana* is generally rare on arable land in Austria and its neighboring countries. The survey and distribution data collected, however, showed that *P. americana* occurred locally more abundant in crop fields. Two factors may have contributed to this phenomenon: (i) high propagule pressure from large forest and ruderal populations, (ii) and small-scale and less intensive cultivation practices (e.g. weed control) of particularly low growing crops such as oil pumpkin. The study illustrates the need to further monitor the occurrence of *P. americana* in crop fields and its potential impact.

Key words: distribution, emerging weed, habitat, invasive alien plants, management

Introduction

Arable land is prone to new introductions of alien plants, naturalization and invasion (Chytrý et al. 2008). Thus, a number of alien plants is already commonly found in crop fields and their number has progressively increased in recent decades in Central Europe (Pyšek et al. 2005), already causing substantial crop yield losses (Fried et al. 2017). Certainly, there are more alien plants, which are in a waiting position or are already in an early stage of invasion ("emerging weeds") in crop fields and are expected to become problematic in the future in agricultural production (EPPO 2021a).

Phytolacca americana L., common pokeweed, is a perennial herb native to the United States (Balogh and Juhász 2008). It usually infests disturbed anthropogenic habitats, but in particular forest edges, open woodlands (Balogh and Juhász 2008), and mixed forests, where it forms dominant and

dense stands (Schirmel 2020). Consequently, attention has been paid to its invasion in forests (e.g. Rupp et al. 2017). In Europe, the increasing spread of the species in near-natural habitats has been the motivation for assessments of the invasiveness and associated risks (e.g. Tanner and Fried 2020). However, the species had also locally emerged as a weed in crop fields in some European countries, such as in France (Fried 2017) and Hungary (Solymosi et al. 2001). Likewise, in Austria, few occurrences of this species in crop fields have recently been observed (Follak 2021). At present, little is known about the species' impact on agronomic crops in Europe. In its native range, though, *P. americana* has already become more prevalent in certain agricultural areas (Nolte et al. 2002) and it is considered difficult to manage (Patches et al. 2017).

Thus, in this paper, i) occurrences of *P. americana* in crop fields in Austria and neighboring countries are presented, (ii) the phytosociological affiliation in crop fields and (iii) the potential agricultural impacts are briefly discussed, and (iv) management recommendations are provided.

Materials and methods

Study species

Phytolacca americana is indigenous to the eastern United States and is presently found from southern Canada (Ontario, Quebec) to Florida, in the west to Minnesota south to Texas (USDA, NRCS 2021). It had been introduced into Europe in the 17th century as a dye-plant in the Mediterranean area (Balogh and Juhász 2008) and at present, it can be found in many European countries (EPPO 2021b). *Phytolacca americana* is a polycarpic perennial non-clonal herb. It reproduces from buds on the taproot and by seeds. Aboveground shoots of this plant arise from the taproot and consist of diffusely, subdichotomously branched fleshy stems that can grow almost 80–250 cm in height. The species is also capable of abundant seed production and the fleshy black fruits are consumed and disseminated by a variety of birds (McDonnell et al. 1984). Main vectors of *P. americana* are among others true thrushes (*Turdus* spp.) and the common starling (*Sturnus vulgaris* L.) (Benvenuti 2007; Balogh and Juhász 2008). Shoots occur in mid-April and seedlings emerge from early April through early summer (up to the end of July), while peak emergence is mid-May (Balogh and Juhász 2008; Patches 2014; Follak pers. observation 2021). Images can be retrieved from the EPPO Global Database (EPPO 2021b) and a detailed description of *P. americana*, its biology, ecology and invasion history can be found in Balogh and Juhász (2008).

Data sources and analysis

Distribution data of *P. americana* were collated from the floristic literature (https://www.zobodat.at/publikation_series.php) and the databases Virtual

Herbarium (http://herbarium.univie.ac.at/) and AgriWeedClim. The latter database is a resource of standardized vegetation plot (relevé) data of agricultural habitats of Central Europe (Glaser *pers. comm.* 2021). A period from 1950 onwards was chosen to take into account the most recent observations. The data was amended by records from the first and last author and other experts (see acknowledgements). The species' occurrence as a weed in crop fields was evaluated based on the description of the habitat in the respective source of the record (if available). A map showing the spatial distribution of the study species on arable land was created based on the grid cells occupied (5 × 3 geographic minutes, ~ 33 km^2) of the Floristic Mapping Project of Central Europe (FMA) (Niklfeld 1999).

In 2021, infestations of *P. americana* were surveyed in detail in a selected area in southern Austria (grid cell 9259/2 of the FMA) in order to better characterize the spread pattern and extent of weedy distribution in agriculture. This area was selected based on the first author's previous observations in 2019. The study area (approximately 3.65 km^2) included parts of the municipalities of Gabersdorf and St. Veit am Vogau. The climate is temperate and humid, average annual temperature and precipitation being 9.7 °C and 941 mm, respectively (reference place: Leibnitz, 46.768056; 15.550833, 1971–2000). The study area is dominated by agriculture (main crops are maize, oil pumpkin, cereals) with some interspersed wooded areas. Populations of *P. americana* in crop fields and in other habitats (i.e. forests, ruderal sites) were recorded on the 31.07.2021 and 26.08.2021. Each location was georeferenced. Phytosociological relevés (n = 5) in the infested crops were recorded according to Braun-Blanquet (1964) to characterize the floristic composition of invaded weed communities and infestation levels. These data was amended by further relevés (n = 2) in southern Austria (Bad Radkersburg, 9362/1 of the FMA). The data were entered into the programme HITAB5 (Wiedermann 1995) to rank the weed species according to frequency. Nomenclature and taxonomy follow Fischer et al. (2008). The maps were produced in ArcMap 10.2.2 (ESRI).

A narrative literature review (Google scholar, specific national floristic journals and databases) and an expert consultation have been conducted to evaluate the occurrence of *P. americana* as a weed in agriculture with a focus on the neighboring countries of Austria (i.e. the Czech Republic, Germany, Hungary, Italy, Slovakia, Slovenia, and Switzerland).

Results

Phytolacca americana *as a weed in Austria*

The data from the database Virtual Herbarium (n = 22 records with habitat information) show that *P. americana* primarily occurs in forest edges, open forests and forest clearings while individual records indicated that the species also occurs in agricultural areas (e.g., "group of bushes between

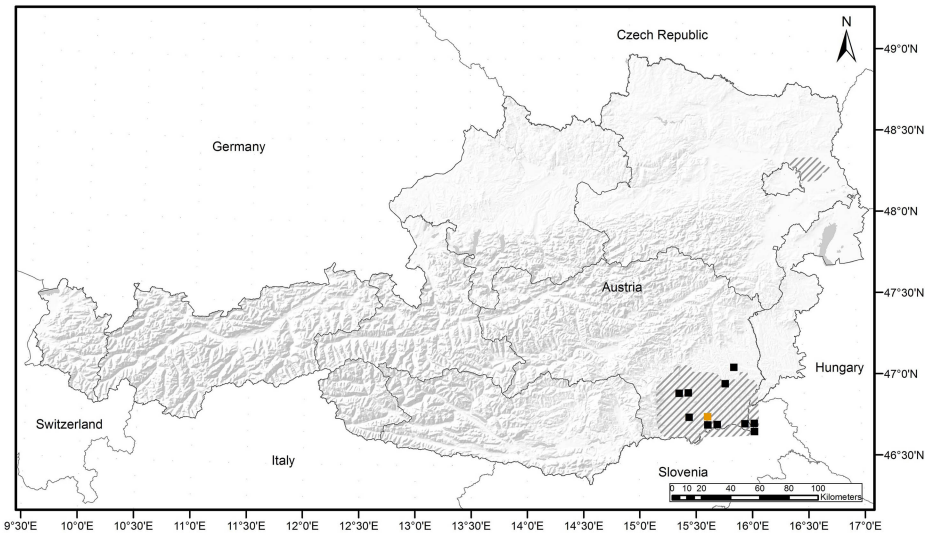

Figure 1. Grid cells of the Floristic Mapping of Central Europe (5 × 3 geographic minutes, ~ 33 km^2) with records of *Phytolacca americana* in crop fields in Austria (note that ocurrences outside of crop fields are not shown). In the single orange marked grid cell (9259/2), occurrences of *P. americana* in crop fields were examined in detail (Figure 3). The two current main "hotspots" of the distribution of the species are roughly shown by shading of the background. Data sources: records compiled within this study (see details in the text).

maize fields"; herbarium collection no.: GZU 000259000). Only a few records have been made in ruderal habitats (e.g. sand pit, landfill site). The habitat affiliation is also confirmed by *P. americana* records published in the literature (e.g. Maurer 1984; Essl et al. 2011).

Other sources (i.e. unpublished data, expert consultation, AgriWeedClim database), however, displayed records of *P. americana* in crop fields. In total, 26 records of *P. americana* in crop fields within 11 grid cells have been collated from these sources. All records were made recently (> 2010) and oil pumpkin was most frequently invaded (54% of all records). Crop infestations were confined to southern Austria (Styria), which is also the hotspot of the species' general distribution in Austria (Figure 1). In eastern Austria (Figure 1), crop infestations have not been noticed so far.

The records compiled within the study area showed that *P. americana* colonized mainly the narrow strip between two crop fields and field margins, but it sometimes also occurred inside the crop field (Figures 2, 3). The species infested predominately oil pumpkin and maize (comprising of > 90% of all records in crop fields), but also soybean and cereals. In this area, *P. americana* was frequently observed in the interspersed wooded areas as well as in ruderal habitats (e.g. roadsides, wasteland), below power pylons and tree stands (for hunting). Population sizes in these habitats ranged from a few (large) individuals to more than 100 (Figures 2, 3).

Phytosociological affiliation

The phytosociological affiliation was documented with seven relevés (Table 1). The invaded weed vegetation belongs to the alliance *Panico-Setarion* Sissingh in Westhoff et al. 1946, which is a widespread weed vegetation in

Figure 2. Representative site images of *Phytolacca americana* in the study area in southern Austria (Styria): (a) specimens in oil pumpkin, (b) seedlings within oil pumpkin, (c) large individuals on the narrow strip between a cereal and a maize field, (d) specimen in soybean, (e) population under a power pylon and (f) infestation of a maize field margin from populations growing in the wood. Photos by S. Follak.

summer crops in Central Europe (Mucina et al. 1993). The most-abundant co-occurring species were *Chenopodium polyspermum* L., *Chenopodium album* agg., *Setaria pumila* (Poir.) Roem. & Schult. and *Amaranthus powellii* S. Watson as well as *Calystegia sepium* L., which is a typical species of crop field margins. Single to a few specimens of *P. americana* were most commonly found in the crop fields studied. However, some specimens observed were very large and sprawling and in combination with newly emerged individuals, higher cover values could be locally achieved (field margins), in particular in oil pumpkin (Table 1, Figure 2).

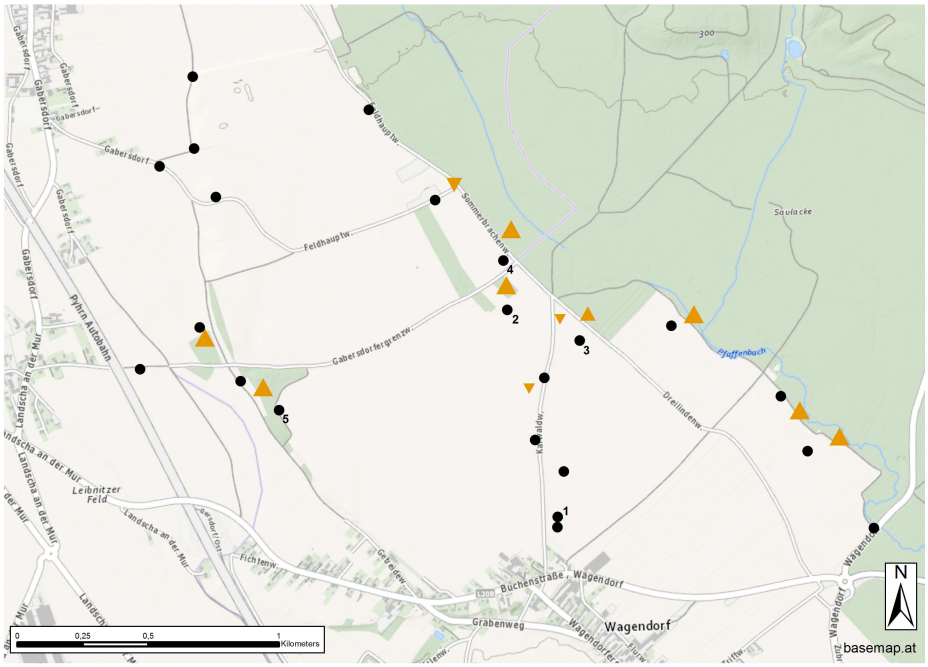

Figure 3. Small-scale distribution of *Phytolacca americana* in the study area in southern Austria (Styria) in 2021. For the exact location in Austria, see Figure 1. Habitats: black dots = field (strip between fields, field margin and/or field center), orange triangels = woodland (peak upwards), ruderal sites/power pylon (peak downwards). The dimension of the triangles indicates different population sizes (small: 1–10, medium: 10–100, large > 100 individuals). Numbers correspond to the phytosociological relevés (see Table 1).

Table 1. Phytosociological relevés with occurrences of *Phytolacca americana*. Plot size 30 m^2. Plant cover scale used: r = 1–2 individuals; + = <1%; 1 = 1–5%; 2m = many, but < 5%; 2a = 5–12.5%; 2b =12.5–25%; 3 = 25–50%; 4 = 50–75%; 5 = 75–100%. For information on locality and site characteristics, see Supplementary material Table S1.

Species	Relevé						
	1	2	3	4	5	6	7
***Phytolacca americana* L.**	**r**	**r**	**1**	**2m**	**2a**	**2b**	**r**
Calystegia sepium L.	1	r	1	2m	2b	.	+
Chenopodium album agg.	2m	1	.	1	2a	.	2m
Chenopodium polyspermum L.	2a	2m	.	2m	+	.	2a
Curcubita pepo L.	3	4	.	4	2b	.	2a
Setaria pumila (Poir.) Roem. & Schult.	+	.	2b	+	.	.	1
Amaranthus powellii S. Watson	.	.	.	+	+	.	+
Digitaria sanguinalis agg.	.	.	+	+	.	.	1
Galinsoga parviflora Cav.	.	.	.	+	2a	.	1
Persicaria lapathifolium L.	r	.	.	.	r	.	.
Solanum nigrum L.	+	r	.	.	.	.	.
Sorghum halepense (L.) Pers.	.	r	.	.	.	.	+
Zea mays L.	.	.	4	.	.	2b	.
Ambrosia artemisiifolia L.	.	.	.	.	.	.	2a
Cirsium arvense (L.) Scop.	.	.	.	.	+	.	.
Cyperus esculentus L.	.	.	.	r	.	.	.
Echinochloa crus-galli (L.) P. Beauv.	r	.	.	.	.	.	.
Panicum dichotomiflorum Michx.	.	.	.	.	.	4	.
Robinia pseudoacacia L.	.	.	.	.	.	r	.
Stachys palustris L.	.	.	.	.	.	.	+
Taraxacum officinalis agg.	.	.	.	.	.	.	r
Tripleurospermum inodorum (L.) Sch. Bip.	.	.	.	.	.	.	r
Urtica dioica L.	.	.	.	.	r	.	.
Veronica persica Poir.	.	.	r	.	.	.	.

Phytolacca americana *as a weed in neighboring countries – a short review*

The species has only rarely been reported as a weed in crop fields in the countries studied. In Hungary, it occurred locally in crops, orchards and (abandoned) vineyards (Solymosi et al. 2001; Balogh and Juhász 2008). Solymosi et al. (2001) described occurrences in crop fields of *P. americana*, such as in pepper, tomatoes and sunflower in the area of Tompa (S-Hungary). Occurrences have recently been reported in soybean in the settlements of Szentdénes and Bicsérd in SW-Hungary (Pinke *pers. comm.* 2021). *Phytolacca americana* is widespread throughout Italy (Portal to the Flora of Italy 2021), but it has been hardly reported from agricultural areas, only sporadically from vineyards or crop fields and their margins (e.g. Zanotti 1991; Pierini et al. 2009; Bovio 2014; Follak pers. observation 2021). Likewise, in Slovenia, *P. americana* is widely distributed and therefore, fields in general are specified as habitats (e.g. Spletni portal Invazivke 2021), but no tangible data on such occurrences is available. In contrast, in the Czech Republic, *P. americana* is rare (http://www.pladias.cz), and so there are hardly any data on occurrences in crop fields available (Glaser *pers. comm.* 2021). For the other countries studied, no observations are currently known.

Discussion

Phytolacca americana *as a weed in crop fields*

The results showed that data on the occurrence of the species in crop fields is scarce indicating that it has not yet emerged as a significant and widespread weed in agriculture in Austria and its neighboring countries. However, the results of the field survey conducted and unpublished data revealed that it locally colonizes arable land in Austria (Figures 1, 3). These data has been collected in the last few years and may suggest that occurrences in crop fields are a quite recent phenomenon. Further surveys in Austria and neighboring countries are required to allow for a better assessment of its distribution in agriculture. It has been commonly observed that invasive alien plants often change and broaden their habitat preferences during their invasion. Recently, this has been shown for e.g. *Ambrosia artemisiifolia* L. (from ruderal habitats to roadsides and crop fields) and *Impatiens glandulifera* Royle (from riparian habitats to forests) (Essl et al. 2009; Čuda et al. 2020).

In the study area surveyed in detail, the species has been known since the 1980s from woodland areas (e.g. Maurer 1984), and currently, large populations can be found in these habitats (Figure 3). Such populations seem to be important for occurrence and success of the species in the crop fields. Seeds from populations growing along forest edges and subsequently also from those growing on the narrow strip between fields lead to occurrences of *P. americana* in the field margins via seed rain (Figure 2).

Seed production of *P. americana* specimens can be very high (McDonnell et al. 1984) and thus, they can easily add and replenish seeds to the soil seed bank. Short-distance spread over several tens of meters most likely occurs via bird dispersal (Rost et al. 2015; Li et al. 2017). For example, the latter authors showed that birds dispersed fruits within 80 m of the mother plants in an urban environment. This dispersal pathway is likely responsible for the small populations and single specimens located farther from the source populations (Figure 3). Movement of seeds within fields and from field to field can occur via contaminated agricultural machinery and/or harvesters (Benvenuti 2007) and this pathway may also apply to *P. americana*. In the crop fields surveyed, recruitment seemed also to be from existing rootstocks, which is reflected by well-developed individuals (Figure 2).

It can be assumed that small-scale and less intensive cultivation practices (e.g. low herbicide input) of particularly low growing crops combined with a reduced weed-suppressive ability, such as oil pumpkin, allow the occurrence of *P. americana*. Weed control in oil pumpkin is more challenging compared to other crops, as there are only a limited number of registered herbicides applicable and its growth habit makes mechanical control difficult (Pinke et al. 2018). Maize was certainly also affected, but it was noticeable that the interior of most maize fields studied was hardly infested. Here, control of *P. americana* may fail due to gaps in the effectiveness of the standard herbicide progammes used.

Potential agricultural impact

The study species is considered competitive, its presence in crop fields hinders the growth, and consequently, yield of the crops could be reduced (Patches et al. 2017). Only little research has been conducted on yield loss due to *P. americana* infestations in crops. Patches et al. (2017) noted that "… not controlling pokeweed reduced soybean yield by about 47% compared to the highest yielding glyphosate treatment (2990 vs. 1453 kg/ha)" (Pennsylvania/United States). Large and sprawling individuals may also interfere with the harvest. Moreover, the berries can stain seed during harvest (Tanner and Fried 2020).

Can the plant become a significant weed in Austria? The current low prevalence of *P. americana* in crop fields in Austria and neighboring countries first indicates that this is currently not the case. Under certain conditions, however, the species can occur—locally—more prominently in crop fields, as the results from this study (i.e. high propagule pressure from nearby large populations combined with specific crop selection and rotation) and observations from other countries, such as France and the United States, show. In SW-France (Landes), *P. americana* has been found in maize fields where it is particularly problematic on sandy-humus and sandy-loam soils (Fried 2017). In the United States, *P. americana* has become more

widespread and problematic in certain agricultural areas (e.g. in Northeastern United States) (Patches et al. 2017). Specifically, the widespread adoption of no-till practices, along with the reduced diversity of crop rotations (maize-soybean) and herbicides, has promoted its spread. In Austria, tillage operations are widely adopted in agriculture. It is assumed that *P. americana* may not likely establish and become weedy under such conditions as the taproot is most likely destroyed. However, it may depend on cultivation depth (ploughing vs. minimum tillage) and intensity (number of passes); individuals may survive and new populations can always develop from the soil seedbank. In this respect, effects of (minimum) tillage on the population dynamics of *P. americana* should be further investigated.

Control options

There may be occasions where control of the species in fields is deemed to be necessary. A first step is for landowners (i.e. forest owners) and farmers to become aware of the problem. It is then important to control plants that are capable of reaching reproductive maturity, thus reducing seed production. Specimens that grow between two crop fields or on the edge of the woods should be controlled in order to stop direct seed influx into the crop fields. Rupp et al. (2017) provided information on different options for mechanical control of *P. americana*. Digging up individual plants with complete roots before seeding was the most successful option. This may also apply to the scattered mature specimens within the crop fields. In case of major infestation (with young specimens), however, the implementation becomes more and more time-consuming.

The use of herbicides is another option, but there is a lack of experience under Central European conditions (e.g. Mamarot and Rodriguez 2003). In North America, research has been conducted with foliar-applied herbicides, such as glyphosate, nicosulfuron and auxin-type herbicides, mostly in maize and soybean under no-till conditions (Marcelli and Glenn 1993; Nolte et al. 2002; Patches et al. 2017). Efficacy could be high (> 90%) depending on herbicides and combinations used and application timing. It is important that classical herbicide programs used in infested areas are supplemented by specifically effective herbicides against *P. americana*. Studies on the control options with herbicides are necessary under local conditions in Austria.

Acknowledgements

L. Balogh, S. Buholzer P. Eliáš, G. Fried, A. Krapf, F. Kuzmič and G. Pinke are greatly acknowledged as they provided information on the species and distribution data, respectively. M. Glaser is appreciated for giving access to the database AgriWeedClim. We appreciate the helpful comments of three anonymous reviewers.

Funding declaration

This study was co-funded through the 2017–2018 Belmont Forum and BiodivERsA joint call for research proposals, under the BiodivScen ERA-Net COFUND programme, and with the funding organisation Austrian Science Foundation FWF (grant I 4011-B32) (to FE).

Authors' contribution

SF: conceptualization, data collection, wrote the manuscript, MS: designed maps and reviewed the manuscript, FE: provided data and reviewed the manuscript.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Phytosociological relevés: Recording date, habitat (crop), altitude (m a.s.l.), community and coordinates (latitude, longitude).

This material is available as part of online article from:
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