Article

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Invasive or threatened? The decline of the old-world *Xanthium strumarium* (*Asteraceae*) in Italy based on herbarium records

Abstract

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Xanthium is a taxonomically intricate genus of the sunflower family (*Asteraceae*). In Italy, two species of *Xanthium* sect. *Xanthium* are present: the native *X. strumarium* and then introduced *X. orientale*. In this study, we assess changes in relative frequency of these two species in Italy based on herbarium records.
Based on our analyses, we could observe a strong decline of the native *X. strumarium* in Italy, started approximately one hundred years ago. Since then, this species has become extremely rare and more effort should be spent to investigate its actual distribution range and potential extinction risk in Italy. This study also demonstrates the importance of herbaria to address questions regarding the dynamics in relative frequency and distribution of competing native and introduced species.

Key words: herbaria; neophyte; alien flora, *Xanthium orientale* subsp. *italicum*.

Introduction

Xanthium L. is a taxonomically intricate genus of tribe *Heliantheae* in the sunflower family (*Asteraceae*). It is a monophyletic genus placed in the core-group of subtribe *Ambrosiinae* Benth. & Hook.f., together with genera like *Ambrosia* L. and *Iva* L. (Tomasello & Heubl 2017; Tomasello & al. 2019). Like the latter genera, it is peculiar among Asteraceae for being wind-pollinated and for bearing unisexual florets placed in separated flower heads. Female heads are very peculiar structures, enclosing completely two female flowers, and are covered by hooked spines and beaks. These structures (burs) can effectively stick to animal fur and human clothing and be dispersed over hundreds of kilometres.

Burs are also very important from a taxonomic point of view, since most of its characters are diagnostic to delimit taxa in the genus. Due to their variability, taxonomic treatments in the genus have varied consistently in the past, ranging from recognising twenty

or more species (Millspaugh & Scherff 1919; Widder 1923), to lumping all taxa into two, very broadly defined species (Löve & Dansereau 1959). The taxonomic situation is particularly complicated in *Xanthium* sect. *Xanthium* (the section including species with unarmed stems). However, studies based on molecular markers have demonstrated that three polymorphic species can be unequivocally recognised in this section, i.e., *X. strumarium* L., *X. orientale* L. and *X. chinense* Mill. (Tomasello 2018). The first species is the only native to the old world. *Xanthium strumarium* is relatively easy to distinguish from the other two species, because of the small burs (up to approximately 1 cm) covered by few spines and with straight apical beaks. Its native presence in Europe is certain, as it can be inferred from the literature [it is one of the about 500 species mentioned by Dioscorides in his *De Materia Medica* (first century BC)], and from fossil records (Löve 1975). Despite the name, *X. brasilicum* Vell. [≡*X. strumarium* subsp. *brasilicum* (Vell.) O. Bolòs & Vigo] is a morphotype of this species native to part of the Mediterranean Basin and the Middle East. In Italy, it has been collected in the past in Sicily, Sardinia, and sporadically in a few other southern Italian regions (Bartolucci & al. 2018).

Xanthium orientale has instead an American origin and in recent times has become cosmopolitan thanks to human trade and human-mediated transport (Tomasello 2018). Many different taxa have been described within the complex in Europe, including *X. italicum* Moretti, *X. riparium* Lasch, *X. saccharatum* Wallr., *X. albinum* (Widd.) Scholz & Sukopp, nowadays considered sometimes as subspecies of *X. orientale* (Greuter 2003). *Xanthium chinense* is the tropical/sub-tropical vicariant of *X. orientale* and originates from the Caribbean and south eastern North America, nowadays being found in many tropical and sub-tropical areas of the world.

In Italy the most common morphotype of the *X. orientale* complex is "*X. italicum*", which since its first observation by Giuseppe Moretti in 1820 in the surroundings of Padua (Moretti 1822) spread all over the Mediterranean Basin. However, these plants have been treated differently in the literature of the last decades, as they are sometimes considered as independent species (e.g., Pignatti 1982; Galasso & al. 2018), treated as members of the *X. orientale* complex (Conti & al. 2005; Pignatti & al. 2017-2019) or even included in a very broad *X. strumarium* complex (e.g., Motti & Ricciardi 2005; Giardina & al. 2007). This inconsistency makes any evaluation of the distribution and conservation status of the above mentioned *Xanthium* species difficult to assess.

With the present work, we wanted to assess the changes in the relative frequencies of *X. strumarium* and *X. orientale* in Italy throughout the last 200 years, based on data retrieved from herbarium collections. For this purpose, we visited some of the most important herbaria in Italy and Central Europe, and examined all specimens collected in Italy for which information on date and place of collection was unequivocal.

Materials and Methods

Data collection. – Eight European herbaria (Table 1) were screened for specimens of *Xanthium* sect. *Xanthium* collected in Italy. A few specimens collected by the authors (ST) were also included in the study. Two additional herbaria were screened only partially: for the herbarium of the University of Pisa (PI), we considered only the vouchers uploaded in

Table 1. List of herbaria visited for this study, along with information on herbarium code (Holmgren & al. 1990) and location, and number of samples included.

Full name of the herbarium	**Location and Herbarium code**	**No. of samples included**
Herbarium Berolinense	Berlin, B	22
Herbari de l'Institut Botànic de Barcelona	Barcelona, BC	6
Università degli Studi di Bari	Bari BI	11
Università di Bologna	Bologna, BOLO	33
Università di Catania	Catania, CAT	24
Herbarium Universitatis Florentinae	Florence, FI	180
Herbarium Göttingen	Göttingen, GOET	4
Herbarium Mediterraneum Panormitanum	Palermo, PAL	7
Università di Pisa	Pisa PI	6
Herbarium of the National Museum in Prague	Prague, PR	3
Private herbarium of S.Tomasello	-	7

the JACQ database (https://jacq.org/); only specimens from Apulia and Abruzzo were included from those deposited at the herbarium of the University of Bari (BI). All specimens were re-identified to species level using morphological traits of the burs and following the treatment published by Tomasello (2018). Immature specimens without burs could not be unequivocally identified and were therefore excluded from the analyses. A complete list of herbarium specimens used in the study, along with complete voucher information is given as Electronic Supplementary File 1 (ESF 1).

Analyses. – Information on the collection place and date was extracted from the labels of the vouchers. Samples for which collection place (at least until the level of Italian administrative regions) and/or year of collection were not reported were excluded from the analyses. Duplicate specimens found in some of the different herbaria visited, were included only once in the analyses. To visualize the relative frequency of *X. strumarium* and *X. orientale* throughout the last two centuries we produced histograms and mosaic graphs (Hartigan & Kleiner 1984) in R (R Core Team 2018) using the packages ggplot2 (Wickham 2017) and ggmosaic (Jeppson & al. 2017). Samples were divided in 10-years age classes. Distribution maps of range expansion of *X. orientale* in Italy were produced using inkscape (Inkscape Project 2021) and the map available at: https://commons.wikimedia.org/wiki/File:Italy_map_with_provinces.svg.

Results

The oldest herbarium voucher among those examined in the present study was a specimen of *X. strumarium* found in the herbarium of the University Bologna (BOLO) and collected by A. Bertoloni in Sarzana (Liguria) in 1807. The oldest evidence of the occurrence of the new world species *X. orientale* in Italy is a specimen dated to 1820 and collected by the botanist Giuseppe Moretti. On the specimen, he annotated that the plant was "common in the surroundings of Pavia, and along the River Po". From this, it can be assumed that the species must have arrived in Italy some years earlier, and spread until the beginning of the 20th century over most of the Italian territory (Fig. 1).

In total, we included information from 287 *Xanthium* herbarium vouchers in the analyses. The number of *Xanthium* specimens peaked in the second half of the 19th century (Fig. 2a), after which there is a change in relative frequencies of the two species (Fig. 2b). The number of specimens of *X. strumarium* drastically declines starting from 1880, and this species became rare since the second half of the 20th century. The last specimen in our dataset belonging to this species was collected in 1973 at "Gorghi Tondi" (Sicily) and it is housed in the herbarium of the University of Catania (CAT020884).

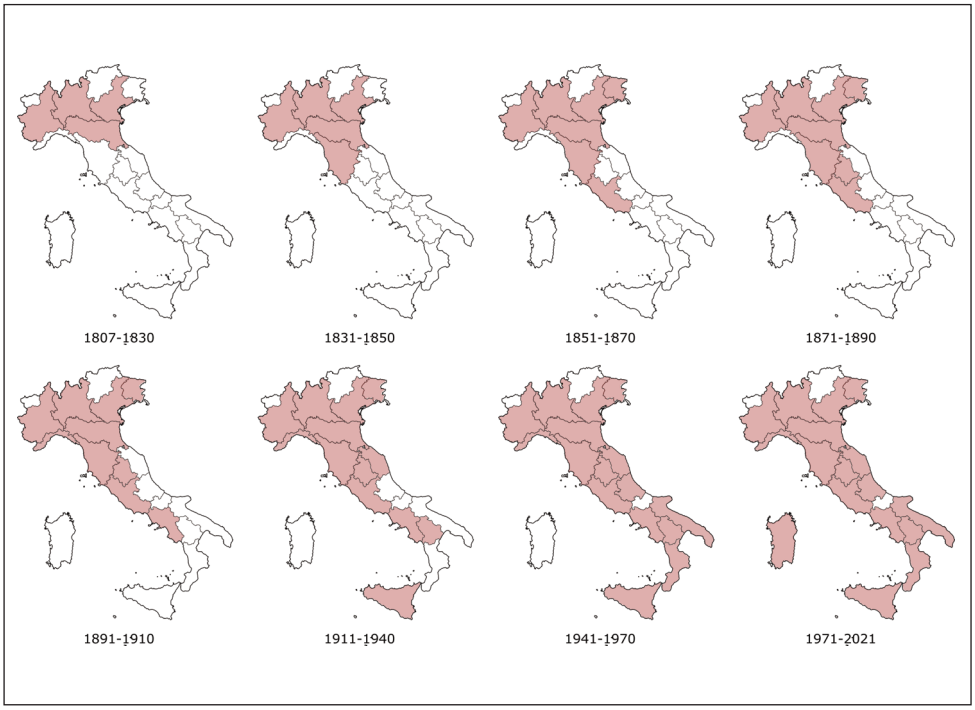

Fig. 1. Maps illustrating the expansion of *Xanthium orientale* in Italy over the last two centuries, based on the specimens housed in the herbaria visited for the present study. Administrative regions where the presence of *X. orientale* was already observed in a specific time interval are coloured in pink.

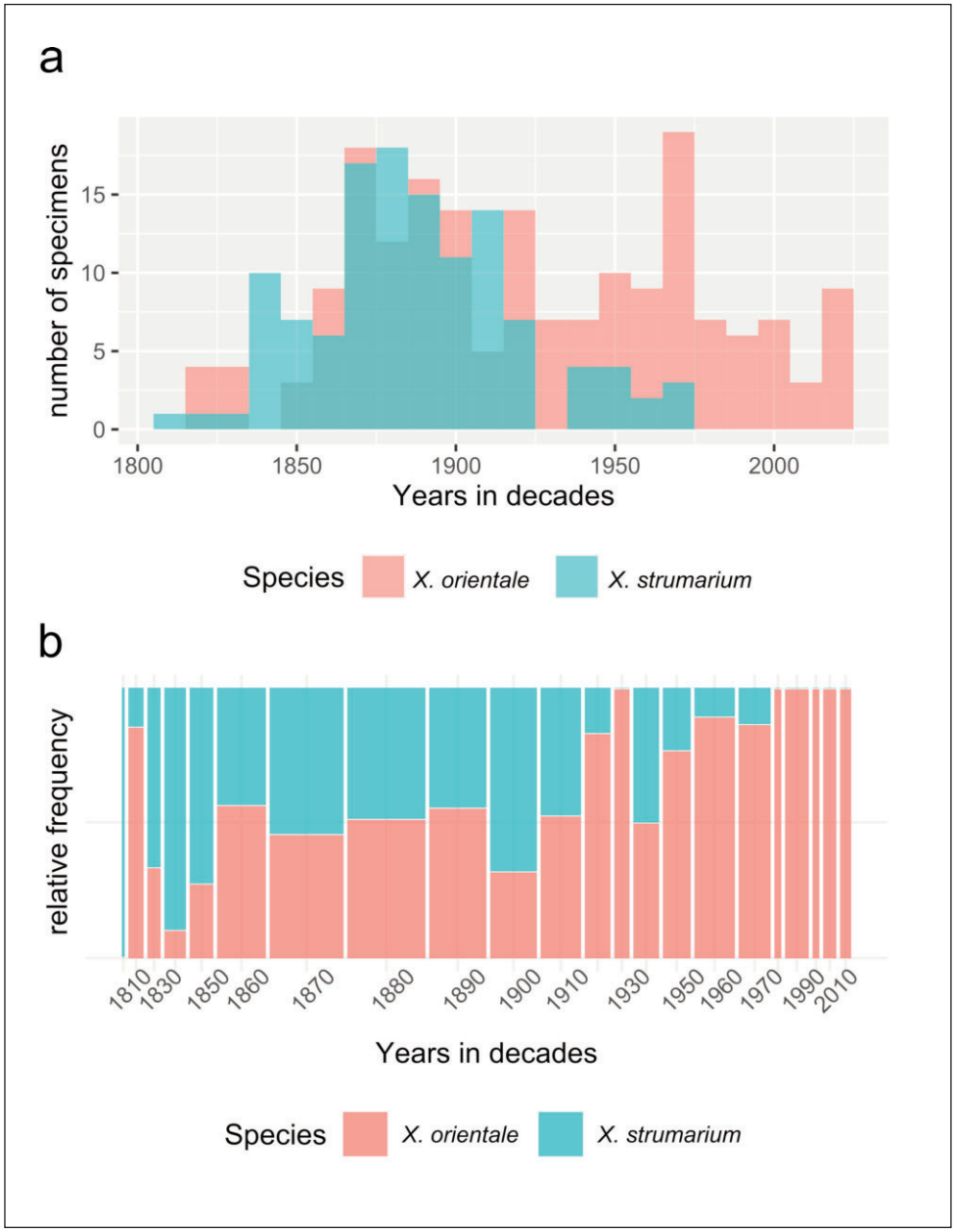

Fig. 2. Frequency of the *Xanthium orientale* (pink) and *X. strumarium* (turquoise) specimens over the last two century. a) Histogram depicting the number of specimens found in the herbaria visited for the present study over time. Samples are subdivided in age classes of 10 years. b) Mosaic graph illustrating the relative frequency of the two species over time. Samples are subdivided in age intervals of 10 years. Bar width is proportional to the number of specimens registered in the specific age interval.

Discussion

Robust taxonomic treatments and correct identification of plant specimens are tremendously important to allow satisfactory assessments of biodiversity and species conservation status. However, there is often confusion about the identity of native and introduced *Xanthium* populations in Europe. These are sometimes correctly treated as independent species (i.e., *X. strumarium* and *X. orientale*, respectively), but often are merged into a single polymorphic species (*X. strumarium* in a very broad sense), making statements on relative frequency and distribution of these two species almost impossible. In Pignatti & al. (2017-2019), even though distinction is done between *X. strumarium* and *X. orientale,* the former is erroneously included in the *X. orientale* complex, which makes the situation even more confusing.

From the specimens examined and the analyses carried out in this study, we could observe a strong decline of *X. strumarium* in Italy, which started approximately one hundred years ago. Using the taxonomic circumscription of the most recent and accurate treatments (Greuter 2003; Tomasello 2018), *X. strumarium* in Italy has become extremely rare and its conservation status should be reconsidered. This species was certainly abundant in the whole peninsula until the 19th and beginning of the 20th centuries, and started declining after the appearance of the introduced *X. orientale* in natural environments.

We were not able to find any *X. orientale* specimen from Italy predating the first collection of "*X. italicum*" by Moretti in 1820. The author first identified the specimen as *X. echinatum* Murr., and two years later, and after correspondence with some Italian and European botanists (Löve & Dansereau 1959), he decided to describe the new species *X. italicum* (Moretti 1822). However, specimens from historical herbaria (e.g., the herbaria of Giuseppe Monti and Ferdinando Bassi in BOLO), were not included in the study. In those herbaria, voucher information is usually scarce and plants might have been cultivated and collected in botanical gardens. A specimen of *X. orientale*, referable to subspecies *orientale* (sensu Greuter 2003) was present in "Erbario Monti" (possibly collected around 1750) and another in the "Erbario Bassi" (second half of the 18th century). The vast majority of specimens belonging to the *X. orientale* complex and examined in this study were referable to *X. italicum* (≡ *X. orientale* subsp. *italicum* (Moretti) Greuter). Only four samples could be identified as *X. orientale* s.str. [≡ *X. orientale* subsp. *orientale* in Greuter (2003)], three of which from Veneto and one collected in the surrounding of Bologna (Emilia Romagna). This is in discordance with the statement of Pignatti & al. (2017-2019) that the latter is the most abundant *X. orientale* subspecies in Italy.

The most recent *X. strumarium* among the specimens examined was a voucher collected by Brullo around the "Gorghi Tondi", in Sicily in 1973. When looking critically at other sources of data, a few more recent, sporadic discoveries might be added (e.g., plants photographed at Castiglione di Cervia (Ravenna), Frigole (Lecce) and Casale di Scodosia (Padova); https://www.actaplantarum.org/galleria_flora/galleria1.php?view=1&id=5329). However, in other cases, other *Xanthium* taxa or deviating forms of *X. orientale* subsp. *italicum* with smaller burs covered by fewer spines [e.g., variety "nigri" sensu Widder (1923)] are often misidentified as *X. strumarium*. In the most recent checklists, *X. strumarium* is reported to occur in most of the Italian territory (Conti & al. 2005; Bartolucci & al. 2018; http://dryades.units.it/floritaly/index.php?procedure=

taxon_page&tipo=all&id=8723). In Giardina & al. (2007) the species is reported as common in Sicily, although the same authors state that they have found it only once close to the "Bronte-Maniaci road". We believe that *X. strumarium* has become extremely rare in Italy in the last 50 years, and more effort should be devoted to investigate the actual distribution range and extinction risk of this species in Italy.

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