

1 **First report of naturalization of *Houttuynia cordata* Thunb. 1783**

2 **(Saururaceae) in Italy**

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22 23 24 25 **ABSTRACT**

26
27 The Chameleon plant (*Houttuynia cordata* Thunb. – Saururaceae) was introduced across all
28 continents from Asia for ornamental and medicinal purposes at least two centuries ago. *H. cordata*
29 is deemed a strong invader thanks to its great ability for rapid vegetative propagation by means of
30 rhizomes and stolons (and their fragments) coupled with a high resistance to herbicides. Moreover,
31 it has been suggested that *H. cordata* has the potential to displace native plants in wet forests and, in
32 general, in wetland ecosystems. In New Zealand and North America, this species has been included
33 in the black list of invasive alien species and it is included in a special control program for
34 monitoring and eradication.

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36 In this study we record the first established naturalized population of *Houttuynia cordata* in Italy. It
37 was found in July 2019 in a riverine *Salix* woodland. After revisiting the location, a significant
38 expansion of the initial population was observed in June 2020, suggesting its naturalization with
39 great invasive potential.

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41 Criteria and procedures defined by the regional intervention priorities on alien species were applied
42 in order to further monitor and eradicate the species, as an example of good practice for the
43 management of alien species.

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57 **Keywords:** Alien plants naturalization, Chameleon plant, Monitoring, New alien plant species,
58 Plant introduction

INTRODUCTION

Biological invasions are known to be a major threat to biodiversity, often leading to severe consequences for ecosystem structure and functioning (Simberloff et al. 2013). In Europe, the main pathway of introduction is usually represented by horticultural trade, which make ornamental plant species the largest pool of potential invaders (Lambdon et al. 2008). More than 3700 plant species are considered naturalized or invasive in Europe, of which more than 1500 in Italy (Brundu et al. 2018).

Houttuynia cordata Thunb. (Fig. 1), also known as fish mint, fish leaf, rainbow plant, chameleon plant, heart leaf, fish wort, or Chinese lizard tail, is a sciaphilous, hygrophilous, perennial herb native to temperate and tropical Asia that can be found from near sea-level to approximately 2,500 m. a.s.l. (Nianhe and Brach 1999). In its native range, it is commonly used as a herbal medicine (Nianhe and Brach 1999; Kumar et al. 2014), as a vegetable or as an ornamental species (Nianhe and Brach 1999; Zheng et al. 2011). *H. cordata* is a creeping herb, up to 60 cm high, with thin, spreading rhizomes (Nianhe and Brach 1999). The leaves are opposite, heart-shaped and have a peppery scent when crushed, their color can vary from green through yellow to red, the brighter colors being more prominent when grown in full sunlight (Alves et al. 2013; Global Invasive Species Database 2020). According to the National Pest Plant Accord (2001), *H. cordata* is a deciduous plant in most of the cases, dying back to the rootstock over winter, although it can be semi-evergreen in warm areas. The flowers are small, crowded into a short spike around 2 cm long, with four white, petal-like bracts at the base. The stamens usually degenerate, and the fruits are dehiscent dry capsules with apomictic seeds and abiotic dispersal, through explosive dehiscence (Shibata and Miyake 1908; Nianhe and Brach 1999; Wei and Wu 2012).

Until now, the species has become naturalized (*sensu* Richardson et al. 2000) in South America (Brazil, Alves et al. 2013) and even invasive in New Zealand, Madagascar, the United States of America (California, Georgia, Hawaii, Louisiana, Washington), and Costa Rica (Global Invasive Species Database 2020). Concerning Europe, *H. cordata* cultivation has been reported for the first time in the Royal Botanic Garden at Kew in 1826 (Hooker 1827) while in Italy the first record dated back to 1874 at the botanical garden of the University of Torino (Delponte 1874) and in subsequent years (1891-1932) it was reported in the botanical gardens of Mortola (Giardino Botanico Hanbury 1891), Siena (Orto botanico della Università di Siena 1914), Palermo (Orto botanico di Palermo 1914) and Napoli (Regia Università di Napoli. Orto botanico 1933). In recent years, it has been recorded as a casual alien species in Austria, Belgium, the Czech republic and the United Kingdom (Verloove 2011; Stöhr et al. 2012; Lustyk and Dole 2018; Global Biodiversity Information Facility 2019) while there are doubtful reports for Germany, Italy, the Netherlands, Slovakia, Spain and

67 Sweden, which probably originate from private gardens and public parks (Global Biodiversity
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268 Information Facility 2019). Only in Hungary it has been reported as a naturalized alien by Lukács et
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469 al. (2014).

570 Although reports of its invasive behavior in scientific literature are scarce (e.g. Staples et al. 2000),
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771 two features seem to make this species a potential strong invader, namely rapid vegetative
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972 propagation and resistance to herbicides (Alves et al. 2013). Indeed, *H. cordata* can produce a large
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1173 amount of propagules due to its abundant production of rhizomes or stolons (or their fragments) or
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1374 by means of parthenogenesis (Mihara 1960). Furthermore, the plant appears to be resistant to
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1575 herbicides, possibly due to its phytotoxic compounds (Lin et al. 2006).

1676 In the United States of America, *H. cordata* has been reported as naturalized or invasive species in
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1877 shaded lowlands and forested banks (USDA, NRCS 2009; Wunderlin et al. 2010). *H. cordata*'s
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2078 habitats in the native range are represented by ravines, streamsides, forests, wet meadows,
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2279 hedgerows and field margins, trailsides, roadsides, ditch banks (Nianhe and Brach 1999). It is
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2480 considered potentially able to replace native plants in forest and wetland ecosystems (Environment
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2681 Bay of Plenty 2003; Global Invasive Species Database 2020).

2782 The species is well known also for its medicinal use, in fact the whole plant has antibacterial,
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2983 antiphlogistic, depurative, diuretic, emmenagogue, febrifuge, laxative and ophthalmic effects. It is
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3184 also used as traditional treatment for many ailments including coughs, dysentery, enteritis and fever
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3385 (Kumar et al. 2014).

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3687 **MATERIALS AND METHODS**

3888 *Introduction site*

4089 The species was found in July 2019 during a sampling campaign aimed at describing plant species
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4290 diversity within the local ecological network.

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4491 The introduction site (Fig. 2, 45.809453N, 13.079031E, 5 m a.s.l.) is along the banks of the river
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4692 Stella in the municipality of Palazzolo dello Stella (Udine, NE Italy), about 300 m far from the town
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4893 and 1 km from the village Rivarotta. We found the species growing in a disturbed riverine wood
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4994 (habitat G1.11 Riverine *Salix* woodland EUNIS habitat classification, Davies et al. 2004). The
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5195 wood is crossed by a dirt road and surrounded by agricultural land-use. The site undergoes
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5396 submergences during high flooding events.

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5698 *Field surveys*

5899 In July 2019, the main *H. cordata* population was accidentally observed in a 10x10 m plot
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6000 randomly placed in the study area. All plants occurring in the plot were identified in the field, and a

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101 *H. cordata* specimen (undetermined at that time) was collected and later identified in the laboratory
102 by the authors (Liccari F. and Boscutti F.) using the “Flora of China” identification key (Nianhe and
103 Brach 1999; eFloras 2008). The occurrence of the species was then confirmed in June 2020, when
104 the area was re-sampled and further samples were collected. Two sampled specimens were sent to
105 FI Herbarium (Fig. 3, Firenze, Italy) to contribute to the alien checklist of Italy: “Notulae to the
106 Italian alien vascular flora: 10” (Galasso et al. 2020).
107 During the second survey of the area, the extension of the population (Fig. 1) was evaluated and
108 possible pathways and vectors related to its presence in the location were identified.

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110 **RESULTS AND DISCUSSION**

111 This record of *H. cordata* represents the first case of a naturalized population of the species in Italy
112 (no published records are present on Web of Science and Scopus databases, accessed on 25 January
113 2021) and the second for Europe. In fact, Lukács et al. (2014) stated that the plant is naturalized in
114 Hungary, even though no further information were provided.

115 No previous records representing naturalized populations of this species in Italy are available in any
116 of the several major databases consulted (e.g. Global Biodiversity Information Facility 2019; Global
117 Invasive Species Database 2020) nor in the major Italian herbaria (e.g. Università degli Studi di
118 Roma La Sapienza, Università degli Studi di Torino). In the rest of Europe, there are many records
119 of the species in the GBIF database mainly represented by cultivated or occasional reports. Among
120 these, only one record refers to an occasional finding in the province of Treviso (NE Italy) near an
121 ornamental garden (Global Biodiversity Information Facility 2019). However, it is worth stressing
122 that the information collected from online databases and data portals are often not singularly
123 checked for reliability, thus there could be a degree of uncertainty and reliability to take into
124 account (Smith et al. 2016; Freitas et al. 2020).

125 The introduction site was dominated by few species: *Salix alba*, *Carex pendula*, *Populus nigra* and
126 *Potentilla reptans*, along with less abundant species, such as *Ulmus minor*, *Rubus caesius*, *Poa* spp.,
127 *Phragmites australis* and *Carex* spp. (see Table 1). The canopy cover within the plot was partially
128 dense with a couple of large clearings where herbaceous species (*Potentilla reptans* and *Carex* spp.)
129 grew abundantly. The shrub layer was almost absent in the plot showing a scattered cover in the
130 habitat patch. In general, the site showed a high presence of ruderal species and other alien species,
131 although with a low abundance. The majority of the species were typical of wetland forest habitats
132 with a medium-high nutrients level in the soil (Poldini et al. 2011). This confirms the preference of
133 *H. cordata*, outside of its native range, for wetlands habitat in particular along rivers and on the

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134 forest floors (National Pest Plant Accord 2001; USDA, NRCS 2009; Alves et al. 2013; Lukács et al.
135 2014).

136 During the two sampling years, we observed a significant expansion of the initial population: in
137 July 2019 it occupied less than 1 m² with less than 10 shoots while in June 2020 the population was
138 formed by 3-4 nucleus, occupying at least 50 m² with more than 70 shoots (Fig. 1). Some plants
139 exhibited stolons with a variable length between 20 and 60 cm and the majority of the individuals
140 were flowering at that time. This annual trend, although limited to one observation year, indicates
141 an ongoing naturalization of the species with great invasive potential.

142 We hypothesize that plants' propagules have reached the place through the river, whose current
143 goes from the village of Rivarotta (north of the invasion site) towards Palazzolo dello Stella (south
144 of the site), during a flood event, probably transported from a garden. Indeed, it is well known that
145 rivers represent a common vector of alien species introduction (Barni et al. 2012), confirmed in loco
146 by the high alien species richness in the sampled plot (see Table 1).

147 Alternatively, the species was deliberately planted for ornamental purposes. It is well known that
148 horticulture still plays a prominent role in current plant introduction (Lambdon et al. 2008; van
149 Kleunen et al. 2018) and this could also be the case for *H. cordata*. Its seeds are easy to buy online
150 and the plant is very simple to cultivate, making it extremely attractive for amateur gardeners. This
151 seems to be the most feasible introduction pathway rather than having escaped from a botanical
152 garden (at least for the studied area where no botanic garden exists in proximity).

153 The native distribution of *H. cordata*, ranging from tropical to temperate Asia, indicates a certain
154 plasticity in the autecology and functional traits of the species. Specifically, it has the capacity to
155 thrive in different environmental conditions such as different temperature regimes, elevation and
156 light availability, also resistant to prolonged period of submersion. All these characteristics, shared
157 by numerous invasive alien species, suggest the species to be a future dangerous invader
158 (Richardson and Pyšek 2006).

159 After our discovery, we reported the finding to the Italian Botanical Society ("SBI - Società
160 Botanica Italiana") and the regional authority for eradication. With the Council Resolution of
161 07/08/2020 n° 1257/2020 the Autonomous Region of Friuli Venezia Giulia (RAFVG) adopted the
162 "Regional Strategy to contrast invasive alien species (2021-2026)". The strategy includes three
163 main criteria to define intervention priorities, namely:

- 164 1) the invasion status, attributed to species a) of Union concern, b) dangerous to health, c)
165 environmental concerns;
- 166 2) invasibility, based on the environment where the species is found a) protected areas, b)
167 mountains, c) other natural habitats;

168 3) cost/benefits, estimated based on a) the quantification of intervention effort, b) effectiveness of
169 intervention to eradicate the species.

170 *H. cordata* is not on the list of invasive alien species of Union concern
171 (<https://ec.europa.eu/environment/nature/invasivealien/list/>) but as a new naturalized species whose
172 diffusion is limited to a single station, as well as due to a potential rapid spread by floating, the
173 biodiversity service of the RAFG decided to implement the intervention during the winter and
174 spring of 2020-2021. The first phase involved the area being cleaned and mowed and then, at the
175 beginning of vegetative regrowth, the *H. cordata* shoots were manually eradicated. The actions will
176 be repeated until the population is extinct. Monitoring of the site and an enlarged area downstream
177 and upstream towards the hypothesized starting point of species spread, will also be carried out.

178 Unfortunately, *H. cordata* is hard to eradicate completely and the Environment Bay of Plenty
179 (2003) suggests to manually removing as much of the roots and plant material as possible and
180 carrying out repeated removals at regular intervals. While for chemical removal both the
181 Environment Bay of Plenty (2003) and the National Pest Plant Accord (2001) report that certain
182 herbicides may be used to control *H. cordata* but without specifying which ones. It is highly
183 probable that the Plant Protection Products containing systemic active products such as glyphosate,
184 are effective to control this species, but their use is restricted by many legislations (e.g. European
185 directive 2009/128/CE establishing a framework for Community action to achieve the sustainable
186 use of pesticides), especially when used in proximity to rivers.

187 In general, a major concern is represented by the large use of the species as ornamental and
188 medicinal plant, which may contribute to its spread. We thus suggest a constant monitoring of
189 shoots near cultivation sites as well as avoiding the indiscriminate dumping of garden or cultivation
190 waste. This and similar good practices are also included in the EPPO/CoE Code of Conduct on
191 Horticulture and Invasive Alien Plants (Heywood and Brunel 2009). We suggest to researchers, for
192 the early detection, to investigate if the species has already reached their countries, especially for
193 neighboring countries (Slovenia and Croatia). Furthermore, we advocate to double check the
194 invasion status for those sites where its presence as an introduced alien is already known (Austria,
195 Belgium, the Czech republic, Hungary, the United Kingdom) as well as to verify the accuracy of the
196 existing reports for the other countries (Germany, the Netherlands, Slovakia, Spain, Sweden). In
197 conclusion, we suggest to treat all the reports for this species carefully, *H. cordata* should be not
198 neglected as has already happened in the past with other alien species (e.g. *Amorpha fruticosa*),
199 which spread undisturbed causing dramatic alterations to pristine ecosystems (Boscutti et al. 2020).

200 As a concluding remark, it is interesting to note that this finding was driven by a random selection
201 of plots during a probabilistic vegetation sampling. This opens new insight through the use of

202 quantitative approaches in monitoring alien flora across large areas, which is often a neglected issue
203 in the biological invasion literature. It is worth noting that, given a traditional, preferential,
204 sampling of vegetation to characterize habitats (via, for instance, phytosociological approach, the
205 standard method used at the EU level), we would probably never have discovered the species
206 occurrence, because the area represented a disturbed part of a riverine wood and thus, not
207 “important” to be sampled. Once more, the application of robust probabilistic sampling protocols
208 resulted in the best solution to characterize and analyze composition and dynamics of vegetation
209 patterns, especially for habitat monitoring purposes (Maccherini et al. 2020).

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211 **Declarations**

212 **Funding:** this research received no external funding.

213 **Conflicts of Interest:** the authors declare no conflict of interest.

214 **Availability of data and material:** original specimens of *Houttuynia cordata* are available for
215 consultation at FI Herbarium (Firenze, Italy).

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332 **Tables**

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333 **Table 1** Species names, cover (%) and belonging vegetation layer (H=Herbaceous, S=Shrub,
 334 T=Tree) of the occurring species in the plot (10x10 m) at the first record site of *Houttuynia cordata*

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Species	Cover (%)	Vegetation Layer	Species	Cover (%)	Vegetation Layer
<i>Amorpha fruticosa</i> L.	1	S	<i>Lysimachia vulgaris</i> L.	< 1	H
<i>Bidens frondosa</i> L.	< 1	H	<i>Lythrum salicaria</i> L.	2	H
<i>Carex acutiformis</i> Ehrh.	3	H	<i>Persicaria lapathifolia</i> (L.) Delarbre	2	H
<i>Carex distans</i> L.	< 1	H	<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	4	H
<i>Carex hirta</i> L.	1	H	<i>Poa annua</i> L.	< 1	H
<i>Carex otrubae</i> Podp.	2	H	<i>Poa sylvicola</i> Guss.	5	H
<i>Carex pendula</i> Huds.	28	H	<i>Populus nigra</i> L.	25	T
<i>Equisetum arvense</i> L.	< 1	H	<i>Potentilla reptans</i> L.	18	H
<i>Equisetum telmateia</i> Ehrh.	< 1	H	<i>Quercus robur</i> L.	< 1	H
<i>Euonymus europaea</i> L.	2	S	<i>Ranunculus acris</i> L.	< 1	H
<i>Eupatorium cannabinum</i> L.	2	H	<i>Rubus caesius</i> L.	7	H
<i>Filipendula ulmaria</i> (L.) Maxim.	1	H	<i>Rumex conglomeratus</i> Murray	< 1	H
<i>Galium mollugo</i> L.	< 1	H	<i>Salix alba</i> L.	40	T
<i>Glechoma hederacea</i> L.	< 1	H	<i>Ulmus minor</i> Miller	8	T
<i>Houttuynia cordata</i> Thunb.	< 1	H	<i>Urtica dioica</i> L.	< 1	H
<i>Ligustrum sinense</i> Lour.	< 1	S	<i>Valeriana officinalis</i> L.	< 1	H
<i>Limniris pseudacorus</i> (L.) Fuss	< 1	H			

337 **Figure captions**

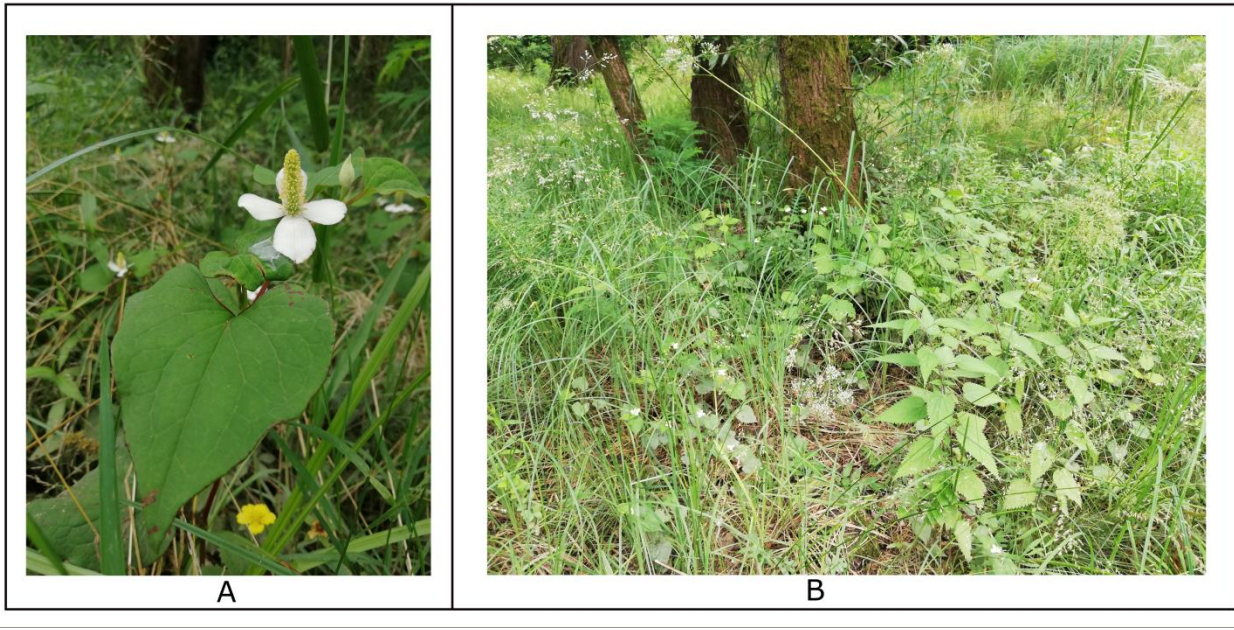
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Fig. 1 A) Flowering individual of *Houttuynia cordata* Thunb. B) Part of the naturalized population of *Houttuynia cordata* Thunb. at the invasion site, Palazzolo dello Stella (Udine) Italy, 16 June 2020

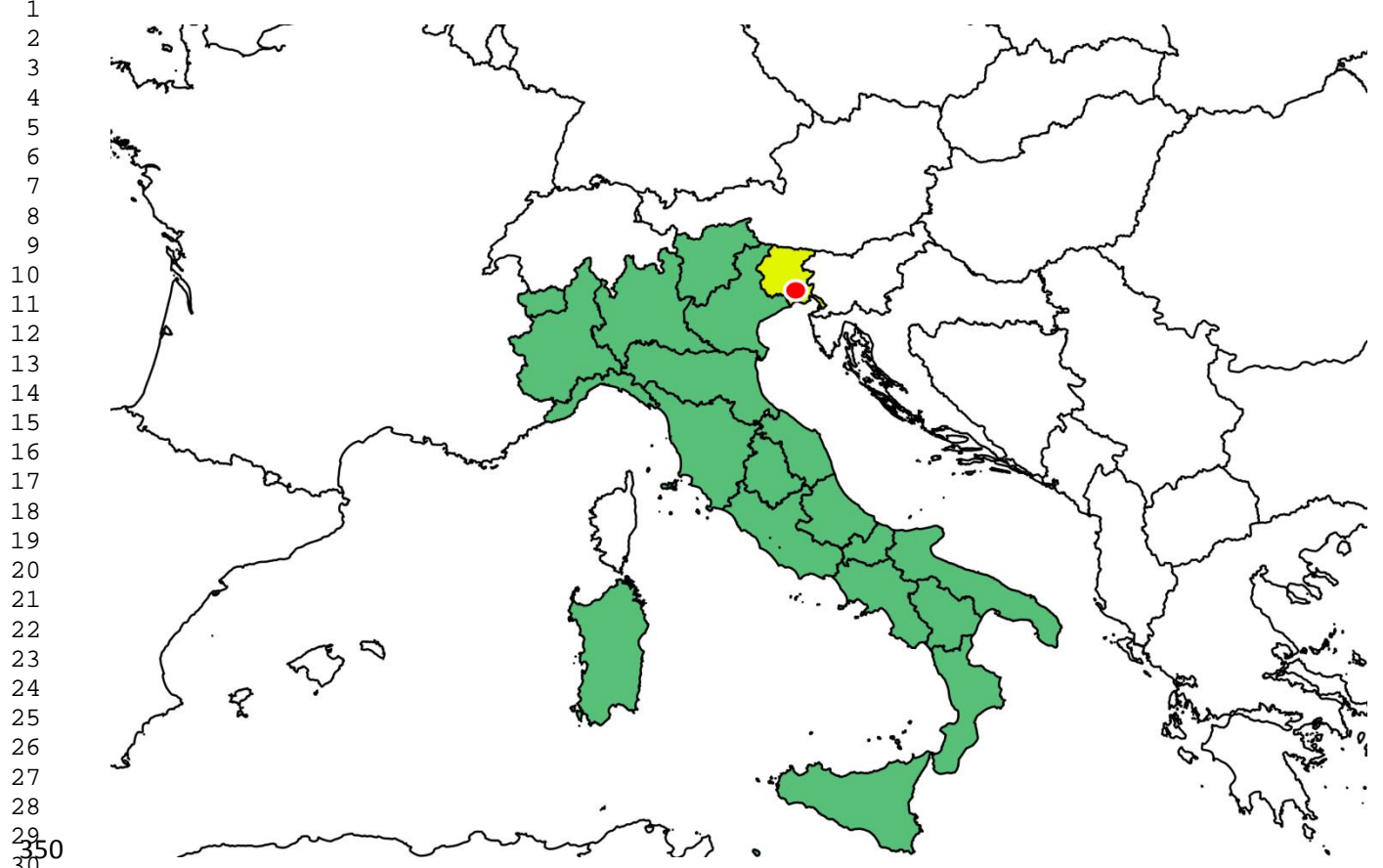
Fig. 2 Location of the invasion site (red dot) in Friuli Venezia Giulia region (yellow) and in Italy (green) respectively

Fig. 3 The two exsiccated sampled plants of *Houttuynia cordata* Thunb. They are available for consultation at FI Herbarium (Firenze, Italy)

346 Fig. 1



349 Fig. 2



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352 Fig. 3

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