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First record of alien naturalized populations of the crop *Cucurbita moschata* (Cucurbitaceae) in Spain, with remarks on typification status

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Abstract – As a result of a floristic survey carried out in riparian ecosystems of the south-eastern part of the Iberian Peninsula (Spain), the first report of well-established populations of the alien cultivated plant species *Cucurbita moschata* Duchesne for the Iberian Peninsula is provided here. Data about the morphological description (compared to other *Cucurbita* species), certain clarification aspects about the typification status of this name and related synonyms, and the ecological and climatic conditions of the riparian area are given together with an identification key of the *Cucurbita* species to facilitate further identification. The alien status and distribution of *C. moschata* together with its relatives *C. ficifolia*, *C. pepo* and *C. maxima* are reviewed for the Spanish references. This study outlines the first record of a naturalized population of *C. moschata* in Spain, well supported by the stability of the population over the years and in the ecological conditions. Finally, detailed ecological data indicate that agricultural activities together with riparian habitatsare starting points and corridors, respectively, for seed dispersal for the process of the invasion of alien plants in the south-eastern Iberian Peninsula.

Keywords: alien plants, *Cucurbita*, Mediterranean, riparian habitats, Spain, typification, xenophyte

Introduction

Cucurbita L. (Cucurbitaceae) comprises about 12-13 species widely distributed on the American continents, of which five species are cultivated (Paris 2016). In Europe, the most important cultivated species are *C. pepo* L., *C. maxima* Duchesne, *C. moschata* Duchesne and *C. ficifolia* Bouché (Teppner 2004, Henning et al. 2017). Tardío et al. (2018) recently included these four species in the Spanish list of the traditional crops for agricultural biodiversity, with *C. pepo* as the main crop species of the genus due to its great commercial importance. In the framework of the *Flora iberica* project, Fernandes (2005) reported *C. pepo*, *C. maxima* and *C. ficifolia* as crop species, without any mention of the possible findings of spontaneous specimens of them, in any Spanish or Portuguese geographical area. In addition, Fernandes (2005) did not include the existence, not even as a crop, of *C. moschata* for the Iberian Peninsula and Balearic Islands. According to The Euro+Med Plant Base (Henning et al. 2017), crops of *C. moschata* are mostly reported from eastern European countries, though the cultivation of this species is also mentioned for Mediterranean countries including Spain (Tardío et al. 2018) and Italy (Lust and Paris 2016). However, as previously stated by Quintero (1981), *C. pepo* and *C. maxima* were the most widely cultivated species along the south-eastern Iberian territories. Probably due to the extensive agricultural use of *C. pepo* and *C. maxima*, there are some reports of the existence of non-cultivated subspontaneous individuals of these two species, but always close to their original field cultures (e.g., Serra 2007, Herrera and Campos 2010). There are a couple of mentions of non-cultivated individuals of *C. moschata*, reported to be ephemerals, for Portugal and Spain (Verloove and Alves 2016, Gómez-Bellver et al. 2019), otherwise no specific geographic reference to the presence of this species outside of cultivation (Mateo et al. 2015). Although species of the genus *Cucurbita* have been considered as invasive alien flora (Sanz Elorza et al. 2004), any specific geographical indications of

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their presence, degree of naturalization, abundance and habitat as alien species are remarkably lacking.

On the basis of the ongoing study of the alien flora of the River Vinalopó (Alicante province, south-eastern Spain), the fieldwork conducted on this river has recently revealed the presence of a high number of casual and even naturalized alien plants (Juan et al. 2019, Terrones et al. 2021). The aims of this study are (i) to report the presence of well-established populations of *C. moschata* outside cultivation, which would correspond to the first record of the species as a naturalized alien population, (ii) to update the presence and alien status of the species of *Cucurbita* in Spain, and (iii) to identify ecological conditions that would favour the fruit dispersal and seed germination of these species, especially focused on *C. moschata*. In addition, the typification of the name *C. moschata* and related synonyms is reviewed.

Materials and methods

The present study was based on fieldwork carried out during the period 2016-2020 on the River Vinalopó (south-eastern Iberian Peninsula, Spain). The ecological features of this river dramatically change from its source, in a mountainous area characterized by a high-water quality, to its mouth, located in saline wetlands close to the Mediterranean Sea. Most of the river flows throughout semiarid territories, which causes the salinization of the waters (José Ramón Coves, pers. comm.) and even a seasonal total lack of flow in several non-continuous areas. The quality and physical-chemical properties of the waters of the river were described by José Ramón Coves (pers. comm.). Climate features of the closest meteorological station to the studied area (Elda) were obtained from the Climate-data online database (https://www.es.climate-data.org), which compiles data from the last 30 years. Based on these data, the bioclimatic characteristics of the area followed the classification of Rivas-Martínez et al. (2001).

Information on species distribution was based on herbarium specimens from GBIF (Global Biodiversity Information Facility – www.gbif.org) and literature. Morphological features were based on the specialized literature (Merrick and Bates 1989, Nee 1990, Lira and Rodríguez Arévalo 1999, Teppner 2004, Paris 2016, OECD 2016), together with the observations based on the population found during this research. The collected plant material of *C. moschata* is preserved in the ABH Herbarium (Thiers 2020), which was used to draw up detailed morphological pictures of this species. In this contribution, an identification key is reported to facilitate further identification. The typification status of *C. moschata* and related names was updated based on original descriptions and the inspection of available material from various herbaria (F, L, MO, NL, U, WAG; Thiers 2020). Ecological data of the alien *Cucurbita* populations are described, including remarks about the origin, degree of naturalization, habitat and the importance of the plant dispersal processes.

Results

Description and typification notes

Cucurbita moschata Duchesne, Essai Hist. Nat. Courges: 7 (1786)

Gymnopetalum calyculatum Miq. in Fl. Ned. Ind., Eerste Bijv. (2): 332 (1861)

Lectotypus (designated here): Label 1: "Gymnopetalum ? calyculatum Mq, Banka, (J. Amand)"; Label 2: A. Cogniaux Monogr. Cucurb. H "Cucurbita moschata Duch." (probably Cogniaux's handwriting); U (U0001457!).

An annual species characterized by softly hairy, non- to shallowly 3-5 lobed leaves, 15-30 × 20-40 cm, without or with whitish blotches; tendrils bifids or trifids; sepals free, mostly linear, but sometimes lanceolate together with flowers with broadened apices (Fig. 1); corolla yellow-orange, 8-12 cm long; fruiting peduncle 5-ribbed thickened and dilated or cylindrical, 5-10 cm long, widely flat at the fruit attachment; fruits covered by a wipeable waxy layer, dumbbell and solid green or pyriform and cream-coloured with light green longitudinal reticulate mottled stripes (usually in bands), up to 35 cm length; seeds elliptical, 8-15 × 4-7 mm, with a rounded marginal bulge, margin mostly with a colour shade slightly different from the surface, marginal wings developed very strongly. Most of these morphological features correspond to the main features used to distinguish it from the other domesticated species of this genus, *C. ficifolia*, *C. maxima* and *C. pepo* (Tab. 1).

Regarding the protologue of *C. moschata*, Paris (2000) already stated that this name was validly published by Duchesne (1786) in the Essai sur l'Historie Naturelle des Courges, and hence, Duchesne was solely responsibility for the authority. On the GBIF database (www.gbif.org), three different entries were found related to the type specimens of the name *C. moschata*. Firstly, the mention of the type specimen of this name held at the Missouri Botanical Garden (MO1722018) should be considered a mistake, since no voucher is apparently held at MO only at F, LPB and NY (Teisher, pers. comm.). The voucher information corresponds to the collection of T.J. Killien (nº 1267) made in Bolivia during 1989, but no publication has been found about this likely typification and, at least, the voucher at F (barcode F2013050!; Bolivia, Santa Cruz, Cordillera, Tatarenda, 30 km S of Rio Grande on road to Camiri, 19º08'S 63º15'W, 700 m, first range of Andes with semi-deciduous forest and slash and burn agriculture, soils generally sandy, Tim Killeen 1267, 16 Oct 1985) does not bear any identification of type material. Therefore, the typification of the name *C. moschata* is still an uncompleted task, as with many other cultivated species, which were initially described without any direct reference to a herbarium voucher or collection. The second mention concerns the accepted synonym *Gymnopetalum calyculatum* Miq., the description of which (Miquel 1860) was based on material collected from Bangka by J. Amann (pseudonym of W.S. Kurz, see Van Steenis-

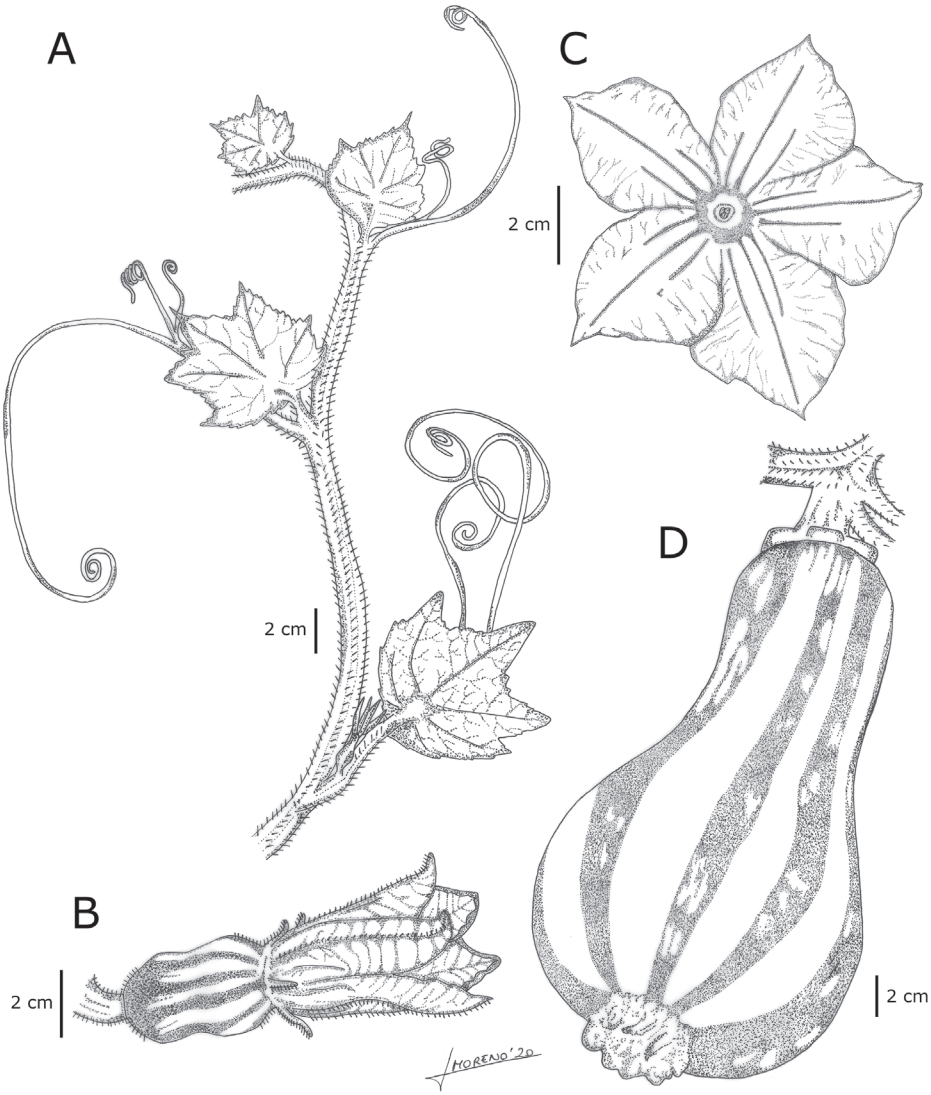

Fig. 1. *Cucurbita moschata* Duchesne. A – habit, B – flower (side view), C – flower (front view), D – mature fruit (drawing by Joaquín Moreno).

Kruseman and Van Steenis 1950). De Wilde and Duyfjes (2010) designated a voucher kept at the herbarium U (barcode U0001457!) as the holotype. However, the use of the term holotype by these authors cannot be adequate, as Miquel (1860) only referred to Amann's gathering activity but not to a specific sheet. Hence, there is no certainty that

Tab. 1. Main morphological features differentiating the four species of *Cucurbita* reported in Spain (based on Lira 1995, Lira and Rodríguez Arévalo 1999, Teppner 2004).

	C. ficifolia	*C. maxima*	*C. moschata*	*C. pepo*
Habit	Perennial	Annual	Annual	Annual
Leaves	Lobed	Not lobed/ shallowly lobed	Not lobed/ shallowly lobed	Shallowly to deeply lobed
Segment leaves	Rounded	Rounded	Acute	Acute
Indument	With short glandular hairs	Stiff-haired/ hispid	Soft-haired	Spiculate
Sepals	Linear, apex non-broadened	Linear, apex non-broadened	Linear or with apex often broadened like leaves	Linear, apex non-broadened
Seed color	Dark brown to black	Orange or white	Tan to brown	Pale tan
Fruit peduncle	Ribbed, moderately broadened at attachment	Cylindrical, non-broadened at attachment	Ribbed, at attachment widely broadened (flat)	Ribbed, slightly, broadened at attachment

other duplicate material was not used to prepare the description of this name by the original author (ICN, Art. 9.1), though no additional specimens were found at NL, L, U and WAG (M. Scherrenberg, pers. comm.). Therefore, the voucher U0001457 should be considered as the lectotype of the name *G. calyculatum*. Finally, the third reference corresponds to a specimen of the name *C. sulcata* Blanco kept at L (barcode L0585284!; *Cucurbita sulcata*, Merrill, Species Blancoanae nº 152, labelled as neotype by J.K. Veldkamp 2/03, labelled as *C. moschata* by W.J.J.O de Wilde & Duyfjes, 2011), which was selected as neotype by Veldkamp on the specimen; however, Veldkamp never published his designation, which is thus ineffective. The name *C. sulcata* is currently considered a synonym of the species *C. maxima*, but the identification of this particular voucher was corrected to *C. moschata* on the specimen by De Wilde and Duyfjes. To avoid the effect of destabilizing the nomenclature of the name *C. sulcata*, an effective typification should be based on a specimen whose identification corresponds to the original description (Blanco 1837).

Habitat and populations

The populations of *C. moschata* were found growing in the central part of the course of the River Vinalopó (named the Middle Vinalopó district), which runs across the inner central part of Alicante Province (Spain), crossing semiarid and arid areas. At this geographical zone of the river, the watercourse is not continuous, and it can remain totally dry for long periods of time, even in excess of one year. This ecological peculiarity, added to the climatic characteristics of the area, contributes to soil salinity.

Four scattered populations, with up to 10 specimens each, of *C. moschata* have been discovered along five kilometres of this river basin, most of them growing clearly away from the direct influence of the main course of the water. The largest population, about 10 individuals, appeared on sandy soils on the upper part of the terrace of the river. At a distance of approximately two kilometres downstream, another well-established population with 5 individuals grew close to secondary dry channels of this river, characterized by gravel and sandy soils. The other two populations, formed by 2–3 individuals, and some isolated individuals of *C. moschata* were placed on the shallow area of meander scars and along the edges of the riverbed, both upstream and downstream in reference to the largest populations.

The first observations of them were noted in 2016, when only the two above-mentioned largest populations were initially identified with five and two reproductive individuals, respectively. Over the years these populations of *C. moschata* have developed autonomously, with increasing numbers of individuals, while new subpopulations or isolated individuals have been found far from them, being fully reproductive. Although the size of the population may be different from year to year, the annual appearance of new specimens seems to be entirely independent, based on the development of functional seeds, which seem to germinate under the ecological conditions of this area. In addition, no crops were found close to the observed populations.

The populations of *C. moschata*, in general, appear intermixed with wild shrubby and grassland vegetation (e.g., *Atriplex halimus* L., *Cynodon dactylon* (L.) Pers., *Tamarix gallica* L., together with other naturalized alien species along the river, such as *Physalis peruviana* L., *Stenotaphrum secundatum* (Walt.) Kuntze, *Solanum lycopersicum* L. and *S. sisymbriifolium* Lam. Independently of the size and location of the population, the observed individuals were fully reproductive, and well-developed mature fruits were easily found.

Climate and watercourse features

On the basis of the recent studies of José Ramón Coves (pers. comm.), the main features of the water of the River Vinalopó along the studied area are an average water temperature of about 20 °C, with an electric conductivity ranging from 2.8 to 5.9 mS cm^{-1}, pH 7.66 (7.3–7.8) and an average nitrate concentration of 75 mg L^{-1} (25–180 mg L^{-1}). The weather conditions of the studied area are characterized by typically Mediterranean climate, with remarkably dry summers. The annual average rainfall is 345 mm, with maximum values in September (43 mm) and minimum in July (6 mm). The average monthly values of temperatures are always above 0 °C, January being the coldest month with minimum average temperatures of 7.7 °C whereas the maximum values were registered in both July and August (mean values of 25.1 °C and 24.9 °C, respectively). According to these rainfall and temperature data, the studied area corresponds truly to a semiarid area belonging to an inferior Mesomediterranean belt.

Naturalized specimens observed of *Cucurbita moschata*

Hs, Alicante: Elda, River Vinalopó, 38°27’09’’N 0°48’12’’W, 337 m, 12 Nov 2017, A. Juan AJ117 (ABH 82475). Elda, River Vinalopó, left side of the river, upper part of the terrace of the river, 38°27’06’’N 0°48’13’’W, 335 m, 20 Nov 2017, A. Juan & I. Juan AJ118 (ABH 82476). Elda, River Vinalopó, upper part of the terrace of the river, 38°27’04’’N 0°48’12’’W, 335 m, 14 Sept 2018, A. Juan, J. Moreno & A. Terrones (ABH 82477). Elda, River Vinalopó, secondary dry channel, 38°26’51’’N 0°48’13’’W, 330 m, 27 October 2018, A. Juan, J. Moreno & A. Terrones (v.v.). Elda, River Vinalopó, terrace of the river, 38°28’16’’N 0°48’15’’W, 370 m, 24 Nov 2019, A. Juan, J. Moreno & A. Terrones (v.v.).

Distribution of the *Cucurbita moschata* in Spain

Specific geographic references to *Cucurbita moschata* as crop have been reported only from the northeast of the Iberian Peninsula (Barcelona province), where it also behaves as an occasional alien growing on the margin of the river (Gómez-Bellver et al. 2019). The newly found *C. moschata* populations in Alicante are very distant. The populations

of *C. moschata* found in Alicante Province have been documented since 2016 and most recently have been observed to be composed of at least 25 reproductive individuals.

Discussion

Morphological aspects

The collected specimens of *Cucurbita moschata* show morphological features that fully fit the typical diagnostic characteristics of the species (Teppner 2004, De Wilde and Duyfjes 2010), though certain variabilities related to the leaves, sepals and fruits were detected among the studied specimens. The leaves were shallowly lobed, and either without or with whitish blotches. Most of the samples were characterized by the unique presence of linear sepals, but some specimens showed flowers with lanceolate sepals together with flowers with broadened sepals. Two types of fruits were observed: (i) dumbbell and solid green with a fruiting pedicel widely flat at the fruit attachment, and (ii) more rarely, pyriform and cream-coloured with light green longitudinally reticulated mottled stripes (usually in bands) with 5-ribbed thickened and dilated peduncles at the fruit attachment. The observed minor morphological variations are likely derived from the existence of numerous cultivars of this species, which vary greatly in fruit shape and colour (Lira 1995, Teppner 2004, De Wilde and Duyfjes 2006).

The main morphological characters distinguishing *C. moschata* plants or fruits from the closely related species, *C. pepo* and *C. maxima*, are basically related to the indument, leaves and fruit stalk (Lira and Rodríguez Arévalo 1999, Teppner 2004, Tab. 1). While *C. moschata* is a soft-haired plant with non- to shallowly lobed leaves, smoothly grooved stems and a hard, smoothly angled fruit stalk widened at the apex, *C. maxima* is characterized by hispid, unlobed (or slightly lobed) leaves and rounded stems, with the fruit stalk soft and rounded, not enlarged at the apex. Finally, *C. pepo* is typically spiculate with grooved stems and palmately lobed, often deeply cut and prickly leaves, with a hard and markedly angular fruit stalk sometimes slightly widened at the apex.

The following dichotomous key is based on Fernandes (2005) to which *C. moschata* was added to facilitate the plant identification:

1. Plants with short glandular hairs, generally climbing; leaves 3-5-lobed, with rounded or obtuse segments; fruit with white flesh, seeds black ..... *C. ficifolia*
– Plants hispid with short, stiff hairs, prostrate or climbing; leaves from entire to clearly lobed, with triangular segments; fruit with pale or yellow or yellow-orange flesh, seeds white or orange 2
2. Leaves entire or slightly lobed; rounded stems; fruit stalk subcylindrical, rounded, soft ..... *C. maxima*
– Leaves shallowly to deeply lobed; grooved stems; fruit stalk different 3
3. Plant prickly, spiculate; leaves palmate, shallowly to deeply lobed; fruit stalk notably angled, slightly broadened at attachment on the fruit apex; fruit with light-coloured yellow to orange flesh; seed margin with similar colour and texture as the surface ..... *C. pepo*
– Plant softly hairy; leaves shallowly lobed; fruit stalk slightly angled, mostly abruptly broadened at attachment on the fruit apex; fruit with orange flesh; seed margin with a different colour and texture than the surface .. *C. moschata*

Distribution and alien status of *C. moschata* and related species

The presence of *C. moschata* out of cultivation is quite scarce not only around the Mediterranean basin but also around the European continent. Ardenghi and Mossini (2015) have reported the presence of two non-cultivated populations in Italy, located along an irrigation canal among rice fields, together with scattered vegetable refuse. According to these authors, the populations almost certainly grow from seeds rejected as food waste, since the observed seedlings likely derived from fruits produced in previous years. In addition, occasional reports of *C. moschata* from northern European territories have been also indicated (Jonsell and Karlsson 2010, Verloove 2018). Jonsell and Karlsson (2010) stated the doubtful mention of this taxon in Sweden during the 1950s and no new mention is available, and, Verloove (2022) reported it on a dump in Belgium. In Spain, Gómez-Bellver et al. (2019) recently reported alien plants of *C. moschata* growing on the margin of the river Llobregat. Based on Richardson et al. (2000), these mentions might be considered as ephemeral casual alien plants. Contrary to these previous reports, our direct field observations yielded the lack of any vegetable crops close to this stretch of the river, including cultivated plants of *C. moschata*. Therefore, the existence of these non-cultivated populations of *C. moschata* might have originated from seeds of old discarded agricultural waste in some remote area upstream of the river, as neither farming litter nor current cultivation has been observed close to the studied area. The existence of a large number of individuals cut off from the riverbed together with their repetitive presence during several years would denote a certain population stability. Consequently, the presence of *C. moschata* populations along the basin of the River Vinalopó, and their subsequent propagation over the years, would be nowadays considered as autonomous and well established, and not directly bound to any current agricultural activity. Although most free-living plants of the cultivated species of *Cucurbita* are reported as casual offspring from nearby fields, on the basis on our observations we consider the described Alicante populations of *C. moschata* as the first ones to be naturalized in Spain.

Regarding closely related species (*C. ficifolia*, *C. maxima* and *C. pepo*), only two mentions (Barcelona and Valencia, based on herbarium specimens) were reported for *C. ficifolia*, growing in fields of carob trees. Conversely, the species *C. pepo* and *C. maxima* both have been largely reported for

different Spanish provinces (e.g., Serra 2007, Sanz Elorza et al. 2009, and more than 250 occurrences on GBIF), including the Balearic and the Canary Islands. Most of the observations of these three species based on the labels of vouchers and existing literature reported the presence of scarce specimens out of the crops (e.g., Serra 2007, Gómez-Mercado 2009, Herrera and Campos 2010, among others). They were considered as casual alien plants as they typically grew in disturbed habitats near crop fields.

Ecological aspects

The existence of numerous small parcels of farmland on which are grown tomatoes, broad beans, peas, onions, and melons, among others things, basically for subsistence, is fairly extensive along the Vinalopó Valley, though they were not the main agricultural use for this territory (Juárez 2010). Nowadays, the discovered naturalized populations of *C. moschata* did not grow close to any pumpkin crops, and therefore, the river would be the main method of seed dispersal along the Vinalopó Valley. In fact, riparian habitats can act as 'conveyor belts' for propagules (Richardson et al. 2007), and they might be important corridors for seed dispersal, both for native and alien species (Pyšek and Prach 1995, Stohlgren et al. 1998). Many alien species spread along watercourses (Richardson et al. 2000), and their invasion success largely depends on their dispersal ability (Pyšek and Prach 1995). Ecological conditions also play an important role on the entrance into and stabilization of alien plant populations along watercourses (Iamonico 2021), especially for annual *Cucurbita* species (Lira 1995, OECD 2016). *Cucurbita* fruits can be buoyant in the watercourse (OECD 2016), and hence, the river would represent a potential means of long seed dispersal. Under the appropriate environmental conditions, including no severe frost, seasonably warm temperatures and well-drained soils (OECD 2016), the germination of seeds and development of offspring of *C. moschata* would be favoured, even in the existence of relative drought. The observed climatic conditions of the studied area coincided with the ecological requirements, although the water quality of this river is slightly alkaline and saline (José Ramón Coves, pers. comm.). In fact, a high number of non-cultivated individuals of *Solanum lycopersicum* (Solanaceae) belonging to different cultivars, including cherry and plum tomatoes, appear clearly naturalized along the Vinalopó river channel and its terrace, comprising well-established populations without direct intervention by humans (pers. obs.). The number of individuals of *S. lycopersicum* is quite high and their presence is so frequent that this species already coexists with the riparian natural vegetation of the river, and the long-time permanence of these individuals would be autonomous and even might be considered as invasive. Similarly, other alien non-agricultural species, as *Drosanthemum hispidum* (L.) Schwanthes, *Ulmus pumila* L., *Rumex cristatus* DC., *Cotula coronopifolia* L. or *Datura inoxia* Mill., have also been observed and their populations are easily found along the River Vinalopó (Serra 2016, Juan et al. 2019). Among them, the species *D. hispidum* clearly shows an invasive behaviour, being the dominant species along the studied upper fluvial terraces of the River Vinalopó and close slopes (pers. obs.).

Conclusions

Agricultural activities are confirmed again as a starting point for the process of naturalization of alien plants, which together with the presence of a river greatly favours the dispersion of these alien plants. Conversely to the casual alien populations of *Cucurbita pepo*, *C. ficifolia* and *C. maxima*, the herein identified populations of *C. moschata* are able to reproduce regularly without any human activities and they are well-established along the central area of the River Vinalopó (southern Iberian Peninsula, Spain), where no regular crops of this species have been located. Therefore, the non-cultivated Spanish populations of *C. moschata* are catalogued as naturalized alien populations, which would be the first reference for Western Mediterranean countries. Nevertheless, further investigations are needed to identify new possible localities of this taxon, both upstream and downstream of the sites discussed.

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