

SPREADING TO NORTH: NATURALISATION OF *FICUS CARICA* (MORACEAE) IN HUNGARY

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Between the years 2015–2018, 147 stands of *Ficus carica* L. was found out of cultivation in Baranya county. In 2008 presence of fig wasp (*Blastophaga psenes* L.) and caprificus individuals that are necessary for pollination, then for producing fertile seeds were detected in Pécs at first time. For germination tests fig seeds were collected from several different stands in Pécs and successful reproduction of the species was confirmed under in vitro conditions. According to former and recent observations (i.e. subspontaneous seedlings and/or successful in vitro germination of common fig seeds in 2010 and 2014) fig wasp may have occurred in Budapest and Máriagyűd too, at least in the last ten years. These results confirm that *F. carica* is an old ‘new’ casual or may be a naturalised neophyte element of the Hungarian flora. According to the new records the northernmost escaped individuals of *F. carica* was found at 47.475° N in the Carpathian Basin, 116.5 km N of the closest Slovenian stand in the latitudinal direction.

Key words: adventive plant, *Ficus carica*, Hungary, naturalisation, urban flora

INTRODUCTION

The genus *Ficus* contains only one subspontaneous and widely cultivated species in Europe: *Ficus carica* L. It is a gynodioecious, deciduous tree or large shrub, growing to a height of (1–)5–7(–10) m. The bark is smooth, grey. The plant has a very distinct smell, especially when it is crushed. The 12–25 × 10–18 cm leaves are deeply lobed with 3–5 lobes. Upper leaf surface is rough, lower leaf surface is tomentose. The shoots and leaves have milky latex, which can be allergenic. The inflorescence, called syconium or syconia, contains the small unisexual flowers. The syconium is pear-shaped, 5–8 cm long and contains many 1-seeded drupelets (Király 2009). At the end of the syconium a small ostiole can be found, which allows the specialised fig wasp, *Blastophaga psenes* L. to enter the fruit and pollinate the flowers (Fig. 1).

This wasp species did not occur in Hungary until the year 2008 (Fazekas and Schmidt 2016, Schmidt 2010). From the point of view of pollination, the female specimens can be divided into three main groups: the Smyrna-type figs 1st crop (breba) will abort because of the lack of pollination and the crop

2nd (main crop) will develop with pollination. The San Pedro-type figs develop their 1st crop with parthenocarpy and the 2nd crop with pollination. The Adriatic-/common-type figs will produce their 1st and 2nd crop with parthenocarpy. The pollination of *F. carica* is complex and based on the followings. There are two types of flowers in male tree syconia, the pollen producing male flowers and female flowers with short styles (psenocarpiums), which allows wasps laying their eggs next to the ovariums. On female trees syconia contains only female flowers with long styles, which prevents the wasps oviposition. The wasp has three generation per year, developing in the syconia of the male (caprificus) trees. The male trees have two to three crops per year. The 3rd crop (the overwintering mamme) contains the first generation of wasps. The wasps develop and mate during spring, but only females are released and get into the 1st crop (profichi) of male trees. In here develops the second generation of the wasps. The first fruits of male trees mature at summer, the wasps mate in the syconia and the male flowers of the first crops are matured too at the same time, so the departing female wasps can carry the pollen. The 2nd crop flowers of female trees are receptive for pollen in this time of the year, therefore, pollination occurs in female trees because the long styles prevent the oviposition of female wasps in female syconia. This part of wasps, which entered in female syconia dies, but others enter into the second crop (mammoni) of the male trees, where they can find short-styled flowers suitable for oviposition. The 2nd crop become matured with the third generation of wasps at autumn and female wasps will enter into the 3rd crops (mamme) for oviposition (Jeszenszky and Kárpáti 1963, Schmidt 2010, Vandeyron and Lloyd 1979) (for further details see Fig. 2). Based on these, viable seeds can only be produced, if *B. psenes*



Fig. 1. Matured female fig wasps on a profichi (caprificus fruit) in Pécs (photo by Cs. Schmidt)

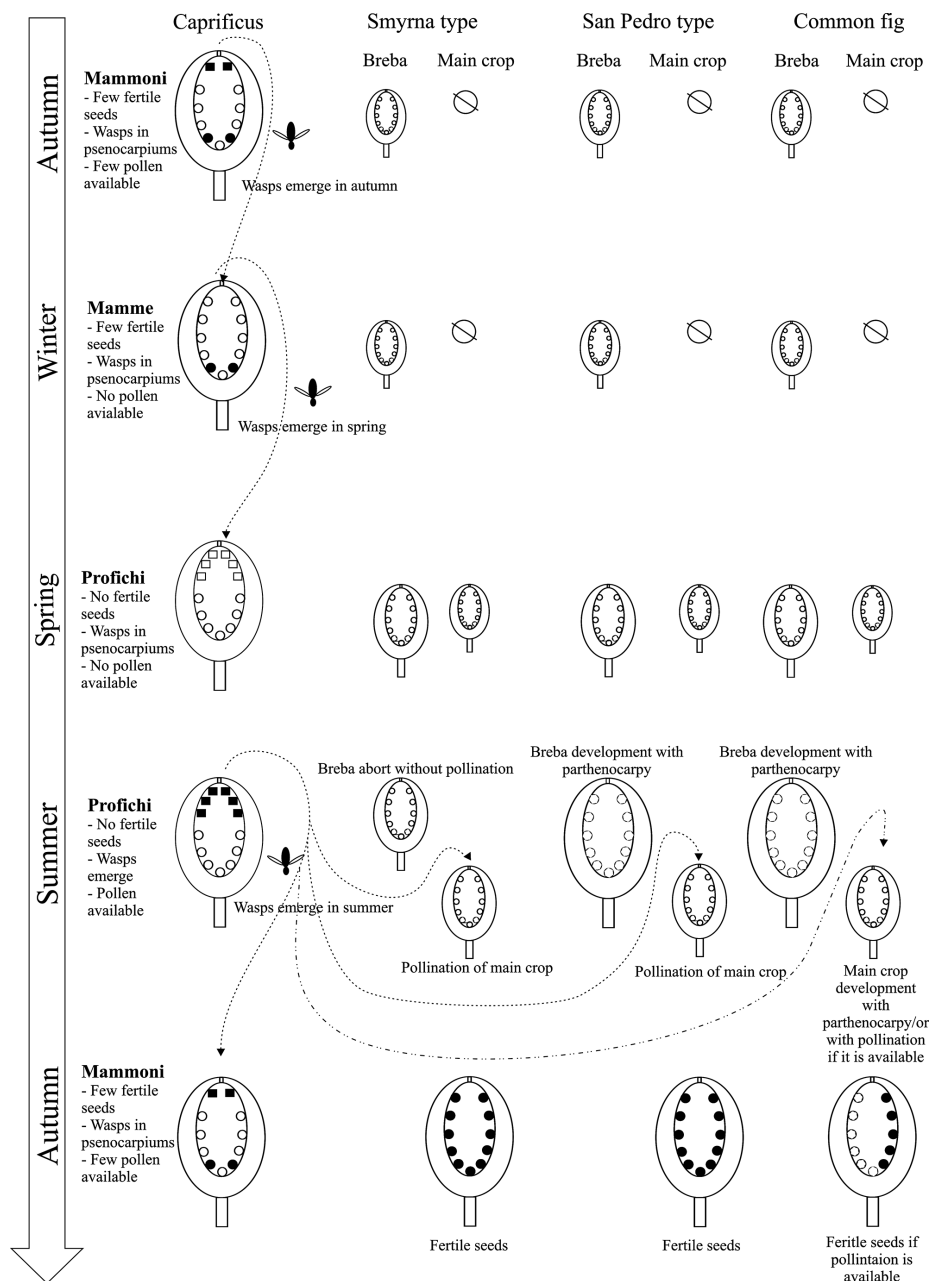


Fig. 2. Schematic diagram about the annual fruit development and pollination of *Ficus carica* in the case of the three pollination types (modified, based on Vandeyron and Lloyd 1979). Legends: circle = female flower, square = male flower, black colour = matured male/fertilised female flower, white colour = occupied psenocarpium/unfertilised female flower, dashed circle = aborted ovule

individuals are present. In contrast, fruit production is only possible with using parthenocarpic (San Pedro-type and common/Adriatic-type) figs out of the native range of *B. psenes*, but in this case no viable seeds will occur.

In Hungary, cultivation of common fig dates back to the 16th century (without any information about the fruit development type of female trees), later the Adriatic-type fig cultivars originated from Italy were became widespread in cultivation and the breeding of Hungarian cultivars was also based on this fruit-producing type in the 1950s (Jeszenszky and Kárpáti 1963). It is worth mentioning that experiments to grow *F. carica* in plantations started in the Transdanubian region in the last decade (Utassy 2012). *F. carica* is a common ornamental tree, originated from southwestern Asia, and mostly planted for its edible fruits. Out of its native range *F. carica* occurs in Great Britain (Allen and Hobson 1995, Dickson and Dickson 1996), Germany (Mazomeit 2018), Austria, Bosnia-Herzegovina, Bulgaria, Montenegro, Czech Republic, Poland, Portugal, Spain (Tutin 1968, Euro+Med Plantbase 2018) and in the USA (Wunderlin 1997). In Hungary the species planted mainly in South Transdanubia and on the southern slopes of the Hungarian Mountain Range, but these plants usually suffer from frost damage in winters (Király 2009). Previous studies mention that the species is a rare food refuse casual alien (from discarded dried syconia) or cultivation relict in the country (Borbás 1879, Jeszenszky and Kárpáti 1963, Priszter 1944, 1997, Simon 2000, Soó 1970, Udvardy 1997). Rapaics (1943) was the first who stated that seedlings and young individuals of *F. carica* in urban environment can be the result of naturalisation in Hungary. Since occurrences of common figs (e.g. in cracks of pavements and bases of walls or in semi-natural habitats) found out of cultivation were formerly treated as cultural relicts, *F. carica* was not listed among the Hungarian neophytes (Balogh *et al.* 2004). During the systematic flora survey of the administrative area of Pécs (Hungary) only three (subspontaneous) occurrences of *F. carica* was detected before 2015. In 2015 the first author found seedlings and young plants of common fig in a private garden of the city district called "Tettye". In the following year these specimens were still alive despite the previous winter conditions, therefore from the year 2016 the authors made a direct search in the suitable parts of the city and in Baranya County, mainly the proximity of the known fruit producing, planted specimens. The aim of this survey was to prove the casual neophyte or naturalised status of *F. carica* in Hungary according to the definitions in Balogh *et al.* (2004).

MATERIALS AND METHODS

Field works were carried out between the years 2015–2018. To characterise the habitat of *F. carica* in urban areas coexisting species were listed in 1 m² plots. In one case when specimen of the species was found in semi-natural/

natural habitat in Pécs, 10 m × 10 m plot were taken according the Braun-Blanquet methodology (Lájer *et al.* 2007). Latitude and longitude coordinates and altitude of the sites were determined with GPS in WGS 84 projection. Nomenclature of the listed species follows the work of Király (2009). Voucher specimens from two gardens (Hatház utca and Galagonya-dűlő, Pécs) were placed in the Herbarium of University of Pécs (JPU), in any other cases photography were used for documentation of stands and sites. For germination tests we collected seeds from six locations and six different sources in Pécs, in August 2018. In the case of fruits, 3–3 syconia were collected from one individual/location. Seeds were collected from ripen fruits on the plants, from fallen intact, from fallen-trampled fruits and furthermore seeds were collected from faecal samples of house sparrows in one case. We also collected seeds from dried fruits of four different products available in Hungarian commercial trade. 150 drupelets were separated and removed from each syconia. The seeds were removed mechanically from the drupelets on the day of collection and soaked in tap water for an hour to wash off the germination inhibitors. After this preparation the seeds were dried on absorbent paper and 15–15 of them were planted in plastic pots with a radius of 7 cm on the same day, filled with dry river sand or with potting soil. The seeds were placed randomly on the surface of the planting medium. The pots were sprayed with tap water in every second day. The pots were at room temperature and in under sunlight, which changed according to the part of the day. To illustrate the spatial relation be-

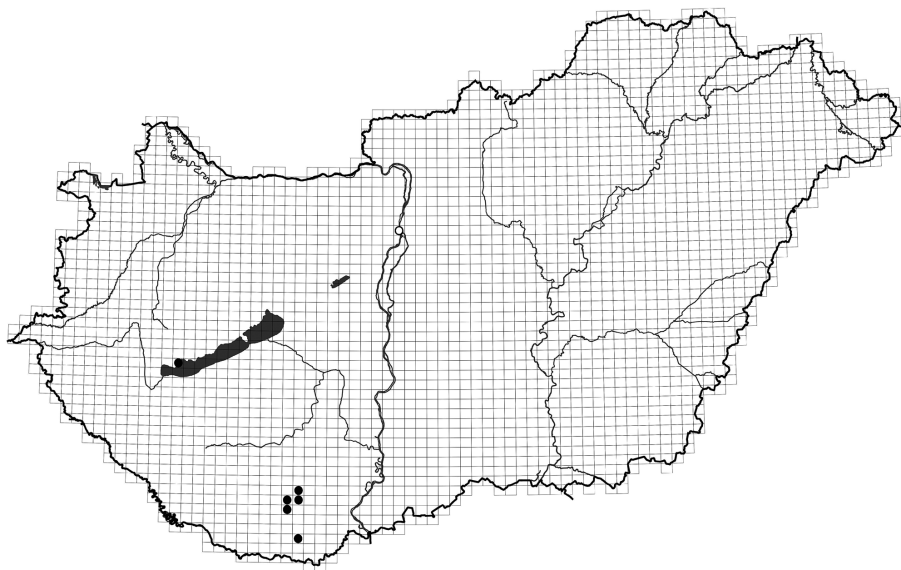


Fig. 3. Distribution of *Ficus carica* L. in Hungary (empty circle = occurrence before 2015, full circle = occurrence after 2015)

tween observed specimens and male fig trees in Pécs, we used a 256 times finer resolution compared to the Hungarian Flora Mapping System (Király 2003). The overlap of the location of caprificus trees with these quadrates was given in a proportional manner. Average distance between the escaped figs and the closest cultivated caprificus individuals was also calculated in Pécs.

RESULTS AND DISCUSSIONS

As a result of the direct investigations, the authors found many seedlings, young and few older specimens in 147 locations in Pécs, Máriagyűd and Kökény within Baranya county. These occurrences can be found in the [9875/4], [9975/1], [9975/2], [9975/3] and [0175/2] Hungarian Flora Mapping Units (Fig. 3) (Bartha *et al.* 2015).

The northernmost stands of escaped figs in Slovenia (Jogan *et al.* 2001) and Croatia (Nikolić 2015) can be found N of the South Transdanubian stands but 39 km S of Balatongyörök [9270/1] and 116.5 km S of Budapest [8580/1] in the latitudinal direction within the Carpathian Basin.

In South Transdanubia, the escaped and naturalising common figs occur mainly in artificial habitat types, usually (85.71%) on manmade solid surfaces (on walls, foot of walls, ducts, in cracks of pavements, etc.) and rarely (14.29%) in soil (Fig. 4). All of the observed specimens grew in southern slopes and most of them in the lower altitudes (mean: 172.97 ± 43.27 m a.s.l.) of the three Hungarian settlements. Specimens found in Hungary preferred the same synanthropic habitats, like in the original range of the species (Lansky and Paavilainen 2010). In terms of the age distributions, most specimens (48.30%) represent very young development stages (seedlings or young plants with 4–5 leaves, height between 0.1–0.3 m), or few years old plants (47.62%) (plants with several, often woody stems, height between 0.3–1.2 m). In six cases (4.08%) plants were elder and estimated at least ten years old (stout trunk, with all stems woody, height up to 2 m) (Fig. 5).

Common fig occurs in Hungary mainly in urbanised habitats characterised by thermophilous, annual and weedy species (e.g. *Conyza canadensis*, *Digitaria sanguinalis*, *Euphorbia maculata*, *Oxalis corniculata*, *Portulaca oleracea*, *Setaria viridis*), in habitats dominated by species with wide ecological spectrum (e.g. *Glechoma hederacea*, *Lolium perenne*, *Polygonum aviculare*, *Taraxacum officinale*) or with other woody adventives (e.g. *Ailanthus altissima*, *Celtis occidentalis*, *Koeleria paniculata*, *Morus alba*) (for further details see Appendix).

One specimen was found in semi-natural/natural habitat accompanied by the following species in Pécs: date: 07.09.2018, relevé made by T. Wirth, location: N 46.087415°, E 18.228955°, altitude 311 m a.s.l., southern exposure, between Kiss József utca and Miléva út, in degraded thermophilous oak forest, total plant cover: 80%, plot size: 10 m × 10 m, E3: 80%, E2: 60%, E1: 75%.

E3: *Quercus pubescens* 4, *Fraxinus ornus* 2, *Celtis occidentalis* 1, *Cerasus mahaleb* 1, *Hedera helix* 1, *Juglans regia* 1, *Sorbus domestica* 1.

E2: *Cornus mas* 3, *Euonymus europaeus* 2, *Fraxinus ornus* 2, *Cerasus vulgaris* 1, *Euonymus verrucosus* 1, *Viburnum lantana* 1, *Cerasus mahaleb* +, *Crataegus monogyna* +, *Juglans regia* +, *Prunus cerasifera* var. *nigra* +, *Sambucus nigra* +, *Sorbus domestica* +, *Celtis occidentalis* r, *Colutea arborescens* r, *Cotoneaster divaricatus* r, *Ficus carica* r, *Robinia pseudo-acacia* r, *Rosa canina* r.

El: *Clematis vitalba* 3, *Hedera helix* 3, *Ballota nigra* 2, *Bromus sterilis* 2, *Geum urbanum* 2, *Glechoma hirsuta* 2, *Quercus pubescens* 2, *Rubus fruticosus* agg. 2, *Setaria viridis* 2, *Vitis riparia* 2, *Ambrosia artemisiifolia* 1, *Arctium lappa* 1, *Calamagrostis epigeios* 1, *Chenopodium album* 1, *Erigeron annuus* 1, *Fraxinus ornus* 1, *Geranium robertianum* 1, *Lolium perenne* 1, *Lunaria annua* 1, *Oxalis corniculata* 1, *Polygonum aviculare* 1, *Arabis turrita* +, *Artemisia vulgaris* +, *Brachypodium syl-*



Fig. 4. The main habitats of *Ficus carica* L. in Pécs, Hungary. A = young plant in crack of a wall, B = an older plant next to a drainpipe, C = young individual at foot of a house wall, D = young specimen in soil between a garden fence and roadside (photos by T. Wirth)

vaticum +, *Celtis occidentalis* +, *Convolvulus cantabrica* +, *Glechoma hederacea* +, *Hieracium sabaudum* +, *Picris hieracioides* +, *Sambucus nigra* +, *Silene noctiflora* +, *Sorbus domestica* +, *Viola hirta* + *Campanula rapunculoides* r, *Helleborus odoratus* r, *Plantago major* r, *Potentilla indica* r, *Sonchus oleraceus* r.

Seedlings of *F. carica* were found in the same habitat types and latitudinal range in Ljubljana (Slovenia), in 2018 (personal observations of the senior author).



Fig. 5. Age groups of subspontaneous common figs found in Pécs, Hungary. A = seedling, B = young plant with 4–5 leaves, C = 2–3 years old specimen mainly with woody shoots, D = the oldest (at least 10 years old) known individual on the top of the old city wall (photos by J. Csiky and T. Wirth)

According to the presence of *B. psenes* (Fazekas and Schmidt 2016, Schmidt 2010) and older trees found outside of cultivation in Baranya County, we can speculate that common fig has been present for a long time in the Hungarian flora. In this respect, it is also interesting that Horvát (1942) mentioned *F. carica* as a cultivated and “semisubspontaneous” species in the flora of Pécs more than 76 years ago.

Ficus carica has an endozoochorous spreading strategy primary. The main consumers are birds and small mammals, but in some cases rain can wash out the seeds from the fell down and decomposed syconia (Lisci and Pacini 1994). In Pécs, observed consumers were house sparrows (*Passer domesticus* L.), common blackbirds (*Turdus merula* L.), feral pigeons (*Columba livia domestica* Gmelin.) and beech martens (*Martes foina* Erxleben) (Fig. 6), which may be responsible for the long distance spreading.

According to Lisci and Pacini (1994) fig seeds germinates only after the drupelets were removed somehow (eaten by animals or washed out by rain) from the syconium and the germinating inhibitors were removed. Then with optimal conditions germination starts in autumn (October to November) in the Mediterranean and sometimes in spring nearer in the continental Europe. In South Transdanubia both cases occurred, due to the sub-Mediterranean climate of Pécs and Máriagyűd, in the favourable years. According to an observation of the senior author about one hundred seedlings of *F. carica* ap-



Fig. 6. Common fig (*Ficus carica* L.) seeds in different vertebrate faeces in Pécs. A = seeds in faeces of house sparrow (*Passer domesticus* L.), B = seeds in faeces of beech marten (*Martes foina* Erxleben) (photos by J. Csiky and T. Wirth)

peared under a fig tree in a garden (Pécs: Patacs) at summer and early autumn in 2016. The occurrences of specimens – especially in the cracks of walls and pavements, drainpipes – may prove that the short-range dispersal of figs was driven by the autumn rains, washing the seeds into the cracks. In Hungary, Lovas-Kiss *et al.* (2017) recorded fig seeds in faecal samples of mallards (*Anas platyrhynchos* L.) from Lake Balaton, but none of the diaspores were capable to germinate. In contrast, at least one sample was successful in germination tests from the seeds collected in different locations in Pécs. We detected germination (46.67%) only in the case when seeds were collected from fallen-trampled fruits (Fig. 7), therefore we assume that fertile specimens (and planted caprifici) are present close to the spontaneous seedlings in the South Transdanubia, Hungary. It is also noteworthy, that germination of seeds collected from commercially available dried fruits were also successful, but with lower mean germination success (6.67%).

Naturalisation of *F. carica* in Hungary is possibly the result of human activities (planting specimens in large numbers) and climate change at the same time (climatic factors, spread of pollinators). Because the lack of information on the reproduction types of figs planted earlier and cultivated nowadays in the country (see comments of Jeszenszky and Kárpáti 1963), we do not have evidence on the origin of the viable seeds on fruit bearing plants. The Hungarian horticultural trade is based on the cultivation of parthenocarpic cultivars primary and experiments to cultivate and dissemination of Smyrna- and San Pedro-type figs just started recently in the country, therefore presence of planted individuals of fig types requiring pollination cannot be excluded in Hungary nowadays. The origin of male common figs (caprifici) in Pécs is questionable. Their presence can be explained by planting the species as an ornamental plant in public areas on the one hand and with the natural reproduction of the species on the other hand, however direct plantation and culti-

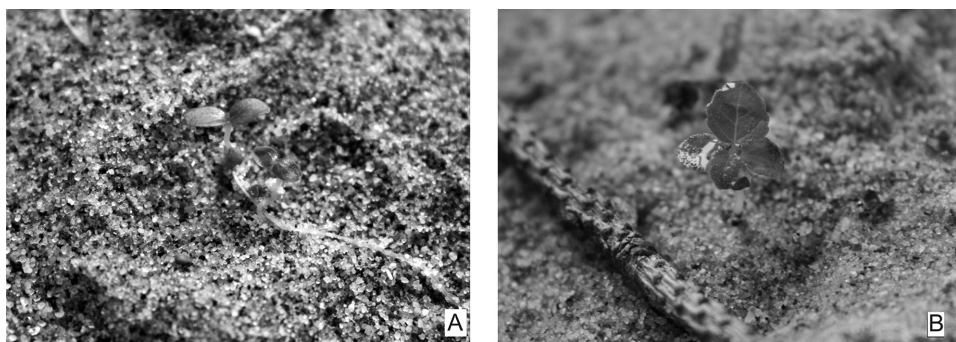


Fig. 7. Development stages of *Ficus carica* specimens, germinated from seeds collected in Pécs. A = 16 days old seedlings with cotyledons, B = 2 months old seedling with 4 leaves (photos by T. Wirth)

vation of caprifici in private gardens also cannot be excluded. To understand the first statement it is required to know, that fruit bearing plants are not tolerated during the maintenance of urban green spaces because of the littering of pavements and street furniture with the fallen and fermenting fruits. The fruit bearing plants will be eradicated as soon as their sex can be determinate, therefore non-yielding specimens are preferred in green spaces instead. The second statement can be explained by grafting the cultivars on caprificus rootstocks. Our investigations revealed the coincidence between the known male trees and the range of escaped and naturalising *F. carica* specimens in Pécs. Therefore, at those locations where escaped figs are documented, caprificus shrubs must be present within 0.1375 km² area with 26.23% probability, and in a circle with a mean radius of 855 m (min. 1 m, max. 9,557 m) (Fig. 8).

Despite the sub-Mediterranean climate of Pécs, there could have been winter weather conditions in the previous years when grafted parts can freeze

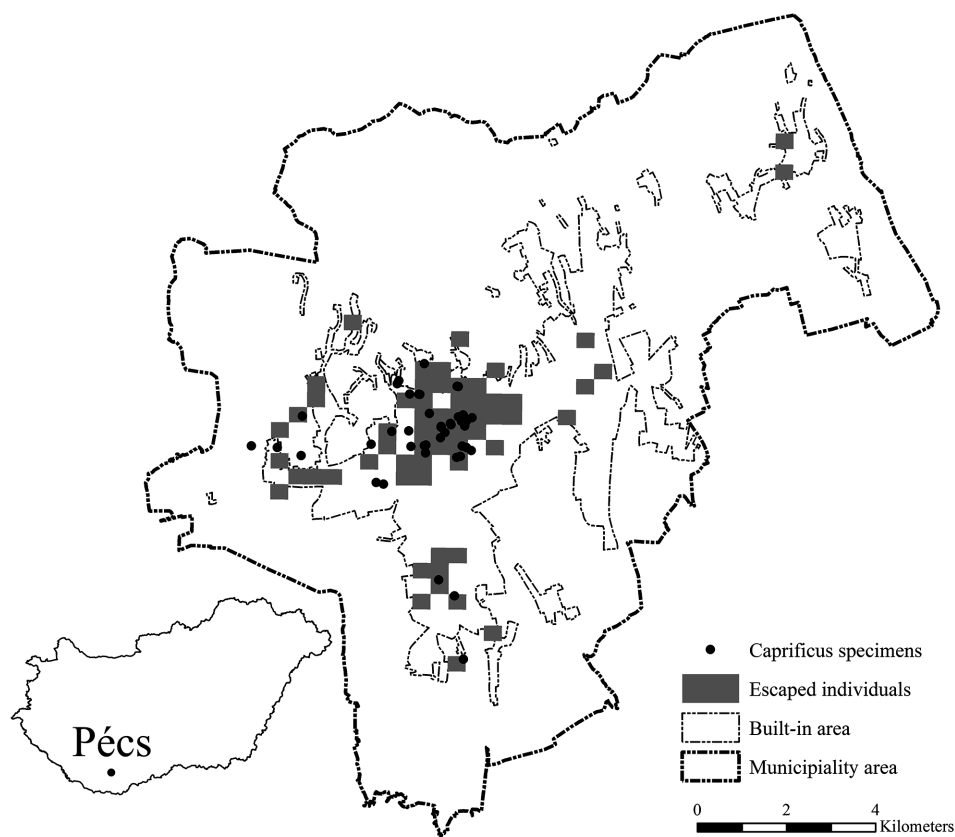


Fig. 8. Occupied area of escaped *Ficus carica* individuals and distribution of caprificus specimens in Pécs, Hungary

Table 1

Main characteristics of *Ficus carica* populations in the investigated Hungarian settlements. Numbers indicate the year of first observation (abbreviations: ? = presence is questionable, – = process not confirmed)

	Budapest	Pécs	Máriagyúd	Kökény	Balatongyörök
Presence of <i>B. psenes</i>	?	2008	?	?	?
Germination observed	2010	2015	–	–	–
Subspontaneous individuals	1940s	2010	2018	2018	2018

to the top of the rootstock. In this case the caprificus rootstock could develop and get to the fruit producing age. Rosianski *et al.* (2016) examined the effect of pollination of common-type figs in commercial orchards in Israel and reported that cultivars basically develop their fruit via parthenocarp can produce fertile seeds after caprification. Since the common-type figs are proven to be planted in Pécs, we can assume that the observed individuals found out of cultivation may be results such as pollination of fig type. Small number of fertile seeds also may occur in the intact, fertilised flowers in male syconia (on caprifici). According to this phenomenon, the viable seed-producing specimens in Pécs may be results of cultivated Smyrna- and San Pedro-type figs or pollinated common-type cultivars and with very low probability the male trees on the one hand and the appearance of *B. psenes* in the last decade in the southern part of Hungary on the other hand (Fazekas and Schmidt 2016, Schmidt 2010).

Our investigations showed that *F. carica* can produce viable seeds on parthenocarpic (Adriatic-type) plants and spread over the years, especially in the city of Pécs. The seedlings and young plants could also survive in harsh winter conditions, persist for long time and with endozoochory the seeds could reach longer distance from the mother plants. Based on the observations of Hungarian botanists, fig-growers and garden owners (Balogh, L. (Balatongyörök, breakwater wall: between stones) ex. lit., Exner, T. (Budapest: Gellért-hegy) ex lit., Herczeg, G. (Budapest: Sváb-hegy, in garden) ex lit., Priszter 1944, Rapács 1943), we assume that the escaping and naturalisation of common figs has been going on for some time now in Baranya county and Budapest. Although *B. psenes* was never confirmed from elsewhere in the country and around Budapest, while seedlings (in vitro) germinated from dried fruits collected on cultivated individuals in the city (Sváb-hegy) was documented in 2010 and 2014 (Herczeg G. ex lit.), it is likely that fig wasp had been present in the fauna of the Hungarian capital at least for 10 years (Table 1). Furthermore, the presence of escaped individuals in other Hungarian settlements (Balatongyörök, Kökény and Máriagyúd) suggests that *B. psenes* has a wider range at least in the Transdanubia. The fact that seedlings of common fig was not continuous-

ly present in Budapest and/or Pécs during the last century raises the chance that fig wasp is a casual species in the Hungarian Fauna and appears periodically in the Carpathian Basin.

Ficus carica reaches its fertile stage in 3–5 years under ideal conditions (Flaishman *et al.* 2008) and in spontaneous populations the male and female trees sex ratio is 1:1 (Kjellberg and Valdeyron 1984). Because most of the detected escaped specimens suffered from extirpation and/or frost damage, and the presence of *B. psenes* was confirmed at the first time in 2008 therefore we observed only vegetative growth and only one caprificus shrub in fruit (with fig wasp) in South Transdanubia so far. Because of the problems mentioned above – such as the indefinable ‘sex’ and the limited possibility to get into fruit producing age of the detected specimens – further investigations are necessary to clarify how *Ficus carica* will expand its range in Hungary due to the warming climate in the future.

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