

## CARDAMINE OCCULTA: A NEW WEED AND ALIEN PLANT SPECIES IN BANANA PRODUCTION GREENHOUSES IN TÜRKİYE

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Banana is a cash crop in Mediterranean Region of Türkiye, which is grown mainly in greenhouses and open fields. In weed flora surveys carried out in 2021 and 2022, an Eastern Asian plant, *Cardamine occulta* Hornem. (Brassicaceae), was determined first time in 60% of banana greenhouses in Türkiye. The species had been recorded in Europe in the second half of the 20th century, and then spread especially in urban areas of many European countries and Mediterranean Basin, which implies many habitats in Türkiye under the threat of *C. occulta*. The main diagnostic morphological features and an identification key are presented in comparison with those for allied *C. flexuosa* With. and *C. hirsuta* L. An eradication program is suggested because it is not scattered but limited with banana greenhouses in Türkiye.

Key words: Brassicaceae, floristic survey, Mediterranean Basin, southern Türkiye, taxonomy

### INTRODUCTION

Brassicaceae with 4,636 species from 340 genera and 52 tribes is a widespread family worldwide, especially in the Northern Hemisphere (Mediterranean basin, Central and Southwest Asia) (Francis *et al.* 2021, Koch and Kiefer 2006). Türkiye is the second in the number of Brassicaceae species followed by USA, which is the fourth largest family in Türkiye with its 93 genera, 583 species and 676 taxa (Al-Shehbaz *et al.* 2007, Dönmez *et al.* 2021, Sevindik *et al.* 2020). In addition, Türkiye has two of the most important diversification centres of the family: Irano-Turanian and Mediterranean.

The genus *Cardamine* L. includes near 200 taxa dispersed on all continents and contains diploids on the way to high polyploids (Kučera *et al.*

2010). There have been many studies about biogeography and paleogeography of *Cardamine* genus including hybridisation, polyploidisation, migration and human impacts (Hurka *et al.* 2003, Koch and Kiefer 2006, Urbanska *et al.* 1997, Zozomová-Lihová *et al.* 2014). Nineteen *Cardamine* taxa have been recorded in Türkiye (Bizimbitkiler 2022). But it includes species such as *Cardamine iberica* that is mainly accepted as *Chorispora iberica* (POWO 2023, Satıl *et al.* 2017). Actually, former literature has 14 species (Cullen 1965, Güner 2012, Karaismailoğlu 2021) as mentioned at Torun *et al.* (2022a) that *Cardamine* taxa including wild edible species that known as a name “bittercresses” (Acitere in Turkish) that are *Cardamine abchasica* Govaerts, *C. amara* L., *C. bulbifera* (L.) Crantz, *C. flexuosa* With., *C. graeca* L., *C. hirsuta* L., *C. impatiens* L., *C. lazica* Boiss. et Balansa ex Boiss., *C. penzesii* Ančev et Marhold, *C. pratensis* L., *C. purpurascens* (Banks et Sol.) Eig., *C. quinquefolia* (M. Bieb.) Schmalh., *C. raphanifolia* Pourr. and *C. tenera* S. G. Gmel. ex C. A. Mey. Among them *C. purpurascens* is native to China, *C. raphanifolia* to S France to N Spain, *C. impatiens* subsp. *pectinata* and *C. penzesii* to Bulgaria, *C. pratensis* to Europe; and the others native to Türkiye (Biyolojiegitim 2022, Flora Iberica 2022, MBG 2022, PIER 2022, Verloove and Barendse 2019, WFO 2022).

*Cardamine occulta* Hornem. is an annual, herbaceous, small, or even miniature plant and octoploid weedy species from the Brassicaceae family (Mandáková *et al.* 2019). *C. occulta*, which came to Europe from East Asia (Japan/China) and was first discussed by the Danish botanist Jens, was introduced by W. Hornemann in 1819, and the plant was known as *C. flexuosa* and some other names (Marhold *et al.* 2016). Furthermore, the same confusion happened in Japan, where *C. occulta* was mentioned as invasive plant (Kudoh 2017). The first findings of *C. occulta* in southern Europe were made in Italy in 1977 and Spain in 1993, and it has been recorded regularly since 2010. For instance, it has been recently recorded in many different parts of Italy (Galasso *et al.* 2018, Stinca *et al.* 2017). Many records came through Europe, namely from Austria, Belgium, England, Germany, Greece, Netherlands, Slovakia, France, Czech Republic, Switzerland, Belarus, Hungary, Finland, Ukraine, Georgia and Sweden (Cooke and Heathcote 2017, Dzhus 2019, GBIF 2023, Marhold *et al.* 2016, Šlenker *et al.* 2018, Takács *et al.* 2020) and Russia (Mayorov 2018, Šlenker *et al.* 2018). In the UK and Poland, it has been recorded in urban areas so far (Cooke and Heathcote 2017, Pliszko 2020) as the pathways for introductions have been mentioned are ornamental plants’ nurseries, flower shops, soil transportation, animal manures, animals and other human activities via seeds or vegetative parts of plants (Dehnen-Schmutz *et al.* 2007, Dudáš *et al.* 2020, Haeuser *et al.* 2018, Myers *et al.* 2000, Reichard and White 2001, Stinca *et al.* 2017). Recently *C. occulta* was reported as a new alien species from Northern Africa (Morocco) in flowerpots, roadsides, and pavements (Sukhorukov *et al.* 2023).

Banana has been produced in a limited area in Türkiye for over a century; but production has increased for the last two decades because of adoption of protected production in basic greenhouses to tackle with unsuitable weather conditions in open field production of banana in Türkiye. Weeds cause yield lost in banana crops (Ávila *et al.* 2020). In the weed surveys in banana production premises that were either covered or open field 68 species from 25 families were detected in 2021 and 2022 (Torun *et al.* 2023). One species was recorded as *Cardamine* L. sp. but it was not fully identified. It was reported as *Cardamine* cf. *flexuosa* With., which is native to Türkiye (Torun *et al.* 2022b). Later on, the specimen was identified as *C. occulta*. In addition, a literature found mentioning *C. occulta* and some records showing *C. occulta* in iNaturalist (2023) during paper writing process. In this paper, *C. occulta* from Türkiye is described and nomenclature problems were discussed as well as its invasive status as a threat for other habitats beyond banana greenhouses was speculated using current data and literature.

## MATERIAL AND METHODS

The specimens from 2021 were not good enough for a proper identification. In 2022, fields were re-visited, and new specimens were collected that were deposited in Herbarium of Duzce University Faculty of Forestry (DUOF) and Hatay Mustafa Kemal University Herbarium of Centre for Implementation and Research of Plant Health Clinic (MKUBK).

The specimens were checked according to the Flora of Turkey and the checklist for vascular plants of Türkiye (Cullen 1965, Davis 1988, Güner 2000). Related literature either had been identified *C. occulta* as a species in Europe or listed (alien) species in Türkiye were reviewed (Güner 2012, Jones and Akeroyd 1993, Leostrin and Mayorov 2019, Marhold *et al.* 2016, Takács *et al.* 2020, Uludağ *et al.* 2017). Morphological description of the species was based on literature (Breitwieser *et al.* 2022, Doğru Koca and Yıldırım 2004, Esser 2020, Hruševar *et al.* 2021, Pliszko 2020, Šlenker *et al.* 2019) as well as the collected individuals from the banana greenhouses. Key to *C. occulta* and closer species in flora of Türkiye that are morphologically similar are prepared using the keys from earlier references (Cooke and Heathcote 2017, Esser 2020, Hruševar *et al.* 2021, Leostrin and Mayorov 2019, Pliszko 2020, Šlenker *et al.* 2019).

The distribution map of *C. occulta* in Türkiye was created according to the grid system in Flora of Turkey (Cullen 1965).

### *Species nomenclature*

*Cardamine occulta* Hornem., Hort. Bot. Hafn. Suppl.: 71. 1819; Marhold *et al.*, Phytokeys 62: 60. 2016; Šlenker *et al.*, Bot. J. Linn. Soc. 187: 468, 473. 2018; Bull. Slov. Bot. Spoločn. 41: 13, Fig. 1A. – *Cardamine flexuosa* var. *occulta* (Hornem.) O. E. Schulz, Bot. Jahrb. Syst. 32: 479. 1903. Type: '*Cardamine occulta* mihi, sponte provenit in terra e China alata [?], ex h. b. Hafn.' (spontaneous in the Copenhagen Botanical Garden, in soil from China), 1817, J. W. Hornemann s.n. (lectotype C, designated by Marhold *et al.* 2016: 60, or perhaps holotype); China, Zhejiang



Fig. 1. *Cardamine occulta* Hornem. – a = habit; b = basal leaf; c = apical leaflet of the lower stem leaf; d = part of lower stem; e = flowers; f = silique; g = seeds, (H. Torun & N. Aksoy (8450!) at DUOF Herbarium)

Province, Linhai County, Kuocang Mountains, 18 Apr. 2014, K. Marhold, Y. P. Zhao & M. Jiang CH18/12/20148 (epitype SAV, designated by Marhold *et al.* 2016: 60) (Fig. 1).

*Cardamine occulta* Hornem. description – Annual, erect to partially decumbent herb, 10–30 cm tall. Stems often branched from the base, slender, angular, longitudinally grooved, bright green, stems usually glabrous, sparsely hairy. Leaves alternate, basal rosettes not dense; petiole 1.2–2.8 mm long; blade thin, 15–30(–50) × 15–30 mm, pinnate with 2–3(–4) pairs of smaller lateral pinnae of irregularly elliptical shape, sometimes lobed, and a larger apical pinna, this 10–15 × 6–10(–15) mm and distinctly (1–)3–5(–7)-lobed with (shallow to) deep sinuses, glabrous to sparsely pubescent, dark green. Racemes 10–15-flowered. Flowers with a pedicel of 1–2 mm length, glabrous; sepals 4, oblong, 1.5–2.0 mm long, hirsute, green; petals wider than the sepals 4, 2.5–3.0 mm, white; stamens 6, 1.8–2.0 mm long, didynamous. Ovaries cylindrical, 2–4 mm long; style short; stigma globose. Siliquae 1.8–2.3 × 0.1–0.2 mm, compressed, erect, greenish brown; seeds ovoid, 1.0–1.2 mm long, pale brown, smooth. Flowering and fruiting, March to November (Fig. 1).

### *Specimens examined*

*Cardamine occulta* – Türkiye, C4 Mersin-Anamur, Bozdoğan Muz Seraları, 20 m, 36° 10' N, 32° 88' E, 14.03.2022, H. Torun & N. Aksoy (8448!). – Türkiye, C4 Mersin-Erdemli, Alata Bahçe Kültürleri Araştırma Enstitüsü, Muz Seraları, 10 m, 36° 63' N, 34° 34' E, 14.03.2022, H. Torun & N. Aksoy (8448!).

*Cardamine hirsuta* – Türkiye, A3 Düzce Üniversitesi, Süs ve Tıbbi Bitkiler Botanik Bahçesi, Fidan Depo Alanı, 300 m, 25.03.2022, N. Aksoy (8451!). – Türkiye, A3 Düzce-Çerkez Taşköprü Köyü, Süs Bitkileri Üretim Bahçesi, 120 m, 29.03.2022, N. Aksoy (8452!).

*Cardamine flexuosa* – Türkiye, A3 Düzce: Akçakoca, entrance of Deredibi köyü, stream banks, 40–75 m, 10.05.2003, A. Dogru-Koca 2246 (HUB & Hb. Yıldırımli), (photographic image!).

### *Field study*

Banana fields were chosen randomly according to district acreages in 2021 and 2022. In each field, sampling unit was randomly chosen five 1 m<sup>2</sup> area where *C. occulta* coverage estimated, and individuals were counted. Average of five sampling units were calculated for each field and then data for all area were presented as average of all fields with *C. occulta*.

## RESULTS AND DISCUSSION

Specimens examined and compared showed that the plant species collected from banana greenhouses is *C. occulta*. Further taxonomic investigation showed that the distinguishing feature is the number of stamens among taxa compared. In *C. flexuosa* it is usually six (four large and two small often hiding) but can also be five and in *C. hirsuta* it is usually four but infuriatingly, can also be five (UKWF 2022).

Detailed morphometric analyses of this and related species were recently carried out by Şlenker *et al.* (2018). It was shown that the species is best differentiated based on its glabrous upper leaf surfaces, the more prominently

lobed terminal leaflets, the absence of a compact basal leaf rosette, the less hairy stem, etc. Interestingly, octoploid *C. occulta* probably originated through hybridisation between the tetraploids *C. scutata* and *C. kokaiensis* (Mandáková *et al.* 2019).

In earlier literature *C. occulta* was confused with *C. flexuosa* or *C. hirsuta* and many records had been re-checked (Kudoh 2017, Marhold *et al.* 2016, Takács *et al.* 2020) but former *C. hirsuta* and *C. flexuosa* records from flora of Turkey (Cullen 1965) have not been re-examined.

- 1a Basal leaf rosette compact; whole plant glabrous, except for few hairs at the base of stem leaves; stamens four, the lateral pair often absent, rarely five or six *C. hirsuta*
- 1b Basal leaf rosette absent or not compact; at least some hairs on stem or on stem leaves; stamens six 2
- 2a Basal leaves not rosulate; stem hairy or glabrous basally, glabrous or rarely sparsely hairy in the upper part; leaflets of middle stem leaf predominantly glabrous on the upper surface; terminal leaflet of the middle stem leaf (1–)3–5(–7)-lobed with deep and sharp sinuses; petals more than two times wider than sepals *C. occulta*
- 2b Basal leaves rosulate; stem markedly hairy; leaflets of middle stem leaf strikingly hairy on the upper surface; terminal leaflet of the middle stem leaf 1–7(–9)-lobed with both deep and shallow sinuses; petals less than two times wider than sepals *C. flexuosa*

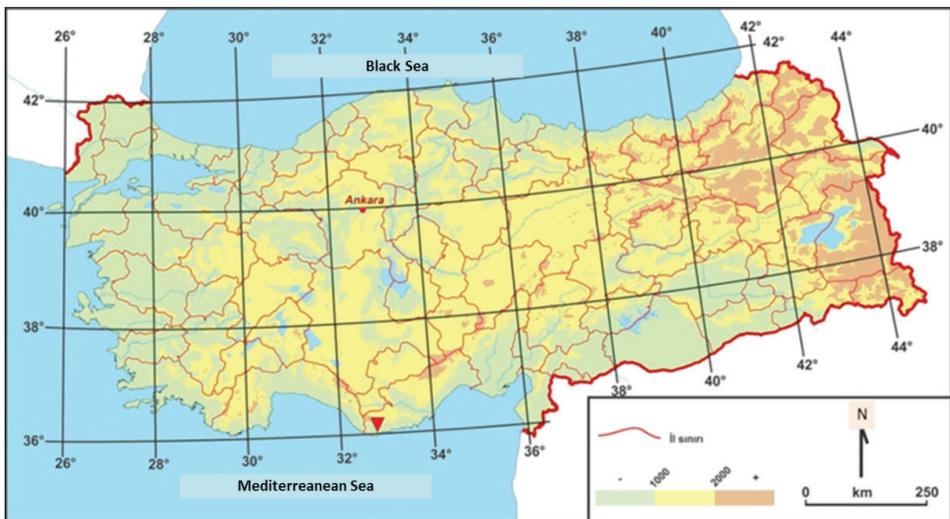


Fig. 2. Sampling specimen map of *Cardamine occulta*, in Türkiye (new locality triangle)

*C. occulta* has been detected in Southern Türkiye in the the provinces of Hatay (Arsuz and Erzin districts), Adana (Yüreğir, Seyhan, Ceyhan, İmamoğlu, Yumurtalık and Karataş districts), Mersin (Anamur, Bozyazı, Aydıncık, Silifke, Erdemli, Tarsus and Akdeniz districts) and Antalya (Alanya, Manavgat and Gazipaşa districts) (Fig. 2). However, there was no *Cardamine* in an earlier survey in Banana greenhouses in the Antalya province (Yılmaz *et al.* 2019). At the same time, the species has been reported from Side (Dzhus 2019), a tourist hub of the Antalya province. Moreover, several observations of *C. occulta* from Turkey are available at iNaturalist (2023). The specimens of *C. hirsuta* and other taxa from earlier records from Türkiye should be checked to make sure the identification, distribution and introduction of *C. occulta*.

It was found only in banana greenhouses although open fields were surveyed as well in Türkiye. In the surveys carried out in the banana production areas of the Mediterranean Region of Türkiye, *C. occulta* was determined in 52.2% and 71.7% of 113 and 52 banana greenhouse in 2021 and 2022, respectively. Their densities were recorded as 2.33 plant m<sup>-2</sup> (3.50% weed coverage) in the first year, and 2.98 plant m<sup>-2</sup> (3.55% weed coverage) in the second year. The presence of *C. occulta* only in the covered banana premises were attributed to muddy ground due to excessive irrigation, nutrient rich soil, warm and humid environment (Figs 3–4). These ecological preferences might be a limiting factor for further distribution of the species. On the other hand, occurrence of *C. occulta* in urban and arable areas in other countries (GBIF 2023, Leostrin and Mayorov 2019, Marhold *et al.* 2016, Sukhorukov *et al.* 2023) im-



Fig. 3. Local and first survey distribution map of *Cardamine occulta* at banana greenhouses in Mersin province

plies that *C. occulta* can invade larger areas in the South Türkiye. In addition, the high amount of seed production of *Cardamine* species and the adhesion of their seeds play an important role in their rapid dispersal by both humans



Fig. 4. The populations of *Cardamine occulta* at banana greenhouses

and animals, which can enlarge and accelerate spreading as naturalised alien plants (neophyte) for urban and arable areas, which can be transfer via seed from soil, irrigation or used as ornamental plants (Pyšek *et al.* 2004). Some *Cardamine* species have also been able to increase its spread potential by using as an ornamental or aquarium plant (Bademakvaryum 2023, Kocaelibitkileri 2023). It is known that they are used as ornamental plants or from soil by seeds and it is estimated that they are inadvertently transmitted to agricultural areas as stated above. The Mediterranean climate is suitable for the environmental demands of the species, suggesting the possibility of contagion in a short time wherever its environmental demands are met. More *Cardamine* species can occur in the region because some other *Cardamine* species have been reported as weed in banana plantations in other countries (Ávila *et al.* 2020, Rakotomanga *et al.* 2021, Space and Flynn 2000). In floral surveys of Türkiye carried out for agricultural areas, *Cardamine* species are rarely encountered as weeds. But *C. hirsuta*, *C. impatiens* and *C. lazica* were mentioned regarding as weed (Uluğ *et al.* 1993), and *Cardamine* species was reported to spread in meadow and pasture areas in Türkiye (Tepe 1998). It has been reported that *Cardamine* species is a main and dominant problematic weed in the rose production gardens in Maryland of USA (Beste and Frank 1985).

In banana greenhouses in Türkiye, producers use mainly mechanical and chemical control methods. In addition, it has been reported that they are very difficult to control with herbicides in the USA and European countries and may even be resistant to herbicides (Post *et al.* 2011). Alternative weed control methods should be employed to control herbicide tolerant and resistant weeds. Current distribution of *C. occulta* is not scattered but limited with banana greenhouses, it can be helpful for an intensive eradication program. This *C. occulta* case made clear need for acquis in Türkiye to tackle with invasive alien species.

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