https://doi.org/10.31298/sl.148.7-8.2

Izvorni znanstveni članci – Original scientific papers
Šumarski list, 7–8 (2024): 341–352

NEW POTENTIALLY INVASIVE SPECIES IN THE FLORA OF CROATIA – *Diospyros virginiana* L. (COMMON PERSIMMON)

NOVA POTENCIJALNO INVAZIVNA VRSTA U FLORI HRVATSKE – *Diospyros virginiana* L. (VIRGINIJSKI DRAGUN)

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SUMMARY

During field research conducted from 2022 to 2023 on the island of Koločep, near the city of Dubrovnik, the spontaneous emergence of the non-native species *Diospyros virginiana* L. (common persimmon) was observed outside its primary cultivation area. This ornamental plant is part of the park dendroflora. *D. virginiana* began appearing spontaneously on the eastern side of the road between the two main settlements of the island, Gornje Čelo and Donje Čelo. It has established itself in an agricultural habitat within an abandoned olive grove covering an area of about 2900 m^2. The plot, no longer under cultivation, is predominantly covered with ruderal and weedy vegetation, featuring an herbaceous ground layer identified as *Dauco majori-Foeniculetum vulgaris*. In this area, *D. virginiana* attains an average height of 1 to 2 meters, enveloping and suppressing the remaining *Olea europaea* L. trees. The plant spreads vegetatively and possesses a robust root system extending laterally for several meters, completely covering the area. Additionally, it has grown into a dry stone wall structure along the road. According to the author's proposal, it was recently entered in the FCD as 2.1.1.3, a potentially invasive species, to provide a basis for future monitoring. Considering its invasive potential and the environmental damage it may cause, the authors suggest the eradication of the species from the area before it spreads to surrounding regions.

KEY WORDS: American persimmon, environmental damage, Koločep Island, neophyte, potential invasive impact, spontaneous appearance

INTRODUCTION
UVOD

Diospyros virginiana L. belongs to the family Ebenaceae, while the genus *Diospyros* according to the POWO database comprises 1666 taxa, of which 874 plant names are accepted. According to Duangjai et al. (2009), the genus *Diospyros* is the largest, most widespread and economically most important genus of the Ebenaceae with over 500 species, and according to Wallnöffer (2001) it comprises 500-600 species. The genus name originates from the Greek words *dios* (divine) and *pyrós* (wheat, fruit), literally translating to "tree with divine fruit" (Vlahović 2019). The greatest species diversity is found in the Asia–Pacific region (ca. 300 species), with several species known for their use as timber or as suppliers of edible fruits and many others as an important source of medicinal products (Lee et al. 1996; Mallavadhani et al. 1998; Wallnöffer 2001; Peyrat et al. 2016; Yi et al. 2016; Rauf et al. 2017, Tang et al. 2019).

The most famous species of the genus is certainly the cultivated persimmon *Diospyros kaki* L. f., which originated

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from China, and which has been long and widely used as a traditional medicine. It was also reported to be the best fruit yielding species (Mallavadhani et al. 1998).

The natural distribution area of the species *D. virginiana* covers the eastern part of the United States (Idžojtić 2013), appearing in habitats from Texas to Connecticut and as far south as southern Florida (Vlahović 2019). Of concern is the fact that in humid areas of South America, it is not uncommon for *D. virginiana* to form thickets from its root suckers on abandoned agricultural land, which have a pronounced invasive potential through generative and vegetative spread (Peters et al. 1970; Burge, 2018). One of the first descriptions of this species was made by an unknown author in the work "Gentleman of Elvas" from the 16th century (Briand 2005). Subsequently, descriptions by Spanish, French, and English explorers who visited the New World compared the fruit of this species with plum (*Prunus domestica* L.) and medlar (*Mespilus germanica* L.). Carl Linnaeus assigned the modern botanical name to the species in his work "Species Plantarum" in 1753, designating it as *Diospyros foliorum paginis concoloribus* (Briand 2005). Today, over 200 cultivars of the species *D. virginiana* are known, differing in fruit characteristics such as shape, size, color, and ripening time (Zhabrovets et al. 2019).

Description – *Opis*

Leaves: Alternate, simple, 6-15 cm long and 3-6 cm wide, acute apex, oval or cordate at the base (Yonemori et al. 2008). The leaves emerge directly from the buds, slightly twisted. The leaf has a simple venation; the midrib is wide and straight, with opposite and conspicuous primary veins. Young leaves are reddish-green, slightly serrated. Adult stems have thicker leaves; dark green, shiny, and smooth on top, lighter on the underside with small hairs along the midrib. In autumn, the leaf color may turn orange or crimson, and sometimes the leaf falls without a change in color.

Petioles: Firm and hairy, stout, brown, pubescent, 2 cm long.

Flowers: Dioecious species with small and inconspicuous flowers, 5-6 mm long, greenish-yellow or creamy white, tubular, four-lobed; lobes imbricate in bud. Male flowers are smaller. The flower calyx is bell-shaped with a margin of four teeth. Female flowers have an elevated ovary. The corolla is tubular. Male flowers often have backward-curved teeth; there are about 16 stamens arranged in two circles (Idžojtić 2013). Persimmon flowers are typically initiated the year before anthesis. Secondary flowering can develop from primordia initiated in the current season under specific environmental conditions. The species flowers in May and June after leafing, and the fruits ripen in the same year in October and November. Pollination occurs through insects and wind, and the fruit, in addition to human use, is attractive to squirrels and other mammals (Gilman et al. 1993; Orwa et al. 2009).

Bark: Deeply divided into scaly plates, somewhat broken by longitudinal fissures. The bark of the mature tree trunk is brownish-black (Vlahović, 2019), while in young seedlings, it is smooth brownish-red, as observed on Koločep.

Fruit: The fruits are spherical or flattened-spherical, approximately 2.4 cm in size, orange-yellow, smooth, juicy, soft, and edible berries. The flesh is astringent when green, becoming sweet and luscious when ripe. The fruit contains 4 to 8 seeds, which are brown, shiny, and flat (approximately 1.5 cm long and 1 cm wide).

Folklore uses of species: The powder of the unripe fruit, inner bark or root bark is taken with wine to treat dysentery, diarrhea (bloody stools), fever, hemorrhoids, as a mouthwash for thrush and sore throat, and as a wash for warts or cancer and other conditions (Sirisha et al. 2018). It is also used in the production of beer, spirits and wine.

Habitat: *D. virginiana* often covers abandoned fields with a shrubby growth, emerging along roadsides and fences. It is frequently the first tree species to grow on abandoned and denuded cropland, well-adapted to environments with high insolation and low water supply (Morris 1965).

According to the authors' findings (Marić et al. 2023), the species *Diospyros virginiana* is included in the Flora Croatica database (Nikolić ed. 2024) to provide a basis for future monitoring.

Records indicate that various species from the genus *Diospyros* were introduced to Europe from the 17th to the 19th century, serving different purposes, including ornamental and non-fruit-related uses. These species were often planted in orchards alongside citrus and olive trees (Kluge and Tessmer 2018). Most of these introductions involved evergreen species, while *D. kaki* L. f., *D. lotus* L., and *D. virginiana* L. are deciduous and adapted to colder climates.

Unlike *D. kaki*, which has consumable (edible) fruits, *D. lotus* and *D. virginiana* are commonly used as rootstocks for fruit varieties suitable for consumption (Intrigliolo et al. 2015).

This species is very adaptable to environmental conditions. *D. virginiana* is particularly resistant to cold growing conditions (Zhabrovets et al. 2019), but also resistant to high solar radiation and drought (Gilman et al. 1993; Orwa et al. 2009; Intrigliolo et al. 2015). The altitudinal limit at which *D. virginiana* does not occur is 1200 m above sea level. According to the literature, the maximum temperatures that the species can tolerate are 35°C in summer and -12°C in winter (Orwa et al. 2009). Although it prefers full sun, the plant can also thrive in the shade. In addition to prolonged drought, the plant also tolerates occasional flooding. It is important that the plant receives at least 46 mm of water from rainfall during the growing season. It thrives on almost all soils, but

grows best on alluvial soils such as clay and heavy loam with a neutral pH (Orwa et al. 2009).

The United States Department of Agriculture (USDA) notes it as a pioneer species, often colonizing abandoned fields, road edges, and fences. Its presence in forest stands and abandoned fields is considered undesirable, although some scientific articles have pointed to its strong invasive potential (Peters et al. 1970; Nesom 2000, Burge, 2018).

Common persimmon is easy to grow in the Mediterranean basin, and currently, there are no limiting factors, aside from water supply in some areas and low spring temperatures in others (Bellini 2002). To our knowledge, data on the invasiveness of this species in other parts of Europe are not available or do not exist."

In the Dubrovnik area, the first known introduction of *D. virginiana* dates back to 1859 (Idžojtić et al. 2019) when it was planted in the Trsteno Arboretum during the ownership by Baltazar Paola Bassegli Gozze (Đurasović 1997; Obad Šćitaroci and Kovačević 2014). It is currently one of the eight oldest living trees in the arboretum (Idžojtić et al. 2019). During that period, plants were introduced to Trsteno from nurseries in Genoa, Padua, and Venice. There is no record of the plant being introduced to any other location in Dubrovnik during that period (Marić 2024).

Throughout the 20th century, this species was planted in Croatia as an ornamental species. It was planted in the first Croatian modern park, Trg kralja Petra Krešimira IV, in Zagreb in 1937 (Vidaković et al. 2020). There is information that *D. virginiana* was planted in the 1960s at the entrance to the historic core of Dubrovnik, in the park at Pile (Vlašić 1962). In addition to planned individual plantings in parks (Vlašić 1962), it was also planted in some private gardens in Zagreb (Jurković and Jurković-Bevilacqua 1996).

The species has not been registered as invasive in the EU or the Republic of Croatia (Nikolić ed. 2024; Mingor 2023). However, *D. virginiana* was recently described as a naturalized potentially invasive species in California (Burge 2018). According to the symposium communication by Marić et al. (2023), it was recently included in the online Flora Croatica Database (FCD, Nikolić ed. 2024) into the module Invasive taxa as a potentially invasive species (category 2.1.1.3 according to FCD). The aim of this study was to determine the distribution and spread of this allochthonous and potentially invasive species on the island of Koločep.

MATERIALS AND METHODS
MATERIJALI I METODE

Study area – *Područje istraživanja*

The island of Koločep (local name Kalamota) is the southernmost inhabited island in the Elaphiti archipelago, covering a total area of 2.44 km^2 (length 3.1 km, width 1.2 km), situated just five kilometers from the main Dubrovnik maritime port of Gruž. The island lacks vehicular traffic, and its landscape features a combination of hamlets surrounded by small agricultural areas, predominantly planted with olives, and to a lesser extent, citrus fruits, vineyards, cherries, and figs, alongside some vegetable crops. The island's highest peak reaches approximately 125 m above sea level.

Most of the island is covered by forests and degraded forms of maquis (78%), mainly *Quercus ilex-Pinus halepensis* and *Myrto-Quercetum ilicis* communities, while a smaller portion is overgrown with garigue (14%), predominantly composed of the Cisto-Ericion alliance. The remaining areas consist of agricultural land, mainly olive orchards or neglected areas where the association *Dauco majori-Foeniculetum vulgaris* from the *Inuletea viscosae* develops (Jasprica 2010).

Due to its floristic value, characterized by a Mediterranean floral element (Hećimović and Hećimović 1987; Jasprica and Kovačić 2002), Koločep is designated as an Important Plant Area (IPA) in Croatia (Jasprica 2010). The island hosts over 450 plant species and subspecies, including 12 Illyrian-Adriatic endemics, of which eight are plant species of endemic character, and their habitats are endangered (Kovačić and Jasprica 2002; Jasprica 2010). Two protected areas exist on the island – the natural area of maquis and Aleppo pine (Donje Čelo area) and the natural area of Aleppo pine (Gornje Čelo area), protected as park-forests since 1951 (approx. 11.5 ha). The entire island of Koločep falls within the Natura 2000 area under the Habitat Directive (Council Directive 92/43/EEC).

Koločep has a Mediterranean climate (Köppen classification: Csa), known as the olive climate, with moderately warm rainy seasons, dry, warm summers, and mild, rainy winters. With no specific meteorological stations on the Elaphiti Islands, meteorological data were retrieved from literature for the Dubrovnik area. The island experiences an average of 215 sunny days annually, with 2613 hours of sunshine. The average annual air temperature is 16.4°C, with the lowest monthly average air temperature in January at 9.1°C and the highest in July at 24.1°C. The Elaphiti Islands expect milder extremes due to increased maritime influence (Magaš et al. 2001). The average annual precipitation is 1250 mm, with the majority falling during the cooler parts of the year (fall and spring) (Makjanić et al. 1989; Jelić 2003; Gajić-Čapka 2008). The main winds during the colder months are "bura" (N-NE) and "jugo" (SE), with "maestral" (NW) prevailing in the warmer months. Koločep, like other islands in the Elaphiti group, is characterized by surface water scarcity typical of karst regions (Glamuzina and Glamuzina 1999).

Data sources – *Izvori podataka*

Research involved field investigations, along with the analysis of literature data and herbarium collections DEND, W, GZU, PI, MJG, LZ, NCU, UNCA (abbreviations according to Thiers 2024), and Atlas of Florida Plants (Wunderlin et al. 2023).

D. virginiana was first observed on the island of Koločep in 2019. Field research to monitor the spread and propagation methods of this then-unknown species was conducted from October 2022 to October 2023 across the entire island, visually and by marking its spread 3 times a year. The plant was inventarized in the area between the settlements of Donje Čelo and Gornje Čelo on the island of Koločep (Figure 1).

Identification of *D. virginiana* based on its morphology, general habit, and leaf shape was conducted according to the morphological description and identification proposed by Hague (1911), Sirisha et al. (2018), Idžojtić (2019), Vlahović (2019), and additional authors' observations. This included comparing specimens of stem and leaf parts in different stages of development from the island of Koločep with those in the Trsteno arboretum.

Herbarium vouchers of the collected plants have been digitized and deposited in the herbarium ZAGR. Images are accessible through the Virtual Herbarium ZAGR

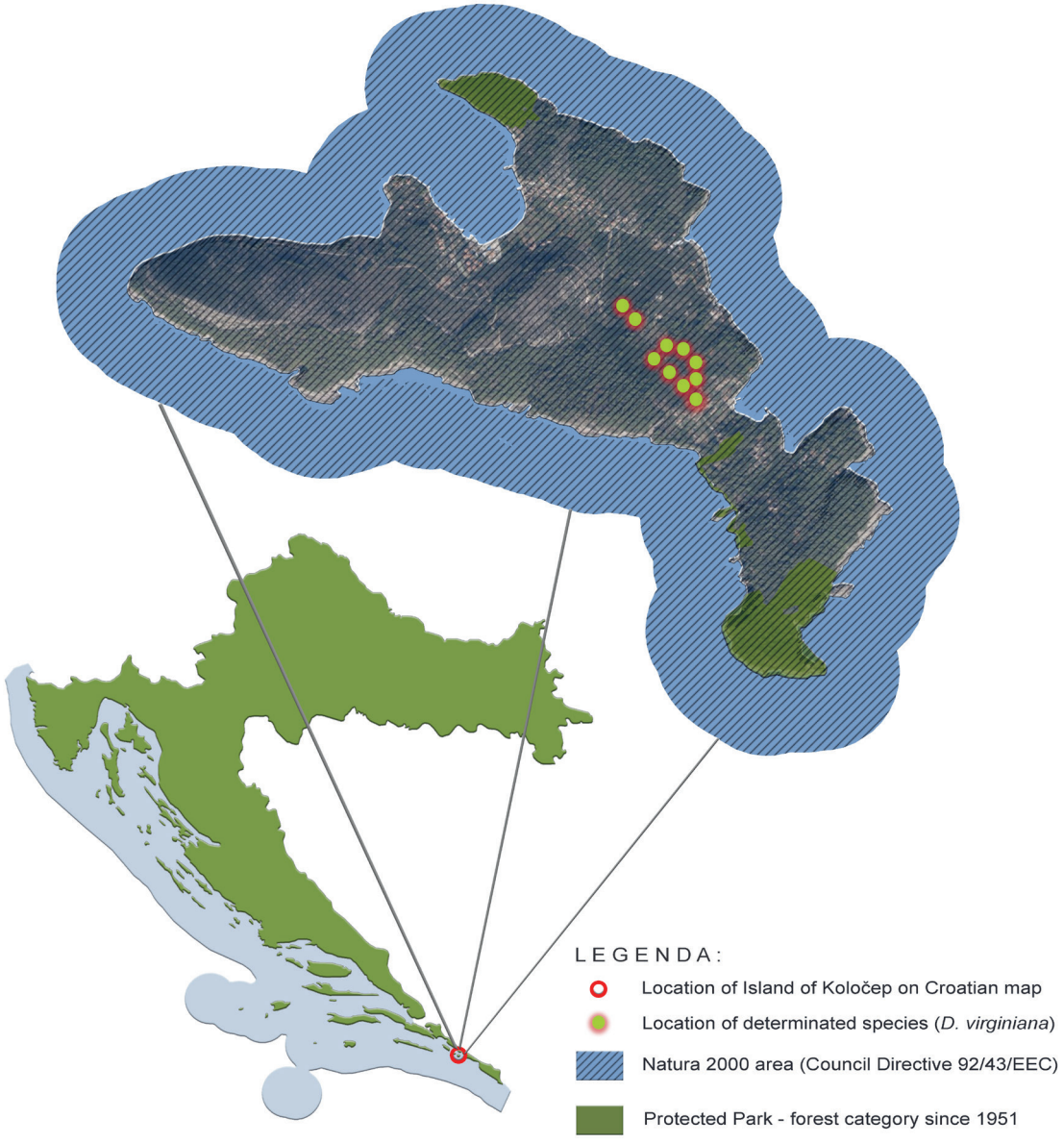

Figure 1. The geographical position of the study site on Koločep island (Coord.: 42°40'21.10"N, 18°0'47.80"E) (map: M. Marić, source: https://geoportal.dgu.hr/ and https://www.bioportal.hr/gis/, accessed on: 10 November 2023)

Slika 1. Geografski položaj lokacije istraživanja na otoku Koločepu (Koord.: 42°40'21.10"N, 18°0'47.80"E) (karta: M. Marić, izvor: https://geoportal.dgu.hr/ i https://www.bioportal.hr/gis/, pristupljeno: 10. studenog 2023.)

Figure 2. Plot of land near the pathway connecting the two main settlements of Gornje Čelo and Donje Čelo on Koločep island where *Diospyros virginiana* L. spontaneously appeared about four years ago (photo: M. Marić, July 2023)

Slika 2. Parcela u blizini staze koja povezuje dva glavna naselja Gornje Čelo i Donje Čelo na otoku Koločepu gdje se *Diospyros virginiana* L. spontano pojavila prije otprilike četiri godine (foto: M. Marić, srpanj 2023.)

(Bogdanović et al. 2016). For confirmation, identified specimens of *D. virginiana* from Koločep (ID numbers: ZAGR78094 and ZAGR78095) were also consulted and compared with Croatian populations from Trsteno (ZAGR78096).

RESULTS AND DISCUSSION
REZULTATI I RASPRAVA

In Croatia, two species of the genus Diospyros have recently been documented in the natural habitat (Nikolić ed. 2024), and with this work we point out the occurrence of the third species.

BASIONYM: *Diospyros virginiana* Linnaeus 1753. First published in Sp. Pl.: 1057 (1753).

Native range: Central & E. U.S.A. It is a tree and grows primarily in the temperate biome (POWO 2023).

Introduced range: Europe, Bermuda, California, Palestine, Transcaucasia (POWO 2024).

Croatian localities outside the area of primary cultivation – 3 sites:

1) The habitat where the species *D. virginiana* appeared about four years ago is in the area of an abandoned olive grove along a road connecting two settlements on the island (Donje Čelo and Gornje Čelo), with an area of approximately 2900 m^2 that is completely occupied by *D. virginiana*, which has started to intertwine with old neglected olive trees (Figure 2). It is anthropogenic soil of fields on colluvium of dolomite and flysch, with reduced water permeability, which is why fields in this central part of the island were the foundation of agricultural activity in the past. In the neglected field, in the herbaceous layer, ruderal and weed vegetation of the association *Dauco majori-Foeniculetum vulgaris* is predominantly present, with individual neglected olive trees (*Olea europeae* L.) and laurel (*Laurus nobilis* L.).

Coordinates of the rectangular abandoned agricultural plot where the species is located are: 42°40'21.6"N, 18°00'45.9"E; 42°40'22.1"N, 18°00'47.1"E; 42°40'20.5"N, 18°00'48.1"E; 42°40'20.6"N, 18°00'48.8"E.

It has been measured that *D. virginiana* at this location has an average height ranging from 1 to 2 m with a stem diameter of up to 1.5 cm. The density of this species at the mentioned location was found to be around 30 plants per 10 m^2, indicating a relatively dense stand (Figure 2), pointing to the invasive potential of this species. It has also been observed that the plant has an extremely strong, woody root system that spreads and networks over very large areas. Attempting to excavate one specimen was not possible precisely due to the fact that it has an extensively branched root system, where the plant continues to spread and develop adventitious roots even after cutting.

2) The area within dry-stone structures (Figure 3) along the main island road, approximately 120 meters away from the neglected olive grove, at the following coordinates:

Coord.: 42°40'23.40"N, 18°0'45.60"E; 42°40'25.2"N, 18°00'41.6"E; 42°40'25.0"N, 18°00'42.0"E; 42°40'23.4"N, 18°00'45.6"E; 42°40'24.6"N, 18°00'42.7"E.

Figure 3. Young specimen of *D. virginiana* grows wild in a dry stone wall on Koločep island, October 2023 (photo: M. Marić)
Slika 3. Mladi primjerak *D. virginiana* samoniklo raste u suhozidu na otoku Koločepu, listopad 2023. (foto: M. Marić)

Figure 4. Continued wild spread of *D. virginiana* on Koločep island, October 2023 (photo: M. Marić)
Slika 4. Kontinuirano samoniklo širenje *D. virginiana* na otoku Koločepu, listopad 2023. (foto: M. Marić)

Figure 5. Young leaves of *D. virginiana,* Koločep island, June 2023 (photo: M. Marić)
Slika 5. Mladi listovi *D. virginiana* na otoku Koločepu, lipanj 2023. (foto: M. Marić)

Figure 6. Leaves of *D. virginiana* - shoot growth complete; foliage fully dark green, Koločep island, October 2023 (photo: M. Marić)
Slika 6. Listovi *D. virginiana* – rast vegetativnih pupova završen; lišće potpuno tamnozeleno, otok Koločep, listopad 2023. (foto: M. Marić)

Figure 7. Leaves of *D. virginiana,* Trsteno Arboretum, October 2023 (photo: I. Paladin Soče)
Slika 7. Listovi *D. virginiana*, Arboretum Trsteno, listopad 2023. (foto: I. Paladin Soče)

On a length of 30 meters along the mentioned dry-stone wall (1.5 m high), 17 specimens of this species were identified (October 13, 2023). In August 2023, there were approximately 50% fewer specimens at the same location. In September 2023, the plants were removed (by the local fire brigade during routine maintenance work), and in October, new shoots emerged from the root suckers.

3) A new spreading site perpendicular to the large abandoned olive grove was identified in October 2023, in a depression and on the embankment of an old drainage ditch for rainwater, coordinates 42°40'22.5"N, 18°00'47.5"E; 42°40'22.5"N, 18°00'47.5"E (Figure 4).

In Figures 5-7 leaves and Figures 8a and 8b, the rooting system of *D. virginiana* from Koločep is showed. Figure 9 shows digitized specimen from ZAGR Herbarium (ID ZAGR78095).

D. virginiana is a dioecious species, and on the Koločep island sites, flower and fruit formation have not yet occurred, making it in this phase impossible to determine whether they are male or female specimens. Also, clonal analysis has not been done yet. Reproduction currently occurs exclusively through vegetative method. Therefore, phenological monitoring of *D. virginiana*, which has a total of 9 main phenological phases and 97 subphases (Zhabrovets et al. 2019), was not possible. On Figures 5-7 show leaves and Figures 8a and 8b rooting system of *D. virginiana* from Koločep. Figure 9 shows digitized specimen from ZAGR Herbarium.

Interestingly, in the Trsteno Arboretum, aside from the original old specimen of Virginia persimmon planted in the

Figures 8.a and 8.b. Rooting system of *D. virginiana,* Koločep island, August 2023 (photo: M. Marić)
Slike 8a. i 8b. Korijenski sustav *D. virginiana*, otok Koločep, kolovoz 2023 (foto: M. Marić)

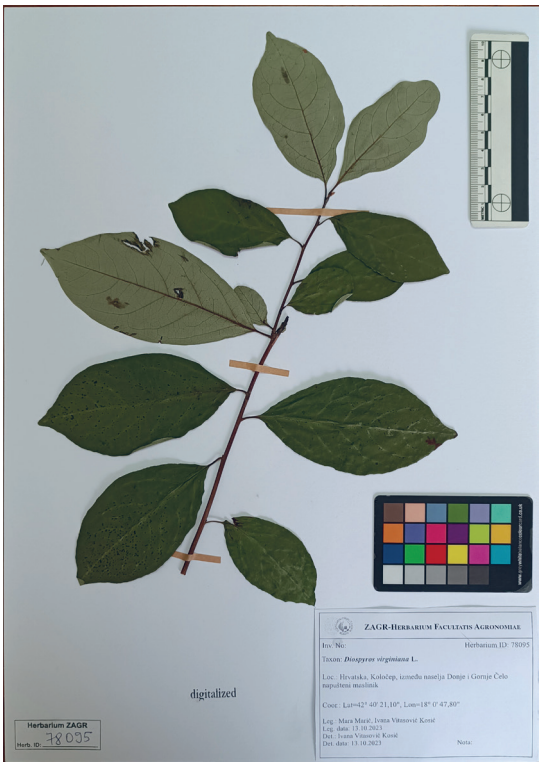

Figure 9. Digitalised specimen of *Diospyros virginiana* L. from Koločep island in ZAGR online Herbarium, November 2023 (photo: I. Vitasović Kosić)

Slika 9. Digitalizirana vrsta *Diospyros virginiana* L. s otoka Koločepa u online ZAGR herbariju, studeni 2023. (foto: I. Vitasović-Kosić)

mid-19th century (over 15 meters in height), which is a female species (fruiting), this species is spreading vegetatively in the area of the old olive grove near a dry-stone structure, showing potential invasive influence. It is worth noting that, out of the three *Diospyros* species present in Croatia, *D. virginiana* and *D. lotus* show high potential of harmful invasive effects on biodiversity. In Šijanska šuma in Pula (a protected forest under the management of Natura Histrica), the highly invasive ability of *D. lotus* (FCD status: 2.1.1.3. Potentially invasive) has been observed by the last author here (oral statement by Vitasović-Kosić I.), rapidly spreading with a large number of specimens on a central meadow. The third species present in Croatia, cultivated *D. kaki*, currently does not show such capabilities, and for now there is no such data).

Mature *D. virginiana* trees are 12-25 meters tall and can form multi-stemmed shrubs, as observed on Koločep. It is believed that the tree reaches optimal fertility at the age of 25-50 years, although it is considered that trees as young as 10 years old can bear fruit (Orwa et al. 2009). Therefore, regardless of the proportions of male and female individuals on Koločep, these specimens on the island have not yet reached the period of fertility. Moreover, for species from the *Diospyros* genus, 100 to 200 hours per year with temperatures below 7°C during autumn and winter months are required for the development of shoots from vegetative and mixed buds. Intrigliolo et al. (2015) note that bud diversification in this genus will depend on several factors, such as plant nutrition, winter pruning, environmental conditions, soil fertility, and the availability of irrigation during the summer months, ultimately resulting in whether buds will develop into so-called "water sprouts", unfruitful branches with vertical growth, or fruitful branches with mixed buds. In well-maintained orchards, this species bears fruit every two years.

According to Burge (2018), in all populations, mature fruits were found in autumn, and these fruits produced viable seeds with filled embryos. It is not yet known if these populations result from asexual reproduction via root sprouting or sexual reproduction via diaspores. However, the production of viable diaspores in all surveyed populations indicates that the sexual seed set is occurring. The size of some populations suggests that some areas in California may be susceptible to invasion by this species. This is important because the climate in southern California, with its Mediterranean characteristics (mild, wet winters and hot, dry summers), is similar to the climate in parts of southern Europe and also southern Croatia.

The species is resistant to aerosol salt. Also, resistance to moderate soil salinity has been observed (Gilman et al. 1993), explaining the successful reproduction on the Koločep Island. In the context of the resistance of the species and its invasive potential, it is also important to mention that regarding diseases and pests, *D. virginiana* is a very resilient species. Namely, only occasional attacking by caterpillars, and occasional exhibits of leaf spot disease (causing defoliation) have been recorded (Gilman et al. 1993; Berbegal et al. 2010).

The question arises about the vector of the introduction of this species to the island of Koločep. The potential of *D. virginiana* for an invasion is evident in its vegetative growth, but this potential is also hidden by the ease with which seeds can spread by animals (primarily birds) rather than by people. However, it is known that mammals, including wild boars (*Sus scrofa* L.), like to consume the fruit of this plant (Briand 2005; Mayer et al. 2009). Since the seeds are relatively large, it is highly likely that wild boars, which reach the island by swimming across the Koločep channel (approximately 1 km from the mainland) (Magaš et al. 2001), could be potential carriers of persimmon seeds to Koločep. The straight-line distance from the first introduced persimmon seedling in the Dubrovnik area, in the Trsteno Arboretum on the sea coast, where both female and male *D. virginiana* plants occur, to the habitat on the island of Koločep is about 5.5 km. Interestingly, the study by Rebein et al. (2017) showed that persimmon seeds that passed through the digestive system of some mammals were as viable as manu-

ally separated ones, or even better in germination compared to those germinating directly from intact fruit after the rotting process. The seeds were dormant in the winter period and begin the germination process in April or May after the soil temperature is above 15°C for about a month (Orwa et al. 2009).

According to Richardson (2000), the definition of a species' invasiveness is associated with its ability to reproduce in larger numbers and at considerable distances from the parent plant (with a measure of distance >100 m; <50 years for species spreading by seeds and other propagules; >6 m/3 years for species spreading by roots, rhizomes, stolons, or creeping stems), enabling them to spread over a larger area. In the case of *D. virginiana* on the island of Koločep, these parameters coincide with the definition of invasiveness.

In addition to reproductive ability, the phenotypic plasticity of a plant is mentioned, allowing plants to occupy a greater number of ecological niches, and the fact that they thrive in abandoned anthropogenic habitats (Vuković 2015). Due to the extremely invasive potential and fragile biological balance on an island ecosystem, this problem is even more pronounced on the small island of Koločep.

Different management methods were tried in America in order to control this species. Peters and Stritzke (1970) compared various rates of herbicides affecting foliage, stems, and roots, with varying effectiveness (Peters, 1970; Nesom 2000), raising ecological concerns. It has been observed that the plant can sprout from root suckers after a fire. According to Halls (1990), inoculation of persimmon stumps with a fungus (*Nalanthamala diospyri* (Crand.) Schroers & M.J. Wingf. 2005) was found to be an effective means of preventing subsequent sprouting. Especially in the European-Mediterranean zone, to which the studied area of Koločep Island belongs, the probability of frequent fires is high, which makes the monitoring and control of the species *D. virginiana* extremely important.

Undoubtedly, the best protection against negative consequences of potential invasiveness is the preservation of natural ecosystems and processes as a basis for the conservation of biological and landscape diversity (Vuković 2015). In the case of *D. virginiana* on the island of Koločep, which has a pronounced invasive potential, eradication should take place before fruits and seeds are formed that allow generative reproduction of this species, which is not yet the case. At this stage, eradication would prevent the further development of this potentially invasive species. As it is still a relatively localized site, combined mechanical and physical eradication methods should be used. It is necessary to carefully remove all fragments from which the plant can regrow and to carry out continuous monitoring over several years.

Regarding the implementation of the eradication process, at the municipal level, there are no strategies and secured funds for managing habitats where invasive plant species occur, including potentially invasive ones. The Law on the Prevention of the Introduction and Spread of Foreign and Invasive Alien Species and their Management (OG 15/18, 14/19) and the Regulation on Foreign Species That Can Be Placed on the Market and Invasive Alien Species (OG 17/17) regulate the introduction of legislatively prescribed invasive species resulting from human activity (Mingor 2023). The Law on Nature Protection (OG 80/13, 15/18, 14/19, 127/19) regulates the nature protection system and its parts, i.e., the conservation of natural habitats and wildlife. It would be necessary at the municipal and city level to regulate the management of habitats where spontaneous invasion processes of certain plant species have been noticed, and for which potential harmful effects on the environment are anticipated.

CONCLUSION
ZAKLJUČAK

In this study, the species *Diospyros virginiana* L. was recorded, and its distribution and spreading methods were identified. This study highlights the highly invasive nature of the species in abandoned agricultural areas of Koločep Island, where it shows a pronounced ability to spread vegetatively, and emphasizes the need for further monitoring of *D. virginiana*.

The species is currently spreading exclusively vegetatively. Although clonal selection has not yet taken place, i.e. it has not yet become apparent that both female and male individuals are present, this study should indicate that the observed rapid vegetative spread poses a major threat to the abandoned agricultural land on Koločep Island. The eradication process should be carried out before the possible differentiation into male and female individuals occurs, and thus before pollination and fruit formation, i.e., generative reproduction. Further research requires clonal selection and several years of detailed phenological observation of this species. This work aims to draw attention to the broader scientific and professional audience about the need to monitor this species in anthropogenic and abandoned agricultural habitats.

ACKNOWLEDGMENTS
ZAHVALA:

We thank Prof. Toni Nikolić, PhD, for valuable suggestions and advice, and Dr. Ivan Šimić, the director of the Trsteno Arboretum, for providing insight into the location where *D. virginiana* is located in the arboretum, as well as to two anonymous referees for their valuable comments.

REFERENCES
LITERATURA

- Bellini, E., 2002: Cultural practices for persimmon production, U. E. Bellini, E. Hiordani (ur.), First Mediterranean symposium on persimmon, CIHEAM, 39-52., Zaragoza, Spain.
- Berbegal, M., Pérez-Sierra, A., Armengol, J. Park C. S., García-Jiménez. J., 2010: First Report of Circular Leaf Spot of Persimmon Caused by *Mycosphaerella nawae* in Spain, *Plant Disease*. 94 (3): 374., Minnesota, USA.
- Bogdanović, S., M. Britvec, I. Ljubičić, D. Dujmović Purgar, I. Vitasović Kosić, 2016: Herbarium ZAGR of the Faculty of Agriculture, Agriculturae Conspectus Scientificus, 81 (1): 1-5. Zagreb, Croatia.
- Briand, C. H., 2005: The common persimmon (*Diospyros virginiana* L.): The history of an underutilized fruit tree (16th – 19th centuries), Huntia 12 (1): 72., Pittsburgh, SAD.
- Burge, D. O., 2018: Common persimmon (*Diospyros virginiana* L.), a naturalized potentially invasive species in the State of California, Mandroño 65(2): 96-100, San Luis Obispo County, USA.
- Duangjai, S., Samuel, R., Munzinger, J., Forest, F., Wallnöfer, B., Barfuss, M. H. J, Fisher, G., M. W. Chase, 2009: A multi-locus plastid phylogenetic analysis of the pantropical genus *Diospyros* (Ebenaceae), with an emphasis on the radiation and biogeographic origins of the New Caledonian endemic species. *Molecular Phylogenetics and Evolution*, 52(3): 602-620.
- Đurasović, P., 1997: Unošenje egzotičnog drveća i grmlja na dubrovačko područje, Šumarski list, 121(5–6): 227–289., Zagreb, Croatia.
- Gajić- Čapka, M., K. Cindrić, D. Mihajlović, 2008: Oborina, U: K. Zaninović (ur.) Klimatski atlas Hrvatske 1961-1990., 1971-2000. Državni hidrometeorološki zavod, 43-59. Zagreb, Croatia.
- George, A. P., A. D. Mowat, R. J. Collins, M. Morely-Bunker, 1997: The pattern and control of reproductive development in non-astrigent persimmon (*Diospyros kaki* L.): a review, Scientia Horticulturae 70(1): 95., Netherlands.
- Gilman, E. F., D. G. Watson, 1993: *Diospyros virginiana*, Common persimmon, Environmental Horticulture Department, Florida Cooperative Extension Service, 1-3, University of Florida, SAD.
- Glamuzina, M., N. Glamuzina 1999: Suvremena geografska problematika otoka Lopuda i Koločepa, Geoadria, 4(1): 91., Zadar, Croatia.
- Hague, S. M., 1911: A morphological study of *Diospyros virginiana*, Botanical Gazette, 52(1): 34-44, Chicago, USA.
- Halls, L. K., 1990: *Diospyros virginiana* L. common persimmon, Silvics of North America, 2: 294-298, Washington, USA.
- Hećimović, M., S. Hećimović, 1987: Flora otoka Koločepa, Acta Botanica Croatica 36(1): 189-205, Zagreb, Croatia.
- IAS list: https://era.org.mt/topic/list-of-invasive-alien-species-of-union-concern/ (Accessed: 18. 10. 2023.)
- Idžojtić, M., 2013: Dendrologija, cvijet, češer, plod, sjeme, Sveučilište u Zagrebu, Šumarski fakultet, Hrvatske šume, 211, Zagreb, Croatia.
- Idžojtić, M., I. Anić, I. Šimić, M. A. Kovačević, I. Poljak, 2019: Dendrološke značajke Arboretuma Trsteno, Šumarski list, 143(3-4):125-142., Zagreb, Croatia.
- Intrigliolo, D. S., F. Visconti, L. Bonet, M. Parra, C. Besada, I. Abrisqueta, J. S. Rubio, J. M. de Paz, 2018: Persimmon (*Diospyros kaki*) Trees Responses to Restrictions in Water Amount and Quality, Water Scarcity and Sustainable Agriculture in Semiarid Environment, Academic Press,149 - 172, Cambridge, Massachusetts, SAD.
- Jasprica, N., 2010: Koločep, U: T. Nikolić, J. Topić, N. Vuković (ur.) Botanički važna područja Hrvatske. Prirodoslovno-matematički fakultet Sveučilišta u Zagrebu i Školska knjiga, 178-181, Zagreb, Croatia.
- Jasprica, N., S. Kovačić, 2002: Koliko je biljnih vrsta na dubrovačkim otocima, Dubrovnik, 1-2: 409 – 415, Dubrovnik, Croatia.
- Jelić, R., 2003: Klimatski podaci za Gruški zaljev, Dubrovnik (Razdoblje 1993.-2002-), Naše more, 50(5-6): 221-230, Dubrovnik, Croatia.
- Jurković, M., B. Jurković – Bevilacqua, 1996: Golemi mamutovac – *Sequoiadendron giganteum* (Lindl.) Buchh. u zagrebačkim parkovima, Šumarski list, 122(1-2): 49, Zagreb, Croatia.
- Kluge, R. A., M. A. Tessmer, 2018: Caqui - *Diospyros kaki*, In: S. Rodrigues, E.O. de Silva, E.S. de Brito, (eds.), Exotic Fruits, Academic Press: 113-119, São Paulo, Brazil.
- Kovačić, S., N. Jasprica, 2002: Endemične, rijetke i ugrožene biljke na dubrovačkim otocima, Dubrovnik, 1-2: 416-422, Dubrovnik, Croatia.
- Lee S., G.G. Michael, W. Frank, 1996: Ebenaceae, in Z.Y. Wu, P.H. Raven, D.Y. Hong (Eds.), Flora of China, Science Press, Botanical Garden Press, Beijing, Missouri, St. Louis, pp. 215-234.
- Magaš, D., J. Faričić, M. Surić, 2001: Elafitko otočje, Fizičko-geografska obilježja u funkciji društveno-gospodarskog razvitka, Geoadria 6(1): 41-42, Zadar, Croatia.
- Makjanić, B., B. Volarić, 1989: Neke osobine klime Lokruma i šire okolice In: Meštrov M. (ed.), Otok Lokrum. Ekološke monografije, knj. I, Hrvatsko ekološko društvo: 27-46, Zagreb, Croatia.
- Mallavadhani, U. V., Panda, A. K., Rao, Y. R., 1998: Review article number 134 pharmacology and chemotaxonomy of *Diospyros*. Phytochemistry, 49(4): 901-951.
- Marić, M., 2024: Island of Lemons in Bloom, The Gardens of Archduke Maximilian of Habsburg on the Island of Lokrum, Dubrovnik Branch of Matica Hrvatska; University of Dubrovnik: 314-326, Dubrovnik, Croatia.
- Marić, M., I. Paladin Soče, D. Žeravica, I., Vitasović-Kosić, 2023: New alien species in the flora of Croatia - *Diospyros virginiana*. In: S.D. Jelaska (ed.), 5th Croatian Symposium On Invasive Species With International Participation, Book of abstract, Croatian Ecological Society: 86. Zagreb, Croatia.
- Mayer, J. J., I. L. Brisbin, 2009: Wild pigs, Biology, damage, control techniques, and management, Savannah River National Laboratory, 118, Aiken, SAD.
- Ministry of Economy and Sustainable Development, MINGOR, 2022: Priručnik o prepoznavanju i postupanju s invazivnim stranim vrstama, Zagreb: https://mingor.gov.hr/UserDocsImages//UPRAVA%20ZA%20ZA%C5%A0TITU%20PRIRODE/IAS//Priru%C4%8Dnik%20o%20prepoznavanju%20i%20postupanju%20s%20IAS.pdf (Accessed: 18. 10. 2023)
- Ministry of Economy and Sustainable Development, Institute for Nature and Environmental Protection: https://www.bioportal.hr/gis/ (Accessed: 18. 10. 2023.)

- Ministry of Economy and Sustainable Development: https://invazivnevrste.haop.hr/katalog (Accessed: 18.10. 2023.)
- Morris, R.C., 1965: Common persimmon (*Diospyros virginiana* L.). In: Silvics of forest trees of the United States, Fowells, H.A. comp. U.S. Department of Agriculture, Agriculture Handbook 271: 168-170., Washington, DC.
- Nesom, G., 2000: Common Persimmon, *Diospyros virginiana* L., USDA, NRCS, National Plant Data Center, Louisiana: https://plants.usda.gov/DocumentLibrary/plantguide/pdf/pg_divi5.pdf (Accessed: 26. 10. 2023.)
- Nikolić T., ed. 2024: Flora Croatica Database: http://hirc.botanic.hr/fcd (Accessed: 20. 02. 2024.)
- Nikolić, T., B. Mitić, I. Boršić, 2014: Flora hrvatske - invazivne biljke, Alfa d.o.o., Zagreb, Croatia.
- Obad Šćitaroci, M., M. Kovačević, 2014: Arboretum Trsteno – perivoj renesansnog ljetnikovca, Art Bulletin 64(1): 101-131, Zagreb, Croatia.
- Orwa, C., A. Mutua, R. Kindt, R. Jamnadass, S. Anthony, 2009: Agroforestry Database: http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp (Accessed: 26. 10. 2023.)
- Peters, E. J., Stritzke, J., F., 1970: Control of Persimmon with Various Herbicides and Methods of Application. Weed Science, 18(5): 572-575, Georgia, USA.
- Peyrat, L. A., Eparvier, V., Eydoux, C., Guillemot, J. C., Stien, D., Litaudon, M., 2016: Chemical diversity and antiviral potential in the pantropical *Diospyros* genus. Fitoterapia, 112: 9-15.
- Poljak, I., M. Idžojtić, A. Vidaković (ur.) 2020: Virtualni herbarij DEND. Šumarski fakultet http://dendherbarij.sumfak.unizg.hr/herbariumdend.html (Accessed: 20. 10. 2023.) (Accessed: 20. 10. 2023.)
- POWO (2023): Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew: http://www.plantsoftheworldonline.org/. (Accessed: 3. 11. 2023)
- Public Institution for the Management of Protected Natural Areas of Dubrovnik-Neretva County: https://www.zastita-prirode-dnz.hr/zasticeni-dijelovi-prirode/zasticena-podrucja (Accessed: 19. 10. 2023.)
- Rauf, A., Uddin, G., Patel, S., Khan, A., Halim, S. A., Bawazeer, S., Ahmad, K.,. Muhammad, N., Mubarak, M. S., 2017: *Diospyros*, an under-utilized, multi-purpose plant genus: A review. Biomedicine & Pharmacotherapy, 91:714-730.
- Rebein, M., C. Davis, H. Abad, E. Stone, J. del Sol, N. Skinner, M. Moran, 2017: Seed dispersal of *Diospyros virginiana* in the past and the present: Evidence for a generalist evolutionary strategy, Ecology and Evolution, 1: 1-7, New Jersey, SAD.
- Richardson, D. M., P. Pysek, M. Rejmánek, M. G. Barbour, F. D. Panetta, C. J. West, 2000: Naturalization and invasion of alien plants: concepts and definitions, Diversity and Distribution 6(1): 97, New Jersey, SAD.
- Sirisha, S. N. V. L., A. Male, A. Kiran, I. Raj, N. Teja, G. Surendra, 2018: A scientific review on three species of Diospyros. Pharmacognosy Reviews, 12(24): 214-217, Bangalore, India.
- Tang, D., Zhang, Q., Xu, L., Guo, D., Luo, Z., 2019: Number of species and geographical distribution of Diospyros L.(Ebenaceae) in China. Horticultural plant journal, 5(2): 59-69.
- The Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora, *Official Jorunal L 206, 22/07/1992 P. 0007-0050*
- Thiers, B., 2015: Index Herbariorum: a global directory of public herbaria and associated staff. New York Botanical Garden's Virtual Herbarium: http:// sweetgum.nybg.org/ih/ (Accessed 3. 11. 2023)
- USDA United States Department of Agriculture, Natural Resources Conservation Service: http://plant-materials.nrcs.usda.gov (Accessed: 20. 10. 2023.)
- Vidaković, A., M. Idžojtić, T. Megyery, D. Turk, I. Poljak, 2020: Park Kralja Petra Krešimira IV. u Zagrebu – Drvenaste biljke, Šumarski list 9–10: 477, Zagreb, Croatia.
- Vlahović, S., 2019: Primijenjena dendrologija, Drveće i grmlje, Školska knjiga d.d., 321, Zagreb, Croatia.
- Vlašić, M., 1962: Mogućnost plantažnog uzgoja japanske jabuke (*D. kaki* L.) u jadranskom rejonu, s osvrtom na preradu i ekonomsku važnost ove kulture, Agronomski glasnik 12(11-12):1051, Zagreb, Croatia
- Vuković, N., 2015: Ekogeografija invazivne flore Hrvatske, Doktorska Disertacija, Prirodoslovno-matematički fakultet, Sveučilišta u Zagrebu, Zagreb, Croatia.
- Wallnöffer, B., 2001: The biology and systematics of Ebenaceae: a review. Annalen des Naturhistorischen Museums in Wien. Serie B für Botanik und Zoologie, 485-512.
- Wunderlin R. P., B. F. Hansen, A. R. Franck, F. B. Essig, 2023: Atlas of Florida Plants: https://florida.plantatlas.usf.edu/SpecimenDetails.aspx?PlantID=3858 (Accessed: 20. 10. 2023.)
- Yi, Z., Qiao, J. J., Lu, G. Y., Wu, G., Xie, G. Y., Qin, M. J., 2016: Identification of six species of medicinal *Diospyros* plants based on leaf macro-and micro-morphology. China Journal of Chinese Materia Medica, 41(21): 3942-3949.
- Yonemori, K., C. Honsho, A. Kitajima, M. Aradhya, E.Giordani, Bellini E, et al. 2008: Relationship of European persimmon (* Thunb.) cultivars to Asian cultivars, characterized using AFLPs, Genetic Resourcis and Crop Evolution 55(1): 81–89, Springer-Verlag GmbH, Heidelberg, Germany.
- Zakon o zaštiti prirode, 2019: Narodne novine: https://www.zakon.hr/z/403/Zakon-o-za%C5%A1titi-prirode (Accessed: 23. 10. 2023.)
- Zhabrovets, Y., O. Grygorieva, A. Kustovska, Z. Schubertova, 2019: Phenological Growth Stages of the *Diospyros virginiana* L., U: J. Brindzan (ur.), 4th International Scientific Conference Agrobiodiversity for Improve the Nutrition, Health and Quality of Human and Bees Life, Slovak University of Agriculture in Nitra, 154, Nitra, Slovakia.

SAŽETAK

Tijekom terenskih istraživanja provedenih od 2022. do 2023. godine na otoku Koločepu (Dubrovnik) primijećeno je spontano pojavljivanje alohtone vrste *Diospyros virginiana* L. (virginijski dragun) izvan područja uzgoja. Ova biljka u Hrvatskoj se koristi kao ukrasna biljka, dio je dendroflore parkova i sadi

se otprilike od 1850-ih do 1950-ih godina u kontinentalnom i primorskom dijelu Hrvatske. Na otoku Koločepu navedena se vrsta počela spontano pojavljivati prije otprilike četiri godine na istočnoj strani ceste između glavnih naselja otoka, Gornjeg Čela i Donjeg Čela. Udomaćila se unutar poljoprivrednog staništa napuštenog maslinika površine oko 2900 m^2. Parcela se više ne obrađuje i prekrivena je ruderalnom i korovnom vegetacijom, s biljnom zajednicom identificiranom kao *Dauco majori-Foeniculetum vulgaris*. Na tom području *D. virginiana* postiže prosječnu visinu od 1 do 2 metra, obavijajući i gušeći preostala stabla maslina (*Olea europaea* L.). Biljka se širi vegetativno i posjeduje snažan korijenski sustav koji se lateralno proteže nekoliko metara, potpuno prekrivajući područje. Osim toga, biljka se proširila u suhozidnu strukturu uz pješačke staze. U ovom istraživanju determinirana je vrsta *Diospyros virginiana* L. te su identificirani njena distribucija i načini širenja. Na otoku Koločepu vrsta je pokazala izrazit invazivni potencijal te se ponaša poput pionirske vrste koja naseljava napuštene poljoprivredne parcele (maslinike). Vrsta se trenutno širi isključivo vegetativno. Proces iskorjenjivanja trebalo bi provesti prije nego što dođe do diferencijacije na muške i ženske jedinke, a time i prije oprašivanja i formiranja plodova, odnosno generativnog razmnožavanja. U daljnjim istraživanjima potrebno je provesti detaljno višegodišnje fenološko praćenje ove vrste. Ovim radom želi se skrenuti pozornost široj znanstvenoj i stručnoj zajednici na potrebu praćenja ove vrste u antropogenim i napuštenim poljoprivrednim staništima.

Na prijedlog autora *D. virginiana* unesena je u bazu podataka Flora Croatica s oznakom 2.1.1.3, kao potencijalno invazivna vrsta, što će pružiti osnovu za buduće praćenje. S obzirom na njezin potencijalno invazivan utjecaj i štetu koju može prouzročiti okolišu, autori predlažu iskorjenjivanje vrste s područja prije nego se proširi na okolna područja.

KLJUČNE RIJEČI: alohtona vrsta, okolišna šteta, neofit, otok Koločep, potencijalno invazivan utjecaj, spontano pojavljivanje, virginijski dragun