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ORIGINAL ARTICLE

The Genus *Fragaria* in Croatia

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Abstract Only three native species of genus *Fragaria* (*F. moschata, F. vesca* and *F. viridis*) are recorded in three regions of Croatia. These species as well as many of their hybrids, are, or once were, cultivated for their edible fruits. The majority of cultivated strawberries in Europe belong to garden strawberries *F.* x *ananassa* (hybrids of *F. chiloensis* and *F. virginiana*). The most expanded wild strawberry species in Croatia is a woodland strawberry (*F. vesca*) whose berries are gathered seasonally as wild edible fruits. They often contain higher amount of nutrients and bioactive compounds in comparison to cultivated varieties. The research on the genus *Fragaria* species distribution in Croatia has not been carried out, and so is the case with many others wild growing fruit species in Croatia. By summing up a number of individual citations and observations, it is possible to get a perspective regarding the current state of their distribution.

Keywords Strawberry · *Fragaria moschata* · *Fragaria vesca* · *Fragaria viridis* · Native species · Wild edible fruits

Die Gattung *Fragaria* in Kroatien

Schlüsselwörter Erdbeere · *Fragaria moschata* · *Fragaria vesca* · *Fragaria viridis* · Einheimische Arten · Essbare Wildfrüchte

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Introduction

Croatia is one of the richest European countries in terms of biological diversity. Croatian flora, with 5593 species and subspecies is characterized by a markedly high level of diversity per unit of surface (Nikolić 2006). The forests and their marginal areas are rich in numerous varieties of self-grown fruits, representing a valuable asset. Important components of biodiversity are the wild edible fruit species, such as strawberries. Strawberry, genus *Fragaria* L., belongs to the family Rosaceae (Nikolić 2015), subfamily Rosoideae (Mägdefrau and Ehrendorfer 1997).

The genus *Fragaria* comprises a relatively small number of species. The present *Fragaria* taxonomy includes 20 named wild species in the world (Hummer et al. 2011), but only five taxa exist in Europe – *Fragaria vesca* L., *Fragaria viridis* Duch., *Fragaria virginiana* Mill., *Fragaria moschata* Duch. and *Fragaria* x *ananassa* Duch. (Tutin 1968). In Croatia three of them are native – *F. moschata, F. vesca* and *F. viridis* (Nikolić 2015). All species mentioned here, as well as many of their hybrids, are, or once were, cultivated for their edible fruits. The most common strawberry cultivars in Europe, and also in Croatia, belong to *F.* x *ananassa*. On the other hand, the most widespread wild species in Croatia is *F. vesca* (woodland strawberry) whose berries are gathered seasonally as wild fruits. These fruits can still be found on local fruit and vegetable markets. Wild strawberry in general have a higher amount of nutrients and bioactive compounds in comparison to cultivated varieties (Yildiz et al. 2014). Humans have likely consumed the fruits of wild *Fragaria* species for millennia (Liston et al. 2014).

The systematic research on the genus *Fragaria* species distribution in Croatia has not been carried out, and so is the case with many others wild growing fruit species in

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Table 1 Distribution range of genus *Fragaria* species in Croatia. (1 – Croatian lowland, 2 – mountainous region of Croatia, 3 – Mediterranean Croatia)

	Regions	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	3	3	3	3	3
No	Species	Strahinčica	Žumberak	Plešivica	Zaprešić	Stupnik	Medvednica	Turopolje	Podravina	Zrinska gora	Konjščina	Krapina	Ravna gora	Panonija	Požega	Papuk	Baranja	Otmanov vis	Gorski kotar	Velebit	Krbavsko polje	Istra	Dalmatinska zagora	Vinodol	Murter	NP Krka
1	*Fragaria moschata* Duchesne	+	+							+	+	+				+				+			+			
2	*Fragaria vesca* L.	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+		+	+	+	+	+	+
3	*Fragaria viridis* Duchesne	+				+				+						+							+			

Croatia. Also, there have been no breeding programmes or introduction of our native *Fragaria* species to production which is the reason why further research on their distribution is required.

The aim of this research was to show the distribution of species of the genus *Fragaria* in Croatia (Table 1; Fig. 2) on the basis of the Croatian literature and from our own research, and to describe the species present in Croatia. The main purpose of this work was to emphasize the potential of those exceptional fruit species.

Material and Methods

In the area of Croatia, genus *Fragaria* was analysed on the basis of existing Croatian literature data (Trinajstić 1972; Regula-Bevilacqua 1979; Ilijanić and Šegulja 1983; Hulina 1984, 1989; Panjković 1990; Stančić 1994; Pandža 1998; Šegulja et al. 1998; Šoštarić and Marković 1998; Regula-Bevilacqua and Šegulja 2000; Vrbek 2000; Vrbek and Fiedler 2000; Plazibat 2002; Vitasović Kosić and Britvec 2005; Cerovečki 2006; Vukelić et al. 2006; Dasović 2007; Mitić et al. 2007; Vukelić and Baričević 2007; Stančić 2009; Trinajstić and Cerovečki 2009; Zima and Štefanić 2009; Buzjak et al. 2010; Pandža 2010; Sedlar et al. 2010; Puača et al. 2011; Nikolić 2015) and data from our own research (Dujmović Purgar 2006; Dujmović Purgar and Hulina 2007).

The nomenclature of plants was outlined according to Tutin (1968). Each species in the flora list includes data of the distribution within the Croatian regions (Table 1). Croatia is divided into three regions according to the State Administration for the Protection of Nature and Environment (Radović 1999, Fig. 1).

Results and Discussion

The distribution of species of the genus *Fragaria* in Croatia (Table 1; Fig. 2), has been shown in this paper on the basis of the literature data and our own research.

Descriptions of all species of the genus *Fragaria* are found in several literature sources (Gelenčir and Gelenčir 1991; Mägdefrau and Ehrendorfer 1997; Miloš 1997; Grdinić and Kremer 2009; Hulina 2011; Franjić and Škvorc 2014).

Some authors have studied botanical description, other authors have studied the quality of the fruit species and some authors have studied medicinal traits and cultivation of strawberries (Gelenčir i Gelenčir 1991; Marušić 1988; Dubravec and Dubravec 1998; Mindel 1998; Miljković 1991; Hummer et al. 2011; Diamanti et al. 2012; Yildiz et al. 2014).

Fragrans in Latin means fragrant and refers to the fruit. An important morphological feature of the genus *Fragaria* are the three-part leaves (leaflets) and nut fruits (Hulina 2011). Nuts on strawberries are linked to multiple fruits with juicy conical protruded floral axis (Mägdefrau and Ehrendorfer 1997).

Woodland strawberry (*Fragaria vesca* L.) as an effective medicinal plant was appreciated even in Ancient times (Theophrastus, Ovid, Virgil), as well as in the Middle Ages when it was regarded as a magical plant for the same reason (Hulina 2011).

Woodland strawberry, a diploid species, is a perennial herb, hemicryptophytes, which are from 8 to 15 cm high. Its stems are long stolons that carry rosettes. Rosette has a root and can develop into good, young seedlings that can be used for vegetative propagation (Miloš 1997; Hulina 2011). The length of stolons varies between 5 and 30 cm. The stem is

Fig. 1 A map of Croatia with main regions highlighted with respect to climate and relief (1 – Croatian lowland, 2 – mountainous region of Croatia, 3 – Mediterranean Croatia)

hairy with protruding hairs in its lower part, and prostrate hairs in the upper part (Franjić and Škvorc 2014).

Leaves are arranged in a basal rosette and have three leaflets and a long pedicel. Leaves are bright green and sparsely hairy on upper surface (Tutin 1968). The leaflets are 1–6 cm long, ovate or obovate to rhombic and coarsely serrate (Grdinić and Kremer 2009; Franjić and Škvorc 2014).

Hermaphrodite, white flowers are 15 mm in diameter. Long flower pedicels are appressed and pubescent. Except ordinary calyx with five sepals, this species has one more external calyx. Five white petals are 4–10 mm long, obovate and hairless. The flower contains a lot of stamens, and 5–10 pistils with hairless ovary (Gelenčir and Gelenčir 1991; Grdinić and Kremer 2009; Hulina 2011; Franjić and Škvorc 2014). The flowering period for woodland strawberry is between May and July (Gelenčir and Gelenčir 1991).

Strawberry fruits are slightly conic to globose, fleshy and juicy, with a strong distinct aroma receptacle with numerous achenes. Sepals are reclining back on a fruit. The fruit is aromatic to very aromatic, of bright or darker red colour (Grdinić and Kremer 2009; Franjić and Škvorc 2014). The seed is small and scattered over (superficial deployed) glabrous receptacle (Miloš 1997). The fruiting period for woodland strawberry is June through July (Labokas and Bagdonaitë 2005).

Woodland strawberry has the largest native ecological range among *Fragaria* species. It has a wide ecological range, most often found on half sunny and sunny habitats such as open forests and fire sites. It grows mostly on fresh, nutritious, slightly open, acid, humic, rocky or sandy soils, from the lowland to the pre-mountain vegetation zone. In Croatia, woodland strawberry is the most common on the edges of mountains with oak and beech forests, the mesophilic hedges and underbrush of continental areas and rarely on coastal areas (Franjić and Škvorc 2014). By the 1300s, the French began transplanting *F. vesca*, from the wilderness into the garden (Hummer et al. 2011).

Woodland strawberries are widespread in all parts of Croatia, but mostly in the lowlands (Fig. 3).

Species *Fragaria vesca* is edible and medicinal plant, as well as a honey plant (Franjić and Škvorc 2014). The fruits of woodland strawberries can be eaten fresh or as processed products (jams, juice). The fruits are rich in carbohydrates and especially in vitamin C (60 mg per 100 g of fruit). The fruits of wild strawberries contain tannins, flavones and traces of essential oils. This species content includes a lot of types of fruit acids, mineral substances (potassium, magnesium, iron, zinc, manganese, copper, cobalt, phosphorus) and some vitamins (Pahlow 1989). Like fruits of other species, strawberries contain proteins, which can cause allergic reaction in humans (Schwab et al. 2009 in Hummer et al. 2011).

Woodland strawberries have delicious fruits that are a remedy for various diseases (gout, arthritis, atherosclerosis, high blood pressure, they improve blood count, and the function of the heart, kidney, gall bladder, liver, etc.) (Hulina 2011). It is known that K. Linnaeus used these fruits to cure severe attacks of gout. That was the reason why woodland strawberry was his favourite fruit (Hulina 2011).

Strawberry leaves, alone or in combination with other herbs may be used for serving tea for blood cleansing and stimulation of the whole body (Hulina 2011). The leaves of strawberry (*Fragaria folium*) collected in the flowering time are used for diarrhea, as a substitute for the Russian tea, to improve the excretion of urine in a variety of gastro-intestinal inflammations and for treatment of haemorrhoids. Strawberry leaves are also rich in vitamin C (100–482 mg%). Leaves are collected together with the stems. Folium is spread out in a thin layer and dried in a shady, dry and ventilated place (Gelenčir and Gelenčir 1991).

As wild strawberry fruits are very fragrant and delicious, they almost cannot be compared with the garden strawberry. Fresh fruits are the best for consumption, but it can also be excellent in a variety of juices, compotes, wines, desserts, cakes and other sweets. They are used for making jams, marmalades, jellies, and can also be frozen (Biličić 2014). Fresh strawberry juice is an excellent cosmetic agent which is applied to the skin in order to clean and refresh (Hulina 2011).

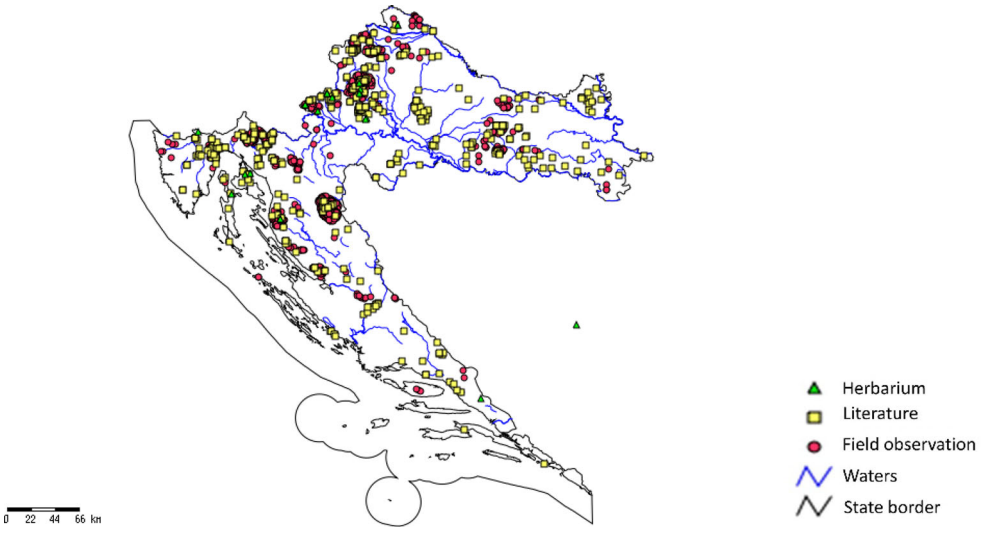

Fig. 2 A map of Croatia with distribution of the genus *Fragaria* (*Flora Croatica Database,* Nikolić 2015)

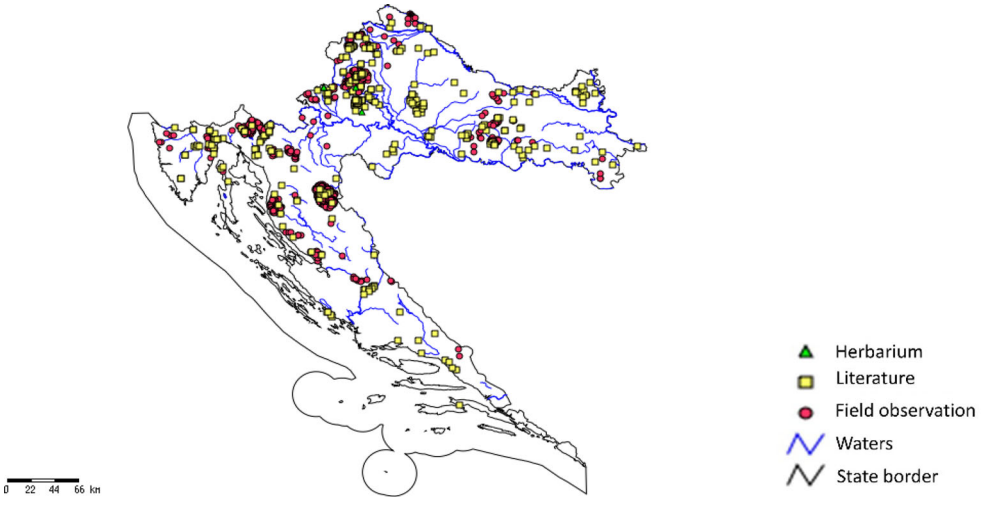

Fig. 3 A map of Croatia with distribution of the species *Fragaria vesca* (*Flora Croatica Database,* Nikolić 2015)

It is concluded in several research that wild strawberries had higher antioxidant activity than cultivated *F. x ananassa*, and that *F. vesca* is a good source of polyphenols, ellagic acid and antioxidants (Yildiz et al. 2014). On the other hand, *F. vesca* is very interesting species for hybridization of strawberries for its excellent fruit quality, plant adaptabiltity and resistance to some pests. A cross between *Fragaria* × *ananassa* and *F. vesca* result with the economically important hybrid *Fragaria* × *vescana* which develops very aromatic fruits and highly resistance to grey mould (Bauer and Bauer 1979).

Another diploid species of wild or green strawberry (*Fragaria viridis* Duchesne) is a less widespread species in Croatia in comparison with woodland strawberries.

Green strawberry bush is poorly developed. Stolons are usually absent, but if present, stolons are small and do not have nodes (Miloš 1997). Leaves with very short pedicels have leaflets which are on both sides silky and hairy (Domac 1994). The creamy white flowers of *F. viridis* are much bigger than those of *F. vesca*, but with *F. viridis* the inflorescence is hidden beneath the rosette leaves (Labokas and Bagdonaitë 2005). This could be a possible reason why no fruiting plants were observed among the accessions of *F. viridis*, although they flowered abundantly (Labokas and Bagdonaitë 2005). Calyx is horizontal or twisted, but external calyx leaves are longer than ordinary calyx (Domac 1994). The flowering period for green strawberry is May and June (Labokas and Bagdonaitë 2005).

The fruit of *F. viridis* has wine red skin while the cortex and pith is yellowish–greenish and the fruit does not easily detach from the calyx (Staudt et al. 2003 in Hummer et al. 2011). The fruit have an apple-like aroma (Labokas and Bagdonaitë 2005).

F. viridis grows on dry sunny slopes and in riverine meadows (Labokas and Bagdonaitë 2005). *F. viridis*, the "green" strawberry, was also gathered and eaten (Hummer et al. 2011).

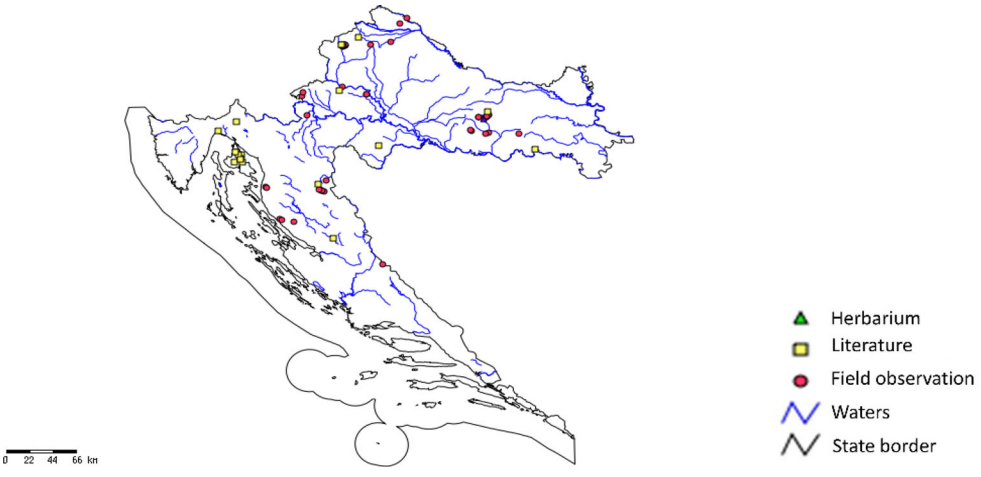

Fig. 4 A map of Croatia with distribution of the species *Fragaria viridis* (*Flora Croatica Database,* Nikolić 2015)

Green strawberries are spread mostly in the lowland part of Croatia (Fig. 4).

The only wild hexaploid species, *Fragaria moschata* Duchesne, is native in the wide area from Europe to the lake Baikal in the far east. This species is commonly known as the musk strawberry (Hancock 1999 in Hummer et al. 2011). Musk strawberry is a dense and tall shrub (up to 40 cm). It has few or no stolons (Tutin 1968) and pubescent stems and pedicels (Franjić and Škvorc 2014). *F. moschata* has big flowers of 1.5–2.5 cm in diameter (Forenbacher 2001) and flower peduncles which are high above the leaves (Miloš 1997). The fruit only has colour on the skin, while the cortex and pith are yellowish-white, with a strong, musky smell and taste (Staudt et al. 2003 in Hummer et al. 2011). The flowering period for musk strawberry is from May to July (Franjić and Škvorc 2014).

F. moschata grows in forests, under shrubs and in tall grass (Hancock 1999 in Hummer et al. 2011).

Karp (2006 in Hummer et al. 2011) described this species as the most aromatic strawberry. For this reason, this species was extensively cultivated in Europe (France and Germany) from period 1400 to 1850 due to its desirable flavour and aroma (Staudt et al. 2003 in Hummer et al. 2011). Musk strawberry has no nutritional value, but can be used to decorate dishes because of the smell of aromatic fruits (Biličić 2014).

Green strawberries are spread mostly in the lowland part and mountainous region of Croatia (Fig. 5).

Fragaria x *ananassa*, the "pineapple strawberry", was the species name given to the accidental hybrid of *F. chiloensis* subsp. *chiloensis F. chiloensis* and *F. virginiana* subsp. *virginiana* in Europe by Duschesne in the early eighteenth century (Hancock 1999 in Hummer et al. 2011).

This octoploid species is known as garden strawberry. Garden strawberry is perennial herb with numerous stolons. This species has a lot of roots 0.7–1.5 m long. More or less dense shrubs are up to 35 cm high (Dubravec and Dubravec 1998). Leaves are trifoliolate in basal rosette, mostly coriaceous, scarcely rugose, blue-green and nearly or quite glabrous on the back side (Dubravec and Dubravec 1998).

White, hermaphrodite flowers of 2.5–3 cm in diameter have 1–3 cm long flower pedicels. The flower has corolla with five white petals and calyx with 10–16 sepals. A lot of stamens (20–30) are arranged in three circles, with different size and length, but their anthers are yellow. A lot of pistils have superior ovary on clear receptacle. The flowering period for garden strawberry is May and June (Miloš 1997).

During maturity receptacle becomes fleshy, juicy and edible. Big fruits are round and heart-shaped to elongated, yellow to yellow-red or red, covered all over with achenes which are on the surface or very slightly sunk (Dubravec and Dubravec 1998).

Garden strawberry is widely cultivated and naturalized throughout of Europe (Tutin 1968). It also grows along paths in the woods and railways (Miloš 1997). The hybrid strawberry fruit of commercial *Fragaria x ananassa* is eaten by millions of people and is cultivated from the arctic to the tropics (orig. Hummer et al. 2011). More than 75 countries produce significant amounts of this fruit (FAO 2010 in Hummer et al. 2011). Since the mid-1800s, breeding in Europe and United States has resulted in hundreds of cultivars from 35 breeding programs (Faedi et al. 2002 in Hummer et al. 2011).

The garden strawberry is known for its pleasant organoleptic qualities, and its high content of vitamin C, polyphenols and elagic acid, the latter of which has cancer-fighting properties (Xue et al. 2001 in Cassiera-Posada 2011). Researches show that strawberries provide a good source of vitamin C and other antioxidant components to humans in the longer period of the year (Voća et al. 2009), their contents of antioxidants that slow aging is high, they have other properties that prevent urinary tract infection, and the ability to reduce the blood sugar (Villagrán 2001 in Cassiera-Posada 2011).

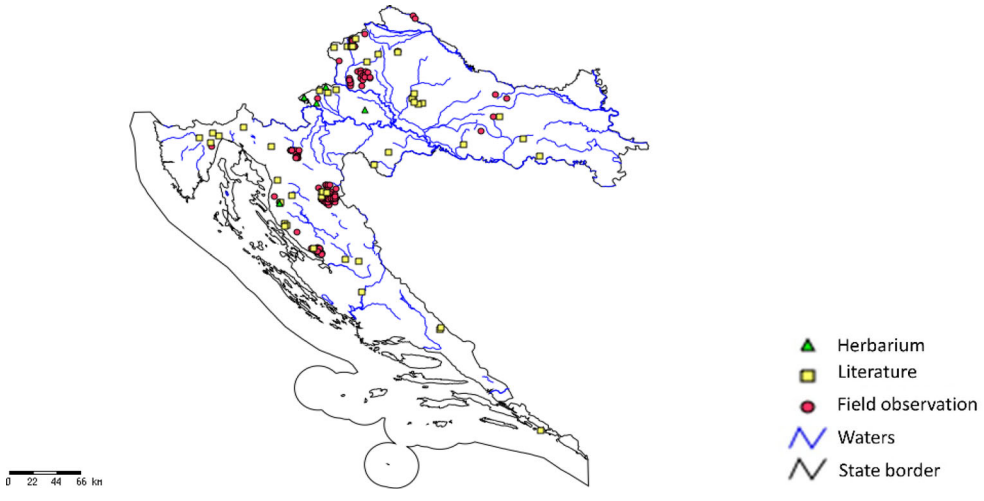

Fig. 5 A map of Croatia with distribution of the species *Fragaria moschata* (*Flora Croatica Database,* Nikolić 2015)

Biological diversity, combined with the availability of genomic resources and the ease of growing and experimenting with the plants, makes *Fragaria* a very attractive system for ecological and evolutionary genomics (Liston et al. 2014).

Conclusions

On the basis of these results it could be concluded that investigated wild growing strawberry species have a very good adaptability on different ecological conditions and great future potential. It is necessary to carry out further inventarisation and evaluation of investigated wild growing fruit species from genus *Fragaria* in Croatia to utilize them in the most appropriate way. The most valuable collected specimens should be preserved in gene banks and, if an interest exists, involved in plant breeding programs.

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