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Micromorphology and fatty acid composition of the cypselae of *Xeranthemum cylindraceum* Sm. (Asteraceae, Cardueae)

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ABSTRACT: The paper presents micromorphology of the cypselae of *Xeranthemum cylindraceum* as revealed by scanning electron microscopy (SEM) and their fatty acid composition as determined on a gas chromatograph coupled with a flame ionisation detector (GC-FID). The cypselae are densely hairy, straight, ribbed, narrowly obconical to obovoid. Micromorphological features are as follows: striate-rugose surface; adaxial detachment area; asymmetrical carpopodium; presence of biseriate, nonglandular, shortly forked twin hairs; and absence of a pericarp crown. The pappus is paleaceous, homomorphic, uniseriate, persistent, and with several wide, scarious, subulate, and apically pinnulate bristles of variable length. Out of 12 fatty acids detected, nine (88.57%) are identified, ranging from palmitoleic (C16:1) to behenic (C22:0) acids. Oleic acid is dominant (55.24%). Unsaturated fatty acids are predominant in the oil (75.02%). The composition of fatty acids in cypselae of the given species is here reported for the first time. The taxonomic value of the analysed characters is briefly discussed.

Keywords: *Xeranthemum*, Cardueae, micromorphology, fatty acids

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INTRODUCTION

The genus *Xeranthemum* L. (Asteraceae-Cardueae) is a member of the *Xeranthemum* group, which includes the genera *Amphoricarpos* Vis., *Chardinia* Desf., and *Siebera* J. Gay (Susanna & Garcia-Jacas 2009); and the genus *Shangwua* Yu J. Wang, Raab-Straube, Susanna & Quan Liu (Wang *et al.* 2013). Genera of the group are easily recognisable due to the presence of a very characteristic pappus of the cypselae and papery silver-white paleae (Susanna & Garcia-Jacas 2009). Nevertheless, the relationships between taxa of the *Xeranthemum* group are still unresolved.

Xeranthemum includes five annual species distributed throughout North Africa, SW Asia, and Southern Europe (Garnatje & Martín 2007). In the flora of Serbia, two species are present: *Xeranthemum annum* L. and *X. cylindraceum* Sm., which grow in open and arid habitats (Gajić 1975). Morphologically, *X. annuum* differs from *X. cylindraceum* in size of the capitulum, shape and incumbent of the outer and inner involucral bracts, and number of fertile florets (Webb 1976). Regarding fruit features, the number of pappus scales (5 and 10–15, respectively) and length of the pappus scales (about equal in length to the cypsela and much shorter than the cypsela, respectively) are different in these two species (Webb 1976).

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The cypsela is a dry, indehiscent, unilocular fruit of the family Asteraceae, with a single seed which is not adnate to the pericarp. It originates from an inferior ovary and possesses a pericarp formed from the ovarian wall cells and extracarpelar cells of the receptacle (Marzinek *et al.* 2008). The fruits of Asteraceae vary in shape and pubescence. Reproductive parts are more reliable indicators of intergeneric relationships than vegetative ones due to the fact that the latter undergo morphological changes more quickly during evolution (Petit 1997). In addition, the morphological characteristics of fruit surface sculpturing are considered to be less affected by environmental conditions (Barthlott 1984). Morphological characters of the cypsela provide taxonomically useful information and have been widely used to elucidate uncertain taxonomic relationships in Asteraceae (Stebbins 1953; Barthlott 1984; Singh & Pandey 1984; Blanca & Díaz de la Guardia 1997; Zhu *et al.* 2006; Garg & Sharma 2007; Inceer *et al.* 2012), especially in Cardueae (Dittrich 1977, 1985; Petit 1997; Häffner 2000; Zarembo & Boyko 2008; Abid & Qaiser 2009; Abid & Ali 2010). The ornamentation of seeds and fruits provides useful characters for taxonomy due to their constant nature, i.e., these characters are relatively less influenced by the environmental conditions (Sears 1922). Its potential taxonomical value has been evaluated in many plant families (Akbari & Azizian 2006; Kaya & Dirmenci 2008; Pinar *et al.* 2009; Bayrakdar *et al.* 2010; Shabestari *et al.* 2013; Hussein & Eldemerdash 2016; Ozcan 2017).

Fatty acids are present in all plant tissues and occur as free acids or esters. For chemotaxonomic studies, the most important ones are fatty acids from fruits and seeds, due to their conservative nature (Janaćković *et al.* 2017). Seed fatty acids can be good taxonomic characters at the inter- and intraspecies levels and can indicate hybridisation between related taxa. Moreover, they can reflect the phylogeny of particular plant groups (Aitzetmüller 1996; Janaćković *et al.* 1996; Özcan 2008; Coutinho *et al.* 2015). At the infra-family level of Lamiaceae, seed fatty acid composition is considered to be a good taxonomic marker (Marin *et al.* 1991). Unusual fatty acids, found in many plants, can be used as a fingerprint in delimitation of taxa (Aitzetmüller 1993, 1996, 1997; Tsevegsüren *et al.* 1997). Also, the U/S index (unsaturated/saturated fatty acids) is used as a reliable taxonomic marker (Marin *et al.* 1991).

Oils of the cypselae of Asteraceae taxa are rich in linoleic acid and contain smaller amounts of oleic and palmitic acid, whereas stearic and linolenic acids are minor (Shorland 1963). Also, in cypselae of some members of the family Asteraceae, unusual C18 unsaturated fatty acids were found as dominant, i.e., > 10% of total fatty acids (Shorland 1963; Hegnauer 1964; Hilditch & Williams 1964). Oils of the cypselae of some Asteraceae genera (*Artemisia* L., *Calendula* L., *Cosmos* Cav., *Dimorphoteca* Moench, *Helianthus* L., *Osteospermum* L., *Tragopogon* L., and *Vernonia* Schreb.) contain epoxy- and hydroxy- fatty acids with conjugated double bonds (Wagner 1977). The presence of γ-linolenic acid, an unusual fatty acid, was recorded in oil of the cypselae of some *Saussurea* DC. species (Tsevegsüren *et al.* 1997). Oil of the cypselae of some Mongolian Asteraceae species contains unusual trans-fatty acids (Tsevegsüren *et al.* 2000).

Xeranthemum cylindraceum has been the subject of phytochemical (Samek *et al.* 1977; Hübel *et al.* 1982; Schwind *et al.* 1990; Nahrstedt & Schwind 1992; Dekić *et al.* 2015), molecular cytogenetics (Garnatje *et al.* 2004), morphological (Petit 1997), and micromorphological (Dittrich 1996; Gavrilović *et al.* 2017) investigations. Working on systematics of the tribe Cardueae, Petit (1997) performed a cladistic analysis of 45 genera of the tribe and considered 75 characters, including (among others) some characters of cypselae.

There is no previous report that treats the fatty acid composition of *X. cylindraceum*. The remaining genera in the *Xeranthemum* group have not been studied in detail regarding the micromorphology and fatty acid composition of their cypselae. The aim of the present work was to examine in depth micromorphological features and fatty acid composition of the cypselae of *X. cylindraceum* and consider their potential taxonomic significance.

MATERIAL AND METHODS

Plant Material. Mature cypselae of *X. cylindraceum* were collected in the Iron Gate region of Serbia (N 44.61238°; E 22.50830°) during the flowering period in 2016. Species identification and classification were done according to Gajić (1975), Jávorka & Csapody (1975), Webb (1976), and Susanna & Garcia-Jacas (2009). The voucher specimen was deposited in the herbarium of the Institute of Botany and Botanical Garden "Jevremovac", Faculty of Biology, University of Belgrade (BEOU 17281).

Micromorphological methods. Micromorphological analysis was carried out using scanning electron microscopy (SEM). Dry cypselae were sputter-coated with gold for 180 s at 30 mA (BAL-TEC SCD 005) and viewed using a JEOL JSM-6460LV electron microscope at an acceleration voltage of 20 kV. Measurements (length and width of 20 cypselae) were done using Digimizer 4.0. The results of measurements are expressed as mean values and standard errors of the mean.

Oil extraction. Oils were obtained from 100 mg of previously powdered cypselae. We added 2 mL of *n*-hexane and vortexed the sample for 10 min. Subsequently, the sample was centrifuged at 9,500 rpm for

5 min. The supernatant was collected and filtered, and the obtained oil was concentrated under a constant flow of nitrogen.

Transesterification of oils. The obtained oil was transesterified with the addition of 250 µL of KOH in methanol (0.5 M). The sample was vortexed for 2 min, added 1 mL of *n*-hexane, and shaken for 2 min. Finally, the sample was centrifuged (4500 rpm, 6 min, 25°C) and the supernatant filtered (0.44 µm) and placed in a vial for subsequent analysis.

GC-FID analysis. Fatty acid methyl esters (FAMEs) were analysed on a gas chromatograph coupled with a flame ionization detector (GC-FID) (Agilent Technology 7890A). One microlitre of sample was injected into a DBS-MS capillary column under the following conditions: initial oven temperature, 150°C (4 min); rate of heating to 280°C, 4°C/min; time of subsequent maintenance at 280°C, 5 min; and injector and detector temperature, 300°C. The split ratio was 1:50. Helium was used as the carrier gas (1 mL/min), hydrogen (30 mL/ min) and synthetic air (400 mL/ min) were used in the conducted flame ionisation, and nitrogen was used as the make-up gas (25 mL/min). Identification of FAMEs was done by comparison to standard retention times using FAME MIX (C4-24 Supelco), and the relative amount was calculated from the integrated area of each peak and expressed as a percentage. All analysis was performed in triplicate.

RESULTS

Cypsela micromorphology

Scanning electron micrographs (Fig. 1A) show that cypselae of *X. cylindraceum* are homomorphic; thus, there are no morphological differences between cypselae derived from ray and disc florets. The fruit is differentiated into cypsela and pappus (Fig. 1A). Cypselae are brownish, densely hairy, straight, more or less laterally compressed, narrowly obconical to obovoid, and with more or less conspicuous longitudinal ribs (Fig. 1A). Mean values of cypsela length and width are 5.37±0.24 mm and 1.96±0.17 mm, respectively. Cells of the cypsela surface are parallel to the longitudinal axis of the fruit (Fig. 1D). Surface structure could be considered as striate-rugose (Fig. 1D). The detachment area is adaxial according to Häffner (2000) (Fig. 1B). In the basal part of the cypsela, the abscission zone is surrounded by a special structure, the carpopodium (Fig. 1B). This carpopodium is considered to be asymmetrical and forms a horseshoe-shaped cup with thickened outermost walls. Cell wall outlines are poorly visible, which caused the smooth appearance of the carpopodium (Fig. 1B). The conducted SEM analysis revealed the presence of biseriate nonglandular twin hairs that are shortly forked on the top (Figs. 1C, 1D). Numerous elongated twin hairs are recorded all over the cypsela surface (Fig. 1C). The forked hairs have more or less equal apical ends (Fig. 1D). Rarely present short twin hairs are sometimes distributed in the lower part of the pappus bristles (Fig. 1E). Cypselae of *X. cylindraceum* lack glandular trichomes on the surface (Fig. 1C-D). The apical pericarp rim is poorly developed and the pericarp crown is totally absent (Fig. 1E). On the upper portion of cypselae, a persistent pappus is present that is homomorphic and uniseriate (Fig. 1A). The pappus is more or less paleaceous, consisting of 10-11 bristles (Fig. 1F-H) of variable length that are wide, scarious, subulate, apically pinnate, and more or less connate at the base. Colour of the pappus varies from golden to yellowish.

Fatty acid composition of cypsela oils

Fatty acid composition of the cypselae of this species is reported for the first time herein. The conducted GC-FID analysis of fatty acid composition of the cypselae of *X. cylindraceum* shows a total of 12 fatty acids detected (99.99%) (Table 1). Out of 12 fatty acids, nine (88.57%) are identified, ranging from palmitoleic (C16:1) to behenic (C22:0) acids. The analysis revealed oleic fatty acid as the major constituent (55.24%) in the oil (Fig. 2). Other fatty acids with a high percentage are linoleic (16.48%) and palmitic (8.88%) acids. A minor fatty acid is palmitoleic acid (0.30%). The fatty acid profile predominantly includes unsaturated fatty acids (75.02%), monounsaturated fatty acids comprising 55.97% of total fatty acids and polyunsaturated 19.05%. Saturated fatty acids therefore represent 13.55% (the U/S index is 5.53). The 18:3/18:2 (linolenate/linoleate) ratio is calculated as 0.156.

DISCUSSION

Carpological features, e.g., cypsela morphology and microsculpturing, have been used as constant characters to separate species within the Asteraceae (Inceer *et al.* 2012; Karanović *et al.* 2016; Ozcan 2017). Our results on morphology of the cypselae of *X. cylindraceum* are in agreement with Dittrich (1996); however, we did not notice the dimorphic fruits Dittrich mentioned for this species. The cypselae of outer florets are narrower, but they are not structurally or otherwise different from those of inner florets.

The shape of cypselae is rarely used in taxonomy because of difficulties in describing it, e.g., shape can be considered in one plane only (Turner 2007), in tridimensional view (Cron *et al.* 1993), or both (Pope 1983; Cron *et al.* 1993; Roy *et al.* 2013). The cypselae of Carduinae are relatively large (up to 12 mm long) and strong-walled, and in most groups they are laterally compressed and obovate in shape (Häffner 2000), which is also documented here. Cypselae in *Staehelina*

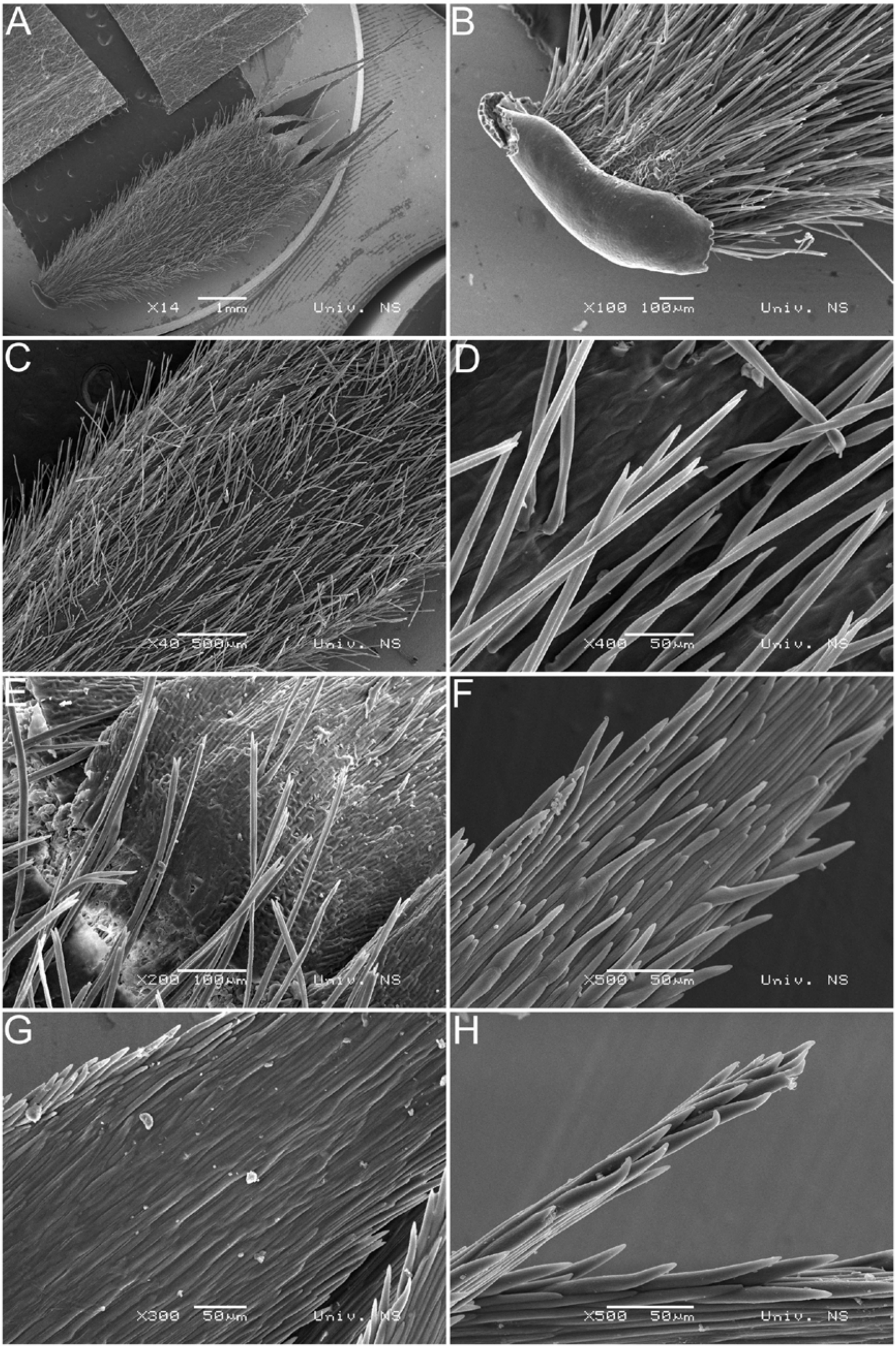

Fig. 1. Scanning electron micrographs of cypsela of the *Xeranthemum cylindraceum*: **A** - densely hairy, straight, narrowly obconical to obovoid cypsela; **B** - adaxial detachment area and asymmetrical carpopodium; **C, D** - biseriate, nonglandular, shortly-forked twin hairs; **E** - pericarp crown absent and short twin hairs in the lower part of pappus bristles; **F** - pappus bristle pinnulate - outer side; **G** - pappus bristle - inner side; **H** - top of the pappus bristle.

Table 1. Fatty acid composition of the oil of *Xeranthemum cylindraceum* cypselae. The presented data are mean values ± standard deviations.

Systematic name	Trivial name	Fatty acid content [%][b]
Ni[a]	-	1.30 ± 0.10
(9*Z*)-hexadec-9-enoic acid (C16:1)	palmitoleic acid	0.30 ± 0.01
hexadecanoic acid (C16:0)	palmitic acid	8.88 ± 0.02
Ni[a]	-	7.72 ± 0.03
Ni[a]	-	2.40 ± 0.06
(9*Z*,12*Z*)-9,12-octadecadienoic acid (C18:2)	linoleic acid	16.48 ± 0.03
(9*Z*)-octadec-9-enoic acid (C18:1)	oleic acid	55.24 ± 0.07
all-cis-6,9,12-octadecatrienoic acid (C18:3)	linolenic acid	2.57 ± 0.10
octadecanoic acid (C18:0)	stearic acid	3.33 ± 0.02
(n-9)-cis-11-eicosenoic acid (C20:1)	eicosenoic acid	0.43 ± 0.01
eicosanoic acid (C20:0)	arachidic acid	0.97 ± 0.04
docosanoic acid (C22:0)	behenic acid	0.37 ± 0.01
Total		99.99

[a]Not identified; [b]Relative fatty acid content determined by GC-FID analysis

L. are linear-oblong, in *Onopordum* Vaill. ex L. they are obovoid-oblong and somewhat tetrangular, in the *Carduus-Cirsium* group they are obovoid-oblong, and in the *Arctium-Cousinia* group they are tigrine (with darker wavy stripes) and very often winged (Susanna & Garcia-Jacas 2009). The cypselae of *Cirsium* Mill. are obovate to oblanceolate and dorsiventrally compressed (Ozcan 2017). As for the *Xeranthemum* group, *Amphoricarpos* has elongated clavate inner cypselae, while *Chardinia* and *Siebera* have oblong obconical cypselae (Dittrich 1996).

The importance of arrangement, shape, and ornamentation of the epidermal cells of fruit is emphasiszed in numerous taxonomic studies (Cron *et al.* 1993; Pak *et al.* 2001; Karanović *et al.* 2016). In general, both ribbed and non-ribbed cypselae ornamentations have been reported for Asteraceae (Abid & Qaiser 2009). Also, Kulkarni (2013) reported four different ornamentation types in Asteraceae. In Carlininae, Cardopatiinae, Echinopsinae, and (rarely) Carduinae, the cypsela pericarp is parenchymatous, whereas in Carduinae and all Centaureinae it is radially lignified. A character which is evident in some natural groups within Carduinae (*Cousinia* group, some genera of the *Onopordum* group, *Jurinea* Cass., *Dolomiaea* DC.) is a rugose pericarp, while smooth pericarp is constant in *Carduus*, *Cirsium* and some other Central Asian Carduinae (Häffner, 2000; Ozcan, 2017). In addition, Hacioğlu *et al.* (2012) found three different striation types in *Carthamus* L. taxa from Turkey. In our study, it is shown that cypselae of *X. cylindraceum* are ribbed with a striate-rugose surface.

Glandular trichomes and setulae (twin hairs) of the cypselae usually occur in most genera of Asteraceae except Barnadesioideae (Robinson 2009). Twin hairs are a specificity of epidermis of the cypsela pericarp in Asteraceae (Hess 1938). Andrés-Sánchez *et al.* (2015) reported the presence of twin hairs in *Filago* L. (Inuleae - Asteraceae). These hairs consist of two elongated parallel cells that originate from an epidermal mother cell which undergoes anticlinal division (Hess 1938; Bremer 1987; Cron *et al.* 1993). The function of non-glandular twin hairs is still unclear. According to Hess (1938), the principal function of these hairs might be water absorption. Thus, myxogenic twin hairs keep moisture around the cypselae, facilitate germination, and perhaps contribute to seed dispersal (Hess 1938). Regarding Cardueae, cypselae are usually hirsute (densely sericeous) in the subtribes Carlininae, Cardopatiinae, and Echinopsinae, and glabrous in most of the Carduinae and Centaureinae (Susanna & Garcia-Jacas 2009). Dittrich (1977) reported that twin hairs are not present in Centaureinae genera. Instead, cypselae of *Centaurea* L. and related genera possess unicellular hairs that are directly fixed on epidermal cells of the pericarp (Dittrich 1966). Thus,

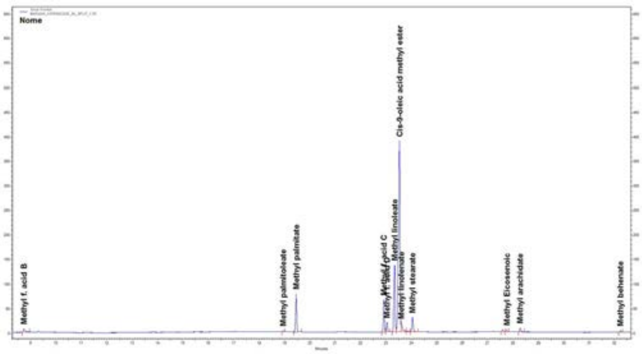

Fig. 2. GC-FID chromatogram of the fatty acid profile of the *Xeranthemum cylindraceum* cypsela.

the pericarp surface is glabrous in most Carduinae (e.g., *Staehelina* pro parte, *Onopordum*, the *Carduus-Cirsium* group), except that glands have been found in the *Jurinea-Saussurea* group (Häffner 2000). *Polytaxis* Bunge possesses long thin unicellular hairs (Häffner 2000). Ozcan (2017) did not find twin hairs in any of the investigated *Cirsium* taxa. Our results show that cypselae of *X. cylindraceum* are densely hairy. The presence of twin hairs is an important marker in the tribe Cardueae. They are present in the basal subtribes (Carlininae, Cardopatiinae, and Echinopsinae) and in the *Xeranthemum* group.

The pericarp at the base of cypselae is often differentiated in order to provide for abscission of the cypselae from the receptacle (John 1921). These differentiations can include a separation tissue rich in intercellular space (John 1921) and visible parts of sclerified pericarp epidermis (Haque & Godward 1984), to which the term carpopodium is applied (Mattfeld 1923). Such carpopodia are present in many tribes of the Asteraceae (Haque & Godward 1984). Haque & Godward (1984) suggested that a hairy pappus and the presence of a carpopodium are correlated because both are linked with wind dispersal. Carpopodium cells are morphologically distinct from the rest of cypselar pericarp wall cells, can be formed by one to many rows of cells, and can diverge in form and texture. In addition, the carpopodium can be completely symmetrical or (as is more often the case) asymmetrical, its shape mainly depending on the cypsela's position on the receptacle (Sundberg 1985). Shape and cellular structure of the carpopodium can be useful in taxonomic studies (King & Robinson 1966; Sundberg 1985). Moreover, it can be indistinct to prominent or absent (Haque & Godward 1984; Funk *et al.* 2009). According to Häffner (2000), a typical carpopodium in which the pericarp's epidermal cells have strongly lignified walls occurs only in a few members of the Carduinae (*Onopordum, Olgaea,* and *Synurus*) and the Centaureinae (*Myopordon*). Ozcan (2017) reported that the carpopodium is undeveloped in *Cirsium*. The carpopodium of *X. cylindraceum* is considered to be asymmetrical. As for Cardueae, the detachment area in Carduineae is straight or lateral-abaxial, while in Centaureineae it is concave, lateral-adaxial, very rarely straight (in *Crupina*), often with an elaiosome (Susanna & Garcia-Jacas 2009). Also, Häffner (2000) recorded that in a few genera of Carduineae the detachment area is strictly basal (the *Cousinia* group, *Cynara* L., *Dolomiaea*, and *Pilostemon*), which was also recorded by Ozcan (2017) for *Cirsium*. Dittrich (1977), in his review of systematics of the tribe Cardueae, recorded that the detachment area is straight and basal, or lateral in some genera, e.g., *Cardopatium* Juss., *Chardinia*, *Siebera*, and *Xeranthemum*. This state is in agreement with our study on *X. cylindraceum*.

Pappus features have been traditionally used to define genera within Asteraceae (Mukherjee & Nordenstam 2008). In Cardueae, the pappus consists of scales or bristles that are directly attached to the pericarp wall in the basal subtribes Cardopatiinae, Carlininae, and Echinopsinae, as well as in *Berardia, Staehelina*, and genera of the *Xeranthemum* group of Carduinae. In contrast to this, the pappus is fixed in a parenchymatous ring to the apical plate of the cypselae in the remaining Carduinae genera and all Centaureinae (Susanna & Garcia-Jacas 2009). The basal pappus tissue can show different shapes that are systematically important (Häffner 2000). Insertion of the pappus on the apex of the cypsela is at the edge of the vertical wall in *Xeranthemum* (Dittrich 1970, 1977). In our study, it is shown that the pericarp joins the pappus directly, without forming a crown. Thus, *Xeranthemum* shares this character of the pappus, namely attachment to the pericarp without any special tissue, with all the basal Cardueae (Cardopatiinae, Echinopsinae, and Carlininae). The pappus of Carduineae is simple or in many undifferentiated rows. In Cardopatiinae, on the other hand, the pappus is double, consisting of two rings of short scales, while in Centaureinae it is in two structurally different rows (a double pappus) (Susanna & Garcia-Jacas 2009). Dittrich (1977) reported that the pappus in Carlininae is mostly arranged in one row and possesses bristles of almost equal length. Most Carduinae taxa have a deciduous pappus, whereas a persistent pappus is found in most *Jurinea* and related genera (Häffner 2000). Pappus bristles of the herein studied species are persistent, variable in length, and more or less paleaceous. In Cardueae, pinnules of the pappus bristles are shorter than width of the bristle (scabrate), as long as width of the bristle (pinnulate), or much longer and capillary (plumose) (Susanna & Garcia-Jacas 2009). The pappus bristles display structural features which are suitable for the delimitation of genera in the Carduinae (Häffner 2000). The pappus of *Berardia* and *Staehelina* is formed by scabrid cylindrical bristles, which are retrorsely twisted only in *Berardia*, while *Stahelina* has straight bristles. The pappus of *On-*

opordum is plumose, consisting of barbellate or scabrid bristles, while in the *Cynara* group it is made up of very long plumose bristles basally connate in a ring. In *Carduus-Cirsium* the pappus consists of plumose or barbellate bristles usually deciduous as a single piece, while in the *Jurinea-Saussurea* group it is made up of very long, showy, usually pure white plumose bristles, very often basally connate in a ring (Susanna & Garcia-Jacas 2009). The pappus of the herein studied species consists of 10-11 wide, scarious, subulate, apically pinnulate bristles of variable length, more or less connate at the base. According to Häffner (2000), three different types of pappus bristles are recognised, and *X. cylindraceum* belongs to type 2 (with teeth present on the dorsal surface and at the margins of the bristles, while the ventral surface is smooth). Regarding the *Xeranthemum* group, Dittrich (1996) noted that the pappus may consist of bristles diverging above their base (central cypselae of *Amphoricarpos*) or it may be formed by scales (*Chardinia*, *Siebera*, *and Xeranthemum*). Fragility and colour of the pappus are also taxonomically important characters (Häffner 2000). Most Carduinae have a white to cream-coloured or even brownish pappus (Häffner 2000). Colour of the pappus of the herein studied species varies from golden to yellowish.

Jana & Mukherjee (2014) examined the morphology and anatomy of cypselae in seven Cardueae species, including *X. annuum*. Differences between *X. cylindraceum* and *X. annuum* can be seen in cypsela colour and the number of pappus bristles, which is also in agreement with Webb (1976).

The present study showed that the fatty acid profiles of *X. cylindraceum* cypselae were distinct from those observed in other taxa within the Asteraceae. The dominant fatty acid in cypselae of *X. cylindraceum* is different from that in cypselae of other species of the tribe Cardueae. For example, linoleic rather than oleic acid was the major fatty acid found in oil of the seeds of *X. annuum* (Powell *et al.* 1967), in oil of the seeds of two *Carlina* species (Spencer *et al.* 1969), in oil of *Arctium minus* L. (Morris *et al.* 1968), and in oil of 19 different *Centaurea* species (Janaćković 2004). Oleic acid is also present in these species, but not as the dominant one. The observed differences, especially between *X. cylindraceum* and *X. annuum,* indicate that the linoleic/oleic acid ratio is a chemotaxonomic character that can be used for delimitation of these two species.

CONCLUSION

This study represents a contribution to knowledge about micromophology of the cypselae of *X. cylindraceum* and phytochemistry of their lipids. Our results on cypsela morphology are in agreement with earlier investigations, but we did not notice any dimorphic fruits. The presence of twin hairs is an important marker in the tribe Cardueae, one that links the *Xeranthemum* group with the basal subtribes (Carlininae, Cardopatiinae, and Echinopsinae). The dominant fatty acid is oleic acid, in contrast to what is observed in other species of the tribe Cardueae. The differences between *X. cylindraceum* and *X. annuum* indicate that the linoleic/oleic acid ratio is a chemotaxonomic character that can be used for delimitation of these two species. Our results on cypsela micromorphology and fatty acid composition could be a guideline for similar investigations of other genera from the *Xeranthemum* group. Research on cypsela micromorphology and fatty acid composition should be continued at the tribal and subtribal levels in order to obtain possible valuable characters useful for the classification of certain taxa. Finally, we can say with confidence that consideration of micromorphological and phytochemical characters, combined with analysis of molecular data, will certainly help us to gain a better understanding of the taxonomy and phylogeny of the *Xeranthemum* group.

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REZIME

Mikromorfologija i sastav masnih kiselina cipsela vrste *Xeranthemum cylindraceum* Sm. (Asteraceae, Cardueae)

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U ovom radu analizirana je mikromorfologija cipsele pomoću skenirajućeg elektronskog mikroskopa (SEM), kao i sastav masnih kiselina u cipselama pomoću gasne hromatografije sa plameno jonizujućim detektorom (GH-PJD), vrste *Xeranthemum cylindraceum*. Cipsele su prave, rebraste, usko obrnuto konične do objajaste, gusto dlakave na površini. Na SEM mikrografijama se uočava isprugano-naborana površina cipsele sa dvodelnim, duguljastim, nežlezdanim, spiralno uvijenim dlakama koje se na vrhu kratko račvaju. Zona odvajanja je adaksijalno postavljena neposredno iznad karpopodijuma, koji je asimetričan i u obliku potkovice. Perikarp na mestu formiranja papusa ne obrazuje krunu. Papus je postojan, jednoobrazan, jednoredan, plevičasto-ljuspast, izgrađen od nekoliko, širokih, kožasto-opnastih, šilastih i na vrhu perastih čekinja, različite dužine. Gasno-hromatografskom analizom u cipselama je detektovano 12 masnih kiselina, od kojih je 9 identifikovano (88.57%). Masne kiseline su detektovane u nizu od palmitoleinske (C16:1) do behenske (C22:0) kiseline. Dominantne su nezasićene masne kiseline (75.02%), od kojih je oleinska (55.24%) najdominantnija. Sastav masnih kiselina u cipselama ove vrste po prvi put je utvrđen. Taksonomski značaj analiziranih karaktera je ukratko diskutovan.

Ključne reči: *Xeranthemum*, Cardueae, mikromorfologija, masne kiseline