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A new species of *Aculops* (Acari: Prostigmata: Eriophyidae) from Serbia on *Dipsacus laciniatus* L. (Dipsacaceae), a weed target of classical biological control in the United States of America

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Abstract

A new eriophyoid mite species, *Aculops orlovacae* **n. sp.** (Acari: Prostigmata: Eriophyidae) collected from *Dipsacus laciniatus* L. (Dipsacaceae) in northern Serbia, is described and illustrated, including digital micrographs depicting key morphological characters. Differential diagnosis is provided in comparison with *Aculops salixis* Xue, Song et Hong, *Aculops rhodensis* (Keifer), *Aculops hussongi* Keifer and *Aculops oblongus* (Nalepa). This is the first eriophyoid mite species in the genus *Aculops* described from a host plant in the family Dipsacaceae and it is only the second eriophyoid known from a host species in the genus *Dipsacus* L. This mite was found during surveys for natural enemies of *Dipsacus* spp., as part of a classical biological control program.

Key words: biological control of weeds, Eriophyoidea, invasive species, mite, systematics

Introduction

Amrine and Stasny (1994) listed only three eriophyoid mite species that were known to occur on hosts in the family Dipsacaceae, including: *Aceria squalida* (Nalepa), originally found on *Scabiosa columbaria* L. in France (Nalepa 1892) and since recorded from additional hosts in numerous European countries (Petanovic & Stankovic 1999; de Lillo 2011); *Epitrimerus knautiae* Liro found on *Knautia arvensis* (L.) J.M. Coult in Finland and Poland (Liro 1942; Boczek 1964); and *Epitrimerus succisae* Roivainen found on *Succisa pratensis* Moench in Finland (Roivainen 1947). Petanovic and Rector (2007) described *Leipothrix dipsacivagus* on *Dipsacus laciniatus* L., and *Dipsacus fullonum* L., from specimens collected in Serbia, France and Bulgaria and, in the same study, transferred *E. knautiae* and *E. succisae* to the genus *Leipothrix* Keifer. In May 2007, a new eriophyoid mite species was collected from *D. laciniatus* during surveys in northern Serbia. This new species, *Aculops orlovacae* **n. sp.**, is described and illustrated herein.

Material and methods

Samples of *Dipsacus laciniatus* L. with symptoms of russeting consistent with eriophyoid infestation were collected from Orlovača, a location south of Belgrade, Serbia (44˚ 42.34′ N, 20˚ 24.78′ E). Mites were collected using extraction methods as described by de Lillo (2001) and Monfreda *et al.* (2007) and their presence was confirmed using a stereomicroscope. The morphology of *Aculops orlovacae* **n. sp.** was examined using a phase-contrast microscope (Leica DMLS) with a digital camera attached and connected to a computer. In preparation for light microscopy, the mites were initially cleared in lactic acid for several days and then mounted in Keifer's 'F' medium. Morphometry was performed using the software package IM 1000 (Leica, Wetzlar, Germany). Measurements of

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specimens were taken according to the protocols of Amrine and Manson (1996). Setal notation follows the terminology of Lindquist (1996), while the systematic classification follows Amrine *et al.* (2003). Measurements of the holotype precede the range of paratypes, given in parentheses (see below). Measurements are given in micrometers (μm) and refer to the length of the structure, unless otherwise stated. Body length was measured from the anterior edge of the prodorsal shield to the end of anal lobe. The lengths of legs were taken from the base of the trochanter to the apical margin of the tarsus (excluding empodium and solenidion).

The holotype and eight paratypes are deposited in the Acari Collection, Department of Entomology and Agricultural Zoology, Faculty of Agriculture, University of Belgrade, Serbia. One female paratype slide each has been deposited at the British Museum, London, England and the National Museum, Washington DC, USA, and six paratype slides are deposited with USDA-ARS.

Taxonomy

Superfamily ERIOPHYOIDEA Nalepa 1898

Family ERIOPHYIDAE Nalepa 1898

Subfamily PHYLLOCOPTINAE Nalepa 1892

Tribe ANTHOCOPTINI Amrine and Stasny 1994

Genus *Aculops* Keifer 1966

Type species: *Vasates populivagrans* Keifer 1953, ES21, BCDA 42:68, pl.226, California, a deuterogynous species rusting leaves of *Populus fremonti* S. Wats. (Fremont cottonwood, Salicaceae).
Junior synonyms: *Azimaberoptus* Chandrapatya 1993; *Cecidobia* Banks 1905; *Pedaculops* Manson 1984.

Aculops orlovacae n. sp.
(Figs 1 & 2)

FEMALE (n = 10). Body fusiform, 266 (165–266); width 72 (57–72). Gnathosoma 23 (20–23), downcurved. Dorsal pedipalpal genual seta *d* 8 (6–8), seta *ep* 3 (3–4), chelicerae 17 (15–18). Prodorsal shield subtriangular with a short acuminate lobe over gnathosoma, 38 (35–38), 51 (46–54) wide. Prodorsal shield ornamentation: median line present on 1/3 at the base, connected with admedian lines at basal 1/3 of the proximal part; admedian lines complete and together with submedian lines connected by transverse lines forming four cells at the basal part and three cells in the middle; two cells are present at the lateral sides, and three cells are present at the distal part of the shield. Tubercles of setae *sc* at rear shield margin, 21 (19–22) apart, seta *sc* 47 (32–47). Legs with all usual segments and setae present. Leg I 38 (34–38); femur 12 (9–12), seta *bv* 11 (8–12); genu 5 (5–7), seta *l″* 25 (24–31); tibia 10 (8–10), seta *l′* 7 (7–8); tarsus 7 (5–7), seta: *ft″* 19 (19–25), *ft′* 17 (13–22); solenidion *ω* 8 (7–8); empodium 6 (6–7), simple, bilaterally symmetrical, with 7-paired rays. Leg II 34 (30–36); femur 11 (8–11), seta *bv* 10 (7–13); genu 4 (4–6), seta *l″* 8 (8–11); tibia 7 (7–8); tarsus 6 (5–7), seta: *ft″* 22 (22–25), seta *ft′* 6 (7–10); solenidion *ω* 7 (7–9); empodium 5 (5–7), simple, bilaterally symmetrical, with 7-paired rays. Coxal plates with granules and dots. Sternal line 8 (6–8); setae *1b* 10 (9–11), 13 (10–13) apart; setae *1a* 33 (23–34), 10 (7–10) apart; setae *2a* 47 (33–47), 28 (20–28) apart. Coxigenital area with 9 (8–10) microtuberculated annuli. External genitalia 15 (12–15), 23 (22–24) wide, genital coverflap with 12 (12–14) longitudinal ridges; setae *3a* 44 (33–44), 20 (15–20) apart. Opisthosoma with 54 (47–57) dorsal annuli and 93 (87–98) ventral annuli. Dorsal annuli with rounded microtubercles, ventral annuli with bead-like microtubercles, elongated on the posterior annuli. Setae *c2* 51 (41–51), 63 (46–63) apart, on ventral annulus 21 (14–22); setae *d* 63 (44–65), 45 (30–45) apart, on ventral annulus 41 (33–42); setae *e* 22 (17–22), 24 (15–24) apart, on ventral annulus 63 (52–64); setae *f* 31 (23–32), 26 (19–26) apart, on ventral annulus 89 (82–93) or 5th annulus from rear. Setae *h1* 2 (2–5), 7 (5–7) apart; setae *h2* 60 (59–74), 12 (9–14) apart.

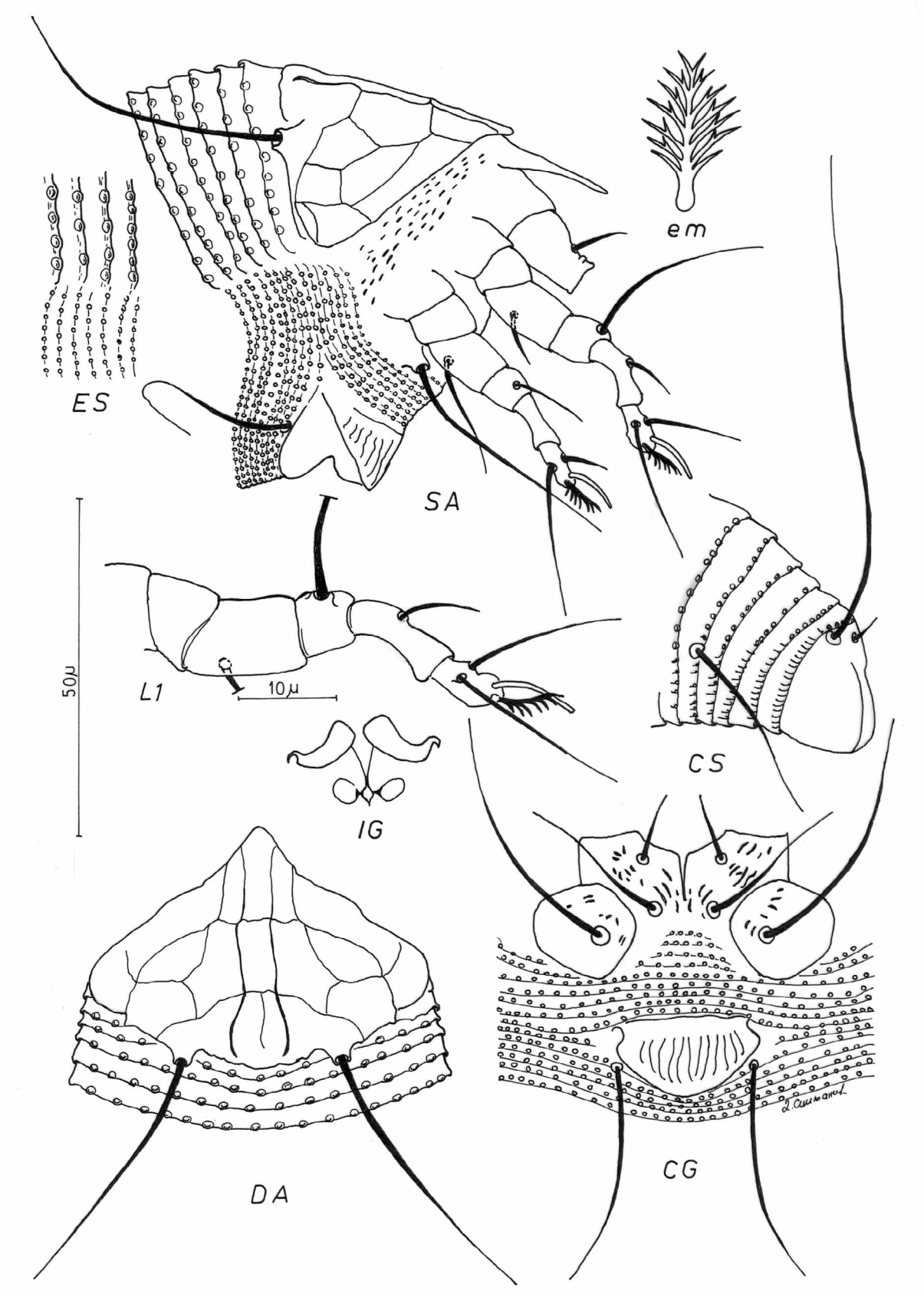

FIGURE 1. Semi-schematic line drawings of *Aculops orlovacae* **n. sp.**: CG. Coxigenital region of female; CS. Lateral view of caudal opisthosoma; DA. Prodorsal shield of female; em. Empodium (in detail); ES. Lateral view of annuli; IG. Internal female genitalia; SA. Lateral view of anterior region of female; L1. Leg I (with separate scale bar).

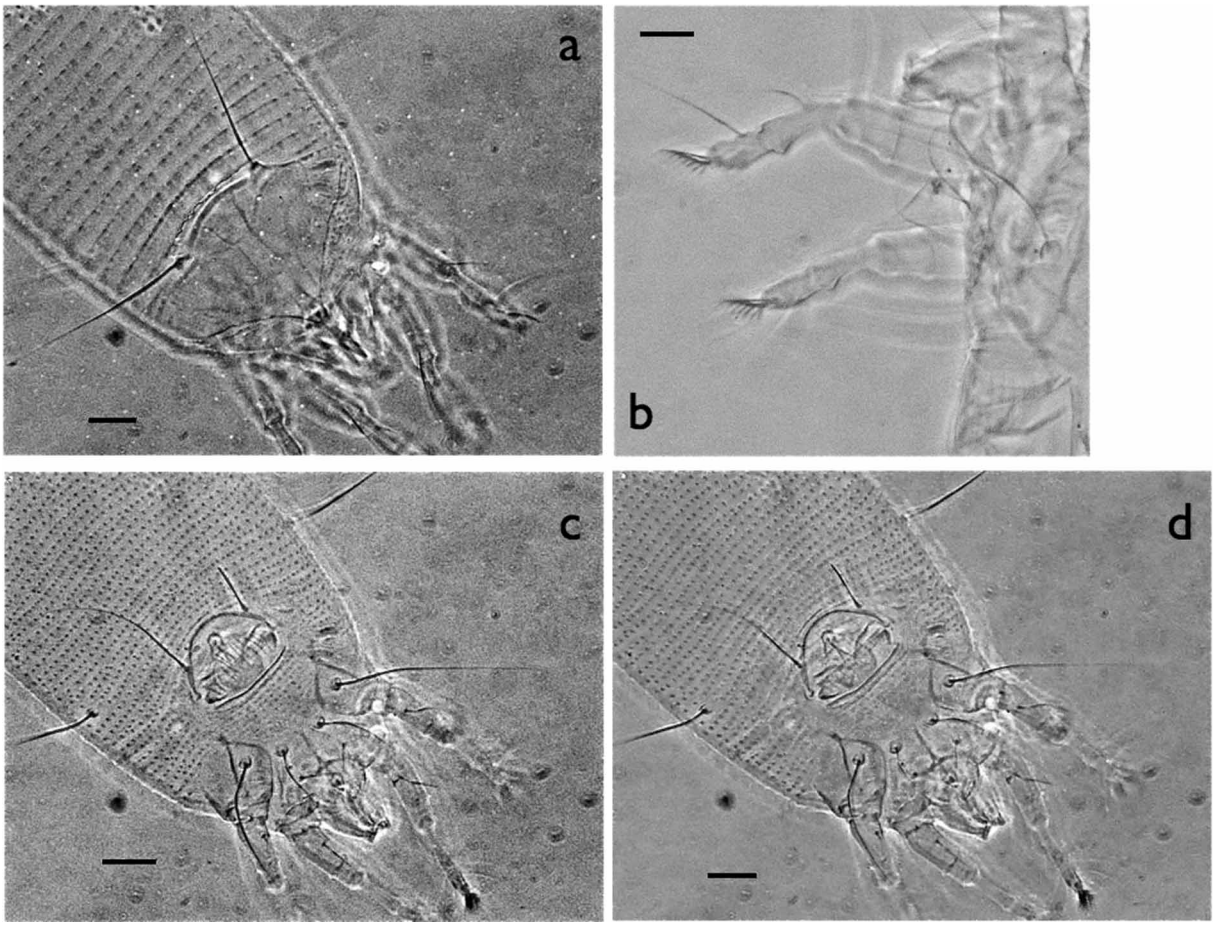

FIGURE 2. Digital micrographs of *Aculops orlovacae* **n. sp.**: a. Prodorsal shield; b. Legs; c. Coxigenital region (internal female genitalia visible); d. Coxigenital region (female genital coverflap visible). Scale bar = 10 μm for a, b, c and d.

MALE: Unknown.

NYMPH: Unknown.

Type material. Holotype female (1102//9) and 19 paratype females, Orlovača, south of Belgrade, Serbia (Lat. 44˚42.34′ N, Long. 20˚24.78′ E), 10 May 2007, collected by the authors. The host plant, *D. laciniatus*, occurred in a large population within a disturbed, uncultivated area adjacent to a roadway.

Host plant. *Dipsacus laciniatus* L. (Dipsacaceae).

Relation to host. Mites are vagrant on the surface of aboveground plant parts, causing russeting of leaves.

Etymology. The specific name is derived from the location of the original collection.

Distribution. To date, only the type population of *A. orlovacae* **n. sp.** has been found, despite repeated and directed searches for this species since its discovery.

Differential diagnosis. When compared to published line drawings and measurements, *Aculops orlovacae* **n. sp.**, is morphologically similar to *Aculops salixis* Xue, Song et Hong (2007), described from *Salix* sp. L (Salicaceae) in Foping County, Shaanxi Province, China. Both species have similar qualitative and meristic characteristics, including but not limited to the prodorsal shield ornamentation; number of empodial rays; number of ridges on the female genital coverflap and ornamentation on the coxae. They differ, however, in the lengths of the *sc*, *1a*, *2a*, *3a*, *c2*, and *e* setae; number of dorsal and ventral opisthosomal annuli and the host plant species (see Table 1). The new species is also similar to *Aculops rhodensis* (Keifer 1957) as described from *Salix* L. (Salicaceae) in Newport, Rhode Island, U.S.A. Both species have similar prodorsal shield ornamentation; number of empodial rays; number of striae on the female genital coverflap; ornamentation of Leg I coxae, as well as other morphometrical characteristics. They differ, however, in the lengths of the *sc*, *3a*, *c2*, *d* and *e* setae; number of dorsal and ventral opisthosomal annuli and the host plant species (see Table 1). The new species is also similar to *Aculops hussongi* Keifer 1966 which was described from *Lupinus obtusilobus* Heller (Fabaceae), upper Kings Creek, Lassen National Park,

Shasta County, California. Both species have similar prodorsal shield ornamentation; number of empodial rays; number of ridges on the female genital coverflap; ornamentation of the coxae and several other morphometrical characteristics. They differ, however, in the length of the *sc*, *c2*, and *d* setae; number of dorsal and ventral opisthosomal annuli and the host plant species (see Table 1).

TABLE 1. Comparison of diagnostic morphometrical and other characteristics between *Aculops orlovacae* **n. sp.**, *A. salixis* (data from Xue *et al.* 2007), *A. rhodensis* (data from Keifer 1957) and *A. hussongi* (data from Keifer 1966). Measurements are given in µm.

Characteristic	*A. orlovacae*	*A. salixis*	*A. rhodensis*	*A. hussongi*
Setae *sc* length	47 (32–47)	25 (23–27)	27	31
Setae *1a* length	33 (23–34)	15 (14–16)	-	-
Setae *2a* length	47 (33–47)	29 (28–31)	-	-
Setae *3a* length	44 (33–44)	18 (17–20)	15	35
Setae *c2* length	51 (41–51)	20 (18–23)	25	29
Setae *d* length	63 (44–65)	55 (49–57)	30	42
Setae *e* length	22 (17–22)	35 (33–36)	28	21
Dorsal opisthosomal annuli,	54 (47–57)	44 (41–50)	33	45
Ventral opisthosomal annuli,	93 (87–98)	64 (61–67)	60–65	72
Type host plant	*Dipsacus* L.	*Salix* L.	*Salix* L.	*Lupinus* L.

Aculops orlovacae **n. sp.** was found on a small number of *D. laciniatus* plants at two locations within a large field of *D. lacinatus* in Orlovača. No other *Aculops* spp. are known from host plants in the family Dipsacaceae. *Viburnum* L., in the plant family Caprifoliaceae, is the closest relative to Dipsacaceae that has been recorded as a host of a mite in the genus *Aculops*, viz. *A. oblongus* recorded from Austria (Nalepa 1894). Given the generally close association between eriophyoid mites and their host plants (Skoracka *et al.* 2010) and the taxonomic proximity between *A. orlovacae* **n. sp.** and *A. oblongus*, a differential diagnosis was also made between these two species (see Table 2). In addition to its original description from Austria, *A. oblongus* has been reported from Denmark (Roivainen 1949), Poland (Soika & Labanowski 2000; Skoracka *et al.* 2005) and Hungary (Farkas 1965, 1966; Ripka 2007). Unfortunately, in the original description of *A. oblongus*, only a few quantitative data were recorded in addition to some qualitative descriptions and a line drawing. Therefore, it is difficult to compare this to *A. orlovacae* **n. sp.** in the way that other, quantitatively described species have been compared. According to Nalepa (1894), the holotype female of *A. oblongus* is 120 long and 40 wide; the dorsal setae (*sc*) are as long as the prodorsal shield; the first ventral setae (*d*) are very long; the second ventral setae (*e*) are also long and the tarsal empodium is 4-rayed. The opisthosoma has 32 annuli (no distinction made between dorsal and ventral); the genital setae (*3a*) are long and the accessory setae (*h1*) are missing. The shield ornamentation consists of one median line; one admedian line on each side and two submedian lines on each side. All mentioned lines are complete, beginning from the base and reaching the anterior edge of the prodorsal shield. The female genital coverflap has about 8 ridges. The mite is free-living on the lower surface of leaves of *Viburnum lantana* L. Specimens of *A. oblongus* from Hungary were similar to those described from Austria (Farkas 1966). One quantitative characteristic (viz. setae *sc* = 26) was supplied for the Hungarian specimens (Farkas 1966; see Table 2). According to Roivainen (1949), *A. oblongus* specimens from Denmark were larger (150–160 long and 55 wide) than those described from Austria. Specimens of *A. oblongus* from Poland were not described, only identified and added to the list of Polish fauna (Soika & Labanowski 2000; Skoracka *et al.* 2005). In summary, *Aculops orlovacae* **n. sp.** differs in comparison with *A. oblongus* in body dimensions (individuals of *A. orlovacae* **n. sp.** are larger than the Austrian, Hungarian and Danish specimens of *A. oblongus*); length of *sc* setae (which are longer than the prodorsal shield in *A. orlovacae*); number of empodial rays (7 vs. 4) and number of opisthosomal annuli (differentiated into 54 dorsal and 93 ventral annuli in *A. orlovacae* vs. 32 annuli in *A. oblongus* (Table 2). In addition, the prodorsal shield ornamentation is different between the two species, there are more ridges on the female genital coverflap of *A. orlovacae* **n. sp.** than on that of *A. oblongus*, and setae *h1* are present in *A. orlovacae*, while absent in *A. oblongus* (Table 2).

TABLE 2. Comparison of diagnostic morphometrical and other characteristics between *Aculops* orlovace **n. sp.** and *A. oblongus*. References are provided for the *A. oblongus* data. Measurements are given in µm.

Characteristic	*Aculus orlovacae*	*Aculus oblongus*	References
Body length x width	266 (165–266) x 72 (57–72)	120 x 40	Nalepa 1894, Farkas 1966
Body length x width	266 (165–266) x 72 (57–72)	(150–160) x 55	Roivainen 1949
Setae sc length	47 (32–47)	26	Farkas 1966
Setae *h1*	Present	Absent	Nalepa 1894
No. of empodial rays	7	4	Nalepa 1894
Dorsal opisthosomal annuli	54 (47–57)	32[a]	Nalepa 1894
Ventral opisthosomal annuli	93 (87–98)	32[a]	Nalepa 1894
Prodorsal shield ornamentation	Median line incomplete; transverse lines form 9 cells with admedian and submedian lines	Median, admedian and submedian lines complete from proximal to distal edges; no cells mentioned	Nalepa 1894
No. of female genital coverflap ridges	12 (12–14)	8	Nalepa 1894
Type host plant	*Dipsacus laciniatus* L.	*Viburnum lantana* L.	Nalepa 1894

[a] No indication of whether annuli were dorsal or ventral.

Discussion

The host plant of *Aculops orlovacae* **n. sp.** is cutleaf teasel, *Dipsacus laciniatus*, which was predominant in the field where the first population of *A. orlovacae* was found. Teasels (*Dipsacus* spp.), belong to the Dipsacaceae, a family of exclusively Old World plants. *Dipsacus fullonum* and *D. laciniatus* are native to wetlands and fallow fields of western Eurasia and *D. laciniatus* is common in Serbia and sporadic throughout central and eastern Europe (Werner 1975; Verlaque 1985). Both *D. fullonum* and *D. laciniatus* have become invasive weed species in the United States of America, currently listed as noxious weeds in five states (USDA-NRCS 2011) and as invasive weeds in 14 states and four national parks (Bargeron & Swearingen 2011). They are invasive mainly in non-agricultural settings with limited weed management activity, displacing native flora and creating a nuisance along highways and in parks (Rector *et al.* 2006). As a result, they became the targets of a classical biological control program organized by the Agricultural Research Service of the United States Department of Agriculture (USDA-ARS). Surveys have been conducted in Europe and parts of Asia over the past decade in order to find co-evolved natural enemies of teasels to develop as candidate biological control agents for export to the USA after testing (Rector *et al.* 2006). Eriophyoid mites have been employed as weed biological control agents on four continents (Smith *et al.* 2010). They are considered to have great promise in weed biological control due to their generally high host-specificity (Skoracka *et al.* 2010).

In May (late spring in Serbia), *D. laciniatus* is typically a tall (≤ 2 m), prominent plant usually found in dense, isolated populations. Damage to the host plant by *A. orlovacae* **n. sp.**, was highly noticeable but slightly different from that caused by the more common *Leipothrix dipsacivagus*. Plants of *D. laciniatus* infested with *L. dipsacivagus*, often show "witch's broom" symptoms of severe stunting due to shortened internode length and leaf deformation, as well as leaf-russeting (Pećinar *et al.* 2007, 2008). On plants infested with *A. orlovacae* **n. sp.**, caudal leaves were deformed and heavily russeted but "witch's broom" symptoms were not observed. Plants had not yet flowered, so the effect on reproductive parts was not observed and return visits to the site later in the same summer did not yield any mites or evidence of them. No plants of other species that were sympatric with *D. laciniatus* within the same field showed eriophyoid damage.

Given that *A. orlovacae* **n. sp.**, was collected from *D. laciniatus* plants that exhibited typical symptoms of eriophyoid mite damage, it is considered to be a biological control candidate worthy of further study of its taxonomy, biology and relationship to the target plant. Following the discovery of the first population of *A. orlovacae* **n. sp.**, repeated and directed searches were conducted to collect additional mites (particularly males and immatures) from

the original population and to find additional populations in the surrounding area. So far, these searches have not been successful. Thus, *A. orlovacae* **n. sp.**, appears to be relatively rare, at least on *Dipsacus laciniatus*, in Serbia.

While *D. laciniatus* is clearly a host plant of *A. orlovacae* **n. sp.**, it is possible that the principal host plant of this mite is something other than *D. laciniatus* and that searching on other plant species might produce additional populations. This seems unlikely, given that ~80% of eriophyoid species are specific to a single host plant species and ~95% are specific to a single host plant genus (Skoracka *et al.* 2010). Nonetheless, candidate plant species to search include other Dipsacus spp., and other genera within the Dipsacaceae plant family (for example, *Cephalaria*, *Knautia*, *Scabiosa* and *Succisa*). Host plant genera of morphologically similar *Aculops* spp., could also be targeted in this search in the event that this morphological similarity could be indicative of phylogenetic proximity and thereby host pant range.

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