TAXONOMY AND BIOECOLOGY OF ERIOPHYIDS (ACARI: ERIOPHYOIDEA) ASSOCIATED WITH CANADA THISTLE, *CIRSIUM ARVENSE* (L.) SCOP.

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TAXONOMY
BIOECOLOGY
SYNONYMYZATION
ERIOPHYOIDEA
CIRSIUM

SUMMARY: Comparison of eriophyid mites occurring on *Cirsium arvense* (L.) over two growing seasons showed two forms of females which were previously called separate species *Aceria? anthocoptes* (Nalepa, 1892) and *Aceria leonthodontis* (Lindroth, 1904). According to our data, two forms of females belong to one species *Aceria anthocoptes* (Nal.). Males studied during the whole growing season had the characteristics similar to protogynes. Damages caused by both forms were the same. In the middle of the season transitional forms between protogynes and deutogynes were often found.

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RÉSUMÉ : La comparaison des eriophyides présents sur *Cirsium arvense* (L.) au cours des deux saisons de croissance a mis en évidence deux formes de femelles qui étaient auparavant désignées comme deux espèces séparées, *Aceria? anthocoptes* (Nalepa, 1892) et *Aceria leonthodontis* (Lindroth, 1904). D'après nos données, les deux formes de femelles appartiennent à une seule espèce, *Aceria anthocoptes* (Nal.). Les mâles qui ont été étudiés pendant toute la saison de croissance avaient des caractères semblables à ceux des protogynes. Les dommages causés par les deux formes étaient les mêmes. Au milieu de la saison, des formes de transition entre protogynes et deutogynes ont souvent été trouvées.

INTRODUCTION

Canada thistle *Cirsium arvense* (L.) Scop. (Asteraceae) is one of the most persistent weeds in regions with a continental climate. It is a Eurasian floral element, and as it spreads equally rapidly both by seed and by creeping root, it is domesticated throughout the world. In Canada, it occurs in all the provinces and with all crops, as well as in the meadows and pastures, causing major economic losses (MCCLAY, 1990). It is on the list of weeds for classical biological control, together with its related species *Cirsium palustre* (L.) and *C. vulgare* (Savi) Tenore in North America (JULIEN, 1992). The European Weed Research Society (EWRS) also regards this as one of the six priority species for biological control (MACELJSKI, 1984).

With more or less success, in Canada, USA, Great Britain, New Zealand, Australia and South Africa, insect species of the following genera were released: *Altica*, *Lema* (Chrysomelidae), *Ceutorhynchus*, *Rhynocyllus*, *Trichosirocalus* (Curculionidae) and *Urophora* (Tephritidae), originating from Switzerland, France, Germany, Great Britain, Austria and Finland (JULIEN, 1992).

The consideration of bioecological bases and the possibilities of eriophyid utilization for biological control of weeds, more than a decade ago (CROMROY,

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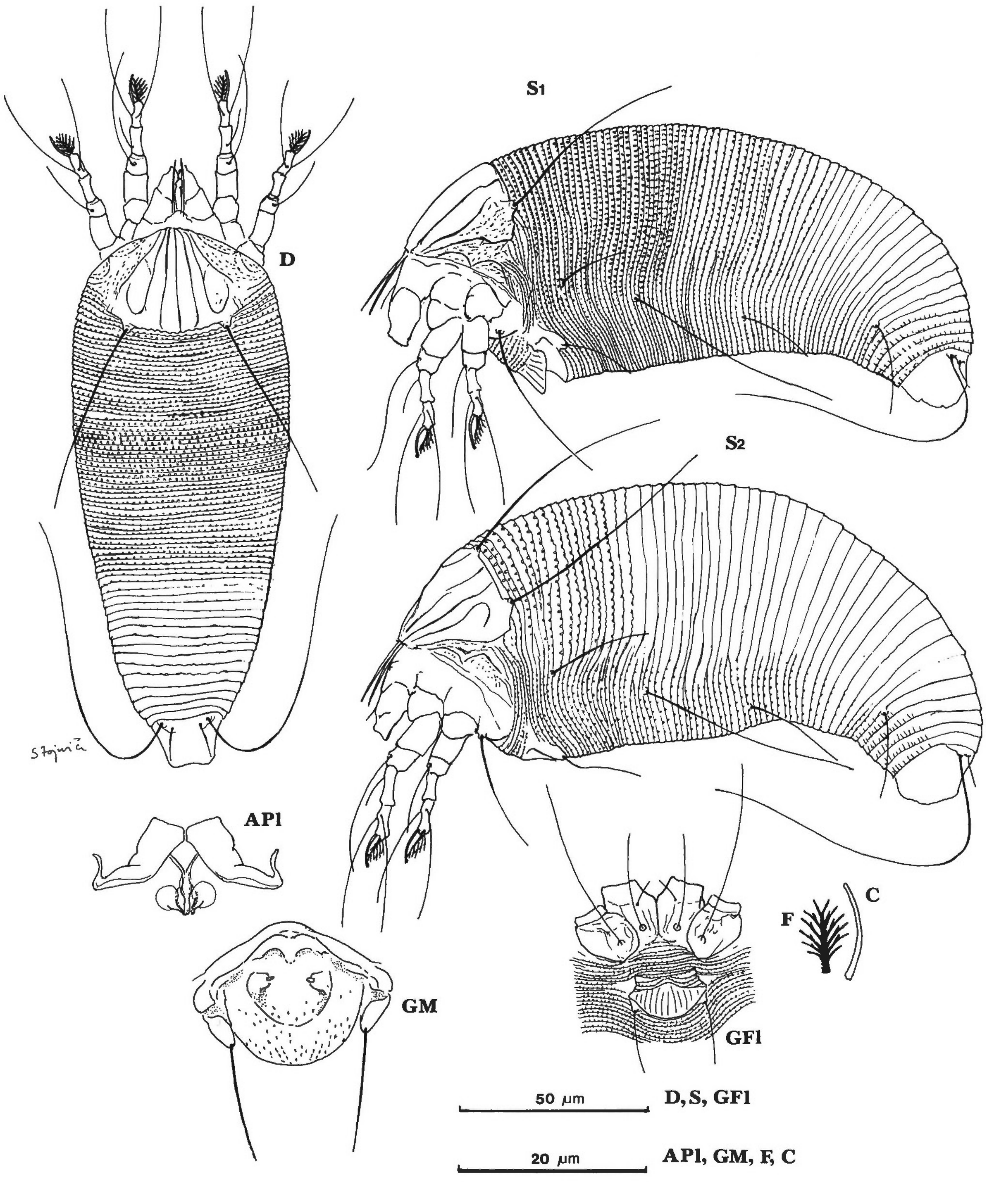


FIG. 1: *Aceria anthocoptes*, protogyne form.

D — dorsal view of mite. S1 — side view of typical form of protogyne female. S2 — side view of "transitional" form. GF1 — external female genitalia. AP1 — internal female genitalia. GM — external male genitalia. F — featherclaw. C — claw.

1979, 1983; ANDRES, 1983), initiated the study and the practical utilization of some species. The eriophyids associated with *Chondrilla juncea* L. (CARESHE & WAPSHERE, 1974), *Convolvulus arvensis* (NUZZACI *et al.*, 1985; BOLDTH & SOBHIAN, 1993),*Centaurea diffusa* Lam. (CASTAGNOLI & SOBHIAN, 1991), *Tamarix gallica* L. (DE LILLO & SOBHIAN, 1994) were practically applied, or tested as potential candidates.

Only two species of eriophyids: *Aceria anthocoptes* (Nal.) and *A.? leonthodontis* (Lindroth) have so far been recorded on *Cirsium arvense* and on related species throughout the world. The former species was recorded in France, Italy, Austria, Sweden, Finland, Bulgaria (DAVIS *et al.*, 1982) and Yugoslavia (PETANOVIĆ, 1988). The latter was recorded in Finland, Austria and Bulgaria (DAVIS *et al.*, 1982). According to FARKAS (1965), both species are widespread in Europe.

In the description of the species *A.? leonthodontis* (Lindroth, 1904), differences were observed in the form and number of hysterosoma rings, which made NALEPA (1910) assume that the fluctuation of the tergite number and width, as well as degree of sculpturing, can be the consequence of the existence of two adult generations.

In addition, ROIVAINEN (1951) described this species in more detail and transferred it into the genus *Vasates*, citing the great morphological similarity between this species and the previously described *Aceria anthocoptes*. As he did not find any essential differences of symptoms in the study of eriophyids on *Cirsium arvense* var. *horridum* in Sweden, ROIVAINEN (1951) suggested that further research should prove that *A. anthocoptes* and *Vasates leonthodontis* (Lindroth) are two forms of the same species, which should be named *Vasates anthocoptes* (Nal.).

AMRINE & STASNY (1994), after inspection of the available references, were of the opinion that *V. leonthodontis* should be transferred to the genus *Aceria*. As they did not dispose either of the original or the borrowed material from Europe, the new combination remained questionable. Also there was no synonymization, in the absence of both new evidence and detailed research on the species.

After working for several years on weed eriophyids, motivated by the fact that eriophyids associated with *Cirsium* spp. have not been sufficiently studied, we started systematic research in Serbia, and especially at several localities in the surroundings of Belgrade, so as to contribute to solving the taxonomic status of the described species, based on a detailed study of morphological and some bioecological characteristics.

MATERIAL AND METHODS

The samples of whole plants or fragments of *Cirsium arvense* were taken in the period 1993–1995 at several localities in Serbia, from the rural sites or from the crops of wheat and maize, grape vine plantings, orchards of kernel fruits, plum-tree plantings and meadows, mowed frequently or rarely. Two populations from Karaburma and Dušanovac (Belgrade) were monitored every 10–15 days during a two-year period. The plants were inspected with a stereoscope for presence of mites on plant organs, vertical distribution from the foot to the top of the plant, horizontal distribution throughout the leaf area and population density. For the sake of the correct identification of taxa, sexes, and development stages, microscope preparations were made in Heinze and Keifer media and observed under a phase-contrast microscope at a magnification of 1250 ×. The quantitative characteristics were measured using a microscopic scale and are expressed in micrometers.

Phase-contrast micrographs were taken at the Department of Applied Entomology of Warsaw Agricultural University.

SEM micrographs were taken according to the method of NUZZACI *et al.* (1991), using a JEOL JSM-35 SEM at the Institute of Biology of the Faculty of Natural Sciences in Novi Sad. The drawings were made using a phase-contrast microscope and *camera lucida* at the Faculty of Agriculture in Belgrade.

Aceria anthocoptes (Nal.)

Phytoptus anthocoptes Nalepa, 1892
Eriophyes anthocoptes (Nal.) Nalepa, 1910
Aceria anthocoptes (Nal.) Roivainen, 1950

Eriophyes leonthodontis Lindroth, 1904
Phyllocoptes leonthodontis (Lindroth) Liro & Roivainen, 1951

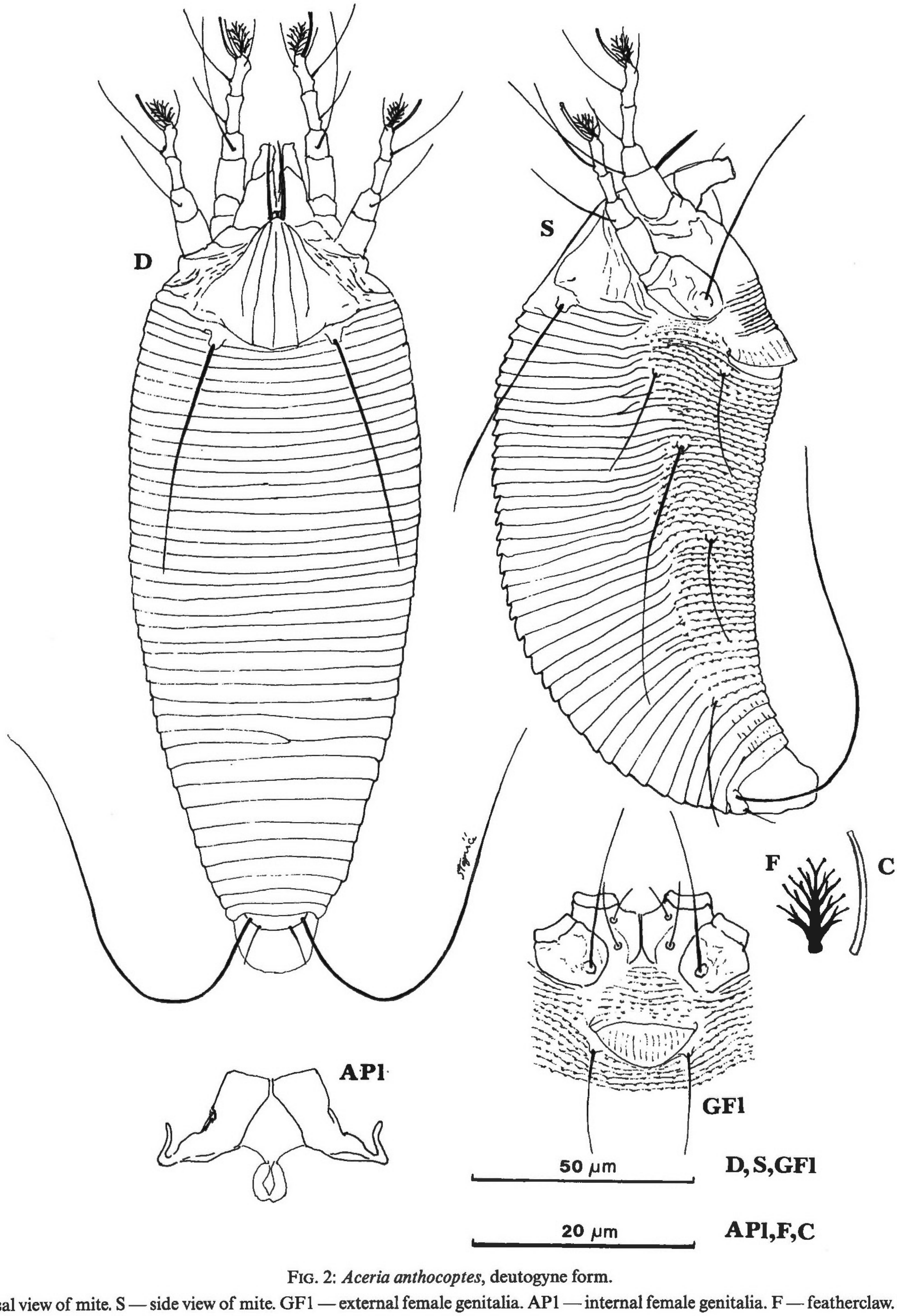


FIG. 2: *Aceria anthocoptes*, deutogyne form.
D — dorsal view of mite. S — side view of mite. GF1 — external female genitalia. AP1 — internal female genitalia. F — featherclaw. C — claw.

Vasates leonthodontis (Lindroth) Roivainen, 1951
Aceria? leonthodontis (Lindroth) Amrine & Stasny, 1994

Protogyne female (fig.1, 3a–c):

170 (135–185) long, 65 (55–65) wide, slightly fusiform, pinkish to white in colour. Rostrum 22 long; anthapical seta 5 long. Chelicerae 20 long, almost straight, shield 32 long, subtriangular, with long median line, two admedian, two submedian lines, with broken lines and dots laterally; without lobe over rostrum. Dorsal tubercles 24 apart, situated on rear shield margin; dorsal setae 60 long, directing to the rear and diverging. Foreleg 35 long, tibia 8 long, tarsus 7 long, claw 9 long, unknobbed, featherclaw 8 long, 5-rayed. Hindleg 32 long, tibia 7 long, tarsus 6 long. Sternum 10 long, forked posteriorly. First forecoxal tubercles 8 apart, setae 6 long, second tubercles 7 apart, 20 long. Hindcoxal tubercles 22 apart, 50 long.

Opisthosoma of 77 (62–78) microtuberculate rings. Microtubercles evenly distributed and pointed, ventrally rounded. Last 15 rings without microtubercles dorsally. Lateral setae 30 long, their tubercles 55 apart, on sternite 16; first ventral setae 80 long, tubercles 42 apart, on sternite 34; second ventral setae 20 long, tubercles 22 apart, on sternite 55; third ventral setae 30 long, tubercles 22 apart on ring 7 from the rear. Accessory setae 7 long. Female genitalia 14 long, 22 wide; coverflap with 14 striae; genital setae 30 long, tubercles 18 apart.

Male:

162 long, shield 29 long, opisthosoma of 66 microtuberculate rings; genitalia 19 wide; genital setae 14 long; tubercles 15 apart.

Deutogyne female (fig. 2, 3d–f):

157 (157–165) long, 52 wide, 70 thick, slightly fusiform, pale orange in colour. Rostrum 21 long with 5 long anthapical setae. Chelicerae 20 long, almost straight. Shield 33 (32–35) long, triangular, with long median line, 2 long admedian lines and 2 submedian lines 2/3 of median line long, with some broken lines laterally, without lobe over rostrum. Dorsal tubercles 25 apart situated on rear shield margin, dorsal setae 70 long directed to the rear and diverging. Foreleg 37 long, tibia 6 long, tarsus 6 long, claw 9 long, unknobbed, featherclaw 8 long, 5-rayed. Hindleg 32 long, tibia 6 long, tarsus 6 long. Sternum 6 long. First forecoxal tubercles 12 apart, setae 13 long; second forecoxal tubercles 6 apart, setae 25 long; hindcoxal tubercles 22 apart, setae 60 long.

Opisthosoma of 41 (38–48) smooth tergites and 56 (44–63) microtuberculate sternites. Microtubercles prominent and oval, lateral setae 25 long, their tubercles 45 apart, on sternite 8; first ventral setae 70 long, tubercles 38 apart on sternite18; second ventral setae 22 long, tubercles 20 apart on sternite 31; third ventral setae 30 long, tubercles 20 apart on ring 5 from the rear. Accessory setae 9 long. Female genitalia 15 long, 21 wide, coverflap with 12 striae; genital setae 22 long, tubercles 18 apart.

Host plant:

Cirsium arvense (L.) Scop. (*Asteraceae*)

Relation to the host plant:

Free living between leaf hairs on the undersurface of leaves, or on the surface of capitula, causing the change of colour to pale brownish when numerous, and dwarf capitula of the host.

Additional Data

In addition to the typical protogyne (=*A. anthocoptes*) and deutogyne (= *A? leonthodontis*) form, a "transitional" form was also identified, in which the dorsal microtuberculation occurs only on the first 20 tergites (fig. 4a–c).

A male similar to the deutogyne form (=*A? leonthodontis*) was not observed.

The measurement of more than 40 quantitative characteristics of both female forms of *A. anthocoptes* (Nal.) did not show any essential differences compared to the measured characteristics quoted by other European authors (Table 1).

The variation of the selected characteristics within one population for both forms of *A. anthocoptes* are shown in Table 2. The only essential differences compared to reference data, are expressed in the deutogyne form of *A. anthocoptes* in the length of lateral setae, which is between 32 and 50 according to reference data, while the specimens from Belgrade range between 18 and 29. The ratio of sternites and tergites is also smaller on average compared to reference data,

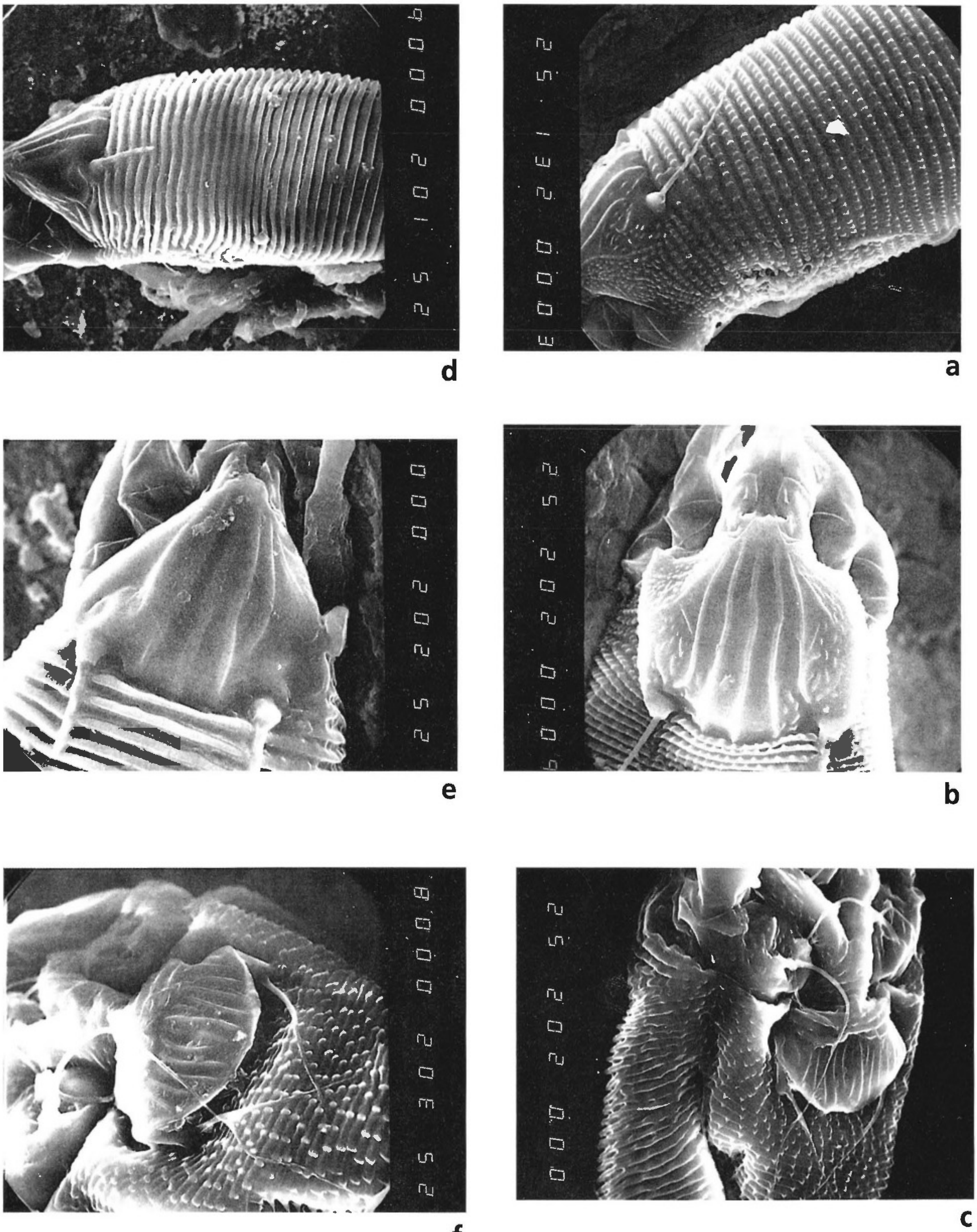
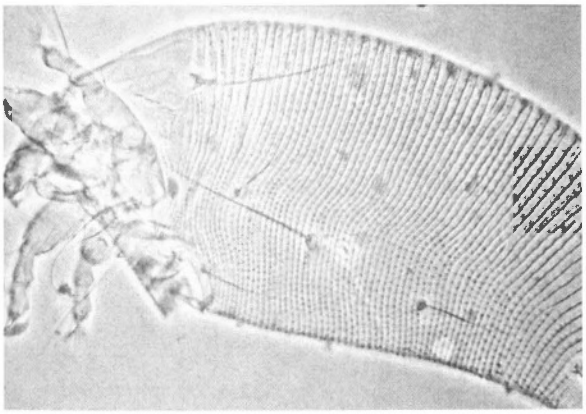
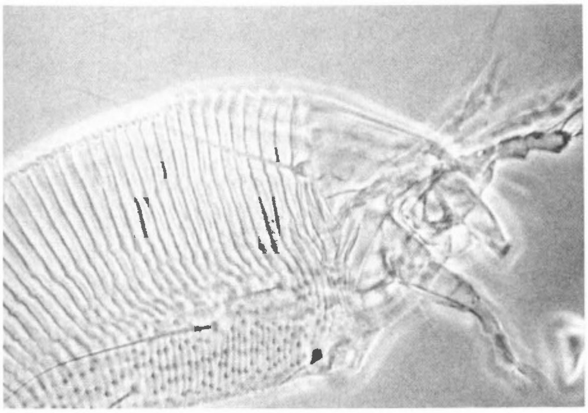


FIG. 3: SEM photographs of two forms of *Aceria anthocoptes*.

a. — Side view of anterior section of protogyne form. b. — Dorsal shield of protogyne form. c. — Ventral microtuberculation on anterior section of protogyne. d. — Side view of anterior section of deutogyne. e. — Dorsal shield of deutogyne form. f. — Ventral microtuberculation on anterior section of deutogyne form.



a



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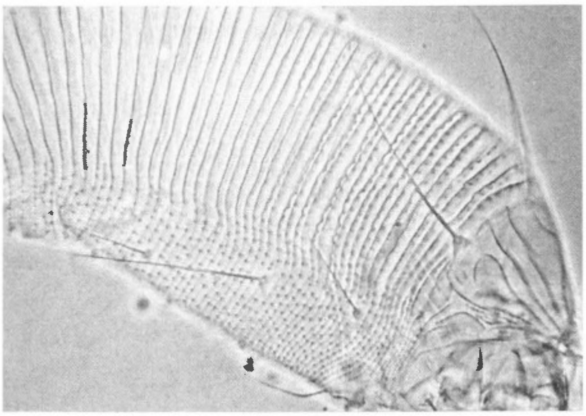

c

FIG. 4: Phase-contrast micrographs of *Aceria anthocoptes*.
a. — Side view of anterior section of typical protogyne form. b. — Side view of anterior section of deutogyne form. c. — Side view of anterior section of "transitional" form.

but their upper values (1.55) are within the limits of measurements by other European authors.

Field observations

By monitoring the preferential feeding places, host-plant colonization, vertical distribution on the stem and horizontal distribution on the leaf surface, as well as the types of damage, it was observed that the species *A. anthocoptes* prefers the upper parts of the plant during the vegetation, colonizing the abaxial sides of upper leaves and inflorescences. It lives and feeds between the hairs, and its population is much more numerous on the varieties of *Cirsium arvense* with hairy abaxial sides of leaves. The distribution of individuals per leaf area is more or less uniform, which is the consequence of their free life (Table 3). Eggs were observed on the abaxial side, between hairs, at the base of inflorescences and on the surface of still unopened capitula, as well as in leaf axils. They were laid individually and irregularly arranged. By making the preparations throughout the year, the percentage of each form in a population was assessed. It can be seen from table 3 that the protogyne form (= *A. anthocoptes*) is present throughout the year and that it is the only form present in summer months, whereas the deutogyne form always appears in the autumn and dominates in the spring. During the winter, individuals were observed on the thickened root shoots underground. They are active in early spring as soon as the first leaves unfold, and subsequently they occur on new seedlings. Field observations did not prove any intensive damage to the host-plants. The colour of the leaves changed to pale brownish, and the capitula were dwarfed. On the mowed areas, leaf curling was observed on the new young shoots, and the consequence of curling was the deformation of the entire young plants.

DISCUSSION AND CONCLUSIONS

As was mentioned in the introduction, two species have been so far identified on species of the genus *Cirsium*: *Aceria anthocoptes* and *A.? leonthodontis*. The species *A. anthocoptes* has been so far recorded on *Cirsium arvense*, *C. heterophyllum* (L.) All. and *C. lanceolatum* (L.) Scop., and *A.? leonthodontis* (Lin-

Literature source	*A. anthocoptes*		*A. leonthodontis*					
	L D Se	No. R	L D Se	L L Se	L I. V Se	No. T	No. S	S/T
NALEPA, 1892	1.5 × shield length	60-65	–	–	–	–	–	–
NALEPA, 1910	- " -	65	45	41-50	41-50	32	50	1.56
LINDROTH, 1904	–	–	45	40-50	40–50	32	50	1.56
ROIVAINEN, 1951	–	–	60-80	30	70	36-39	55-60	1.52-1.53
FARKAS, 1965	60	65	90	–	–	34	–	–
NATCHEFF, 1981	65	68	78	32	65	38	58	1.52
PETANOVIĆ, 1988	50	75	–	–	–	–	–	–

L D Se — Length of dorsal setae; No R — Number of rings; L L Se — Length of lateral setae; L I. V Se — Length of I. ventral setae; No. T — Number of tergites; No. S — Number of sternites; S/T — Sternite-tergite ratio. All measurements expressed in µm.

TABLE 1: Comparative data for some quantitative characters of *Aceria anthocoptes* (Nal.) and *A.? leonthodontis* (Lindroth), according to the literature.

Character	Protogyne form				Deutogyne form			
	min	max	M ± SE	CV ± MV	min	max	M ± SE	CV ± MV
L D Se	45	63	53.77 ± 1.17	9.78 ± 1.54	49.5	76.5	61.95 ± 1.47	10,41 ± 1,57
No. R	62	78	71.25 ± 1.03	6.48 ± 1.02	–	–	–	–
L L Se	–	–	–	–	18	28.8	24.03 ± 0.63	11,73 ± 1,85
L I. V Se	–	–	–	–	49.5	72	59.88 ± 1.43	10,40 ± 1,68
No. T	–	–	–	–	38	48	42.09 ± 0.69	7,50 ± 1,15
No. S	–	–	–	–	44	63	54.71 ± 1.05	8,81 ± 1,35
S/T	–	–	–	–	1.07	1.55	1.29 ± 0.09	31,78 ± 4,90

L D Se – Length of dorsal setae; No R – Number of rings; L L Se – Length of lateral setae; L I. V Se – Length of I. ventral setae; No. T – Number of tergites; No. S – Number of sternites; S/T — Sternite-Tergite Ratio.

TABLE 2: Statistical parameters of some morphological characters of two forms of *Aceria anthocoptes* (n = 20) (in µm).

Vertical distribution per stem			Horizontal distribution per leaf area			Date
upper part (10 cm)	middle part (10 cm)	lower part (10 cm)	base of leaf (1 cm wide)	middle part	apical part	
68.36	23.59	8,04	25,61	40.67	33,70	7.9 Aug.
			44,18	23,25	32,58	19.10 Oct.
			24,50	40,72	35,09	1.11 Nov.
			38,90	38,56	22,52	5.12 Dec.

TABLE 3: Vertical and horizontal distribution of *Aceria anthocoptes* individuals per stem and leaf area respectively (in%).

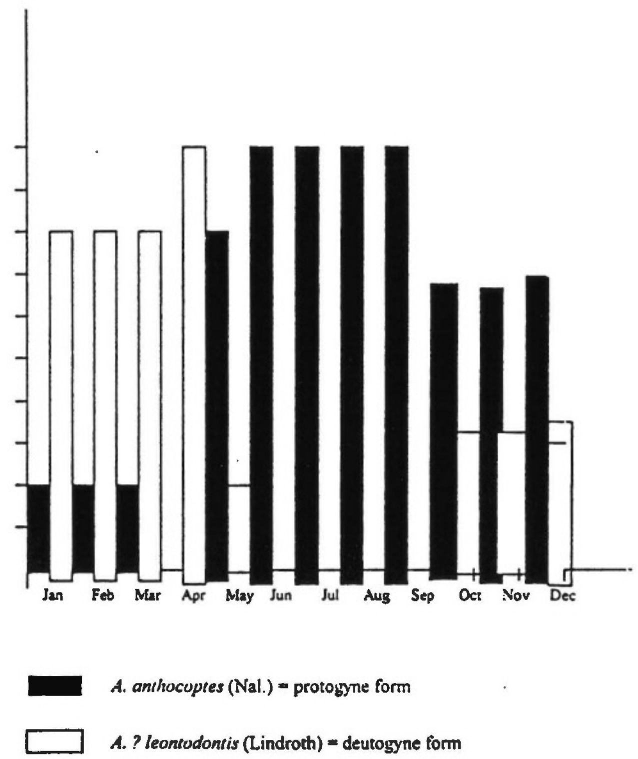

FIG. 5: Seasonal dynamics of two female forms of *Aceria anthocoptes.*

droth) on *Leonthodon autumnalis* L., *C. arvense* and *C. heterophyllum* (L.) All.

The original description (NALEPA, 1892), as well as the subsequent ones (NALEPA, 1910), included a relatively low number of quantitative characteristics and were mainly based on their relative values. CANESTRINI (1892) and ROIVAINEN (1950) only quoted the presence of this species in Italy, or Sweden, and the deformations caused. FARKAS (1965), in the illustrated key of eriophyids in Central Europe, gave several new elements of description and illustration, stating that of 65 tergites only 42 have microtubercles, the others being smooth. The other data were a compilation of the original description. Only NATCHEFF (1981) gave a more detailed description of this species and presented, along with qualitative data, additional data for about 20 measured characteristics. FARKAS (1965) and PETANOVIĆ (1988) recorded the presence and the dimensions of the male of this species, without giving more detailed characteristics.

According to NALEPA (1892), *A. anthocoptes* (Nal.) causes the hardening of green inflorescences, and sometimes also the formation of additional capitula on *Cirsium arvense*. ROIVAINEN (1950) stated that this species is partly free-living on the abaxial side of the leaves, and partly the agent of the characteristic numerous dwarfed capitula of the host plant. He also claimed that, on some Canada thistle individuals, eriophyids seem to be entirely free-living, causing the change of colour to pale brownish when numerous, but not any other damage.

NATCHEFF (1981), discussing the relationship to the host plant, claims that *A. anthocoptes* individuals are encountered on the abaxial side of leaves, close to the nerves; their number is low, from three to nine individuals per leaf. The leaves with more numerous eriophyids turn reddish-brown. Inflorescence deformations were not observed in Bulgaria.

The description of the species *A.? leonthodontis* (Lindroth) includes about 30 characteristics with more precisely measured data. All the subsequent descriptions (NALEPA, 1910, ROIVAINEN, 1951, NATCHEFF, 1981) are also more detailed compared to those for *A. anthocoptes*, which permits the comparisons and comments. Great differences occur in the length of dorsal, lateral and first ventral setae (Tab.1). According to the original description (LINDROTH, 1904), this species causes leaf curl, erineum (early in the season) and it is free-living and causes rust (later in the season). The description mentions two forms: the so called eriophyine form (after the subfamily Eriophyinae) which occurs in the summer and the phyllocoptine form (after the subfamily Phyllocoptinae) which is encountered in the autumn. ROIVAINEN (1951) and NATCHEFF (1981) consider that this species is free-living on leaves, and when the population is more numerous, it causes a slight change of colour to brown. LINDROTH (1904) and NALEPA (1910) gave the dimensions of the males of this species, but they did not indicate the characteristics pertaining to its form.

Bearing in mind the pronounced similarity of the essential qualitative and measured characteristics, such as ornamentation of the dorsal shield and epigynium, number of rays on the featherclaws, the similarity of the majority of measured characteristics and the absence of clear, characteristic symptoms on the host plant, ROIVAINEN (1951) proposed the hypothesis of the possible synonymy of these two species.

Based on the results of two-year research of eriophyid morphology and the essential elements of bioecology of eriophyids associated with *Cirsium arvense*, we are of the opinion that the two species are synonymous and that *A. anthocoptes* represents a protogyne, *A.? leonthodontis* a deutogyne form of the female of the same species. It should be named *Aceria anthocoptes* (Nal.) in accordance with the principle of the priority (International Code of Zoological Nomenclature).

The main arguments for the synonymization of the two species are as follows:

1. The only essential differences between them are the number and appearance of opisthosomal rings, the appearance and spacing of sternal microtubercles and the lateral ornaments of the dorsal shield. The absence of dorsal microtuberculation and the different form and arrangement of ventral microtubercles is one of the adaptive characteristics of the overwintering-deutogynous forms of eriophyids that, by decreasing the surface of the body also reduces the adverse effects of desiccation and cooling.

2. The absence of a male similar to the female of the species *A.? leonthodontis*, i.e. the exclusive presence of a male similar to the female of the species *A. anthocoptes*.

3. The presence of a "transitional" form with dorsal microtubercles on only one fourth of the body.

4. Based on measurements of more than 40 quantitative characteristics of both female forms of *A. anthocoptes*, the majority of them did not show any essential differences, compared to the measured characteristics quoted by other European authors.

The results of the variation of the selected characteristics within one population for both forms of *A. anthocoptes* indicate that the only essential differences, compared to the reference data, are observed in the deutogyne form of *A. anthocoptes* in the length of lateral setae, which is between 32 and 50 according to references, and the specimens from Belgrade ranged between 18 and 29. The ratio of sternites and tergites is also lower on the average, compared to reference data, but their upper value (1.55) is within the limits obtained in measurements by other European authors.

Such a ratio of sternites and tergites is a crucial argument that the species in synonymization should not be named *Vasates anthocoptes* (Nal.), as was suggested by ROIVAINEN (1951), because one of the distinctive characteristics of the subfamily Phyllocoptinae, to which the genus *Vasates* belongs, is the ratio of sternites and tergites above 1.5 or higher, and a thicker lobe over rostrum compared to the genus *Aceria* (subfamily Eriophyinae) or the presence of lateral lobes on tergites.

5. The seasonal alteration of the two forms within the population, which incontestably confirms that it is one species and not two sympatric species.

6. The absence of characteristic symptoms, free life on the surface, predominantly between leaf hairs on the abaxial surface of upper leaves and on capitula, as well as the relatively uniform distribution of individuals on the leaf surface, point out that it is not justified to ascribe the symptoms of green inflorescence hardening and formation of additional capitula predominantly to the species *A. anthocoptes*, and the discoloration to the species *A.? leonthodontis*. Both forms are free-living between leaf hairs, on the stem and on capitula, causing according to our observations a light discoloration of leaves to pale brown, as well as dwarfing of the capitula. Leaf curl was also observed on young plants when more intensively infested.

ACKNOWLEDGEMENTS

We would like to thank Miss Suzana JOVANOVIĆ and Mr Miloš BOKOROV for technical assistance, and Mrs Ana TONIĆ for translating the manuscript. This work was supported by a grant from the Serbian Fund of Science.

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