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Three new *Aceria species* (Acari: Eriophyoidea) on *Centaurea* spp. (Asteraceae) from Turkey

ABSTRACT

During 2001 and 2002, we examined Turkish populations of eriophyid mites infesting *Centaurea solstitialis* L. and *C. squarrosa* Willd. (Asteraceae). The analyses of the morphometric data, induced symptoms, and the morphological comparison with the descriptions of known species allowed us to identify three new *Aceria* species, here described and illustrated.

Aceria solcentaureae and *A. solstitialis* were collected on *C. solstitialis*, and *A. squarrosae* was associated with *C. squarrosa* in Cappadocia. Infested plants were stunted, showing reduced growth, a heavy broom-like appearance being bushy, with the apical parts of the stems and flowerheads still green and fresh during the hot and dry season, less spiny than usual, and producing smaller seedheads.

Additional information is given about the ecology of these associations and on the potential role of these eriophyids as control agents.

Key words: mites, Eriophyidae, weeds, knapweeds, biological control.

INTRODUCTION

Plants of the genus *Centaurea* are collectively referred to as knapweeds and starthistles. The genus comprises over 1,000 species of predominantly Eurasian origin (WAGENITZ, 1975; ROCHÉ & ROCHÉ, 1991). The interest on herbivores of these *Centaurea* spp. is very relevant on the basis of the "weed" status assigned to some of these host plants that were accidentally introduced in North America during the mid-1800s (FORNASARI *et al.*, 1993; ROSENTHAL, 1996; PIPER, 2001). Many of them, such as *C. diffusa* Lam. (diffuse knapweed),

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The first author provided with the morphological and taxonomic studies of the species, the other two authors collected several samples and made ecological observations.

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C. solstitialis L. (yellow starthistle), *C. squarrosa* Willd. (squarrose knapweed), and *C. calcitrapa* L. (purple starthistle), are highly invasive. Several attempts have been made to find an efficient eriophyoid in controlling these hosts without the application of an establishment program of any enemy in the infested areas (SOBHIAN *et al.*, 1989; CASTAGNOLI & SOBHIAN, 1991).

Ten species of eriophyid mites have been reported on plants belonging to the genus *Centaurea* (Asteraceae): *Aculops centaureae* (Farkas) and *Epitrimerus jaceae* Liro are considered vagrant species; *Aceria acroptiloni* Kovalev & Shevtchenko, *A. calathidis* (Gerber), *A. grandis* (Nalepa) and *A. paniculatae* (Cotte) cause severe deformations of flower- and seedheads; similar damages are reported for *A. prima* (Cotte); *A. brevisetosa* (Cotte) and *A. centaureae* (Nalepa) cause blistering on leaves and stems; *A. thessalonicae* Castagnoli causes abnormalities in growth, with broomlike appearance (Amrine & de Lillo, unpublished electronic database).

None of these species have been found so far on *Centaurea solstitialis* in the field, and only *A. centaureae* was able to develop stable populations on this target weed during laboratory host specificity tests (SOBHIAN *et al.*, 1989).

Unfortunately, most of the eriophyid occurrences on different *Centaurea* species have been recorded only on the basis of the symptoms observed on the hosts, without any morphological specific identification of the associated mite populations. Therefore, *A. centaureae* seems to have a large geographical and host distribution (Amrine & de Lillo, unpublished electronic database) that needs confirmation.

During 2001-2002 two of us began surveys of *Centaurea* spp. in Turkey, attempting to find additional biological control agents mainly against yellow starthistle. The purpose of the present paper is to describe new eriophyid mites found on these plants, and to report ecological observations.

MATERIALS AND METHODS

Specimens were recovered from dried and ethanol (70%) preserved plant materials; they were prepared and slide mounted according to Keifer's method (KEIFER, 1975). Lindquist's (1996) terminology and setal notation of the morphological details have been adopted in the descriptions. All measurements of mites were made according to Amrine and Manson (1996), are given in micrometers, and measurements and means are rounded off to the nearest integer; range values are given in brackets. The generic classification was made according to Amrine (1996) and Hong and Zhang (1997).

Type materials are deposited at the Dipartimento di Biologia e Chimica Agro-forestale e Ambientale (Di.B.C.A.), Entomological and Zoological Section, University of Bari, Italy.

DRAWING ABBREVIATIONS

AP1, internal female genitalia; CS, lateral view of the caudal region; DA, dorsal view of the prodorsal shield; E, empodium; ES, lateral view of annuli; GF, coxal and genital region of a female; L, foreleg; SA, lateral view of the anterior region.

***Aceria squarrosae* de Lillo, Cristofaro et Kashefi**

Female (fig. 1) - Body wormlike, colour whitish, 227 (195-240, n = 10) long, 41 (35-48) wide and 45 (40-50) thick. Gnathosoma 27 (24-28) projecting obliquely downwards, chelicerae 23 (20-26) long, seta *d* 7 (6-7) long. Prodorsal shield 27 (24-30) long, 27 (24-33) wide, semielliptical in anterior shape with anteromedian lobe over gnathosoma base 6 (5-7) long; shield pattern composed of median line, admedian, and submedian lines; submedian lines curved, ending posteriorly in a space between the posterior end of the admedian line and the *sc* tubercle. A few dashes are included between the admedian field, many dashes are on the median fields. Tubercles *sc* are on the rear shield margin 21 (19-24) apart, *sc* setae 47 (42-50) long.

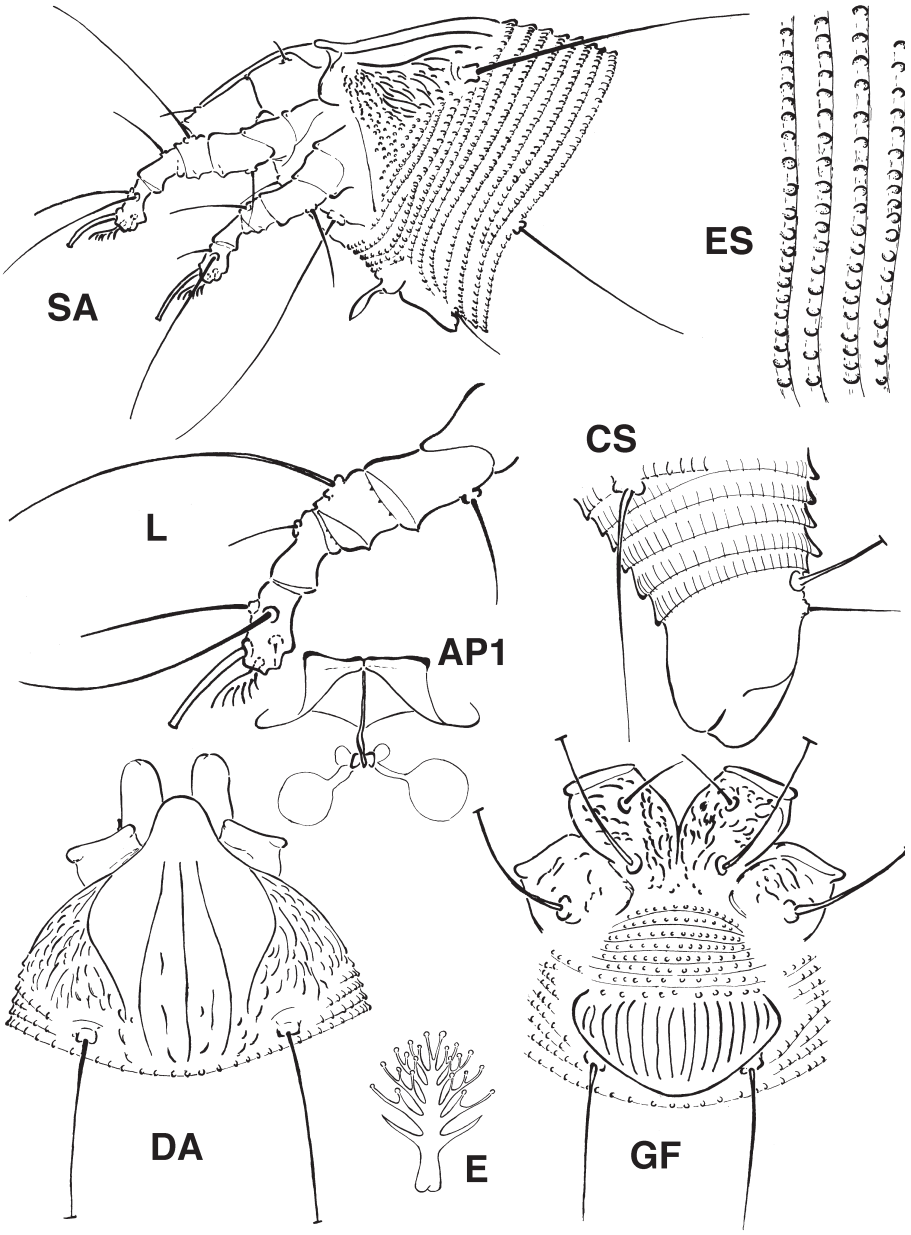
Foreleg 31 (27-34) long, tibia 7 (5-8) long, tarsus 7 (6-8) long, *w* 8 (8-9) long distally rounded, empodium simple, 6 (5-6) long, 6-rayed. Hindleg 26 (25-28) long, tibia 5 (4-5) long, tarsus 6 (5-7) long, *w* 10 (9-10) long distally rounded, empodium simple, 6 (5-6) long, 6-rayed.

Coxae ornamented by short striae; *1b* setae 13 (12-15) long, *1b* tubercles 10 (8-12) apart, *1a* setae 23 (21-25) long, *1a* tubercles 8 (7-9) apart, *2a* setae 48 (45-52) long, *2a* tubercles 20 (19-23) apart. Prosternal apodeme 4 (4-5) long.

Opisthosoma with 61-75 annuli. Microtubercles rounded on the rear margins of the annuli. Setae c_2 29 (23-33) long on annuli 8-10, *d* 60 (55-65) long on annuli 22-27; *e* 22 (20-27) long on annuli 38-44; *f* 22 (20-25) long on annuli 58-69. Last 5-6 annuli with elongated and linear tubercles ventrally. Setae h_2 76 (66-80) long very thin at the apex, h_1 7 (6-8) long.

Genitalia 12 (10-14) long, 21 (20-22) wide. Female genital coverflap with 12-18 striae; *3a* 16 (14-18) apart, 20 (18-22) µm long.

Male - Similar to the female, 176 (165-185 n = 4 specimens) long, prodorsal shield 27 (27-28) long; *sc* setae 38 (36-42) long; opisthosoma with 61-62 annuli.



15-17 striae; *3a* 25 (23-27) apart, 27 (24-31) long.
Fig. 1 - *Aceria squarrosae* de Lillo, Cristofaro et Kashefi: semischematic drawings.

Host plant - *Centaurea squarrosa* Willd. (Fam. Asteraceae), squarrose knapweed.

Habitus: infested plants were stunted, showing reduced growth, a heavy broom-like appearance being bushy, with the apical parts of the stems and flowerheads still green and fresh during the hot and dry season, less spiny than usual, and producing smaller seedheads.

Type locality - 30 km from Askary, on the road from Nevsehir to Aksery (38°29.39 N, 34°16.20 E), Cappadocia, Turkey.

Type material - Holotype: 2 females on a slide, dated 30, July 2001; Paratypes: many slides prepared from material collected in the same locality on the same date.

Collected by - Kashefi J.

Other material - Ethanol preserved stems and leaves from which the above slides were made.

Aceria solcentaureae **de Lillo, Cristofaro et Kashefi**

Female (fig. 2) - Body wormlike, colour whitish, 278 (243-310, n = 10) long, 72 (63-78) wide and 64 (50-75) thick. Gnathosoma 27 (22-30) projecting obliquely downwards, chelicerae 24 (22-28) long, seta *d* 9 (7-10) long. Prodorsal shield 40 (36-43) long, 39 (35-42) wide, semicircular in anterior shape with anteromedian lobe over gnathosoma base 6 (5-7) long; shield pattern composed of median line, admedian, and submedian lines; the submedian lines end about 1/4 before the rear prodorsal shield margin. Some short dashes are included between the lines, many dashes are on the median fields. Tubercles *sc* are on the rear shield margin 32 (28-35) apart, *sc* setae 50 (45-55) long.

Foreleg 40 (36-44) long, tibia 10 (9-11) long, tarsus 9 (8-10) long, *w* 10 (9-10) long distally rounded, empodium simple, 7 (7-8) long, 5-rayed. Hindleg 33 (26-38) long, tibia 8 (7-8) long, tarsus 8 (7-9) long, *w* 10 (9-11) long distally rounded, empodium simple, 7 (7-8) long, 5-rayed.

Coxae ornamented by short striae and coarse granules; *1b* setae 13 (11-14) long, *1b* tubercles 16 (15-18) apart, *1a* setae 28 (24-30) long, *1a* tubercles 14 (11-14) apart, *2a* setae 56 (50-62) long, *2a* tubercles 31 (29-34) apart. Prosternal apodeme 8 (6-9) long.

Opisthosoma with 74-87 annuli. Pointed microtubercles on the rear margins of the annuli. Setae c_2 30 (24-35) long on annuli 9-10, *d* 63 (50-72) long on annuli 25-28; *e* 24 (20-31) long on annuli 42-48; *f* 23 (21-24) long on annuli 68-79. Last 6-7 annuli with elongated and linear tubercles ventrally. Setae h_2 59 (50-65) long very thin at the apex, h_1 5 (4-6) long.

Genitalia 22 (18-25) long, 33 (30-35) wide. Female genital coverflap with

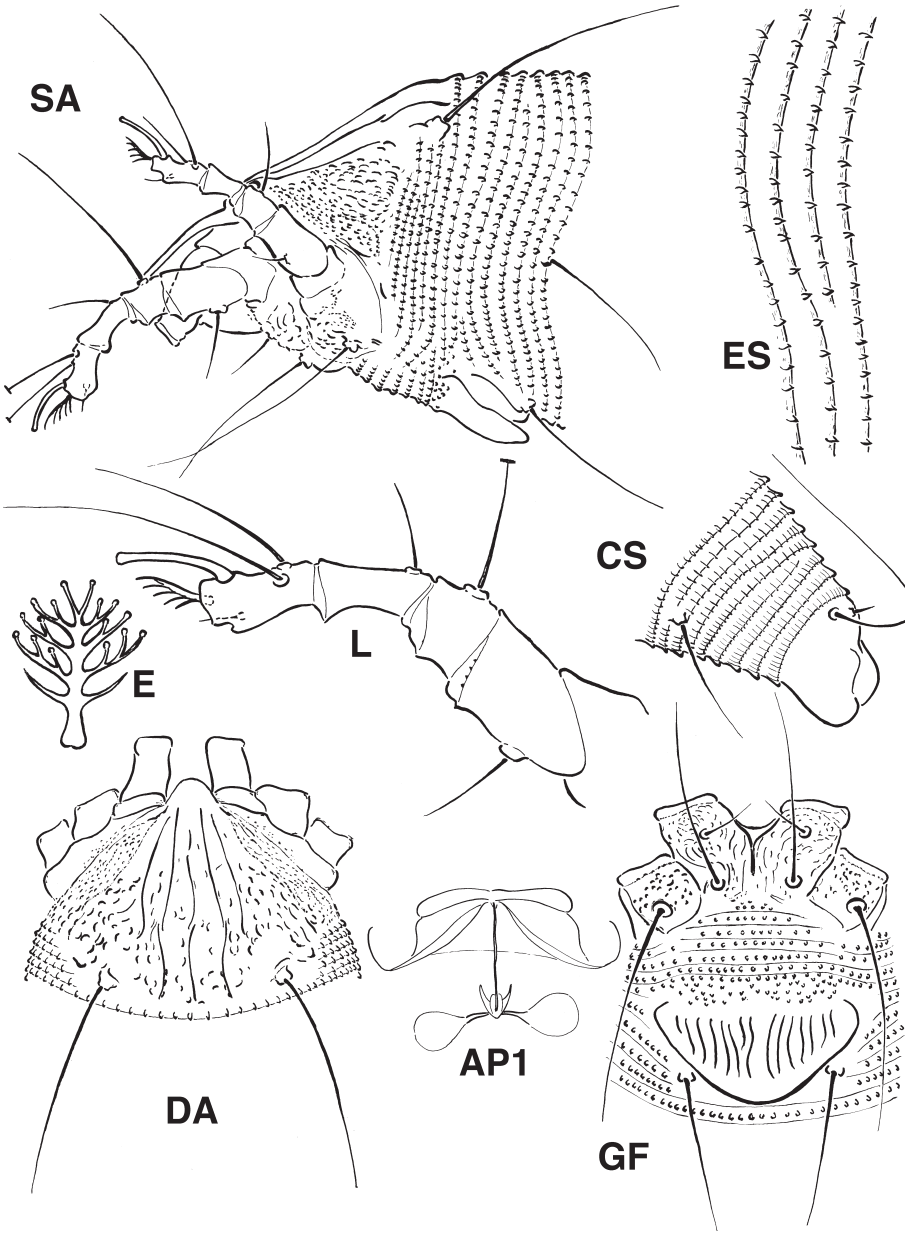


Fig. 2 - *Aceria solcentaureae* de Lillo, Cristofaro et Kashefi: semischematic drawings.

Male - Similar to the female, 247 (220-260 n = 3 specimens) long, prodorsal shield 40 long; *sc* setae 39 (38-41) long; opisthosoma with 72-73 annuli.

Host plant - *Centaurea solstitialis* L. (Fam. Asteraceae), yellow starthistle.

Habitus: infested plants were stunted, showing reduced growth, a heavy broom-like appearance being bushy, with the apical parts of the stems and flowerheads still green and fresh during the hot and dry season, less spiny than usual, and producing smaller seedheads.

Type locality - Goreme (38°39.87 N, 35°49.73 E), near Kayseri, Cappadocia, Turkey.

Type material - Holotype: 5 females and 1 male on a slide, dated 2, August 2001; Paratypes: many slides prepared from material collected in the same locality on the same date.

Collected by - Kashefi J.

Other material - Ethanol preserved stems, flowerheads and leaves from which the above slides were made.

Aceria solstitialis **de Lillo, Cristofaro et Kashefi**

Female (fig. 3) - Body wormlike, colour whitish, 235 (215-280, n = 10) long, 47 (43-50) wide and 46 (40-56) thick. Gnathosoma 28 (27-30) projecting obliquely downwards, chelicerae 23 (20-26) long, seta *d* 8 (6-10) long. Prodorsal shield 35 (31-38) long, 35 (33-38) wide, semielliptical in anterior shape with anteromedian lobe over gnathosoma base 6 (5-8) long; shield pattern composed of a median, admedian, and submedian lines; the submedian lines do not reach the rear prodorsal shield margin. A few dashes are included between the admedian field close to the rear prodorsal shield margin, many dashes are on the median fields. Tubercles *sc* on the rear shield margin 27 (20-30) apart, *sc* 42 (38-45) long.

Foreleg 35 (30-40) long, tibia 8 (7-8) long, tarsus 7 (6-7) long, *w* 10 (8-11) long distally rounded, empodium simple, 7 (6-8) long, 6-rayed. Hindleg 31 (28-34) long, tibia 6 (5-9) long, tarsus 7 (5-8) long, *w* 12 (10-13) long distally rounded, empodium simple, 8 (7-8) long, 6-rayed.

Coxae ornamented by short striae and coarse granules; *1b* setae 12 (10-14) long, *1b* tubercles 15 (13-15) apart, *1a* setae 23 (20-25) long, *1a* tubercles 10 (9-13) apart, *2a* setae 47 (40-50) long, *2a* tubercles 27 (25-30) apart. Prosternal apodeme 6 (5-8) long.

Opisthosoma with 76-90 annuli. Rounded microtubercles on the rear margins of the annuli. Setae c_2 21 (19-26) long on annuli 11-15, *d* 52 (45-60)

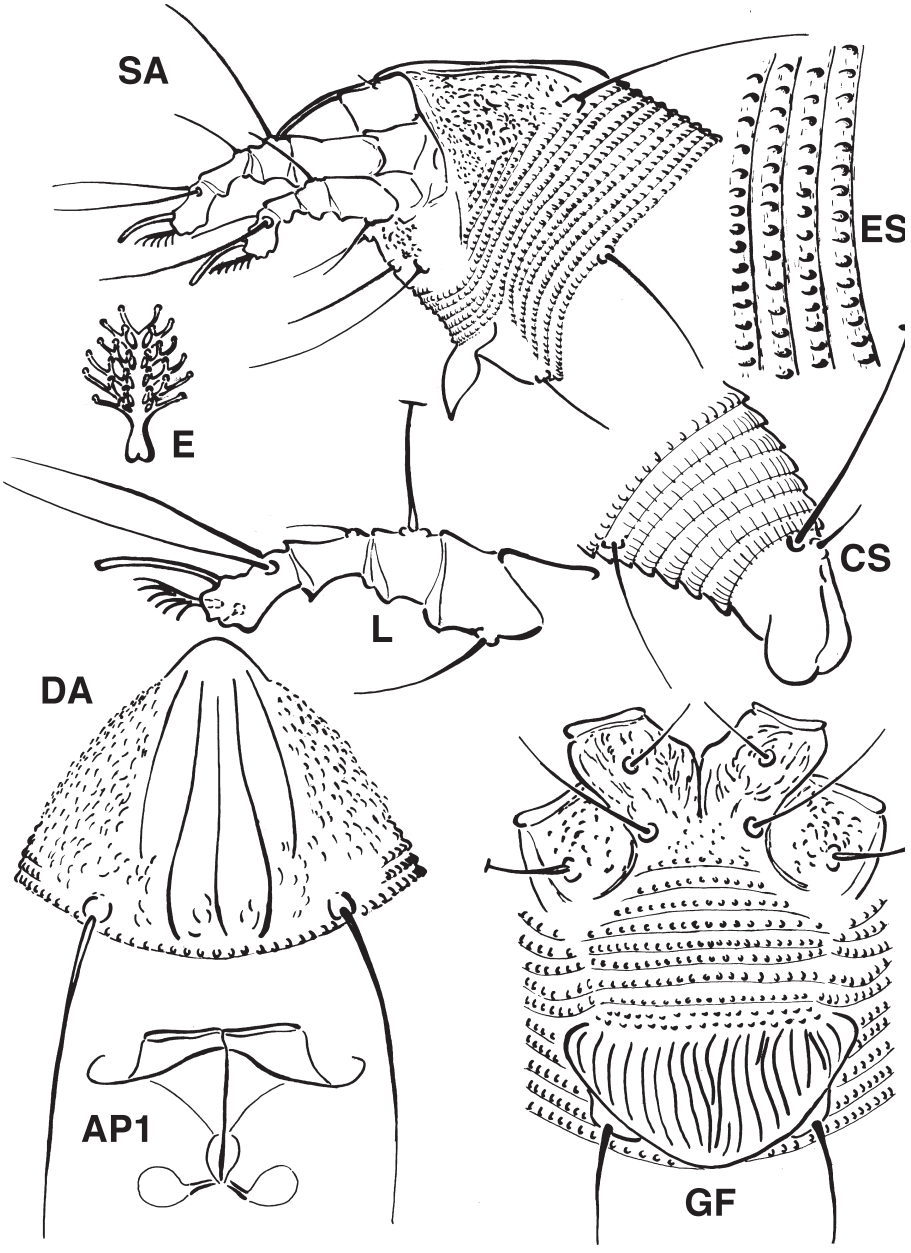


Fig. 3 - *Aceria solstitialis* de Lillo, Cristofaro et Kashefi: semischematic drawings.

long on annuli 29-33; *e* 15 (12-19) long on annuli 48-52; *f* 16 (15-20) long on annuli 70-79. Last 5-6 annuli with elongated and linear tubercles ventrally. Setae h_2 51 (42-65) long very thin at the apex, h_1 5 (5-6) long.

Genitalia 18 (15-20) long, 27 (22-30) wide. Female genital coverflap with 17-20 striae; *3a* 21 (18-24) apart, 16 (11-20) long.

Male - Similar to female, 176 (160-185 n = 6 specimens) long, prodorsal shield 29 (25-32) long; *sc* 32 (28-36) long; opisthosoma with 64-77 annuli.

Host plant - *Centaurea solstitialis* L. (Fam. Asteraceae), yellow starthistle.

Habitus: infested plants were stunted, showing reduced growth, a heavy broom-like appearance being bushy, with the apical parts of the stems and flowerheads still green and fresh during the hot and dry season, less spiny than usual, and producing smaller seedheads.

Type locality - on the road from Nevsehir to Aksaray, about 1200 m a.s.l., Cappadocia, Turkey.

Type material - Holotype: 2 females and 1 male on a slide, dated 25 September, 2001; Paratypes: many slides prepared from material collected in the same locality on the same date. Another population collected in Goreme, Central Cappadocia, Turkey on 21 June, 2002.

Collected by - Cristofaro M., Tronci C.

Other material - Ethanol and dried preserved stems, flowerhead and leaves from which the above slides were made.

TAXONOMIC REMARKS

The three new *Aceria* differ in the prodorsal shield pattern from all *Aceria* spp. found up to now on knapweeds (fig. 4). Unfortunately, no semischematic drawings are available for *A. prima*, *A. paniculatae*, and *A. brevisetosa* and the description of this group is somewhat incomplete. *Aceria brevisetosa* comes from *A. centaureae* var. *brevisetosa*; *A. prima* comes from *A. calathidis* var. *primus*. Both species were elevated to binomial status by Amrine and Stasny (1996). The length and the arrangement of the lines are quite similar for all drawn *Aceria* spp. infesting *Centaurea* spp., even if the median and admedian lines are briefly interrupted in *A. solcentaureae* and *A. acroptiloni*, the submedian lines reach the prodorsal shield rear margin in *A. calathidis*, and more than a pair of submedian lines are present in *A. centaureae* [more evident in Nalepa's drawings (Nalepa, 1891)] and in *A. acroptiloni,* though they are very short. All the examined specimens of the populations of the new *Aceria* species consistently have granules or dashes in the space between the median and the admedian lines, which have not been observed in the other

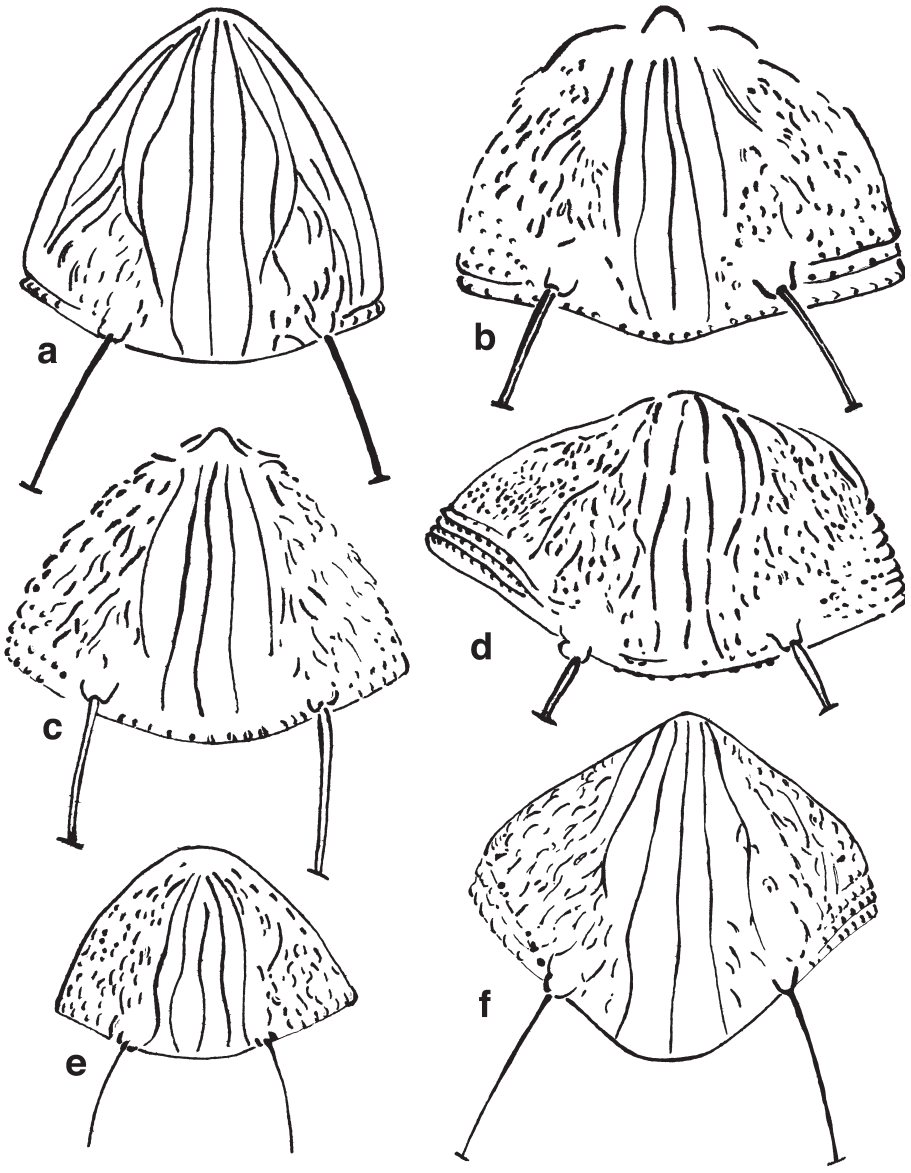


Fig. 4 - Prodorsal shield of *Aceria centaureae* a) redrawn from Nalepa (1891), b) redrawn from Castagnoli and Sobhian (1991); c) *Aceria thessalonicae* redrawn from Castagnoli and Sobhian (1991); d) *Aceria acroptiloni* protogyne redrawn from Kovalev *et al.* (1974); e) *Aceria calathidis* redrawn from Gerber (1901); f) *Aceria grandis* from Nalepa (1904).

species.

Some differences in other characters are summarized in Table 1.

No comparison can be made with *A. brevisetosa* because the description is inadequate. Cotte (1924) stated that this mite is longer than *A. centaureae* and has shorter setae without adding any other morphological comment on the identification. Balas (1941) simply recorded this mite on *C. jacea* L. in Hungary.

According to Gerber (1901) and Farkas (1965), *A. calathidis* has short *sc* and h_2 setae and the ratio between *sc* seta and prodorsal shield length is less than one, the empodium is 4-rayed; these details do not match the species here described. Other differences regard the ratio between *sc* and c_2 setal length.

The morphometric data reported by Nalepa (1891), and Castagnoli and Sobhian (1991) regarding *A. centaureae*, *A. thessalonicae*, and *A. acroptiloni* are not in accordance with the new Turkish *Aceria* regarding the ratio of many characters (Tab. 1).

The original description of *A. grandis* (Nalepa, 1900, 1904), except for differences in the drawings of the prodorsal shield pattern, indicates a population with c_2 seta length about equal to the prodorsal shield (such as *A. squarrosae*, but different from the other two species), seta *e* a bit shorter than *f* (such as in *A. solcentaureae*, but differing from the other two species), h_2 seta short, and a 5-rayed empodium (as in *A. solstitialis*, but differing from the other two species).

Cotte's (1924) description of *A. paniculatae* points out *sc* setae just a bit longer than the prodorsal shield length (similar to *A. solstitialis*), c_2 and *sc* setae similarly long and a bit shorter than *d* setae, a 4-rayed empodium (not matching any Turkish species), and a few other differences.

The description of *A. prima* (Cotte, 1924) does not match the Turkish *Aceria* for the *sc*, *d*, *3a* setae length, and the empodial rays.

ECOLOGICAL ASPECTS

The mite populations of these new *Aceria* were found in Cappadocia, a peculiar highland region of Central Turkey, characterized by dry continental weather. They occur in dry open habitats, with sandy or rocky soil, on stunted plants showing reduced growth (15-20 cm tall instead of 70 cm tall), and a heavy broom-like and bushy appearance. The apical stems and the inflorescences appear fresh and green during the hot and dry season, and the smaller seedheads have flexible, soft spines (fig. 5). First symptoms were observed on rosettes in early June, while the distortion of flowerhead spines appeared in early July. Galled plants remained green in the field for a longer period compared with healthy plants, until the end of September. The

Tab. 1 – Main differences between mean values of some morphological traits for some *Aceria* spp. living on *Centaurea* spp. This table has been partly modified from Castagnoli & Sobhian (1991).

	Aceria squarrosae	*Aceria solicentaureae*	*Aceria solstitialis*	*Aceria thessalonicae* - Castagnoli Sobhian, 1991	*Aceria centaureae* - Castagnoli & Sobhian, 1991	*Aceria acroptiloni* summer female - Kovalev *et al.*, 1974	*Aceria acroptiloni* spring female - Kovalev *et al.*, 1974
body length/width	4.8	3.8	4.3	3.1	4.5		
prodorsal shield length/ prodorsal shield width	1.0	0.8	0.9	>1.5	>1.5	0.7	0.8
sc seta length/ prodorsal shield length	1.6	1.3	1.3	1.8	1.9	1.3	1.3
c_2 seta length/ prodorsal shield length	1.0	0.8	0.6	0.9	0.9	1.0	0.7
e setae length/ *f* setae length	1.0	1.1	0.8	1.2	0.5	1.1	0.8
d setae length/ *e* setae length	2.8	2.9	3.5	2.3	4.7	3.0	3.6
d setae length/ *f* setae length	2.9	3.0	3.0	2.7	2.2	3.3	2.9
1b setae length/ *1a* setae length	0.6	0.5	0.5	0.6			
hindleg length/ *w* II length	2.6	3.3	2.6	2.9	3.8	3.4	2.3
foreleg length/ *w* I length	3.5	4.1	3.5	3.5	2.4	3.9	2.5
sc setae length/ *sc* tubercles distance	2.3	1.7	1.8	2.3	2.8	1.5	1.7
w II length/ empodium II length	1.7	1.6	1.8	1.8	1.3		
w I length/ empodium I length	1.4	1.5	1.5	1.6	2.3		
tibia II length/ tarsus II length	0.8	0.8	0.8	0.7	0.9	0.9	0.8
tibia I length/ tarsus I length	0.9	0.8	1.0	0.9	1.0	1.2	1.0
genital setae length/ *e* setae length	0.9	1.1	1.1	0.7	1.5	1.0	1.1
body length/ *sc* setae length	4.3	5.0	4.9	3.3	4.0		

damage apparently causes a reduction of biomass, especially for young plants. The most typical damage is the distortion and failure of flowerheads to develop, consequently reducing seed production. Unfortunately, these symptoms are similar to all *Aceria* found on *Centaurea* in Turkey, so it is not possible, at least at present, to clearly distinguish these species based on symptomology of infested plants. Moreover, no plants have been found containing populations of both *A. solstitialis* and *A. solcentaureae*. Nor, do we have reason to presume the presence of a deutogyne stage. More field observations and laboratory tests are needed to provide a better understanding of these mites.

Certainly, these symptoms cannot be confused with those produced by *A. centaureae* and *A. brevisetosa*, which induce blister galls, discoloration, etc., on the leaves of many *Centaurea* spp. (COTTE, 1924; CASTAGNOLI & SOBHIAN, 1991).

DISCUSSION S AND CONCLUSIONS

Three new eriophyid mite species have been described on *C. solstitialis* and *C. squarrosa*. They induce similar effects on the developmental growth of stems and flowerheads. Similar symptoms and morphology have been previously observed for other *Aceria* found on other knapweeds. This fact (slight morphological differences between the eriophyids infesting closely related host plants) might be explained by the large number of *Centaurea* species and by a co-evolutionary process that has been inducing a pool of sibling *Aceria* species specifically adapted to each plant species.

Eriophyid mites are considered extremely important for biological control of weeds (BRIESE & CULLEN, 2001). In this specific case, their narrow host range, combined with a strong impact on the target plant, multivoltine life cycle and great fertility, give these agents the possibility to play a key role in controlling both annual and perennial knapweeds. Their attack often produces an apparent decrease of the biomass and seed production of target weeds.

A large scale study of the eriophyoid species associated with the knapweeds is needed to discover effective agents in the biological control strategy against *Centaurea* in North America, considering the apparent high degree of host plant specificity. A DNA molecular approach would be of benefit, confirming the host specificity and helping in the evaluation of the tested species (FENTON, 2002).

AKNOWLEDGEMENTS

Fig. 5 - *Centaurea solstitialis* L. showing symptoms produced by *Aceria solstitialis* (above), and *Aceria solcentaureae* (below).

We wish sincerely to thank Mrs. M. Baldari, who provided her precious skill in arranging the slide materials, Dr. C. Tronci (BBCA, Italy), who collected samples of *Centaurea solstitialis* L. from Turkey, Dr. M. Castagnoli (Istituto Sperimentale di Zoologia Agraria of Florence, Italy), who allowed access to her *A. centaureae* slides, and who along with Prof. J.W. Amrine Jr. (Division of Plant and Soil Sciences, West Virginia University, U.S.A.), and Dr. L. Smith (USDA ARS, Albany, Ca., USA) critically reviewed the manuscript.

RIASSUNTO

TRE SPECIE NUOVE DI *ACERIA* (ACARI: ERIOPHYOIDEA) SU *CENTAUREA* SPP. (ASTERACEAE) DALLA TURCHIA

Durante il biennio 2001-2002, campioni di *Centaurea solstitialis* L. e *C. squarrosa* Willd. (Asteraceae) a sviluppo alterato sono stati raccolti in Turchia ed esaminati per individuarne le cause. L'analisi dei dati morfometrici della popolazione di eriofidi rinvenuta e la comparazione di questi e della sintomatologia con le altre specie note sul gruppo delle *Centaurea* hanno consentito di individuare 3 nuove specie di Eriophyidae appartenenti al genere *Aceria*.

Sono state, quindi, descritte e illustrate *A. solcentaureae* e *A. solstitialis,* raccolte su *Centaurea solstitialis*, e *A. squarrosae* rinvenuta su *C. squarrosa*. Le piante infestate mostravano una crescita stentata e ridotta in altezza, ad aspetto cespitoso e affastellato, con le parti apicali dei fusti e delle infiorescenze ancora verdi e fresche nel periodo caldo e secco, con capsule provviste di "spine" morbide ed elastiche, e con una minore produzione di semi.

Informazioni aggiuntive vengono riportate circa gli aspetti ecologici di questa associazione e il potenziale impiego delle specie come agenti di controllo biologico.

Key words: acari, Eriophyidae, erbe infestanti, controllo biologico.

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