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Field assessment of host plant specificity and potential effectiveness of a prospective biological control agent, *Aceria salsolae*, of Russian thistle, *Salsola tragus*

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ARTICLE INFO

Article history:

Received 21 June 2008

Accepted 21 November 2008

Available online 11 December 2008

Keywords:

Acari
Eriophyidae
Weed control
Chenopodiaceae
Field assay
Nontarget host
Host plant specificity
Kochia
Aceria salsolae
Tumbleweed

ABSTRACT

The eriophyid mite, *Aceria salsolae* de Lillo and Sobhian, is being evaluated as a prospective classical biological control agent of invasive alien tumbleweeds, including *Salsola tragus*, *S. collina*, *S. paulsenii* and *S. australis*, in North America. Previous laboratory experiments to determine the host specificity of the mite indicated that it could sometimes persist and multiply on some nontarget plants, including *Bassia hyssopifolia* and *B. scoparia*. These are both European plants whose geographic range overlaps that of the mite, but the mite has never been observed on them in the field. A field experiment was conducted in Italy to determine if the mite would infest and damage these plants under natural outdoor conditions. The results indicate that this mite does not attain significant populations on these nontarget plants nor does it significantly damage them. *Salsola tragus* was heavily infested by *A. salsolae*, and plant size was negatively correlated to the level of infestation. Although *S. kali* plants were also infested, their size did not appear to be affected by the mites. The other nontarget plants were not as suitable for the mite in the field as in previous laboratory experiments. We conclude that there would be no significant risk to nontarget plants as a result of using *A. salsolae* as a biological agent to control *Salsola* species in North America.

Published by Elsevier Inc.

1. Introduction

Aceria salsolae de Lillo and Sobhian (Acari: Eriophyidae) was first collected from plants of *Salsola tragus* L. (sensu lato) (Chenopodiaceae) in Turkey (de Lillo and Sobhian, 1996). It is known to also occur in Greece, Uzbekistan (de Lillo and Sobhian, 1996) and possibly Iran (R. Sobhian personal communication), but is probably more widespread. It has only been collected on *S. tragus* (sensu lato), but there has been no recorded effort to look for the mite on other plant species. *Salsola tragus* (Russian thistle) and some of its close relatives are invasive alien weeds in North America that are the target of a classical biological control program (Goeden and Pemberton, 1995; Smith et al., 2007). There is much confusion in the literature regarding the taxonomy of these plant species. For example, Rilke (1999) listed 55 synonyms of *S. tragus*, and the names *S. kali* L. and *S. australis* R.Br. have been mistakenly used for this species in the literature pertaining to *A. salsolae* (de Lillo and Sobhian, 1996; Sobhian et al., 1999). Recent revisions and molecular genetic techniques have helped to clarify the tax-

onomy of these plants (Mosyakin 1996, 2003; Rilke, 1999; Ryan and Ayres, 2000; Hrusa and Gaskin, 2008). The principal species that are invasive in the United States are *S. tragus*, *S. collina* Pallas, *S. paulsenii* Litvinov, *S. australis* R. Brown (Mosyakin, 2003) and some of their hybrids (Ayres et al., 2005; Hrusa and Gaskin, 2008). *Salsola tragus*, *S. collina* and *S. paulsenii* probably evolved in Central Asia and are considered to be native over large areas of Eurasia (Bochantsev, 1969; Rilke, 1999). *Salsola kali* has two subspecies (*kali* and *pontica* [Pallas] Mosyakin) whose native range is generally restricted to the saltwater beaches of Europe (Rilke, 1999; Mosyakin, 2003). *Salsola australis*, which was previously synonymized with *S. tragus* (Rilke, 1999), has just been redescribed (Hrusa and Gaskin, 2008). This species is unknown in Eurasia (Ryan et al., 2007) and may possibly be native to Australia, which is surprising considering its morphological and genetic similarity to *S. tragus*. *Salsola australis* previously has been called “type B” by some authors (Ryan and Ayres, 2000; Sobhian et al., 2003; Ryan et al., 2007). Akhani et al. (2007) recently placed all these species, with the possible exception of *S. australis* which was not studied, in the resurrected genus *Kali*, based on cladistic analysis of molecular genetic data. However, it is not certain that this name will be accepted, so in conformity with existing literature the name *Salsola* is used in this paper.

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Because eriophyoid mites are generally highly host-specific (Boczek and Petanovic, 1996; Rosenthal, 1996; Briese and Cullen, 2001), *A. salsolae* is being evaluated as a prospective biological control agent of *S. tragus*. A population of the mite collected on *S. tragus* near Kozani in northern Greece (500 m elevation) was used in quarantine laboratory experiments to determine host plant specificity and potential impact (Smith, 2005). No-choice experiments on 41 species of Chenopodiaceae demonstrated that the mite could multiply only on *S. tragus*, *S. paulsenii*, *S. collina*, *S. australis* (“type B”) and the hybrid *S. x ryanii* Hrusa (“type C”). These plants all belong to the *Salsola* section *kali* subsection *kali* (Rilke, 1999). Subsequent laboratory experiments showed that the mite could sometimes multiply on *Bassia* (= *Kochia*) *scoparia* (L.) A.J. Scott, *Bassia* (= *Kochia*) *hyssopifolia* (Pallas) Kuntze and *Suaeda calceoliformis* (Hook.) Moq. (Smith, unpublished data). Plant nomenclature is based on the *Flora Europaea* (Tutin et al., 1976). Because the first two species are relatively common ruderal plants in Eurasia and this mite had never been reported from them, it is possible that the laboratory results overestimated the ability of this mite to feed and reproduce on these plants under field conditions. Because little is known about the life history of eriophyoid mites and their ability to survive and reproduce on “nonhost” plants, and because of the low tolerance for damage to non-target plants by introduced biological control agents (USDA-APHIS 1998; Louda et al. 2003), it is important to determine if the mite can multiply on these nontarget plant species in the field.

The purpose of this study was to evaluate the ability of *Aceria salsolae* to infest and multiply on nontarget plant species considered to be at risk in the field, and to measure its potential impact on the target plant, *S. tragus*, to determine if it would be suitable for introduction as a classical biological control agent.

2. Materials and methods

2.1. Plants

The experiment was conducted in a 1 ha tilled field on the campus of ENEA C.R. Casaccia (Institute of New Technology for Energy and the Environment) research center near Rome, Italy in 2007. *Bassia hyssopifolia*, *B. scoparia*, *S. calceoliformis*, *S. kali* and *S. tragus* plants were grown from seed in flower pots starting in mid March, 2007. On 12–13 June, potted plants were set in holes in the garden arranged in a pseudo Latin square design (six plant “treatments” [including “inoculated” and “uninoculated” *S. tragus*], 12 replicates, 6 rows × 12 columns) (Fig. 1). Plants were 1 m apart, and the ground was covered with white plastic to prevent growth of weeds. Plants were watered as needed using a drip irrigation system. By 25 June, some *B. scoparia* and *S. calceoliformis* plants were beginning to senesce. Senescing plants were replaced by young plants of *B. scoparia* and *S. calceoliformis* on 17 July. Two plants of *S. vera* J.F. Gmel. (= *fruticosa*) were planted on 17 July as replacements for dead *S. calceoliformis*. One plant of *Chenopodium album* L. that was growing in the test garden was also sampled in September.

2.2. Mite inoculation

In this paper, the term “inoculated” refers to plants to which infested *S. tragus* cuttings were attached and “infested” to plants which contained mites. Because mites must move from the cuttings onto and remain on inoculated plants, these plants may or may not become infested. Furthermore, because mites naturally disperse by wind, plants that were not experimentally inoculated could become infested. Naturally-infested *S. tragus* plants were collected from the

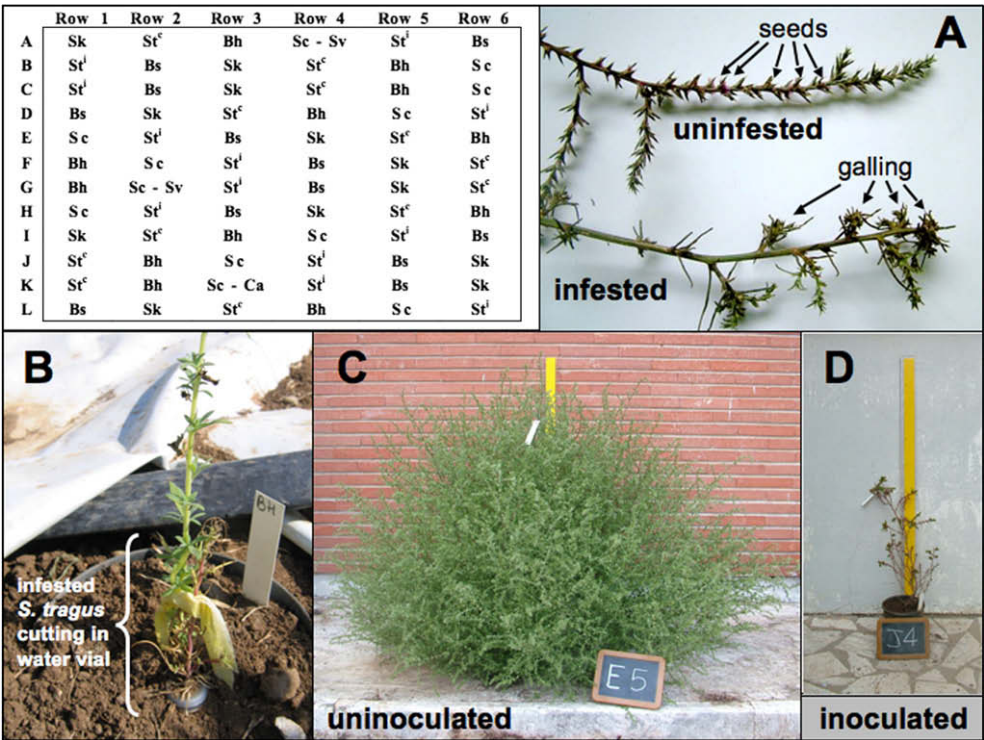


Fig. 1. Position of plants in experimental field garden near Rome Italy (Bh, *Bassia hyssopifolia*; Bs, *B. scoparia*; Ca, *Chenopodium album* (replacement by volunteer); Sc, *Suaeda calceoliformis*; Sk, *Salsola kali*; Stⁱ, *S. tragus* (not inoculated); Stⁱ, *S. tragus* (inoculated); Sv, *Suaeda vera* (replacement in July)). Effect of *A. salsolae* infestation on development of *S. tragus* (A). Placement of infested *S. tragus* cutting in water vial to inoculate *B. hyssopifolia* test plant (B). Typical size of plants at the end of the experiment on 17 October: E5 = uninoculated *S. tragus* (C), J4 = inoculated *S. tragus* (D), meter stick in background.

field in Kozani, Greece on 12 June and held at cool temperature (5–15 °C) until they were used to inoculate the test plants. Individual stems under a stereo microscope and only stems with at least 10 live mites were used. On 15 June, an infested cutting, which was inserted in a water vial (Fig. 1B), was attached to each nontarget plant and to half the *S. tragus* plants. After completion of the first sampling of mites on the test plants (described below), the inoculation procedure was repeated on 23 July using infested *S. tragus* cuttings collected in Kozani, Greece on 19 July, to provide sustained exposure of plants to the mite. The mean number of mites counted on the July cuttings was 194 (± 31 SE), but this was probably an underestimate because it is not possible to see all the mites present during quick visual counts. Counting all mites would require either destruction of the cuttings or a laborious extraction process that removes mites from the plant, both of which complicate the procedure to inoculate plants. Precise numbers of mites were not considered necessary to ensure that each plant was exposed to mites. After one week (30 July), water was no longer added to the inoculation cutting water vials to encourage the mites to disperse, and the cuttings were removed after they dried.

2.3. Mite sampling

Between 16 and 23 July, a sample of five 10-cm apical branch cuttings was collected from each of the *S. tragus* plants, from five of the *S. kali* plants, and from one of each of the other plant species to assess the success of the inoculation procedure. Mites that were motile were recorded as being alive. Cuttings were first examined for presence of live mites at 30 \times magnification, then all mites were extracted from the cutting using a soapy solution and counted (Monfreda et al., 2007). On 13 September a sample of five 10-cm branch cuttings was collected from each plant and held in a refrigerator until mites were extracted and counted. Specimens were identified by E. de Lillo and R. Monfreda, and voucher specimens are held at the Entomological and Zoological Section, Bari University, Bari, Italy. Plant height and diameter were recorded at the time of the two mite collections on 16 July and 13 September. Plant “volume” was calculated by the formula for an ellipsoid solid (volume = $4/3 \cdot \pi \cdot \text{height} \cdot [\text{diameter}/2]^2$). Any signs of damage by mites or other organisms, presence of predators (especially mites), and plant developmental stage (flowers or fruits) were also recorded.

On October 17 all the plants were harvested for measurement of wet weights of the whole plant and the root. To obtain dry weights, whole plants were dried in paper bags at 60–65 °C until the weight stabilized, which took 3–6 days.

2.4. Statistical analysis

Differences in numbers of mites per sample (five 10-cm branch cuttings) were transformed by square root ($Y + 0.5$) and differences among means were tested using planned contrasts in analysis of variance (ANOVA) (Abacus Concepts, 1998). Linear regression was used to determine if mite density was related to plant size (height, diameter, volume, wet weight of plant, wet weight of root, root wt./plant wt. ratio, dry weight of plant). A negative exponential model was used to fit the relationship of mite numbers to plant volume of *S. tragus* using nonlinear regression (StatSoft, 1998).

3. Results and discussion

On 16 July, most of the first inoculation cuttings in water vials were still alive and had live (i.e., motile) mites, indicating that the test plants had been exposed to mite infestation for 1 month. Numbers of live mites were highest on the inoculated *S. tragus*, followed by *S. kali* and uninoculated *S. tragus* (Fig. 2A). One live mite was found on the one plant of *S. calceoliformis* sampled in July, but none were present on five plants sampled in September. The total number of mites (live or dead) in July was highest on *S. kali*, followed by inoculated *S. tragus* plants (Fig. 2B). Trace numbers of mites were on the other plant species. However, mites occurred on 83% of the uninoculated *S. tragus* plants in July, indicating that the mite was dispersing naturally throughout the field, presumably carried by wind (Bergh, 2001; Duffner et al., 2001). By September, all of the 12 uninoculated *S. tragus* plants were infested. Mite densities increased substantially on inoculated *S. tragus* and *S. kali*, but remained extremely low on the three nontarget plant species, *B. hyssopifolia*, *B. scoparia*, and *S. calceoliformis*. The number of live mites per sample for a given plant species did not differ significantly between July and September ($P > 0.05$), which suggests that live mites disperse as the population increases, maintaining a fairly constant density. The total number of mites (live and dead) also did not differ between July and September for the three nontarget

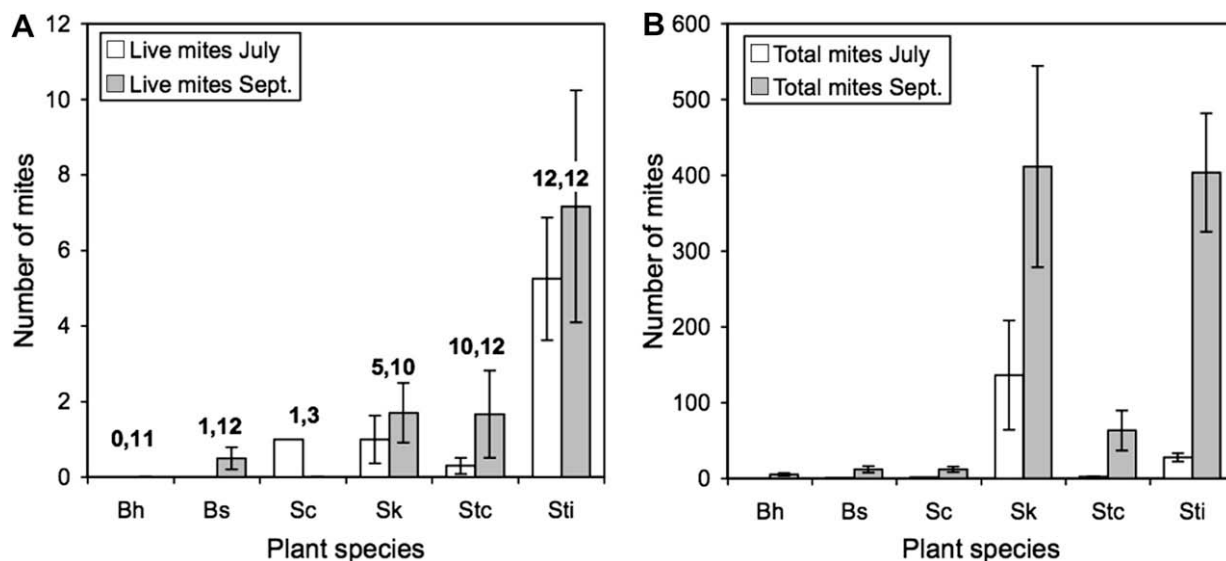


Fig. 2. Number of live (i.e., motile, A) and total (live and dead, B) eriophyid mites per sample (five 10-cm branch tips) in July (1 month after the first inoculation) and in September (2 months after the second inoculation) (mean \pm SE). Bh, *Bassia hyssopifolia*; Bs, *Bassia scoparia*; Sc, *Suaeda calceoliformis*; Sk, *Salsola kali*; Stc, *Salsola tragus* (not inoculated); Sti, *Salsola tragus* (inoculated). Numbers above columns are number of plants sampled in July, number in September.

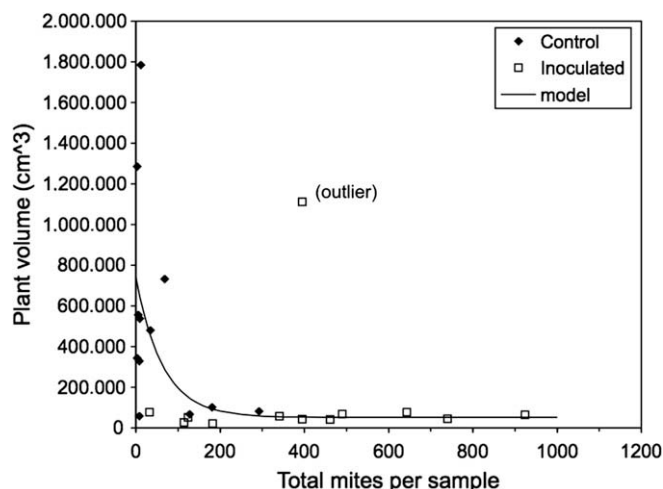


Fig. 3. Relationship of size of *Salsola tragus* plants in September to total number of eriophyid mites per sample in September. Negative exponential equation fitting the data (omitting the outlier point): $\text{plant vol} = 688,358 * \exp(-0.015571 * \text{Mites}) + 51,936$.

plants; however, it increased on the three types of *Salsola* plants. This suggests that when the mites multiply on a plant, the density of live mites at the branch tips remains fairly constant, but that large numbers of dead mites are left behind. This explains why only 2% of the mites found on the host plant, *S. tragus*, in September were alive. The extremely low numbers of mites (dead or alive) found on the three nontarget plants is consistent with the hypothesis that when mites arrive on these plants they do not stay and multiply, but rather depart in search of a suitable host plant or are consumed by predators (McMurtry, 1984).

Of the two *S. vera* plants that were transplanted and inoculated in July, and sampled in September, one plant had no mites and one plant had one mite which was lost before identification. One *C. album* plant that grew at the location of a dead *S. calceoliformis* plant had four mites that were a species of *Aceria* different from *A. salsolae*.

The mites caused substantial damage to infested *S. tragus* plants, as indicated by the extremely small volume of plants that had more than about 100 mites per sample (Fig. 3). The one plant labeled “outlier” had a highly variable number of mites on its branch cuttings, suggesting that the mites were not well established on this plant. This plant was in the northwest corner of

the field, which was the lowest part of the field in elevation, but there was no obvious reason why it had fewer mites. The relationship of mites per sample to final plant volume was fit by the negative exponential equation: $\text{plant volume} = A * \exp(-B * \text{mites}) + C$, where $A = 688,358 \pm 197,530$ (SE), $B = 0.015571 \pm 0.013212$, and $C = 51,936 \pm 124,422$; $R^2 = 0.38$. The parameters represent: A, volume of uninfested plants; C, volume of heavily infested plants; and B, exponential rate of decrease in plant volume related to total number of mites per five 10-cm long branch tips. The exponential relationship between mite density and plant size suggests that a relatively small number of mites can effectively prevent the plant from growing, whereas a linear relationship would suggest that mite impact is directly proportional to the photosynthate that they are consuming. The mites kill growing meristems (Smith, 2004a, 2005), which amplifies the impact of relatively low numbers of mites. Plant volume was highly correlated to dry weight (dry wt. = $0.072 * \text{vol} - 215.3$, $P = 0.0001$, $R^2 = 0.91$) and wet weight (wet wt. = $0.091 * \text{vol} - 205.5$, $P = 0.0001$, $R^2 = 0.83$), so a similar relationship to mite density applies to these parameters. The height of *S. tragus* plants did not significantly change during the period from 16 July to 13 September (paired *T*-test, $P > 0.05$), regardless of whether or not inoculated, as indicated by proximity of points along the unity line ($Y = X$ in Fig. 4A). However, canopy diameter of uninoculated plants generally increased ($P < 0.01$), whereas that of inoculated plants did not (Fig. 4B). Although the data indicate that the impact of mites on *S. tragus* was primarily to reduce plant diameter, this corresponded to plants with a markedly reduced apparent size (Figs. 1C and D and 3).

Comparison of inoculated to uninoculated plants also showed significant impacts on the size of *S. tragus* plants. Inoculated plants had 20% the weight (wet or dry) of uninoculated plants (wet weights: $196 \pm 138[\text{SE}]$ g vs. 984 ± 293 g, $P < 0.03$; dry weights: 136 ± 109 g vs. 695 ± 227 g, $P < 0.04$) and their wet root weight was 36% that of uninoculated plants (5.0 ± 1.1 g vs. 14.1 ± 3.4 g; $P < 0.02$). The ratio of root weight to plant weight was 169% higher in inoculated than uninoculated plants (0.086 ± 0.17 g vs. 14.1 ± 3.4 g; $P < 0.02$), reflecting that mite inoculation reduced aerial biomass (80% reduction) more than root biomass (64% reduction). Inoculated plants had 40% the volume of uninoculated plants (4633 ± 1295 cm³ vs. $11,593 \pm 2267$ cm³; $P < 0.02$). Plant height did not differ, but the diameter of inoculated plants was 49% that of uninoculated plants (36.3 ± 7.7 cm vs. 74.1 ± 9.7 cm; $P < 0.01$). All these estimates of mite impact are conservative, because they include one unusually large inoculated plant

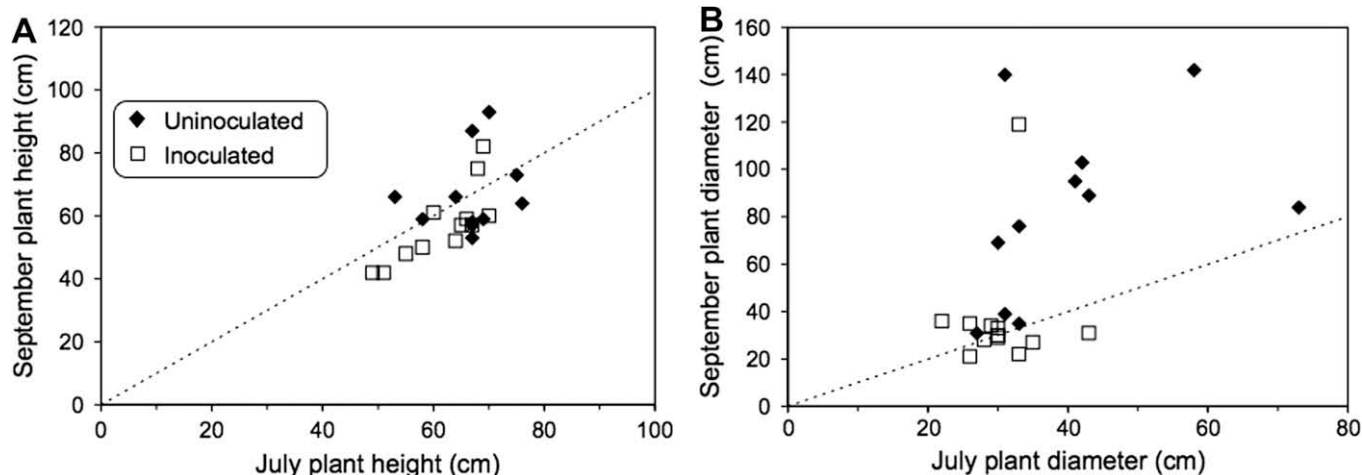


Fig. 4. Growth of inoculated and uninoculated *Salsola tragus* as represented by change in height (A) and diameter (B) of individual plants between 16 July and 13 September. Dashed line represents slope of 1, so points lying above it represent increase in size.

(“outlier” in Fig. 3) and three uninoculated plants that had more than 100 mites in September.

The ability of this mite to reduce the size of the target plant will directly reduce the damage that tumbleweeds cause, such as reducing soil moisture in fallow dryland agriculture, disrupting automobile traffic, clogging irrigation systems, piling up against fences and buildings, raising risk of wildfires, and harboring populations of the beet leafhopper (*Circulifer tenellus* (Baker)), Say's stinkbug (*Pitadia sayi* (Stal)) and lygus bug (*Lygus hesperus* Knight) (Smith, 2005). Plants about 0.5 m tall can produce about 1500–2000 seeds, and large plants can produce over 100,000 seeds (Evans and Young, 1972). Because seed production is related to plant size, reducing plant size reduces the potential number of seeds produced per plant (Borger et al., 2007). Tumbleweeds blown by wind disperse seed over distances as far as several kilometers; however, smaller plants do not disperse as well as larger plants (Stallings et al., 1995; Baker et al., 2008). So, reduction of plant size should reduce dispersal ability of the weed. Mite feeding also prevented development of flowers and seeds on *S. tragus* (Fig. 1A). Heavily infested *S. tragus* plants did not produce any seeds, whereas uninfested plants had 34.1 seeds per 10-cm branch tip (± 2.2 SE, $n = 10$; ANOVA, $F_{(1, 18)} = 247$, $P = 0.0001$). So, the mite has the potential to greatly reduce reproduction of *S. tragus*.

There was no visible damage to any of the nontarget plant species nor was there a significant relationship between plant size (height, diameter, or volume) to the number of mites per sample. The fact that *S. kali* maintained high densities of mites without any apparent impact on its growth suggests that this species has a high tolerance to the mite and that the symbiotic relationship between the mite and this plant is balanced (Stowe et al., 2000). The mite has not previously been reported on *S. kali*; however, this may be because there has been little effort to look for mites on this plant. *Salsola kali* subsp. *kali* primarily occurs along the Atlantic and Baltic seashores of Europe, and *S. kali* subsp. *pontica* occurs along the seashores of the Mediterranean and Black Seas, whereas *S. tragus* usually occurs inland (Rilke, 1999). Given that *A. salsolae* apparently can multiply on *S. kali* and that *S. kali* and *S. tragus* occur in different habitats, it would be interesting to know more about the occurrence of this mite on *S. kali* in Eurasia.

Identifications were made of all the mites found on the nontarget plants and a large portion of those found on the *Salsola* species. At least 98.8% of the mites on *S. tragus* and 98.5% of those on *S. kali* were *A. salsolae*, but only 45–74% of those on the nontarget species were *A. salsolae* (Fig. 5). Of all the *A. salsolae* specimens collected,

98% were on *Salsola* species. The other mites have not yet been identified to species level. However, 16 plants were colonized by another species of *Aceria*, representing a total of 53 specimens, including females and males. This *Aceria* sp. was collected from all the plant species sampled except *S. vera*, but only two individuals of this plant species were sampled. The morphometric characters of this mite did not correspond with any described *Aceria* species known to be associated with Chenopodiaceae. The other eriophyid species that were collected were very rare: one *Epitriemeris* specimen each on *B. hyssopifolia* and *S. tragus*, and one *Aculops* specimen on *B. hyssopifolia*; so they appear to be incidental on these plants. Despite inoculating the nontarget plants twice with *A. salsolae*, by the end of the season there were almost as many other mites as *A. salsolae* on the *Bassia* and *Suaeda* plants. This suggests that under a worst case scenario, *A. salsolae* would not be significantly more abundant than other species of mites already present in the environment on these plants.

The level of suitability of plants to a host-specific herbivore is hypothesized to be highly correlated to phylogenetic distance (Wapshere, 1974). Thus plant species that are most closely related to the preferred host plant are expected to be most susceptible to attack. Therefore, knowing phylogenetic relationships of plants to a target of biological control, can help guide the choice of which plants to test, placing highest priority on those with the highest likelihood of risk (Briese and Walker, 2002). According to the most recent phylogenetic analysis, *S. tragus*, *S. paulsenii* and *S. kali* are sister species belonging to the recently resurrected genus *Kali* Miller (Akhani et al., 2007), which is analogous to the previous *Salsola* section *Kali* (Rilke, 1999). *Aceria salsolae* reproduced on four species in this clade: *S. australis*, *S. collina*, *S. paulsenii*, and *S. tragus* in laboratory experiments (Smith, 2004a, 2005). *Bassia* is in a different tribe (Camphorospermae) within the same subfamily (Salsoideae), and *Suaeda* is in a different subfamily (Suaedoideae) (Kapralov et al., 2006; Akhani et al., 2007). Thus, these species are very distantly related to the presumed normal host, *S. tragus*. Two more closely related species, *S. soda* L. and *Halogeton glomeratus* (M. Bieb.) C.A. Mey. (Akhani et al., 2007), which are in a different clade from the *Kali* clade (Akhani et al., 2007), were not suitable for mite multiplication in laboratory experiments (Smith, 2004a, 2005). Failure to find many mites on the *Bassia* and *Suaeda* plants in this field study suggests that other plants that are even more distantly related to *S. tragus* are not likely to sustain this species, which is consistent with results of previous laboratory host specificity experiments (Smith, 2005).

The results indicate that the nontarget plants which were most suitable for development of *A. salsolae* in the laboratory (*B. hyssopifolia*, *B. scoparia* and *S. calceoliformis*) seldom had mites and never in high numbers in the field, despite exposure to two inoculations of *A. salsolae* and to mites dispersing aerially about the field for at least 3 months. No impact was observed on *B. hyssopifolia*, *B. scoparia* or *S. calceoliformis* in the field. We do not expect *A. salsolae* to pose risk of damage to any nontarget plants in North America and recommend that it be approved for release as a biological control agent of *S. tragus*, *S. australis*, *S. paulsenii* and *S. collina*. The highest densities of *A. salsolae* occurred on *S. tragus* and *S. kali*, which are invasive alien weeds in North America, and mites markedly reduced the size of *S. tragus* plants at densities above about 100 mites per five 10-cm branch tips. The failure of the mite to affect the growth of *S. kali* indicates that it would not be a good biological control agent for this plant species. However, in North America, this plant has a very restricted distribution, primarily limited to seashores on the Atlantic and Caribbean coasts (Mosyakin, 2003), and is not an important target for control.

Aculus hyperici Liro, which was introduced to Australia for biological control of St. Johnswort, *Hypericum perforatum* L., provides another example in which an eriophyid mite could colonize a

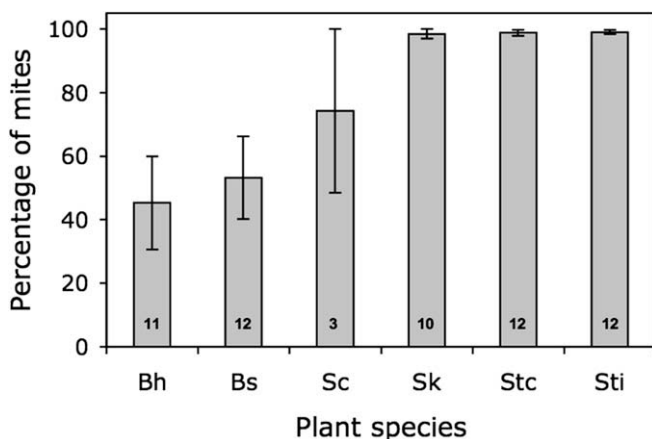


Fig. 5. Proportion of eriophyid mites in September that were identified as *Aceria salsolae* (mean \pm SE). Bh, *Bassia hyssopifolia*; Bs, *Bassia scoparia*; Sc, *Suaeda calceoliformis*; Sk, *Salsola kali*; Stc, *Salsola tragus* (not inoculated); Sti, *Salsola tragus* (inoculated). Numbers on columns are number of plants sampled.

nontarget plant but not cause significant damage (Willis et al., 2003). In greenhouse experiments the mite survived and reproduced on a nontarget native Australian species, *H. gramineum* G. Forst., but did not significantly damage it. In field experiments, nontarget plants were less likely to be colonized, had lower mite populations, and were stressed less than target plants. At least two other species of eriophyids have been observed to colonize nontarget plants in pre-release laboratory experiments: *Aceria malherbae* Nuzzaci and *Phyllocoptes nevadensis* Roivainen (Rosenthal and Platts, 1990; Littlefield and Sobhian, 2000). *Aceria malherbae* was released in 1987 (Rosenthal, 1996) and has become established in parts of the USA, but has not been observed to damage nontarget *Calystegia* spp. in the field (D. Bean and R. Hansen, personal communication). On the other hand, no request to introduce *P. nevadensis* was made because of concerns about nontarget effects, which was prudent considering the currently high aversion to risk (Louda et al., 2003). However, our results on *A. salsolae* and those on *A. hyperici* (Willis et al., 2003) suggest that field experiments can provide a more realistic assessment of the risk of damage to nontarget plants, which may allow regulatory approval of prospective biological control agents which otherwise would be rejected.

Potential indirect nontarget effects (Pearson and Callaway, 2005; Carvalheiro et al., 2008), such as the contribution of *A. salsolae* to the food web, were not directly assessed in this study. However, 14 phytoseiid and 5 tarsonemid mites were incidentally collected in the branch tip samples. These specimens have not been fully identified, and no direct observations regarding predation of *A. salsolae* by these mites were made. Some phytoseiid mites are known to prey on eriophyid mites (Sabelis, 1996), and it is plausible that some tarsonemids may prey on eriophyid mites (Perring and McMurtry, 1996). All the phytoseiids were collected on *S. kali* (12 mites on 4 plants) and *S. tragus* (2 mites on 2 plants), which were the plant species that generally had the most eriophyid mites. However, the overall rarity of these potential predators compared to *A. salsolae* suggests that there was not a strong trophic relationship. Thus, there was no evidence that *A. salsolae* was consumed by predators in this experiment, although this was not the focus of this study. It would be useful to survey for natural enemies of the mite in its natural range and determine susceptibility of the mite to predation, which would compromise its potential to control the target weed (Goeden and Louda, 1976; Smith, 2004b).

Acknowledgments

We thank Javid Kashefi, USDA ARS EBCL, Thessaloniki, Greece for assistance to collect mites in Greece; Francesca Lecce and Franca Di Cristina, BBKA, Rome, Italy, for their help in collecting field samples, and for extracting and counting the mites; and Carlo Tronci and Domenico Charetti, ENEA, Rome, Italy for their help with the field plot. The senior author primarily planned the experiment, assisted collection and release of mites, analyzed the results and wrote the manuscript; the second author supervised execution of the field experiment and collected mites for release; the third and fourth authors assisted mite collection, and prepared and identified the mite specimens; and the fifth author collected field samples, and extracted and counted mites. This research was supported in part by a grant from the California Department of Food and Agriculture.

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