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Observations on the host specificity and biology of *Lixus salsolae* (Col., Curculionidae), a potential biological control agent of Russian thistle, *Salsola tragus* (Chenopodiaceae) in North America

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Abstract: No-choice host specificity tests were performed on *Lixus salsolae* Becker (Col., Curculionidae) in a quarantine green house near Montpellier, France. Several varieties of seven species of economic and ornamental plants from six genera of Chenopodiaceae were tested. Adult feeding was observed on almost all test plants and larvae successfully developed on nine of the eleven species/varieties tested. Sex ratio of field-collected overwintering adults was close to 1 : 1. While no-choice tests may indicate a wider host range under field conditions, we no longer consider *L. salsolae* as a potential biological control agent of *Salsola tragus* L. (Chenopodiaceae) in North America.

Key words: *Lixus salsolae*, *Salsola tragus*, biological control agent, host specificity, no-choice tests, weevil

1 Introduction

Russian thistle or salwort, *Salsola tragus* L. (= *S. australis* Brumitt = *S. iberica* Sennen & Pau = *S. pestifer* A. Nelson) (Chenopodiaceae), is an introduced annual weed having widespread distribution in the United States. The plant was introduced in the USA in the late 1800s and since then has become one of the most troublesome weeds in the drier regions of western North America (Whitson, 1992). It infests range and semiarid pasture lands as well as cropland, railroad, and highway rights of way, and vacant agricultural, residential and industrial areas. Moreover, the plant is a primary summer host of the beet leafhopper, *Circulifer tenellus* (Baker) (Cicadellidae), which is a vector of curly top virus to several important crops including sugar beets, tomatoes, beans, melons, and cucurbits (Goeden, 1968; Bennett, 1971). Russian thistle is a road hazard as tumbling plants surprise drivers and cause traffic accidents. Windblown plants fill irrigation canals and catchments, pile against fences and dwellings and accumulate other windblown debris (Goeden and Pemberton, 1995). It is a weed of wheat in the northwestern United States, where infestations have caused yield losses of greater than 50% in spring wheat (Pan et al., 2001).

Field surveys on *S. tragus* and the closely related species, *Salsola kali* L., during 1994, 1996 and 1997 in Turkey, France, Uzbekistan and China, yielded several promising natural enemies for the biological control of the Russian thistle. Among these were arthropods *Desertovelum stackelbergi* Mamaev (Dipt., Cecidomyidae) in Uzbekistan; *Piesma salsolae* (Becker, 1867) (Hem., Heteroptera, Piesmatidae) in Turkey, France and Uzbekistan; *Aceria salsolae* Delillo & Sobhian (Acari, Eriophydae) in Turkey and Uzbekistan, and *Gymnancyla canella* Dennis & Schiffermüller (Lep., Pyralidae) in Turkey and France. The rust fungus *Uromyces salsolae* Reich. was found on *Salsola* sp. in western Turkey and Uzbekistan. Preliminary studies on the biology and host specificity of the fungus indicated that its host range is restricted to *S. kali* and *S. tragus* (Hasan et al., 2001). Studies on the biology and host specificity of the above-mentioned arthropods are ongoing. The weevil, *Lixus salsolae* Becker (Col., Curculionidae) was found in France, Turkey, Uzbekistan, and China and was considered a promising biological control agent because damage from larval feeding was substantial. Preliminary studies carried out in Turkey gave the impression that the weevil was host-specific to *S. tragus*, because eggs were laid on *Beta vulgaris* L. (Swiss chard) but larvae died in early stages, while complete larval development occurred only on *S. tragus* (Sobhian et al., 1999). Therefore, a more extensive series of host specificity tests were carried out on the weevil during 2001 in a quarantine green house at the European Biological Control Laboratory (EBCL) in Montpellier, France, which is the subject of this paper.

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2 Material and methods

The host specificity of *L. salsolae* was examined in 2001 using 10 species or varieties of Chenopodiaceae and one species of Amarantaceae, including five crop plants, three ornamentals, *S. kali* (local French plants) and two varieties of *S. tragus*, genotypes A and B from California (Ryan and Ayres, 2000) (table 1). All plants were grown from seeds in sterilized soil on 6–25 June 2001 in plastic pots with 20 cm diameter and were kept in the quarantine green house [26°C and 55% relative humidity (RH)], at EBCL until they were used for the tests. All the seeds were obtained from commercial sources except the three *Salsola* varieties, which were collected by the authors.

2.1 Host specificity tests

The host specificity tests were performed as follows: each test plant was separately caged using a metal frame covered with a screen bag. One male and one female *L. salsolae* adult were placed in each cage. The description given by Kashefi (1993) was used to sex the adults. Overwintered *L. salsolae* adults were obtained from field populations on 30 May, 2001 about 60 km NE of Afyon, Turkey, along the road to Ankara (39°08.20′N to 31°12.90′E). On 5–6 June 2001, 90 plants were inoculated with adults. Eight replicates/plant species or variety were used except nine for *Kochia trichophylla* and *S. kali*, as control. Dead adults (29 females and four males) were replaced on 20 June 2001 with adults field collected on 18 June 2001 from the same population in Turkey. The males and the females were marked with a red nail polish to be distinguished from the adults of the new generation (F1) (males on the left elytra, females on the right) and to obtain information on their mortality. The plants were watered as needed. Data on adult feeding and mortality, oviposition, and larval development were collected on six occasions from 13–18 June 2001 to 5 September 2001. On 23–24 July 2001, as soon the first adults of the F1 generation started to emerge, the adults of the parent generation were removed from the cages to avoid heavy damage to the test plants and the number of adults surviving was recorded.

On 24 July 2001, adults of the F1 generation produced from six species/varieties were caged on new plants of the same species/variety from which they were reared, to see if they would produce a second generation (for the list of plants see table 2). The same kind of cages was used as before. All tests were carried out in a quarantine green house. All the plant material including the soil used to grow the plants was autoclaved at the end of the experiment.

3 Results and discussion

As shown in fig. 1, oviposition and complete larval development occurred on nine of 11 test species/varieties. Heavy adult feeding on stems and leaves was observed on all test plants. The mortality of females was much higher than in males, both during the transport and after exposure to the test plants. Adult weevils were produced by every test species/variety except the table beet, Red Ace, and *S. kali*. The sex ratio of field collected adults was almost 1 : 1 [48.4% females and 51.6% males ($n = 246$)]. Development from egg to adult took about 1-month.

Oviposition by the females of the F1 generation and subsequent larval development occurred on *Atriplex hortensis* and *Amaranthus caudatus*. By 19 August 2001, many of the adults of the F1 generation were found dead for unknown reasons. However, under laboratory conditions the insect produced two generations per year. The number of generations per year under field conditions is not known.

Under the conditions of these no-choice tests, it appears that *L. salsolae* would attack plants from

Table 1. *Plant species or varieties used in no-choice host specificity tests for* Lixus salsolae

Number	Family	Genus	Species	Variety	Plant type
1	Chenopodiaceae	*Beta*	*vulgaris*	Holly Hybrids 120	Sugar beet
2	Chenopodiaceae	*Beta*	*vulgaris*	Beta seed 8757	Sugar beet
3	Chenopodiaceae	*Beta*	*vulgaris*	Beet root Red Ace	Table beet
4	Chenopodiaceae	*Beta*	*vulgaris*	Lucullus	Chard
5	Chenopodiaceae	*Atriplex*	*hortensis*	–	Ornamental
6	Chenopodiaceae	*Chenopodium*	*quinoa*	Andean	Economic
7	Amaranthaceae	*Amaranthus*	*caudatus*	Viridis	Native ornamental
8	Chenopodiaceae	*Kochia*	*trivhophylla*		Native ornamental
9	Chenopodiaceae	*Salsola*	*tragus*	Genotype A	Weed
10	Chenopodiaceae	*Salsola*	*tragus*	Genotype B	Weed
11	Chenopodiaceae	*Salsola*	*kali*	–	Weed

Table 2. *The plant species or varieties used for testing the behavior of the F1 generation of* Lixus salsolae

Number	Genus	Species	Variety	Number of replicates	Number of inoculate insects	Number of Adult, F2 generation
1	*Beta*	*vulgaris*	Holly Hybrids 120	1	8	0
2	*Beta*	*vulgaris*	Beta seed 8757	1	2	0
5	*Atriplex*	*hortensis*	–	2	8 + 9	1
7	*Amaranthus*	*caudatus*	Viridis	1	2	3
8	*Kochia*	*scoparia*	Trychophylla	1	4	0
10	*Salsola*	*tragus* (control)	Genotype B	1	13	0

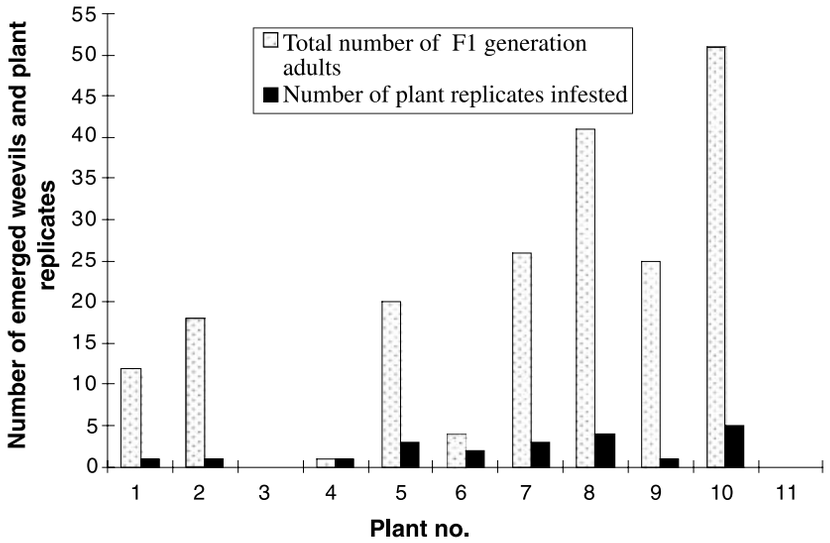

Fig. 1. *Number of* Lixus salsolae *adults that emerged from the test plants during no-choice host specificity tests, 2001, Montpellier, France. The numbers 1 to 11 correspond to the same numbers for plants in table 1. The adults reared from all replicates were pooled together*

several genera of Chenopodiaceae. Most practitioners of biological control feel that these kind of tests can indicate a broader host range than the insect will actually use in the field (Zwölfer and Harris, 1971; Wapshere, 1989). This broader host range has been called the 'physioslogical host range' indicating the array of plants on which an insect may potentially feed and develop (Cullen, 1990). The more narrow range of host plants the insect will actually utilize in the field is referred to as the 'ecological host range' (Delfosse, 1993). In previous studies by Sobhian et al. (1999), *L. salsolae* attacked only *S. tragus* and *S. kali*. It is likely, that *L. salsolae* will have a much narrow host range under field conditions. However, because of large number of adults feeding on all plants and because of the successful larval development on most of the test species, we no longer consider this insect an agent for biological control of *S. tragus* in North America.

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