Explorations in Central Asia and Mediterranean basin to select biological control agents for *Salsola tragus*

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Summary

Russian thistle, *Salsola tragus* L., (Chenopodiaceae), a troublesome weed complex in the drier regions of western North America, is native to Central Asia and widely distributed throughout the Palaearctic Region. Since 2003, several exploration and survey trips to discover new potential biological control agents for the weed were carried out in Italy, Russia, Turkey, Tunisia, Kazakhstan, Greece, Egypt and Morocco. Twenty-five arthropod species (one gall midge, one heteropteran, two flea beetles, three moths and 18 weevils) and two fungi were preliminarily selected during the surveys. Among them, four arthropod species (two weevils and two moths) were selected for further biology and host-specificity studies. At the moment, the most promising among these is the stem-boring weevil *Anthypurinus biimpressus* Brisout. Preliminary host range no-choice tests and life cycle observations showed that this species is restricted for feeding, oviposition and development to Russian thistle.

Keywords: *Salsola*, Russian thistle, foreign exploration, tumbleweed, natural enemies.

Introduction

Russian thistle or tumbleweed, *Salsola tragus* L., (Chenopodiaceae) is an invasive alien weed originating from Central Asia and is the target of classical biological control in the United States (Goeden and Pemberton, 1995; Pitcairn, 2004). This plant has commonly also been called *Salsola australis* R. Br., *Salsola iberica (Sennen and Pav)* Botsch ex Czereparov, *Salsola kali* L. and *Salsola pestifer* A. Nelson, and many synonyms occur in the literature (Mosyakin, 1996; Rilke, 1999). The taxonomy of Russian thistle is complicated because of high morphological variability of species in the genus and the occurrence of hybrids and polyploids; however, biochemical and molecular analyses are beginning to clarify the taxonomy. Similar species that are also invasive in North America include *Salsola paulsenii* Litv., *Salsola collina* Pallas, *Salsola* 'type B' and various hybrids (Ryan and Ayres, 2000; Akers *et al.*, 2003; Gaskin *et al.*, unpublished data). *S. kali* L also occurs in North America but is limited to seashores, primarily on the Atlantic coast (Mosyakin, 1996). In Eurasia, this species occurs primarily on seaside beaches of the Mediterranean and Atlantic coasts (Rilke, 1999), whereas *S. tragus* occurs primarily inland. All of these species are taxonomically closely related and have been placed in the *Salsola* section *kali*, sub-section *kali*, which is historically distributed across Eurasia (Rilke, 1999).

During a survey of genetic variability of *S. tragus* in California, a new variant, called 'type B' was discovered (Ryan and Ayres, 2000). Subsequent searches for the geographic origin of this population have revealed the same species only in South Africa and Australia. Until now, we have not been able to locate any specimens of Eurasian origin. Morphological and biochemical analyses support the restoration of this species to *S. australis* R. Brown (F. Hrusa, California Department of Food and Agriculture, personal communication). The origin of 'type B' is important to biological control because it differs significantly from *S. tragus* with re-

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spect to susceptibility to two prospective agents: a gall-inducing midge, *Desertovellum stackelbergi* Mamaev (Diptera: Cecidomyiidae; Sobhian *et al.*, 2003a,b) and a fungus, *Colletotrichum gloeosporoides* (Penz.) Penz. and Sacc. in Penz (Bruckart *et al.*, 2004). However, apart from 'type B', the other species all appear to originate from Eurasia and can be attacked by some of the same prospective biological control agents (Smith, 2005).

Foreign explorations to look for prospective biological control agents were previously conducted in Afghanistan, Pakistan, Egypt, Turkey, Uzbekistan, China and on the Mediterranean coast of France (Baloch and Mushtaque, 1973; Goeden, 1973; Hafez *et al.*, 1978; Sobhian *et al.*, 1999; Hasan *et al.*, 2001). As a consequence, two species of Coleophorid moths, *Coleophora klimeschiella* Toll, 1952, and *Coleophora parthenica* Meyr., 1891, were introduced in the 1970s to California and nearby states (Hawkes and Mayfield, 1976, 1978). These became widespread, but predators and parasites prevent them from becoming abundant enough to control the weed (Goeden and Pemberton, 1995). Other species that have been evaluated but were rejected for lack of specificity include *Lixus incanescens* Boheman 1836 [= *L. salsobe* Becker, 1867] (Coleoptera: Curculionidae), *Piesma salsolae* (Becker, 1867) (Hemiptera: Piesmatidae) and the fungus *Colletotrichum gloeosporioides* (Penzig) Penzig et Saccardo (Sobhian *et al.*, 2003a,b; Bruckart *et al.*, 2004). The blister mite *Aceria salsolae* DeLillo and Sobhian, 1996 (Acari: Eriophyidae) has been petitioned for permit to release (Smith, 2005), and *Gymnancyla canella* [Denis and Schiffermüller], 1775 (Lepidoptera: Pyralidae) is undergoing the final stage of evaluation before petitioning for release (Table 1). No other prospective agents worth evaluating were known. In the latest years, explorations were mainly targeted to Central Asia, the closest region to the probable centre of origin of *S. tragus*, and North Africa, which has the closest climatic match to the San Joaquin Valley of California, the locality where *S. tragus* is most problematic.

Methods

Field surveys

In 2004, the Biotechnology and Biological Control Agency (BBCA) began involvement in a program of explorations for Russian thistle natural enemies in the Mediterranean Basin and in Western and Central Asia. During the past 3 years, several surveys were carried out in Italy, North African countries, Turkey and Kazakhstan during late spring until late summer.

Italy

Bibliography and herbarium surveys reported mainly *S. kali* in Italy: this Russian thistle species is found in this country only on undisturbed sandy sea shores. The weed is very common, mainly along the Central, Southern and island sandy beaches.

North Africa

Similar habitat and weed species have been recorded in the three North African countries that we have inspected: Tunisia, Morocco and Egypt. All of them have

Table 1. Status of prospective biological control agents of Russian thistle.

Taxonomic name	Common name	Current information
Evaluated species		
Aceria salsolae (Acari: Eriophyidae)	Blister mite	The mite attacks developing tips. Petition approved by TAG, permit submitted to Animal and Plant Health Inspection Service (APHIS)
Gymnancyla canella (Lepidoptera: Pyralidae)	Seed and stem moth	Caterpillar feeds on seeds and young branch tips. Host specificity testing almost completed
Lixus incanescens [=*salsolae*] (Coleoptera: Curculionidae)	Stem weevil	Adults feed on many plants in choice test at Montpellier, France (Sobhian *et al.*, 2003a,b). Rejected
Piesma salsolae (Hemiptera: Piesmatidae)	Plant bug	Develops on beets in no-choice lab test at Montpellier, France (R. Sobhian, personal communication). Rejected
Colletotrichum gloeosporioides (Phyllachorales: Phyllacoraceae)	Fungus	More damaging to Russian thistle type A than to type B (Bruckart *et al.*, 2004). Being evaluated by W. Bruckart, US Department of Agriculture-Agricultural Research Service (USDA-ARS), Maryland
Uromyces salsolae (Uredinales: Pucciniaceae)	Rust fungus	Damages Russian thistle type A (Hasan *et al.*, 2001). Being evaluated by W. Bruckart, USDA-ARS, Maryland
Newly tested species		
Anthypurinus biimpressus (Coleoptera: Curculionidae)	Jumping weevil	Found in Tunisia in 2004. Larvae and adults feed on leaves. Biology is unknown
Baris przewalskyi (Coleoptera: Curculionidae)	Weevil	Abundant on *Salsola* sp. in Kazakhstan in 2004. Biology is unknown
Philernus sp. (Coleoptera: Curculionidae)	Weevil	Found in Kazakhstan in 2004. Probably monophagous

a peculiar combination of sandy beaches and sandy deserts. Among them, only in Tunisia was the target weed recorded in oases and in sandy areas at the beginning of the desert, while Russian thistle occurs in the other two countries only on the sandy dunes along the sea shore.

Turkey

S. kali and *S. tragus* are both present in Turkey, but they occur in different areas and habitats. The first is always associated with sandy beaches along the Mediterranean coast, while the latter occurs in more rocky habitats, especially in the Central and Eastern Anatolia. Furthermore, climatic conditions are very different, with a classic Mediterranean climate along the coast and a continental climate in the interior regions.

Kazakhstan

Explorations were carried out mainly in the south-eastern part of the country, in the region north of Almaty. Russian thistle was relatively common in disturbed areas, mainly along roads, in dense populations. Scattered populations were also found in wild fields. In both cases, the weed was associated only with sandy soils.

During the field explorations, the field sites where Russian thistle was present were recorded, adult insects were sampled, plants were dissected and eggs and immature larvae transferred into artificial diet for rearing. In addition, plant parts (leaves, shoots, roots) with immature stages or signs of mite or pathogen attack were collected and taken back to the laboratory, where immature stages were reared to adult and sent, together with field-collected adults, to taxonomists for identification.

Results and Discussion

Potential biological control agents

Tunisia: *Anthypurinus biimpressus* Brisout 1869 (Coleoptera, Cu culionidae): This stem- and leaf-mining weevil is recorded from one area in Tunisia (near Gabes) and was identified by one of us (E. Colonnelli). It is a univoltine species, and larvae attack the plant in May and June during the early phenological stages. From field observations, the insect has gregarious behaviour: the adults were found in 2004 and 2006 at two different sites near Gabes in large numbers on single individual plants. Almost all the Russian thistle plants at the sites were heavily attacked.

Broconius biscrensis, Capiomont, 1874 (Coleoptera, Curculionidae): A weevil has been reported on Russian thistle in Central Tunisia according to a record in E. Colonnelli collection. Additional surveys are planned to collect and rear this weevil.

Kazakhstan: *Baris przewalskyi Zaslavskii* 1956 (Coleoptera, Curculionidae): This root-mining weevil was collected at one site in Kazakhstan (near Ushtobe). It has been identified by B. Korotyaev. The species was found as large number of adults resting and feeding on young shoots and around the crown of young Russian thistle plants. Unfortunately, the species has been found at one site only, together with three other oligophagous *Baris* spp. (*Baris sulcata* Boheman, 1836, *Baris convexicollis* Boheman, 1836 and *Baris memnonia* Boheman 1844), all very similar in appearance. In addition, *Cosmobaris scolopocea* (Germar, 1826) and *Elasmobaris signetera* (Faust, 1821) were found at the same spot.

D. stackelbergi Mamaev (Diptera, Cecidomyiidae): This stem-galling midge was found for the first time in Uzbekistan by R. Sobhian (EBCL). During 2004, two populations were recorded at two sites in south-eastern Kazakhstan. This family is reported to be extremely specific. Preliminary tests carried out by Sobhian in Uzbekistan confirmed the narrow host range of the species. Additional tests carried out at the USDA, Albany, CA, showed that gall formation may depend on the presence of an unknown symbiotic fungus (Biscet and Borkent, 1988).

Other biological candidate agents

Kazakhstan: A weevil, *Philernus* sp., was collected in south-eastern Kazakhstan during 2004. Its biology is unknown, but preliminary bibliography surveys do not report any weevil of this genus associated with any crop plant.

During 2006, two populations of a root-boring moth were found in south-eastern Kazakhstan. The larvae were found in silken tunnels on the side of the roots, and feeding was observed on the external part of the root, near the place where the tunnel was affixed with the root system.

Italy: Several moths are reported to be closely related to Russian thistle (*S. kali*) in the Central Mediterranean Basin (A. Zilli, Museo Civico di Zoologia, Rome, Italy, personal communication). In particular, *Discestra sodae* Rambur, 1829 and *Discestra stigmosa* Christoph, 1887 (Noctuidae) are considered having a narrow host range within the genus *Salsola* and occur in Sardinia, Central Italian coasts, and Sicily. Similar distribution was also reported for several *Cardepia* spp., such as *Cardepia sociabilis* Graslin, 1860, *Cardepia deserticola* Rotschild, 1920, and *Cardepia hartigi* Parenzon, 1988. Moreover, a new species of *Gymnancila* sp. prope *canella* was found near Cefalù, northern Sicily. A population of *G. canella* from southern France is currently being evaluated for specificity (Sobhian, 2000; Smith *et al.*, 2007). Finally, noctuid moths of the genera *Lacanobia* Billberg, 1820 and *Pseudohadena* Alpheralay, 1889, even if not very common, are reported as oligophagous for the genus *Salsola*.

Preliminary screening of new potential biological control agents

Tunisia: *Lixus sp.*: This weevil from eastern Tunisia is probably *L. incanescens*, already tested by R. Sobhian (EBCL) and shown to be *oligophagous*. We carried out a quick screening on newly collected live specimen in no-choice conditions. Feeding and in some cases oviposition have been recorded on all Chenopodiaceae species tested (common beet, sugar beet, Russian thistle). The insect was rejected.

A. biimpressus Brisout: This weevil from eastern Tunisia was found for the first time on *Salsola kali* near Gabès during late May 2004 (spring) and identified as a probable monophagous species. Larvae and/or adults feed on young leaves caused severe damage. Oviposition and larval development were obtained in the laboratory from adults collected in the field in spring, although larvae could not complete pupation. Preliminary laboratory observations showed that larvae appear to be external feeders; this is uncommon for weevils. The insect is likely univoltine because in 2006 at the Gabès site, no larvae or adults were seen in late June on plants that had been attacked in May. The generation collected in September (autumn) behaved differently from the one collected in spring. The autumn collected insects fed on host plant and mated but did not oviposit. Preliminary host range tests, carried out during 2006, tested four crop plants within the family Chenopodiaceae and indicate that the host range does not include species in the subfamily Chenopodioideae (e.g. *Chenopodium album* L., beets and spinach).

Eastern Kazakhstan: A wide range of arthropod fauna has been found associated with the target weed in Kazakhstan. The following species are likely monophagous: the weevil *Philernus* sp., the gall midge *D. stackelbergii* Mamaev and the weevil *B. przewalskyi* Zaslavskii. The following weevil species are likely oligophagous: *Lixus rubicundus* Zoubkoff 1833, *Lixus polylineatus* Petri 1900, *Lixus scabricollis* Boheman 1843, *C. scolopacea*, *B. sulcata*, *E. signifera*, *B. convexicollis*, *B. memnonia Temnorhinus elongatus* (Gebler 1845).

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