Possibilities for the Biological Control of Russian Thistles, Salsola spp. (Chenopodiaceae)[1]

by

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INTRODUCTION

Russian thistle is a native of Eurasia but has been accidently introduced into, and became a serious pest in, the western U.S.A. and Canada. It is a weed pest of overgrazed rangeland, grain-fields, fallow land and field-, and roadway-margins. Besides being a competitor for water and nutrients, Russian thistle is a favoured summer host of the beet-leafhopper, *Circulifer tenellus* (Baker), the vector of curly-top virus of cucurbits, etc. Moreover, woody stems of dry and dead plants fracture at ground level and are blown away by wind into irrigation and drainage ditches and are also piled up against fences and dwellings, thereby creating possibiliiies for fire hazards (Goeden and Ricker, 1968).

Since herbicidal control is expensive and fraught with dangerous side-effects, biological control seems to be most desirable. Therefore, investigations on the natural enemies of the Russian thistle *Salsola ruthenica* Iljin. were initiated in Pakistan from 1963 under a PL-480 programme. The results obtained to date are presented here.

RESULTS OF INVESTIGATIONS

Insect enemies recorded in association with *S. ruthenica* and *Halogeton glomeratus* (M. Bieb.) C. A. Mey. (a very closely related plant to Russian thistle) in Pakistan up to 1970, and preliminary studies on the apparently promising enemies have been reported by Baloch and Mushtaque (1973). At that time they considered 9 insect species as probably promising biocontrol agents for the two weeds. However, detailed studies later indicated that only three of these were actually host-specific and effective destroyers of these weeds. These are *Coleophora parthenica* Meyr., *C. klimeschiella* Toll. and *Heterographis monostictella* Rag. An account of these is given below:

(i) *Coleophora parthenica* Meyr.
(Lepid.: Coleophoridae)

This is a stem-borer of *S. ruthenica* at Warsak near Peshawar in the North-West Frontier Provine (N.W.F.P.) and of *H. glomeratus* in the northern Pakistan (Gilgit and Baltistan areas). *Halogeton* does not occur at Warsak, while both weeds grow side by side in Gilgit and Baltistan, but here *C. parthenica* is mainly a stem-borer of *Halogeton* and only occasionally infests *Salsola*. *C. parthenica* from *Halogeton* was referred to as *Coleophora* sp. but J. D. Bradley of the Commonwealth Institute of Entomology, London, stated that it was conspecific with *parthenica* Meyr. from *Salsola* at Warsak (personal communication).

Studies on the biology, ecology, host-specificity, etc. of *C. parthenica* in *Salsola* stems have been reported by Baloch and Mushtaque (1973). Such investigations on this insect in the Gilgit and Baltistan from *Halogeton* are given in this paper.

Oviposition by the overwintered generation usually takes place in June and the first generation is completed by about mid-July. Insect activity continues till the end of September, when it goes into hibernation as full-grown larvae inside the dry host-stems.

The life-cycle here is similar to that in *Salsola* stems at Warsak. Oviposition occurs on leaves or tender shoots. Hatching larvae feed inside leaves for the first few days and then enter the stems, going downward. At the completion of the feeding period, larvae retreat to the middle of the tunnel and, before pupation, cut a hole in the stem for the emergence of adults.

Although *C. parthenica occurred* at most of the localities between 1200 m. and 1800 m., it was comparatively more abundant at Haritangdas (1350 m.) in the Gilgit area. Its incidence is usually low during June-August, being a average one larva per plant, but increases considerably in September, when there is an average of 8 larvae per plant. Plants growing in comparatively moist

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places are more susceptible than those in dry and sandy situations.

No alternate host for *C. parthenica* has ever observed in any of its distribution areas. In the laboratory, oviposition tests were made with 8 ovipositing females (4 laboratory-reared and 4 field-collected) by releasing them on caged potted-test-plants and using *Salsola as* control. Plants tested were: sugar-beet and table-beet (*Beta vulgaris* L.), swiss chard (*B. vulgaris* var. *cicla*), Kochia (*Kochia indica* Wight) and spinach (*Spinacia oleracea* L.).

Although oviposition took place on all the five test plants (8-23 eggs) by both types of females, it was much less than that on *Salsola* (37-52 eggs). However, no hatching was observed on any of the test plants, while 65 to 70% of eggs on *Salsola* hatched and the larvae bored the stems.

Larval-feeding tests were also made by transfering eggs laid on *Halogeton* leaves individually to those of the potted-test-plants (50 on each) for hatching and larval feeding. *Salsola* was used as control and the same technique was applied for egg-transfer. In addition to the five test-plants given for oviposition, lettuce (*Lactuca sativa* L.), purslane (*Portulaca oleracea* L.) and egg-plant (*Solanum melongena* L.) were also used.

Here also, no hatching took place on any of the test-plants while more than 70% of those on *Salsola* hatched. About 60% larvae from these eggs were found feeding inside the stems a week after transfer. Thus, *C. Parthenica* in stems of *Halogeton* in the Gilgit and Baltistan areas, like that in *Salsola* stems at Warsak, is highly specific to its hosts, *Halogeton* and *Salsola*.

Larvae of *C. parthenica* were parasitized to the extent of 70% by *Apanteles* sp. (Braconidae) and *Eurytoma* sp. (Eurytomidae).

As a result of these studies, *C. parthenica* from both the hosts (*Salsola* and *Halogeton*) was introduced into the U.S.A., re-tested in quarantine for host-specificity and released at several sites in California against their two host-weeds (Hawkes, *et al.*, 1975). That from stems of *Halogeton* was also introduced into Canada for direct releases. Information received to date (end of 1975) indicates that *C. parthenica* in stems of *Salsola* released in early 1973 has become very well-established at a number of release sites in California, has attained reasonably high populations within the subsequent period of 3 years and is causing appreciable damage to its host. That from *Halogeton* also seems to have become established but its populations are still low since it was released only recently (early 1975). Nothing is yet known of the fate of *C. parthenica* released against *Halogeton* in Canada.

(ii) *Coleophora klimeschiella* Toll.
(Lepid.: Coleophoridae)

This is the case-bearing leaf-miner of *S. ruthenica* discovered during 1974 in the Gilgit and Baltistan areas. A detailed account of this species is being published separately by Khan and Baloch (in press).

C. klimeschiella is also known to occur on *Salsola iberica* Sennen and Pau in Turkey (Goeden, 1973), and is probably synonymous with *Coleophora keireuki* Falkovitsh associated with *Salsola rigida* in the U.S.S.R. (B. Wright, Nova Scotia Museum, Canada - personal communication).

Studies on the biology ecology, host specificity etc. have shown that in Pakistan *C. klimeschiella* is a multivoltine insect having 2-3 generations a year. It causes heavy damage to its host in the early stages of growth (a single larva destroying 15-21 leaves).

Eggs are laid singly on leaves, leaf-bases, and stem-nodes. In the early stages larvae feed as leaf-miners. After reaching the third instar, they start constructing cases out of mined-leaf-portions and remain encased for the rest of the larval period. Pupation takes place inside the cases, which are then closed from both ends and attached to the dry, undamaged parts of the host. Hiberation takes place in various larval stages inside the cases. At $20°C \pm 1°$, the incubation, the five larval-instars together and the pupal period occupied 6, 18-24 and 8-9 days, respectively.

Field observations showed that, although *Salsola* plants infested by *C. klimeschiella* grew interspersed with other vegetation (such as halogeton, wheat, alfalfa, *Sophora* sp., *Artemisia* sp., *Cousinia* sp., *Chenopodium* spp. and *Suaeda* sp.), none of these was attacked.

In the laboratory, *C. klimeschiella* was tested for oviposition and larval feeding against potted-test-plants of halogeton, sugar-beet, table-beet, Swiss chard, kochia, spinach, purslane and lamb's-quarters (*Chenopodium album* L.). Five replications were made for each test plant using a single mated-pair of moths in each. For larval feeding, 30 larvae each of the first and fourth instar and 15 of the third were used. A potted plant of *Salsola* was kept as control against each test, both for oviposition and larval feeding.

Although a few eggs were deposited on the leaves of kochia (3 eggs), lambsquarters (24 eggs) and purslane (68 eggs) — against 126-217 on the host-which hatched, no feeding by any larval instar was observed on the test-plants except halogeton. On the latter, the number of eggs laid was higher than any other test-plant (126 eggs), and larvae also fed on its leaves. However, first instar larvae failed to complete their development even on this plant, though some of them survived up to 33 days, while third and fourth instar larvae fed and developed to the adult stage. Thus, *C. klimeschiella* appears to be highly host-specific, and a promising biocontrol agent against Russian thistles. However, in Pakistan its larvae are heavily parasitized by *Avga* sp. (Braconidae) and *Hockeria* sp. (Chalcididae) and this would indicate that heavier damage might ensue following introduction into other areas. *C. klimeschiella* has also been recently introduced into the U.S.A. in quarantine and is being further tested for host-specificity at the Biological Control of Weeds Laboratory, Albany, California.

(iii) *Heterographis monostictella* Rag.
(Lepid.: Phycitidae)

A preliminary account of the biology, host-specificity, etc. of this species has also been given by Baloch and Mushtaque (1973). It is mainly a stem-borer of *Salsola* in the Gilgit and Baltistan areas but occassionally also attacks *Halogeton*. It does not occur at Warsak.

H. monostictella overwinters as larvae in the soil within silkin cocoons coated with sand. Adult emergence and oviposition from the overwintered generation takes place in the first half of June. Second generation adults appear in the second half of July and by about the end of September all stages disappear from the host *Salsola*.

Oviposition occurs on leaves or leaf-axils and the young larvae first feed inside leaves and then enter the stems. After destroying a tender branch larvae enter another, and in this way a single larva destroys many branches before reaching maturity. Heavy infestations have often been observed in dry, sandy soils where dying plants could be observed from a distance.

In the laboratory, oviposition tests were made with 5 laboratory-reared pairs on each of an ornamental amaranth (*Amaranthus* sp.) a wormwood (*Artemisia* sp.), five-hooked bassia (*Bassia hysopifolia* (Pall.) Ktze.), alkali seepweed (*Suaeda fruiticosa* (L.) Forsk.), an ornamental rose (*Rosa* sp.), spinach (*Spinacia oleracea* L.), and broad bean (*Vicia faba* L.). No oviposition took place on any of these. On the host *Salsola*, 85-112 eggs were laid in each test. Female longevity was also less on all the test-plants (3-10 days) than on the host (6-14 days).

Since earlier larval-feeding tests (Baloch and Mushtaque, 1973), were made with plant-pieces in petri-dishes, these were repeated on potted-test-plants with the addition of a few others. Test-plants used were: sugar-beet, table-beet, Swiss chard, kochia, lettuce, purslane, spinach, amaranth, wormwood, rose, five-hooked bassia, alkali seepweed, broad bean, and lambs-quarters. Twenty larvae each of first, second and third instar were used in these tests. A potted plant of *Salsola*, with the same instar and number of larvae, was used as control.

First instar larvae only slightly nibbled, but died quickly on most of the chenopod plants except alkali seepweed and halogeton where 4 and 10 (out of 20), respectively, fed and completed development to the adult stage. On the host *Salsola*, more than 70% larvae completed their development. Second instar larvae also fed slightly on all those plants on which first instar had nibbled. However, third instar larvae fed and developed to adults on most of the Chenopods and broad bean. Thus, young larvae of *H. monostictella* appear to be unable to to feed and develop on any of the economically important chenopods. It therefore seems to be restricted to the two weeds, Russian thistle and halogeton, but young larvae are likely to feed and develop on seepweeds, *Suaeda* spp., though females do not appear to oviposit on this and in nature its larvae have never been observed to attack this plant.

Since *H. monostictella* and *C. parthenica* are both stem-borers (though in the Gilgit area the former is mainly confined to *Salsola* and the latter to *Halogeton*), competition tests, both for oviposition and larval feeding, were made to see if they could co-exist in one host or not. A laboratory-reared pair of each species was released on the two weeds both separately and the two together. Eggs laid were counted and left undisturbed for about 2 months for larval feeding and development. Adult emergence during this period was also noted.

It was observed that the two insects were capable of ovipositing on both the weeds when provided separately as well as together. However, the high averages of eggs of *C. parthenica* on *Halogeton* and those of *H. monostictella* on *Salsola* in both separate and combined tests, indicated the preference of both for the host-plant on which they exist in nature. Hatching larvaee from these eggs were also able to co-exist in the same plant of either host but their preference for the respective hosts was again evident from the high averages of mature larvae present and emerged adults in the individual tests. However, *H. monostictella* dominated over *C. parthenica* in the combined experiments, in both hosts, though they were still able to co-exist in either host. *H. monostictella's* dominance was possibly because of its greater mobility (as its larvae move from branch to branch) than that of *C. parthenica* (being mainly confined to the original branch till maturity). Thus, although *H. monostictella* and *C. parthenica* may be able to co-exist in either host, there would definitely be some competition resulting in the dominance of the former.

H. monostictella larvae were parasitized by *Apanteles* sp. and *Phanerotoma* sp. (Braconidae); *Campoplex* sp. (Ichneumonidae); and *Perilampus chrysonotus* Foester (*Pteromalidae*). Combined parasitism of the hibernating larvae was as high as 70% in some years.

DISCUSSION AND CONCLUSIONS

Investigations into the possibilities of biological control of Russian thistles, *Salsola* spp., over a period of 12 years in Pakistan have resulted in the discovery of three lepidopterous insects which are host-specific and effective destroyers of the weeds. These are: *Coleophora parthenica, Coleophora klimeschiella* and *Heterographis monostictella.*

Whilst Russian thistle, *Salsola ruthenica,* occurs at two climatically very different areas in Pakistan (one at Warsak near Peshawar in the North-West Frontier Province with an altitude of 350m., mean annual rainfall 340 mm, mean annual temperature 22°C. and the other in the Gilgit and Baltistan in the northern areas with an altitude of 1050-2600 m., mean annual rainfall 130-160 mm. and mean annual temperature 10°-16°C), *C. Parthenica* at Warsak, where *Halogeton* does not occur, is a stem-borer of *Salsola,* whereas it attacks mainly *Halogeton* in Gilgit and Baltistan, where both weeds grow side by side. Whether there are two different boilogical races involved, each prefering its natural host, or whether it attacks *Salsola* at Warsak because *Halogeton* is not present, remains to be determined. However, the insects from both ecological areas could very well feed and breed in the stems of the other weed in the absence of its natural host.

C. parthenica has never been observed to attack any other plant in the field except *Salsola* and *Halogeton.* In laboratory screening tests in Pakistan, Egypt and the U.S.A. (Hawkes, *et al.,* 1975), its larvae proved to be highly specific to the two weeds. As a result, this insect has been introduced and released against its hosts in the U.S.A. and Canada and is reported to be doing very well, especially that in the stems of *Salsola.*

Although *C. klimeschiella* has been known from *Salsola iberica* and possibly also *Salsola rigida* for quite some time in Turkey and in the U.S.S.R., it was only in 1974 that it was found causing considerable damage to *S. ruthenica* in Pakistan. It is a highly specific enemy of the Russian thistles, so much so that its young larvae do not seem to be able to survive even on *Halogeton,* very closely related to *Salsola,* where both weeds have most of their natural enemies in common. It is a very effective destroyer of its host (a single larva could damage 15 to 21 leaves in its feeding period). This insect has also been introduced into the U.S.A. in quarantine and is likely to be released in the field very soon.

Whilst *H. monostictella,* like *Coleophora* spp., has never been observed to attack any other host in the field, in the laboratory its larvae, in all stages, fed and developed on alkali seepweed, *Suaeda fruticosa.* Thus, it appears that in the presence of its hosts *Salsola* and *Halogeton, H. monostictella* may not attack *Suaeda* spp. but is quite capable of feeding on it when the hosts are not available. Therefore, its usefulness as a biocontrol agent for Russian thistles will depend upon whether seepweeds are economically important or not in areas where biological control of *Salsola* spp. is desired. *H. monostictella* is also a very effective biocontrol agent as a single larva damages many branches during its feeding period.

Goeden and Ricker (1968), while discussing Russian thistle insects in Southern California, remarked: "In any case, foreign exploration can now proceed with the knowledge that stem-, root-, and fruit-infesting insects subsequently imported to supplement the phytophagous insect fauna of this weed, at least in southern California, will find largely unoccupied niches awaiting them". Thus, the two stem-boring insects dealt with here can, at least, fill the unoccupied stem-niches in the U.S.A. The leaf-miner will supplement the action of others already present.

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REFERENCES

Baloch, G. M. & Mushtaque, M. 1973. Insects associated with *Halogeton* and *Salsola* in Pakistan with notes on the biology, ecology and host specificity of the important enemies. Proc. 2nd Intern. Symp. Biol. Contr. Weeds. Commonw. Inst. biol. Control, Misc. Publ., *6*: 104-113.

Goeden, R. D. & Ricker, D. W. 1968. The phytophagous insect fauna of Russian thistle (*Salsola kali* var. *tenuifolia*) in southern California. Ann. Entomol. Soc. Amer., *61*: 67-72.

Goeden, R. D. 1973. Phytophagous insects found on *Salsola* in Turkey during exploration for biological weed control agents for California. Entomophaga, *18* (4): 439-448.

Khan, A. G. & Baloch, G. M.—*Coleophora klimeschiella* Toll. (Lepidoptera: Coleophoridae)—a promising biocontrol agent for Russian thistles, *Salsola* spp. (Accepted for publication in Entomophaga Vol. 22, No. 1).

Hawkes, R. B., Goeden, R. D., Mayfield, A. & Ricker, D. W. 1975. Biological control of Russian thistle. California Agric., *29* (4): 3-4.