Biological Control of Puncturevine, Tribulus terrestris (Zygophyllaceae): Post Introduction Collection Records of Microlarinus spp. (Coleoptera: Curculionidae)

by

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ABSTRACT

Prior to introduction into the United States for biological control of puncturevine, *Tribulus terrestris*, *Microlarinus lareynii* and *M. lypriformis* were found to have a wide feeding range but to have only a few zygophyllaceous plants on which they could reproduce. Despite this polyphagous habit, and although the weevils are now well-established over much of the southwest (Calif., Ariz., New Mexico) and have been collected from a number of plant species, there has been only one incident of documented damage to a plant of agricultural importance.

INTRODUCTION

In 1961 the seed weevil, *Microlarinus laryenii* (Jacquelin duVal), and the stem weevil, *Microlarinus lypriformis* (Wollaston), were introduced to the United States from Italy for biological control of puncturevine, *Tribulus terrestris* (L.) (Huffaker *et al.* 1961). Since that time these weevils have become established in areas of California, Arizona, New Mexico, southern Nevada, southern Utah, Texas, Oklahoma, Kansas, and Nebraska (Maddox 1976). Also, the stem weevil has been reported from Florida (Stegmaier 1973), and both species have been introduced into the Hawaiian Islands (Davis and Krauss 1966) and the West Indies (Bennett 1968) where they are established. This spread to other areas infested by *T. terrestris* and related species will undoubtedly continue.

Prior to the introduction of the two weevils to the United States, biological and host specificity tests conducted in Europe and the United States demonstrated that both species would feed on a wide range of plants if they had little choice, but that they reproduced only on *Tribulus terrestris* or closely related species (Andres and Angalet 1963). Thus, despite the polyphagous habit, the weevils did not appear to be a threat to plants of recognized value because of their restricted reproductive capability, and introduction to areas infested by *Tribulus* proceeded on this assumption. Since the time of the original releases and establishment of *Microlarinus* spp. weevils in North America and Hawaii, both species have been collected from a wide range of plants and other objects at various times of the year. However, in only one instance have they been implicated in damaging a crop plant. Herein are recorded some of the collection records of these insects.

BACKGROUND

Interest in the use of *Microlarinus* spp. to control puncturevine began when they were collected from *T. terrestris* in India by George Angalet, entomologist, ARS, USDA. Subsequently these weevils were collected in France and Italy where the major portion of the biological and host specificity work was done (Andres and Angalet 1963). Both weevils were found to be multivoltine and passed the winter as adults in various sheltered places on and around plants growing near previous stands of *Tribulus*. These overwintering adults fed periodically on whatever green plants were available to them, a rather polyphagous feeding habit that enabled the adult to survive an entire spring and summer without *Tribulus*. None of the adults studied survived a second winter.

In starvation tests, the two weevil species fed appreciably on almost all plants to which they were exposed though somewhat less than on *Tribulus*. When permitted a choice, they preferred *Tribulus* and continually sought out and congregated on this plant. When large numbers of adults (100+) were released in unconfined but marked areas of crop plants in the absence of *Tribulus*, the weevils dispersed rapidly and were quickly lost. No damage to the crop plants was ever observed.

Dissections of females demonstrated that they could develop eggs only while feeding on *Tribulus*, *Kalstroemia*, and *Zygophyllum* (Andres and Anga-

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let 1963; C. B. Huffaker, 1959 unpublished report). Whenever the females were withdrawn from these plants and placed on a non-zygophyllaceous host, the eggs were reabsorbed. Seed weevils could develop in the pods of *Kallstroemia*, but the seed of *Kallstroemia* were smaller and seemed less suitable than the seeds of *Tribulus*. (Inability to germinate *Kallstroemia* seeds in the greenhouse precluded the testing of *M. lypriformis* on this genus in Europe.)

METHODS AND RESULTS

Within 1-2 years after the original releases of the *Microlarinus* species in California in 1961, the weevils attained high population levels in California, Arizona and New Mexico. The first record of adult weevils collected on other hosts was in 1963 when they were reported on cotton, *Gossypium hirsutum* L., in the Imperial Valley of California in June and on citrus nursery stock at Yuma, Arizona in December. An examination of the collection records of the California Department of Food and Agriculture for 1963, 1964, 1965 and 1971 (Jan.-Sept.) revealed 38 additional reports of either the stem or seed weevil (predominately the latter) collected from plants or objects other than *Tribulus*. These records are summarized in Table I. Also included in the table are records of interceptions of these insects at the border between Mexico and the United States by border quarantine inspection (Girard 1968) and host records from Hawaii (C. J. Davis, formerly State Entomologist, Hawaii Dept. of Food and Agriculture, personal correspondence, 1965).

The majority of the collections were seed weevils taken on alfalfa, 11 by the same collectors, between August 12 and 20, 1965 in Fresno Co., California, but a single stem weevil was recovered from alfalfa at the same time. All but one of the infestations on alfalfa were subjectively rated as "light", that one was rated as "medium". The actual numbers were not recorded. None of the infestations were noted as damaging to the plants.

The first of the two collections listed in Table I that were considered damaging to the host plant was reported from citrus at Yuma on December 13, 1963, in a note in the Arizona Cooperative Insect Survey: "Puncturevine weevil found damaging young citrus in the Yuma area, Yuma County, Arizona" (Roney 1963). Both the stem and seed weevils had been released near Tucson, Arizona in July and August 1961; then in late July 1963, *Microlarinus*-infested *Tribulus* plants were placed

Table I. Records of *Microlarinus* spp. from plants or sites other than *Tribulus* spp.[1] (No. of collections - month/year).

AMARANTHACEAE: *Amaranthus spinosus* L.[2], BATIDACEAE: *Batis maritima* L.[2] BORAGINACEAE: *Coldenia* sp. 1-3/71. CHENOPODIACEAE: *Chenopodium album* L.[2] COMPOSITAE: *Chrysanthemum* sp. 1-10/65[3], 2-11/65[3]; *Palafoxia linearis* (Cav.) Lag. 1-3/71; *Verbesina encelioides* Cav. Benth & Hook[2]; Yellow composite 1-10/64. CRUCIFERAE: *Raphanus sativus* L. 1-6/71. GRAMINEAE: *Cynodon dactylon* (L.) Pers. 1-7/66; *Zea mays* L. 1-8/65; Grasses 1-4/71. LEGUMINOSAE: *Medicago sativa* L. 15-8/65. MALVACEAE: *Gossypium hirsutum* L. 1-6/63; *Malva parviflora* L.[2] *Malva* sp. 1-4/71; *Sphaeralcea* sp. 1-10/64. MUSACEAE: *Strelitzia* sp. 1-6/65. PITTOSPORACEAE: *Pittosporum* sp. 1-9/65. PORTULACACEAE: *Portulaca oleracea* L.[2] RUTACEAE: *Citrus* sp. 1-12/63. SOLANACEAE: *Capsicum frutescens* L. 1-8/65. VERBENACEAE: *Lantana* sp. 1-10/64. VITACEAE: *Vitis* sp. 1-3/64. ZYGOPHYLLACEAE: *Kallstroemia* spp.[4]. ?-8/64. OTHER SITES: Automobile 1-8/65[5]; On person 1-5/71; Cotton gin 1-10/64, 2-11/64, 1-12/63; Cotton trash 1-1/64,1-10/65[3], 1-11/65; Sweet potato box near cotton field 1-11/65; Fence post near gardenia plant 1-11/65. TOTAL=44+

[1] Partial listing of records from the 1963, 64, 65 and 1971 file, California Department of Food and Agriculture, unless otherwise indicated.

[2] Hawaii, temporary feeding recorded by C. J. Davis, Formerly State Entomologist, personal communication.

[3] Animal Plant Health Inspection Service (APHIS) quarantine interception, El Paso, Texas.

[4] R. B. Hawkes, USDA, ARS, Albany, Californian, personal communication.

[5] APHIS, quarantine interception, Calexico, California.

in the Yuma area.) A close examination of the damage was made by C. A. Fleschner and D. W. Ricker (University of California, Riverside, unpublished notes, December 17, 1963), who found that the damaged citrus was young Valencia orange scions on rough lemon rootstock, budded October 1963. The most serious damage was found just above the bud union, these being 5 inches above ground, but only a few of the most heavily attacked plants "may suffer seriously from a girdling effect; however, no scions had been killed at the time of examination".

The interesting aspect of the attack was that the feeding was heaviest along the outside row of citrus near the southeast corner of the nursery. Weevil damage was first noted about 10 days after a young citrus orchard to the east had been rototilled and an uncultivated strip of land about 75 feet wide to the south of the nursery had been disced. Both areas had contained weevil infested puncturevine prior to cultivation. In fact, one estimate indicated that 60% of the ground cover in the field to the south was *Tribulus*. After cultivation, almost no vegetation remained in the 75 foot strip south of the nursery, and only a Bermudagrass was left in the citrus grove to the east. Thus the citrus nursery offered the only vegetation available to the overwintering puncturevine weevils. Moreover, as Fleschner and Ricker (unpublished notes, December 17, 1963) and D. M. Tuttle (Univ. of Arizona, Yuma, in correspondence 1963) noted, the parent rootstock on which the scions were budded had been broken above the bud and bent over to the ground, thus providing an excellent hiberating site and easy access to the plant by the *Microlarinus* weevils. The damage was described as scarring along the length of the stem on the outer or sharper angles, which left a brown appearance. Apparently the cuts healed over rapidly and were of little consequence unless the chewing had been extensive. The nursery manager treated the infested stock with DDT (1,1,1-trichloro-2,2-bis [p-chlorophenyl] ethane, an isomeric mixture of dichlorodiphenyltrichloroethane) about December 9 and on December 12 treated five of the most severely infested rows with dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1-4-*endo-exo*-5,8-dimethanonaphalene) Tuttle, in correspondence, 1963). Subsequently Tuttle (in correspondence, 1968) reported that there was no obvious economic loss due to this weevil feeding. We cannot know whether loss would have occurred had the grower not treated the plants.

Since no damage from *Microlarinus* has been recorded from other citrus nurseries in Arizona or California, the occurrence of damage is laid to the several unusual circumstances: (1) the plowing under of the weevil-infested *Tribulus,* (2) the proximity of the nursery plants and the suitable hibernating shelter they offered, and (3) the absence of other ground cover on which the beetles could hibernate.

The second incident had to do with damage allegedly done by *M. lareynii* to grape in the Borrego Valley, San Diego County, California. (Seed weevils had been released on the puncturevine in that area in July 1962.) In March 1964, identified weevils collected from under the wraps on grape vines "seemed to be girdling the young rootings" (H. Black, Univ. of California, Extension Service, in correspondence, 1964). Black did not see the damage himself and reported that the grower was treating for the weevils. A later report by D. A. Chant, formerly Univ. of California, Riverside (correspondence to C. B. Huffaker, 1964) noted that an entomologist from the University of California, Riverside, could not correlate the amount of damage with the number of weevils present; in fact, other phytophagous insects were in evidence including *Ulus crassus* (LeConti.) (Tenebrionidae), which is recorded as being damaging to young plants (Essig 1938). In veiw of the overwintering habits of *Microlarinus,* it would not be surprising to collect them under the wraps on young grape vines, nor to observe them feeding on grape though there remains doubt whether their feeding caused the reported damage.

We are certain that the number of host records of adult *Microlarinus lareynii* and *M. lypriformis* could easily be increased, merely through close observation of plants associated with *Tribulus* or of plants remaining in the habitat after puncturevine had disappeared for the winter. The weevils are continually taken from the gin trash in the cotton-producing desert areas of New Mexico and Arizona and occasionally in southern California (J. W. Gentry, Animal Plant Health Inspection Service, USDA, in correspondence, 1966). U. S. Plant Qrarantine Division records list three border interceptions of *M. lareynii* on *Chrysanthemum* sp. (cut flowers) and one on *Gossypium* sp. (cotton linters) from Mexico (Girard 1968).

Also, the stem weevil, *M. lypriformis,* has been recorded attacking *Kallstroemia* spp. in Arizona, primarily Arizona poppy, *K. grandiflora* Torr. ex Gray. Some plants have been killed though death seems to be the result of the combined attack of an unidentified species of cerambycid, the *Microlarinus* weevils, and a species of *Cuscuta* (R. B. Hawkes, Agric. Res. Service, USDA, Albany, Calif., unpublished notes, 1964). There was relatively little feeding by the adult *Microlarinus* on the erect or suberect poppy stems, but damage did occur where the stems touched the ground. The weevil larvae were found to be abundant tunneling in the crowns of the plants. However, Hawkes noted that the seed weevil was not much of a threat to *Kallstroemia* and that after a day and a half of searching, only five or six infested pods were found. There was still a good crop of seed present, seemingly sufficient to assure perpetuation of the plant.

Both the stem and seed weevil were introduced into Hawaii in 1961 and now control the perennial *Tribulus cistoides* L. and the annual *T. terrestris* over widely separated areas. In Hawaii, the weevils have been collected feeding on nearby plants in the absence of the regular host (C. J. Davis, in correspondence, 1965). These plants include *Amaranthus spinosus* L., *Chenopodium album* L., *Malva parviflora* L., *Portulaca oleracea* L., *Verbesina encelioides* (Cav.) Benth. & Hook., and *Batis maritima* L. Feeding was only temporary and there was no reproduction.

DISCUSSION

Approximately 60 plant-feeding spceies have been introduced into North America and Hawaii for weed control (Goeden *et al.* 1974). Not all have become established or increased to population levels capable of controlling the weeds, but a sufficient number have to clearly demonstrate both the safety and efficacy of this technique. Since establishment and buildup, many species of these introduced insects have been reported from plants other than the target weeds. Almost as frequently, these observations are recorded, evaluated, and eventually dismissed as unworthy of further not. Thus, Greathead (1968), in reporting the migration of the introduced *Teleonemia scruplulosa* Stal from the defoliated weed host, *Lantana camara* L., to *Sesamum indicum* L. in Uganda, said that "such temporary break-down of host specificity has been noted on other occasions in the biological control of weeds when hoards of starving insects have invaded nearby crops". He felt that it was unfortunate that so few such observations have been published. The present report is an effort to correct this oversight to some extent.

The erratic appearance of *Tribulus* has seemingly prompted the evolution within *Microlarinus lareynii* and *M. lypriformis* of an effective system of exploiting their short-lived annual host: The polyphagous feeding ability assures extended adult survival without *Tribulus*; the ability of the female to form or reabsorb oocytes in direct relation to the presence or absence of suitable *Tribulus* enables the weevils to focus their reproduction energy on the host plant; and finally, their multivoltinism permits rapid exploitation of the host plant during the limited time it is present. This strategy is similar to that employed by some r-strategist entomophagous parasites against insect pests of annual or short-cycle crops (Ehler and van den Bosch 1974).

The value of the biological control of puncturevine has been difficult to assess, primarily because of the sporadic appearance of the plant from one season to the next. However, testimony from farmers, agricultural extension workers, and weed scientists indicates that the weevils have provided an appreciable degree of control and that herbicidal treatments of *Tribulus* have often been discontinued (Maddox, in manuscript). Although these benefits are not expressed in terms of dollars, they do appear to be substantial and should offset the approximately 3.5 scientific man years that went into the development of these insects as biological control agents. At an estimated $80,000 per SY (USDA, ARS, 1976 estimated cost for one scientist year), this equals $240,000. (The costs of evaluating the impact of *Microlarinus* are not included in this figure, but these have varied in direct proportion to available time and funding.)

Since the 1961 introduction of *Micrlarinus* spp. to the United States, there has been a gradual increase in the distribution of both weevils. Maddox (in press) noted that shortly after introduction, the weevils were present primarily in the southwest, including west Texas, an area with a climate not too unlike that in Italy. The weevils are now present as far north as the Kansas-Nebraska border, which suggests some adaptation to climate.

Prior to the release of these weevils there was some concern as to whether we should proceed with introduction solely on the basis of the restricted reproduction. In view of the ascribed benefits and the limited losses reported, the introduction was justified. However, there is still much work to be done on the biological control of *Tribulus*. A search for additional natural enemies is being considered, and a more precise evaluation of the impact of the seed and stem weevil may be made.

REFERENCES

Andres, L. A. and G. W. Angalet. 1963. Notes on the ecology and host specificity of *Microlarinus lareynii* and *M. lypriformis* and the biological control of puncturevine, *Tribulus terrestris*. J. Econ. Entomol. 56(3): 333-40.

Bennett, F. D. 1968. Progress report on current biological control projects in St. Kitts and Nevis, June 1968. West Indian Stn., Commonw. Inst. Biol. Control. 4 pp.

Davis, C. J. and N. L. H. Krauss. 1966. Recent introductions for biological control. Proc. Hawaii Entomol. Soc. 19: 210-7.

Ehler, L. and R. L. van den Bosch. 1974. An analysis of the natural biological control of *Trichoplusia ni* (Lepidoptera: Noctuidae) on cotton in California. Can. Entomol. 106: 1067-73.

Essig, E. O. 1938. Insects of Western North America. The MacMillan Co., New York. 1035 pp.

Girard, D. H. 1968. List of intercepted plant pests, 1967. USDA, ARS 82-6-2, 76 pp.

Goeden, R. D., L. A. Andres, T. E. Freeman, P. Harris, R. L. Pienkowski, and L. R. Walker. 1974. Present status of projects on the biological control of weeds with insects and plant pathogens in the United States and Canada. Weed Sci. 22: 490-5.

Greathead, D. J. 1968. Biological control of lantana. A review and discussion of recent developments in East Africa. Pest Articles and News Summaries (Pans) 14(2): 167-75.

Huffaker, C. B., D. W. Ricker and C. E. Kennett. 1961. Biological control of puncturevine with imported weevils. Calif. Agric. 15(12): 11-12.

Maddox, D. M. 1976. History of weevils on puncturevine in and near the United States. Weed Sci. 24: 414-19.

Roney, J. N. 1963. Arizona Cooperative Insect Survey, December 13, 1963. Publ. jointly by Ariz. Agric. Expt. Stn., Ariz. Agric. Ext. Serv., Ariz. Agric. and Hort. Comm., and the USDA

Stegmaier, C. E., Jr. 1973. Colonization of the puncturevine stem weevil, *Microlarinus lypriformis* (Coleoptera: Curculionidae) with notes on parasitism in South Florida. Fla. Entomol. 56(3): 235-41.