THE BIOLOGICAL CONTROL OF WEEDS WITH INSECTS IN THE UNITED STATES[1/]

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In this discussion we will trace briefly the development of the biological control of weeds in the United States, both in the Hawaiian Islands and on the mainland, and also comment on several current weed projects.

HAWAII

Since 1902 when work first began on the biological control of lantana (*Lantana camara* L.) with insects, the state of Hawaii has introduced several dozens of insect species to help control 16 species of weedy plants (see Table 1). "Substantial" to "complete" control has been obtained in several instances (e.g., *Eupatorium*, *Emex*, *Lantana*, *Opuntia*, *Tribulus*). Although the weedy areas have not always been extensive, this has not detracted from the effectiveness of the method, but rather has demonstrated its applicability to weed problems in the early stages of their development.

The weed program in Hawaii is funded by the State Department of Agriculture and is carried out under the direction of the State Entomologist. The *modus operandi* of the program differs from that followed in continental areas, and can be attributed to the insular nature of the state. When working on a weed present in the continental United States, it is a common practice for the United States Department of Agriculture to station an entomologist in the native home of the plant to study and test the associated entomofauna, prior to shipping any insect into a quarantine handling room in the United States. The Hawaiian entomological explorer, on the other hand, frequently ships these insects directly into the quarantine facility in Honolulu for rearing, identification and study without prior testing. This has speeded the work in some respects, reducing the cost per insect introduced. However, unlike the early lantana project, where some of the insects were introduced solely on the judgment of the exploring and receiving entomologists, precautions are now taken to assure that each weed feeding insect is fully tested on a wide range of plants. Before release the test data is reviewed by an Advisory Committee, made up of 5 entomologists, whose recommendation is then considered by the State Board of Agriculture.

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The environmental diversity encountered in the Hawaiian Islands plus the number of ongoing weed projects make Hawaii an ideal area for practicing and studying the biological control method.

THE CONTINENTAL UNITED STATES

The importation of insects to control Klamath weed, Hypericum perforatum L., marked the first use of an exotic insect species to control a weed in the continental United States. The outstanding success of this project contributed greatly to the expanded study of insects to control weeds in the United States. During the work on Klamath weed, and up until 1956, the United States Department of Agriculture had one entomologist working part-time on the biological control of weeds. This has since been increased to 8 full-time entomologists, located at several stations across the United States and in Italy and Argentina. The University of California now has 3 entomologists working part or full-time on weed control, while the Virginia Polytechnic Institute has one. Entomologists in other states are also working on projects directly or indirectly related to the biological control of weeds. Until recently all funding for this work came exclusively from federal or state sources, whereas now, private interest groups contribute to the collection and release of weed-feeding insects.

Although there are several ways of using insects to control weeds the program in the United States has for the most part followed the classical approach: the search for and study of new natural enemies to control introduced weeds. The foreign work is centered at the laboratories in Rome, Italy, and Buenos Aires, Argentina. In addition, we are working closely with entomologists in Poland, Yugoslavia, Egypt, Israel, Pakistan and India to search out insects and other natural enemies of weeds originating in these areas. Limited testing and handling of exotic weed insects are also carried out at the quarantine laboratory at Albany, California.

In 1970, a weed-insect laboratory was established at Gainesville, Florida, for implementing the biological control of alligatorweed and other aquatic weeds. In January, 1972, an entomologist will be transferred to Fort Lauderdale, Florida, to work on water hyacinth and other aquatic plants. Another entomologist was recently assigned to the new United States Department of Agriculture laboratory at Stoneville, Mississippi, to work on weeds of row crops and humid pastures. This laboratory is unique in the United States in that the entomologist will be part of a team of weed specialists, including seed ecologists, plant physiologists and agronomists, assembled as the Southern Weed Science Laboratory, to develop a comprehensive control program of weeds infesting agricultural crops.

Although we are concerned here with the use of insects to control weeds, organisms other than insects are being studied. The aquatic snails, Marisa cornuarietis (L.) and Pomacea australis (d'Orbigny), herbivorous fish, e.g., Tilapia mossambica Peters, Ctenopharyngodon idella Valenciennes, as well as plant pathogens are all under experimentation for weed control by scientists of the Plant Science Research Division, U. S. Department of Agriculture.

Weed projects in the United States

The success of the Klamath weed project stimulated interest in the use of insects to control other western range weeds. In 1953, a seed weevil was introduced to reduce the spread of gorse, Ulex europaeus L., a pest in the coastal areas of Oregon and California (Holloway and Huffaker 1957). In 1956, exploration for insects to control Halogeton glomeratus (M. Bieb.) C. A. Mey. was initiated. This weed is a poisonous chenopodiaceous plant commonly found throughout much of the Great Basin. Between 1956 and 1960, projects were initiated on puncturevine, Tribulus terrestris L., Mediterranean sage, Salvia aethiopis L., Dalmatian toadflax, Linaria dalmatica (L.) Mill., Scotchbroom, Cytisus scoparius (L.) Link, tansy ragwort, Senecio jacobaea L., plus various thistles. Several insects have been introduced and some degree of progress on biological control of a number of these weeds has been achieved (see Table 2). Several of the projects have yet to come to fruition.

Almost all of the projects initiated during the late 50's and early 60's involved western range or pasture weeds, in part a direct result of the Klamath weed success in the northwest and the placement of the United States Department of Agriculture biological control of weeds investigations laboratory in California. The only non-western project initiated during this period was the work on alligatorweed, Alternanthera philoxeroides (Mart.) Griseb., an aquatic weed in the southeastern states.

Although emphasis will continue in the control of weeds in range and pasture areas we are now attempting to select species that are of importance across the entire United States and not just in the west. Canada thistle, Cirsium arvense (L.) Scop. and musk thistle, Carduus nutans L., are two examples; both occur across the country, and are pests in crop as well as pasture and meadows areas. The Canadians and the Commonwealth Institute of Biological Control have already pioneered much of the work with these two weeds (Zwölfer 1965; Harris and Zwölfer 1971; Peschken 1971). We have also initiated work on field bindweed, Convolvulus arvensis L., another major pest throughout the entire United States.

Our efforts at biological control have met with varying success. Klamath weed, we will not discuss further, other than to say it has been the major success of the several projects undertaken. The alligatorweed project has been relatively successful in several southeastern states and is continuing to look better each season (Maddox et al 1971). The tansy ragwort project has been successful at Fort Bragg, California, and at one site in Oregon. We would like to comment briefly on these two projects.

Alligatorweed, Alternanthera philoxeroides (Mart.) Griseb: This South American plant was first recorded in Florida about 1894 (Weldon 1960) and by 1970 infested an estimated 66,551 acres throughout the southeastern United States (E. O. Gangstad, U. S. Army Corps of Engineers, Chief, Aquatic Plant Control Section, personal communication). It grows primarily as an emersed or floating plant blocking waterways and otherwise generally adding to water management problems. In 1959 and 1960 a survey of the insects associated with this plant was funded by the Army Corps of Engineers, and carried out in South America. Of the 40 odd species of insects found on the plant, three were later selected for introduction to the United States (Vogt 1960, 1961).

The leaf-feeding chrysomelid beetle, Agasicles hygrophila Selman and Vogt, was the first insect introduced and in 1964 several thousand adults were released at the Savannah National Wildlife Refuge (South Carolina). Despite the abundance and seemingly healthy nature of the plant at this site, the beetles, although established, have never reached effective control levels. A second release of Agasicles was made near Jacksonville, Florida, in 1965. Here the beetles established quickly and destroyed the mats of alligatorweed at the release site within 15 months (Hawkes et al. 1967; Zeiger 1967). The Jacksonville population has provided the chief source of beetles for distribution to other alligatorweed areas throughout the southeast.

Despite the startling control at Jacksonville, the results obtained with Agasicles at other sites has been varied. For example, the beetle is destroying alligatorweed on that arm of the Jim Woodruff Reservoir, Georgia, fed by the Flint River, but is providing only poor to mediocre control in that area fed by the Chattahoochee River. Chlorotic patches of the host plant are also free from attack by Agasicles. Limited laboratory studies with plants deficient in phosphorus and calcium suggest that nutritional differences in the plants may be involved (Maddox et al. 1971).

Another explanation for the striking control achieved at Jacksonville, may lie with the seasonal growth pattern of the plant. At Jacksonville, the alligatorweed mat can renew itself in a single season. During the period of active spring growth, the mat's carbohydrate reserves are diminished, reaching a low point in June (Blackburn and Weldon 1964). Coincidental with this rapid plant growth, there is increased feeding by Agasicles and a build-up in the population level. It is speculated that the removal of the new growth by the beetle, when the plant's energy reserves are at a low level, contributes to rapid destruction of the plant. The growth pattern of the plant at the Savannah Wildlife Refuge, on the other hand, is somewhat different. Here the growth rate is less and the mat renews itself only once every three years. The carbohydrate reserves are not depleted to the low levels observed at Jacksonville, but tend to fluctuate throughout the growing season (Blackburn and Weldon 1964). Also, the Agasicles population does not reach its peak level until later in the season. Although other factors are undoubtedly involved in determining the effectiveness of Agasicles, there is sufficient evidence to suggest that an examination of the seasonal carbohydrate levels of the plant at other areas may aid in explaining the observed variations in control. It may also help in pinpointing the periods of plant vulnerability, a first step to plant management, either with insects or other methods of control.

In the more northern alligatorweed areas (the Carolinas, Arkansas, etc.) the plant is frozen back to the water's surface each winter, and high mortality of Agasicles occurs. In an effort to offset this winter mortality, in 1970 and 1971, large numbers of the beetles were shipped from areas in Florida and Louisiana to infestations of the weed further north. Beetles collected in Florida were released on the Santee Cooper Reservoir, South Carolina, in April, 1970. These multiplied rapidly and spread several miles from the release site before the onset of cold temperatures. A large number of beetles were found to have survived at this site the following spring and a second population increase was observed in 1971. Following these two seasons of high beetle populations there was still no appreciable destruction of the mat, although alligatorweed was being sufficiently suppressed to permit an increase in other plants.

The Agasicles present in the United States originated in the area of Buenos Aires, Argentina, about as far south in South America that the plant occurs in any abundance. A cold hardy strain of Agasicles, which might be more adaptable to more northern climes in the United States, is being sought on scattered pockets of alligatorweed 300 km south of Buenos Aires.

Several natural enemies have been noted attacking Agasicles in the United States, but have never been found in abundance (Maddox et al. 1971). The coccinellid, Coleomegilla maculata (DeGeer), will feed on the eggs and young larvae; the stink bugs, Podisus maculiventris (Say) and P. mucronatus Uhler, will feed on the larvae and adults. A tachinid (Pseudomyothyria ancilla (Walker)) stings the larvae and emerges from the pupa or prepupa inside the stem internode but is unable to exit from the stem.

Two other insect species have been introduced into the United States against alligatorweed. The thrips, Amynothrips andersoni O'Neill, reported to be the most ubiquitous insect on alligatorweed in South America (Vogt 1960), was introduced to several states beginning in 1967, and is now established in Florida, Georgia and South Carolina. It has not yet increased to high population levels and its impact on the plant remains unknown. Vogtia malloi Pastrana, a stem-mining pyralid moth, was released in Florida, Georgia and the Carolinas in 1971 and has already caused considerable stem collapse at one release site in Florida (Brown and Spencer 1971). The eggs of this moth are laid on the tips of the plants and the young larvae girdle the inside of the stem causing it to wilt even though only a limited amount of tissue may be consumed (Maddox 1970). This insect may prove a suitable adjunct to Agasicles in the control of alligatorweed.

These are but a few of the high points of the alligatorweed project. For a more detailed account see Maddox et al. 1971.

Tansy Ragwort, Senecio jacobaea L.: This toxic range and pasture weed is present in the more coastal areas of northern California, Oregon and Washington. Three species of insects have been introduced to the United States for its control, all from Europe, the original home of the plant. The first, a foliage-feeding arctiid moth, Tyria jacobaeae (L.) was introduced to California in 1959 and reached effective population levels in 1963 at the original release site (Frick and Holloway 1964; Hawkes 1968). At that time Tyria larvae defoliated the weed over about 2 acres; in 1965 the defoliated area was increased to 5 acres, and in 1966 this increased to 12 acres or almost the entire extent of the tansy ragwort infestation at this site. The moth can be credited with reducing the ragwort from 15-19 to 3-4 flowering stems/sq. yd. at this site (Hawkes, unpublished data). There has also been a marked reduction of ragwort at two of the Tyria release sites in Oregon. Although Tyria has demonstrated its capacity to reduce ragwort, its effectiveness has varied between the several release sites. Studies are underway to explain these variations.

The seed fly, Hylemya seneciella (Meade), was introduced into California in 1966 (Frick 1969), but due to destruction of the release field by mowing, and again by sheep, we are uncertain whether the fly is established. Several generations were completed in the release area and the fly was spreading prior to the inadvertent destruction of the ragwort.

The chrysomelid, Longitarsus jacobaeae (Waterhouse) was first released in California in 1968 and apparently is now established (Frick 1970). The larvae of this insect attacks the crown of the plant while the adult feeds on the leaves of the rosette.

FUTURE OUTLOOK

The use of insects for weed control has still not achieved wide recognition in weed control circles, the reasons for which may be varied. The fear that weed-feeding insects may at some time switch their attack to crop plants has been a major obstacle to their acceptance in the past, although these fears have been allayed somewhat through the years. Certainly as our techniques for assessing host specificity improve, so should the safety of each introduction.

Certain limitations inherent in the use of weed-feeding insects suggest their greatest use will continue in areas where their host plants experience a low degree of disturbance and are in the presence of competing vegetation (e.g. pasture, range). However, as our knowledge of plants and their development increases, so should our ability to manipulate the populations of weed-feeding insects more effectively, extending their use to a wider range of weed situations. Presently, insects are felt to be of little value for controlling weeds in cultivated areas. However, their possible use in suppressing these same weedy species in less disturbed situations surrounding cultivated fields should not be overlooked. A reduction in weed abundance in non-crop areas could conceivably reduce the abundance of the weed in adjoining cultivated fields.

One roadblock to an expanded use of insects against weeds is the question of conflicting interests: Which weeds are suitable for biological control? The role of some weeds in providing food and shelter to wildlife may offset their noxious qualities. Previously, biological control workers had to assure only that plants of economic importance would not be endangered by the introduced weed-feeding insect. Now they must also consider the impact of each candidate insect on plants of "ecological" importance. For example, where introduced weeds have crowded out native plants, birds and other animals have been forced to accept the intruder as a source of food and shelter, or migrate from the area. Thus by virtue of their abundance, the invading plants have assumed a positive value. Salt cedar (Tamarix pentandra Pall.), an introduced phreatophyte, forms dense stands over washes and stream beds in the southern areas of Arizona, New Mexico and parts of Texas, where it impedes water flow, often resulting in flooding during rainy periods while transpiring large volumes of water to the atmosphere the remainder of the year. On the plus side, the plant provides nesting sites for the white-winged dove, Zenaida asiatica L., a favorite game bird, native to the area. Salt cedar is also considered an important source of nectar by beekeepers. For these reasons, plans to control salt cedar by biological means are being questioned. A number of submersed water weeds in the United States also serve as food for fish and waterfowl. A conflict of interest may limit the use of insects against these weeds.

The success achieved with alligatorweed has spurred renewed interest in the biological control of weeds with insects in the United States. Currently $250,000 is budgeted annually to support the United States Department of Agriculture effort in this area (excluding state programs). Emphasis will continue against introduced weeds. The techniques for testing and introducing exotic weed-feeding insects are known and it is now a question of implementing them. Efforts will also be directed towards manipulating populations of both native and exotic phytophagous insects to enhance their control action. For example, the production and release of large numbers of Bactra sp. against Cyperus rotundus L. is being planned in the southeastern United States.

Certainly biological control suffers many limitations as a method of weed control. However, if properly developed, it can be an effective weed management tool, offering economic returns exceeding those of other weed control techniques.

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Table 1. The Status of Biological Control of Weeds in Hawaii--1971

WEED: Species	Site of Infestation: Kauai	Oahu	Molokai	Maui	Hawaii	INSECT: Species and Year of First Release	REMARKS
Clidemia hirta (L.) D. Don (Koster's curse)	-	+	-	-	-	Liothrips urichi Karny (Thysanoptera: Thripidae), 1953	Partial control on Oahu.
						Blepharomastix ebulealis (Guenée)(Lep.: Pyralidae), 1970	No recoveries to date.
Cyperus rotundus L. (Nut grass)	+	+	+	+	+	Bactra truculenta Meyrick (Lep.: Olethreutidae), 1925	Ineffective control, sometimes heavy parasitism.
						Athesapeuta cyperi Marshall (Col.: Curculionidae), 1925	Ineffective control.
Elephantopus mollis H.B.K. (Elephant's foot)	+	-	-	-	-	Tetraeuaresta obscuriventris (Loew) (Dip.: Tephritidae), 1961	Partial control on Kauai.
Eupatorium adenophorum Spreng. (Maui Pamakani)	-	+	-	+	+	Procecidochares utilis Stone (Dip.: Tephritidae), 1925	Control complete on Maui, substantial on Hawaii, partial on Oahu.
Eupatorium riparium Regel (Hamakua Pamakani)	-	+	-	+	+		No suitable biocontrol candidates yet discovered.
Emex spinosa Campd. and Emex australis Steinh. (Emex)	-	+	+	+	+	Apion antiquum Gyllenhal (Col.: Curculionidae), 1957	Control substantial on Maui, incomplete on Oahu and Molokai. On Hawaii control varying from complete (1200 m) to partial (600 m); no control below 150 m.

Table 1. (Continued)

Hypericum perforatum L. (Klamath weed)	- - - - +	*Zeuxidiplosis giardi* (Kieffer) (Dip.: Cecidomyiidae), 1965	Substantial control on Mt. Hualalai on Hawaii.
		Chrysolina quadrigemina (Suffrian) (Col.: Chrysomelidae), 1965	Present in low numbers only.
		Chrysolina hyperici (Förster) (Col.: Chrysomelidae), 1965	Present in low numbers only; established on *Hypericum degeneri* Fosberg.
Lantana camara L. (Lantana)	+ + + + +	*Teleonemia scrupulosa* Stål (Hem.: Tingidae), 1902	Defoliation during the winter months by *Catabena*, *Hypena* and *Syngamia* complement the summer defoliation by *Teleonemia*. *Uroplata* and *Octotoma* continue to increase and spread. Their action combined with *Plagiohammus* exerts stress on lantana in some localities. Control by this insect complex ranges from partial to substantial on Hawaii and Maui.
		Octotoma scabripennis Guérin-Méneville (Col.: Chrysomelidae), 1954	
		Catabena esula (Druce) (Lep.: Noctuidae), 1955	
		Syngamia haemorrhoidalis Guenée (Lep.: Pyralidae), 1956	
		Hypena strigata F. (Lep.: Noctuidae), 1957	
		Plagiohammus spinipennis (Thomson) (Col.: Cerambycidae), 1960	
		Uroplata girardi Pic (Col.: Chrysomelidae), 1961	
		Leptobyrsa decora Drake (Hem.: Tingidae), 1970	*Leptobyrsa* is well established on Maui but effectiveness not yet determined.
Melastoma malabathricum L. (Indian rhododendron)	+ - - - +	*Selca brunella* (Hampson) (Lep.: Arctiidae), 1964	Partial control on Kauai and Hawaii.

Table 1. (Continued)

Myrica faya Ait. (Faya bush)	- - - - +	Strepsicrates smithiana (Walsingham) (Lep.: Olethreutidae), 1956	Not recovered from M. faya, but established on M. cerifera L.; no other biocontrol candidates yet discovered.
Opuntia spp. (Cactus, panini)	+ + + + +	Dactylopius confusus (Cockerell) (Hom.: Dactylopiidae), 1949	Substantial to complete control on Hawaii by Dactylopius and Cactoblastis; action slow at higher elevations. Archlagocheirus is effective in some localities on Hawaii. Insects released only on Hawaii; however, Cactoblastis wind-borne to other islands.
		Cactoblastis cactorum (Berg) (Lep.: Pyralidae), 1950	
		Archlagocheirus funestus (Thomson) (Col.: Cerambycidae), 1951	
Pluchea odorata (L.) Cass. (Sour bush)	+ + - + +	Acinia picturata (Snow) (Dip.: Tephritidae), 1958	Neither species effective; no further introductions planned.
		Trichotaphe aenigmatica Clarke (Lep.: Gelechiidae), 1957	
Rubus penetrans Bailey (Blackberry)	+ + - + +	Apotoforma sp. (Lep.: Tortricidae) 1964	Only Apotoforma and Schreckensteinia are established. Partial control on Kauai, Maui, and Hawaii.
		Schreckensteinia festaliella (Hübner) (Lep.: Heliodinidae), 1963	
		Chlamisus gibbosus (F.) (Col.: Chrysomelidae), 1969	No recoveries made to date.
Schinus terebinthifolius Raddi (Christmas berry)	++ - - +	Acanthoscelides atronotatus (Pic) (Col.: Bruchidae), 1960	Insects have given only partial control on Kauai, Oahu, and Hawaii.
		Episimus sp. (Lep.: Olethreutidae), 1954	

Table 1. (Continued)

Tribulus cistoides L. (Nohu)	+ + + + +	Microlarinus lypriformis (Wollaston) (Col.: Curculionidae) 1963	Control by M. lypriformis complete on Kauai and Oahu, substantial on Maui, partial on Hawaii. Also established on Molokai. M. lareynii weakly established on Kauai.
Tribulus terrestris L. (Puncturevine)	+ + + + +	Microlarinus lareynii (Jacquelin du Val) (Col.: Curculionidae), 1962	
Ulex europaeus L. (Gorse)	- - - + +	Apion ulicis (Förster) (Col.: Curculionidae)	Ineffective on Maui and Hawaii.

Table 2. The Status of Biological Control of Weeds in the United States[a]--1971

WEED	INSECT Species & Year of First Release	REMARKS
Alternanthera philoxeroides (Mart.) Griseb (Alligatorweed)	Agasicles hygrophila Selman & Vogt (Col.: Chrysomelidae), 1964	First released in Calif. & S. C., good control in Fla. and other southeastern states.
	Amynothrips andersoni O'Neill (Thysanoptera: Thripidae), 1967	First released in Fla. and S.C.; established in S.C., Ga., Fla.; little effect on plant to date.
	Vogtia malloi Pastrana (Lep.: Pyralidae), 1971	Released in Fla., Ga., S.C. and N.C. Established in Fla.
Opuntia littoralis (Engelmann) Ckll. Opuntia oricola Philbrick (Prickly pear cactus)	Dactylopius sp. (Hom.: Dactylopiidae), 1951	Main agent for control on Santa Cruz Is. (S. Calif.), effects of other introduced agents not significant.
Linaria dalmatica (L.) Mill. (Dalmatian toadflax)	Calophasia lunula (Hufnagel) (Lep.: Noctuidae), 1967	Released in Idaho, Wash., & Wyo. between 1967-71. Not established.
Ulex europaeus L. (Gorse)	Apion ulicis (Förster) (Col.: Curculionidae), 1953	Established in Calif., Ore., and Wash., but satisfactory control only at San Rafael, Calif.; project inactive pending results of New Zealand work.
Hypericum perforatum L. (St. Johnswort or Klamath weed)	Chrysolina hyperici (Förster) (Col.: Chrysomelidae), 1945	Initially established at low levels in Calif., Nev., Ida., Mont., Ore., and Wash.; beetle now absent in Calif. Status in states other than Hawaii unknown.
	Chrysolina quadrigemina (Suffrian) (Col.: Chrysomelidae), 1946	Main factor in control of weed;beetle population at low levels in Calif., Colo., Ida., Mont., Ore., and Wash.
	Chrysolina varians (Schaller) (Col.: Chrysomelidae), 1950	Released in Calif. and Idaho; not established.

Table 2. (Continued)

Hypericum perforatum L. (Cont'd.) (Klamath weed)	Agrilus hyperici (Cruetzer) (Col.: Buprestidae), 1950	Established in Calif., Ida., Mont., Nev., and Wash.
	Zeuxidiplosis giardi (Kieffer) (Dip.: Cecidomyiidae), 1950	Established in Calif.
Salvia aethiopis L. (Mediterranean sage)	Phrydiuchus spilmani Warner (Col.: Curculionidae), 1969	Released in Ore.; not established.
	P. tau Warner, 1971	Released in Ore.
Tribulus terrestris L. (Puncturevine)	Microlarinus lypriformis (Wollaston) (Col.: Curculionidae), 1961	First released in Ariz.; established in Ariz., Calif., Colo., and Nev.
	Microlarinus lareynii (Jacquelin du Val) (Col.: Curculionidae), 1961	First released in Nev.; established in Ariz., Calif., N. M., Tex. and Nev.
Senecio jacobaea L. (Tansy ragwort)	Tyria jacobaea (L.) (Lep.: Arctiidae), 1959	First released in Calif.; established in Calif., Ore. and Wash.; effective control in Ft. Bragg, Calif. and slight but increasing control in Ore.
	Hylemya seneciella (Meade) (Dip.: Anthomyiidae), 1966	Released in Calif.; establishment probable.
	Longitarsus jacobaeae (Waterhouse) (Col.: Chrysomelidae), 1968	Italian strain first released in 1968, Swiss strain first released in 1969; Italian strain established in Calif.
Cytisus scoparius (L.) Link (Scotch broom)	Leucoptera spartifoliella (Hübner) (Lep.: Lyonetiidae), 1960	First released in Calif.; colonies present in Ore. and Wash. prior to first release; partial control in coastal areas of Calif.
	Apion fuscirostre (F.) (Col.: Curculionidae), 1964	Partially effective in coastal areas of Calif.; additional insects being considered as biocontrol candidates.

Table 2. (Continued)

Cirsium arvense (L.) (Scop.) (Canada thistle)	Altica carduorum Guerin-Meneville (Col.: Chrysomelidae), 1966	Released in Calif. and other states; not established; other strains of A. carduorum from different climatic areas are being sought.
Silybum marianum (L.) Gaertn. (Milk thistle)	Rhinocyllus conicus (Froelich) (Col.: Curculionidae), 1969	Released in Calif., 1969, 1971; establishment unknown.
Carduus nutans L. (Musk thistle)	Rhinocyllus conicus (Froelich) (Col.: Curculionidae), 1969	Established in Va. and Mont.
Centaurea solstitialis L. (Yellow starthistle)	Urophora sirunaseva (Hering) (Dip.: Tephritidae), 1969	Released in Calif., 1969-71; not established.

a/ Excluding Hawaii.

DISCUSSION

HARRIS Last time I saw the Senecio jacobea infestation at Fort Bragg, there were many rosettes but few flowering stalks. I would like to know if this situation has continued. Dr. Dempster, who is working with the weed in Britain has found that the plant, after defoliation increases from rosette root buds. So, every time a plant is defoliated by cinnabar larvae you get six or eight new plants coming up the following year.

ANDRES I know you do get killing back of the stem and at the base of the stem you get development of a number of rosettes. It seems like the flowering stems put up by the latter are generally smaller. Based on counts of the number of flowering stalks, we have seen a reduction in plants, but we need to make additional counts (i.e. total ground covered by the plants, etc.). Hopefully, Longitarsus will be able to show or stop plant recovery from Tyria attack.

WATERHOUSE I was very interested in Longitarsus. This is a species which we haven't attempted to bring into Australia. Did it prove to be highly specific in the tests you did before it was liberated?

ANDRES Yes, it did. We tested it on about 40 species of composites and right off hand I can't say exactly which plants it fed on, but it has a very narrow host range. Senecio cruentus, a species very closely related to jacobeae was one of the plants attacked.

SANKARAN I am most interested in your work on alligator weed insects because this weed has recently been reported from south India. Last year it was found in an area adjoining the Dum Dum airport in Calcutta, and I found it in a lake in Bangalore. We are trying to introduce alligator weed insects from the U.S.A. or South America.

Regarding Agasicles, I know that it pupates in the hollow stem of the plant and that is one of the factors that tie the insect to the weed. Have you studied the factors that restrict Amynothrips to Alternanthera?

ANDRES We tested Amnyothrips on a wide range of plants and we got feeding only on alligatorweed. However, we didn't study the particular factors that might be involved such as feeding stimulants or things of that nature. Several ornamental Alternanthera were included in the tests.

SANKARAN We have economic plants in the Amaranthaceae in India among which are Amaranthus gangeticus and also Telanthera ficoidea which is a hedge plant, so I would like to know what other economic plants, in the Alternanthera group particularly, have been tested.

ANDRES I can furnish you a summary of our testing.

FRANK Alligator weed occurs commonly in areas where it is desirable or necessary to conduct mosquito abatement programs. Have you had occasions or experiences where mosquito abatement programs interfere with releases of insects?

ANDRES Low dosages of malathion used for mosquito abatement on Lake Seminole in western Florida apparently had little or no ill effect on the adult beetle population. On the other hand, I've had mixed reports from areas where they have sprayed to control the mosquito borne Venezuelan equine encephalitis. In some areas in Louisiana the beetles were reported dead and in some areas they were not.

HASAN I see that a dodder, Cuscuta sp. is one of the weeds in your list. In Russia, some work has been done on this weed and they have found a fungus, Alternaria cuscutacidae controlling this weed. I don't know if you have considered this fungus on this project or not.

ANDRES No, we have not considered the fungus but, I'm certain the U.S.D.A Plant Science Research Division would be interested in looking into this. Have the Russian workers been able to duplicate their control results in other areas? I think there were only one or two publications which came out on the fungus work.

HASAN There are a few publications in which the Russian workers have examined the effect of the fungus on dodder in different crops and they have found that in most of the crops the fungus was very effective.

BUCKINGHAM You mentioned conflict of interest with the white wing dove and others. Is this going to bring your projects under the control of the Environmental Protection Agency in the future?

ANDRES I don't really know. Our existing machinery for resolving conflicts of interest isn't very good. What I've been telling people is that if they are interested in having work done on a particular weed, they should find out how important that weed is in their local area then express their interest to the local Agricultural Commissioner. Hopefully, the latter person will bring the question before the State Agricultural Commissioner's Meeting to learn if there would be any conflict of interest in other areas of the state. In turn the Agricultural Commissioners should present the conflict question to their Regional Plant Board to ascertain whether other states in their region value the subject weed. We presently have a Federal Working Group on the Biological Control of Weeds which often offers a number of suggestions on where conflicts of interest might exist, but I don't feel it is the Group's role to resolve these conflicts. So, at the present there is no set mechanism for solving these conflicts. Whether the Environmental Protection Agency will step into this problem remains to be seen.

CAVERS How was the growth rate of alligator weed actually measured? Was the flowering pattern of the plant different in the different locations that you described and would such differences have an effect on the growth rate?

ANDRES As I recall the growth rate was measured just by stem elongation and the weed was measured every two weeks, and I don't know if flowering rates were involved, but at least you get profuse flowering.

CAVERS Was it a dry weight measurement?

ANDRES It was a stem elongation measurement, and we didn't actually do it. The measurements were taken by Dr. Weldom at Ft. Lauderdale, Florida.

FRANK You mentioned collecting numbers of beetles and introducing them into other areas. I know you have a program at Savannah, Georgia where you have attempted to rear them indoors. What is the productivity of that program? Do you have any cost figures for rearing the beetles?

ANDRES No, we haven't. The rearing program really hasn't worked out that well yet. At Savannah we were using plastic green houses for rearing the beetles and we had a number of technical difficulties. I think it will actually be better to collect beetles in southern areas and to carry them north, but this is something we are going to have to work out.

ROBERTS I was interested in your speculations about the role of the plants' physiology in the attack on alligator weed by the chrysomelid. Recently a colleague of mine, Mr. T.J. Ridsdill Smith, working with rye-grass, showed that with root-feeding scarabaeid beetle larvae, the growth rate and the amount of feeding were greatly reduced in treatments involving frequent clipping of the foliage. However, in an infrequently clipped part of the experiment the insects were very healthy and rapidly gained weight. We believe that the relative amounts of young roots and the partitioning of carbohydrate or other nutrients between roots and shoots were important in determining the amount of feeding in the two treatments. Thus the intensity of grazing would affect the plants' physiology and whether they would direct more nutrients into roots or shoots, and could concievably affect many insect species.

END OF DISCUSSION

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