Releases of Natural Enemies in Hawaii since 1980 for Classical Biological Control of Weeds

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Abstract

A comprehensive review of biological control of weeds in Hawaii was last published in 1992, covering 74 natural enemy species released from 1902 through 1980. The present review summarizes releases of 21 natural enemies targeting seven invasive weeds from 1981 to 2010. These projects were carried out by Hawaii Department of Agriculture (HDOA), USDA Forest Service (USFS), University of Hawaii (UH), and US Geological Survey Biological Resources Discipline. An appendix summarizing the chronology and outcomes of releases is included (Appendix 1).

Introduction

The practice of classical biological control of weeds began in Hawaii in 1902, with the release by the Territory of Hawaii of a tingid lacebug (*Teleonemia scrupulosa* Stål) for control of lantana (*Lantana camara* L.) (Swezey, 1924). Since that time, Hawaii has witnessed several spectacular successes in weed biological control, and today continues the science of managing weeds at the landscape level using natural enemies introduced from the target's native range after thorough testing and evaluation. The most recent comprehensive review of weed biological control in Hawaii (Markin et al., 1992) summarized 74 introductions of natural enemies between 1902 and 1980. Additional information for introductions through the mid-1990s was included in the worldwide compilation by Julien and Griffiths (1998). Hawaii's weed biological control projects from 1902 to1980 resulted in establishment of 42 insects and one fungal agent on 19 target weeds.

Our objective here is to provide an updated report of agents released for weed biological control in Hawaii. We briefly summarize results for each natural enemy released since 1981, and we include an appendix listing all weed biological control agents released in Hawaii from 1902 to 2010 (Appendix 1).

Methods

Data on weed targets and weed biological control agents released since 1981 were compiled from published and unpublished sources, including records of the Hawaii Department of Agriculture and personal observations of biological control specialists and weed management partners.

Results

Passiflora tarminiana Coppens & V. E. Barney (Passifloraceae), banana poka

Passiflora tarminiana (formerly *P. mollissima*) is a vine native to the South American Andes, apparently introduced into Hawaii in the early 1900s (Wagner et al., 1990). It is invasive in native forests on the islands of Hawaii and Kauai, and is found in alien forest habitat in the Kula area of Maui (Hauff, 2006). Funding for the biological control program in Hawaii came primarily from the USFS and National Park Service. *P. tarminiana* also is invasive in New Zealand, where a biological control program is being implemented (Williams and Hayes, 2007).

***Scea* (= *Cyanotricha*) *necyria* (Felder & Rogenhofer) (Notodontidae)**

Scea necyria was imported from Colombia and subsequently released on the islands of Hawaii, Kauai and Maui, but failed to establish. Despite repeated releases between 1988 and 1992 totaling over 15,000 individuals (including adult moths, defoliating larvae, and eggs), no evidence of establishment was ever observed. Larvae and pupae collected from the field exhibited 17% and 9% parasitism, respectively, while no parasites were recovered from field collected eggs (Campbell et al., 1995). It was suspected that *S. necyria* pupae may have been significantly preyed upon by birds. Research in Colombia has suggested that adult moths may be missing an obligate nectar source in the Hawaii environments where this species was released (Campbell et al., 1995).

***Pyrausta perelegans* Hampson (Crambidae)**

Pyrausta perelegans imported from Venezuela was released on Hawaii, Maui, and Kauai islands in 1991-1992, but established only on Hawaii and Maui. Larvae feed inside flower buds, consuming the ovary, anther, gynophore, inner flower tube, and petals (Ramadan et al., 2008). *P. perelegans* populations have remained at low levels, with vine infestation rates averaging 2-11% in post-release monitoring in 1992-1993 by Ramadan et al. (2008), and around 2% or less of flower buds infested a decade later (M.T. Johnson, unpublished data). While generalist lepidopteran parasitoids were known to be active in the study area and could utilize *P. perelegans* in lab tests, no field-collected larvae or pupae were found to be parasitized (Ramadan et al., 2008). *Trichogramma chilonis* (Trichogrammatidae) parasitism affected from 0 to 26% of field collected eggs (Ramadan et al., 2008), and may be a significant factor suppressing *P. perelegans* (Campbell et al., 1995). Several common predators of lepidopteran larvae were noted also, but definitive evidence of their impacts on *P. perelegans* was lacking (Campbell et al., 1995; Ramadan et al., 2008).

***Septoria passiflorae* Syd. (Mycosphaerellaceae)**

Septoria passiflorae, a fungus originally from Colombia, attacks P. tarminiana leaves, first forming distinct yellow spots which eventually spread to cover much of the leaf and cause premature abscission. It was released on Hawaii Island in 1996 (Trujillo et al., 2001), and quickly controlled a large infestation of banana poka, which had smothered native forest canopy at approximately 2,000 m elevation. S. passiflorae was much less effective in the drier habitat of Kula, Maui (G. Shishido, pers. comm.). In Kokee, Kauai, defoliation of vines was observed at inoculation sites, but the clumped distribution of the weed in the forest may have inhibited dispersal of the pathogen (G. Kawakami, pers. comm.). Furthermore, the climate in Kokee is somewhat drier than the windward inoculation sites on the island of Hawaii, where infection and control results were substantial (Trujillo, 2005).

Coccinia grandis (L.) Voigt (Cucurbitaceae), ivy gourd

Ivy gourd is probably native to central East Africa, and was most likely moved to the Indo-Malayan region in centuries past. It may have come to Hawaii as a food or medicinal plant, via immigrants from that region. Ivy gourd was first reported on Oahu in 1968, and has since spread to Hawaii, Maui, Kauai and Lanai. This climbing vine blanketed large areas of alien wayside trees and shrubs on the island of Oahu, and less so in drier Kona (Hawaii). Three insects were released for biological control between 1996 and 1999 (Chun, 2002).

***Melittia oedipus* Oberthür (Sessiidae)**

Melittia oedipus, a clear-winged moth from

Kenya, was released from 1996 through 2002. Larvae feed in both roots and stems of the vine, forming galls. Galls can grow larger than 1.5 cm and cause breakage of the vine, so that the foliage above in the tree canopy dies. *M. oedipus* appears to be responsible for a widespread reduction in ivy gourd foliage density in tree and shrub canopies on Oahu. Development of land for housing also contributed to the decline of ivy gourd in the Kona area on Hawaii Island. Rat predation on *M. oedipus* larvae and pupae appeared to be significant, but the potential for biotic interference has not been studied further (Chun, 2002).

***Acythopeus coccineae* O'Brien and Pakaluk, *Acythopeus burkhartorum* O'Brien and Pakaluk (Curculionidae)**

Two weevil species of the genus *Acythopeus* were first released in 1999. *A. burkhartorum,* a stem gall former, failed to establish, despite many releases in different habitats. *A. coccineae*, whose larvae are leaf miners, established on Oahu and in Kona, and appears capable of some impact. Ivy gourd has been a target of physical containment on Kauai, Lanai and Maui, and these efforts, on Maui in particular, likely contributed to lack of establishment of *A. coccineae* there. The parasitoid *Eupelmus* prob. *cushmani* (Eupelmidae) has been reared from *A. cocciniae* larvae and pupae, and may contribute to the low numbers of *A. cocciniae* in field populations (M. Ramadan, pers. comm.). Both *Acythopeus* species were also released for the biological control of ivy gourd in Guam, however, biotic interference by an unidentified hymenopteran parasitoid emerging from *A. coccineae* pupae was noted (Muniappan et al., 2009).

Miconia calvescens DC. (Melastomataceae), miconia

Miconia was introduced to Hawaii as an ornamental tree around 1961 and planted on four of the major Hawaiian Islands before it was recognized as a serious invasive threat to native forests and watersheds (Conant et al., 1997). Miconia containment programs have been in effect since 1991 on Hawaii and Maui, and eradication programs continue on Oahu and Kauai. The containment effort on Maui has been very expensive, entailing aerial application of herbicide and chemical/mechanical control on the ground. On Hawaii, the task is even more daunting, given the large area invaded, and resources are presently not available to maintain extensive control. A single fungal pathogen has been released for miconia biological control, in both Hawaii and Tahiti. Additional agents are under development (Johnson, 2010).

***Colletotrichum gloeosporioides* (Penz.) f. sp. *miconiae* Killgore et al. (Glomerellaceae)**

This anthracnose fungus, released in 1997, is currently the only natural enemy approved for miconia control in Hawaii (Killgore, 2002). Although laboratory tests by Meyer et al. (2008) found significant mortality of miconia seedlings infected with *C. g.* f. sp. *miconiae* in Tahiti, the effects of the fungus on flowering and fruiting remain unknown. Post-release evaluation studies found this agent causing premature leaf drop in wild sapling plants in Hawaii (Brenner, 2000). At higher elevations in Tahiti, partial defoliation of large monospecific stands have increased light levels penetrating the canopy so that some limited regeneration of native flora is occurring (Meyer et al., 2011).

Lantana camara L. (Verbenaceae), lantana

Lantana has been a target of weed biological control work worldwide since 1902, when the first ever natural enemy was released here in Hawaii (Swezey, 1924). A total of 25 agents have been released to control this weed in Hawaii, with only one release made after 1980.

***Septoria* sp. (Mycosphaerellaceae)**

Septoria sp. collected from lantana in Ecuador was first released in 1997 by Dr. Eduardo E. Trujillo (UH) on the islands of Hawaii and Kauai (Trujillo, 2005). He reported excellent control of lantana at inoculated sites at Kokee on Kauai. There has been no further update published on the impact of the fungal pathogen on its host.

Clidemia hirta (L.) D. Don (Melastomataceae), Koster's curse

Clidemia hirta was first collected in Hawaii in 1949, but was known to occur on Oahu since 1941 (Wagner et al., 1990). It is now highly invasive on all

the islands except Niihau and Kahoolawe, which are probably too dry. It is a large shrub that dominates the subcanopy of both native and alien wet forests, and also can be a serious pest of windward pastures. Effectiveness of biological control agents released before 1981 is thought to be limited to open, sunny habitats (Reimer and Beardsley, 1986; Reimer and Beardsley, 1988). As a result of HDOA exploration and testing in the Republic of Trinidad and *Tobago*, four more insect agents were released between 1988 and 1995. Additional natural enemies are still needed for sufficient control.

***Lius poseidon* Napp (Buprestidae)**

Larvae of *Lius poseidon*, released in 1988, are leaf miners of *C. hirta*, while adult beetles are leaf feeders (Conant, 2002). Larvae are parasitized by at least one natural enemy, intentionally released for the control of agromyzid leaf miners (Conant, 2002). Combined foliar damage by adults and larvae to wild plants has been minimal.

***Antiblemma acclinalis* Hübner (Noctuidae)**

Antiblemma acclinalis was first released in 1995 (Conant, 2009). This leaf feeder is recorded as established on Oahu and Kauai, but appears to never have become common, perhaps due to parasitism.

***Carposina bullata* Meyrick (Carposinidae)**

Carposina bullata, first liberated in 1995 failed to establish, possibly due to the low number of pupae that survived shipment from Tobago (Conant, 2009). Poor survival resulted in only about 140 adults being released, primarily on Hawaii and very few on Oahu.

***Mompha trithalama* Meyrick (Coleophoridae)**

Mompha trithalama survived shipment from *Tobago* much better than *C. bullata*, resulting in a higher number of individuals released on Hawaii and Oahu in 1995 (Conant, 2009). *M. trithalama* was subsequently moved to Kauai and Maui. Larvae can now be found statewide, commonly feeding on the seeds of green fruit. It is possible that *M. trithalama* damage can result in premature fruit drop, but the overall impact of this agent on seed production has not yet been quantified. A pteromalid wasp parasitoid has been reared from the young fruit of Koster's curse, suggesting possible biotic interference (T. Johnson, unpublished data).

***Colletotrichum gloeosporioides* f. sp. *clidemiae* Trujillo (Glomerellaceae)**

This pathogen was imported by Trujillo (2005) from Panama and released in 1986. Repeated annual inoculations were observed to reduce *C. hirta* cover in one area, and similar mycoherbicidal application has been pursued elsewhere on a limited basis. More recently, natural defoliation events affecting as much as 90% of *C. hirta* cover were observed on the wet windward side of Kauai, but plants appeared to recover with time (N. Barca, pers. comm.). This phenomenon has been commonly observed on several islands at unpredictable intervals once the fungus became well established in the 1990s. Cool, rainy, windy weather conditions appear conducive to outbreaks.

Morella (= *Myrica*) *faya* (Aiton) Wilbur (Myricaceae), firetree

Morella faya is thought to have been introduced by Portuguese plantation workers who emigrated from Atlantic islands in the 1800s. Firetree was used for reforestation in Hawaii in the 1920s, and now occurs on the islands of Hawaii, Maui, Lanai, Oahu and Kauai (Whiteaker and Gardner, 1992). *M. faya* is considered one of the worst invasive species in Hawaii Volcanoes National Park, since its ability to fix nitrogen allows it to thrive in low-nutrient lava soils (Whiteaker and Gardner, 1985). A tortricid moth released for biological control of *M. faya* by HDOA in 1956 is considered ineffective, because it only affected a minor population of *Morella cerifera* (L.) Small (Markin, 2001). The National Park Service provided most of the funding for *M. faya* biological control efforts in the 1980s and early 1990s. Two natural enemies were released since 1980, but neither appears to have any noticeable impact (G. Markin, pers. observation).

***Caloptilia coruscans* (Walsingham) [= *C.* sp. nr. *schinella* (Walsingham)] (Gracillariidae)**

Caloptilia coruscans, whose larvae are blotch miners and leaf edge rollers, was released in 1991 from

collections made in the Azores and Madeira (Markin, 2001). Populations have remained low, and foliar damage has been minimal. Field collected larvae were infected by a fungal pathogen, hymenopteran parasitoids emerged from pupae, and lab tests found that local parasitoids attack its egg stage (Markin, 2001). Evidence of biotic interference also includes high levels of predation of *C.coruscans* larvae within leaf rolls (P. Yang and D. Foote, unpublished data).

Septoria hodgseii Gardner (Mycosphaerellaceae)

Septoria hodgseii, a fungus collected from wax myrtle, *Morella cerifera*, in North Carolina, was tested for host specificity at the HDOA Plant Pathogen Containment Facility in Honolulu and was subsequently released and briefly monitored on Hawaii Island in 1997 (Culliney et al., 2003). *S. hodgsei* was found established, but was never abundant in the experimental area, and no follow up work has been done. Smith (2002) mentions a personal communication from Trujillo, which suggested that acid rain near the volcano could be inhibiting spore germination, and that the fungus should be released elsewhere.

Ulex europaeus L. (Fabaceae), gorse

Ulex europaeus was introduced to Hawaii in the 1800s possibly as a cultivated hedge row plant from Europe, and may also have been used as a grazing plant for sheep. It now occupies over 2,000 ha on Mauna Kea (Hawaii) and over 2,000 ha in the Olinda area on Maui. The first biological control effort against gorse was launched by HDOA in 1927 and more recently has been a cooperative effort among HDOA, USFS and Landcare Research of New Zealand. In total, eight agents have been released, but only four became established (Markin and Conant, in these proceedings).

Agonopterix ulicetella (Stainton) (Oecophoridae)

Agonopterix ulicetella was first released in 1988 and became established on both Hawaii and Maui (Markin et al., 1995). This species is univoltine and overwinters as adults. In the spring larvae feed on terminal shoots, sometimes causing considerable damage, which can reduce flowering (Markin, unpublished data). Three species of parasitoids attack *A. ulicetella* pupae, but no larval parasitoids had ever been found, even with intensive searching, and egg parasitism by *Trichogramma* sp. appeared low (Markin et al., 1996).

Stenopterapion scutellare (Kirby) (Brentidae)

Stenopterapion scutellare was first liberated in 1961 (Markin and Yoshioka, 1989) on Maui (186 released), but failed to establish and so was re-released in 1989 on the island of Hawaii (788 released). None of the characteristic galls caused by the weevil were ever seen outside the field release cages in the 1990s, nor have they been seen since then.

Sericothrips staphylinus Haliday (Thripidae), gorse thrips

Two biotypes of this thrips, both a winged and brachypterous form, were released in Hawaii between 1991 and 1994 (Markin et al., 1996). The thrips feed on the mesophyll of gorse foliage, producing pale stippled areas on leaves, spines, and stems (Hill et al., 2001). Both biotypes became established and widespread in the gorse infestation on Hawaii Island, but finding visible feeding damage in the field on mature plants is difficult. Seedlings may be more affected, given that *S. staphylinus* at high densities in lab experiments can damage and kill gorse seedlings (Fowler and Griffin, 1995). Populations of this agent may be limited by predators (Markin and Conant, in these proceedings).

Tetranychus lintearius Dufour (Tetranychidae), gorse spider mite

First released in 1995 (Culliney and Nagamine, 2000), *Tetranychus lintearius* dispersed rapidly throughout the gorse infestation on Hawaii Island, and was subsequently released on Maui. *T. lintearius* populations increased tremendously during summer seasons, and resulted in considerable damage to gorse foliage in disjunct patches. *T. lintearius* feeding induces mottled chlorosis with stunting, and flowering may be aborted on damaged shoots in spring. Some shoots may even die from heavy feeding (Hill et al., 1991). However, after the year 2000, annual *T. lintearius* population explosions

ceased, presumably caused by an accumulation of predacious mite populations.

Pempelia genistella (Duponchel) (Pyralidae), gorse hard shoot moth

Releases of *Pempelia genistella* on Hawaii were conducted by USFS 1996-1997, but after initial establishment all populations apparently were eradicated as a result of a 2001-2002 control effort using herbicide and burning (Markin et al., 2002; Markin and Conant, in these proceedings). In its native habitat in Europe, larvae feed during fall and winter months, followed by pupation and adult emergence in early summer. Larvae often feed gregariously within webbing on older spines and may girdle the terminal shoots (Markin et al., 1996).

Uromyces pisi (DC.) Otth f. sp. *europaei* Wilson and Henderson (Pucciniaceae)

This rust fungus was released on Hawaii Island in 2000, and was seen once soon after, but never recorded again during occasional searches over several years (Markin et al., 2002; Markin and Conant, in these proceedings).

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Appendix 1. Agents introduced to Hawaii for biological control of weeds 1902-2010, compiled from Julien and Griffiths (1998), recent publications cited in this review, and unpublished records of the Hawaii Department of Agriculture.

Target Weed	Agent Origin	First Release	Agent Family	Agent Species	Impact
Lantana *Lantana camara* L. (Verbenaceae)	Mexico	1902	Agromyzidae	*Ophiomyia lantanae* (Froggart)	Ineffective
	Mexico	1902	Brentidae	*Apion*, 2 spp.	Not established
	Mexico	1902	Cerambycidae	*Parevander xanthomelas* (Guérin-Méneville)	Not established
	Mexico	1902; 1955	Cerambycidae	*Aerenicopsis championi* Bates	Not established
	Mexico	1902[1]; 1953	Chrysomelidae	*Octotoma scabripennis* Guérin-Méneville	Partial
	Mexico	1902	Gracillariidae	*Cremastobombycia lantanella* Busck	Partial
	Mexico	1902	Hepialidae	*Hepialus* sp.	Not established
	Mexico	1902	Lycaenidae	*Strymon bazochii gundlachianus* (Bates)	Ineffective
	Mexico	1902	Lycaenidae	*Tmolus echion* (L.)	Ineffective
	Mexico	1902	Pterophoridae	*Lantanophagapusillidactyla* (Walker)	Ineffective
	Mexico	1902	Tephritidae	*Eutreta xanthochaeta* Aldrich	Ineffective
	Mexico; Cuba; Belize; Florida, USA; Trinidad; Brazil	1902; 1952; 1953; 1954; 1954; 1954	Tingidae	*Teleonemia scrupulosa* Stål	Partial
	Mexico	1902	Tortricidae	*Crocidosema lantana* Busck	Partial
	Cuba	1953	Chrysomelidae	*Octotoma gundlachi* Suffrain	Not established
	Mexico	1953; 1965	Crambidae	*Pseudopyrausta santatalis* (Barnes & McDunnough)	Not established
	Honduras	1954	Chrysomelidae	*Octotoma championi* Baly	Not established
	Panama; Mexico	1954; 1962	Noctuidae	*Diastema tigris* Guenée	Not established
	California	1955	Noctuidae	*Neogalia sunia* (Guenée)	Partial
	Florida, USA; Cuba	1956	Crambidae	*Salbia haemorrhoidalis* Guenée	Substantial
	Kenya/Zimbabwe; Philippines	1957; 1965	Noctuidae	*Hypena laceratalis* Walker	Substantial
	Mexico	1960	Cerambycidae	*Plagiohammus spinipennis* (Thomson)	Partial
	Brazil	1961	Chrysomelidae	*Uroplata girardi* Pic	Partial
	Colombia/Peru via Australia	1970	Tingidae	*Leptobyrsa decora* Drake	Ineffective
	Ecuador	1997	Mycosphaerellaceae	*Septoria* sp.	Uncertain[2]

Target Weed	Agent Origin	First Release	Agent Family	Agent Species	Impact
Purple nutsedge *Cyperus rotundus* L. (Cyperaceae)	Philippines	1925	Curculionidae	*Athesapeuta cyperi* Marshall	Ineffective
	Philippines	1925	Tortricidae	*Bactra venosana* (Zeller)	Ineffective
Gorse *Ulex europaeus* L. (Fabaceae)	England; England via New Zealand; France	1927[1]; 1949[1]; 1955	Brentidae	*Exapion ulicis* (Forster)	Partial
	Portugal	1958	Brentidae	*Apion* sp.	Not established
	Portugal; Spain; France	1961; 1989; 1990; 1991	Brentidae	*Stenopterapion scutellare* (Kirby)	Not established
	England; Portugal	1988; 1991	Oecophoridae	*Agonopterix ulicetella* (Stainton)	Partial
	England; Portugal; France	1991; 1992; 1992	Thripidae	*Sericothrips staphylinus* Haliday	Uncertain[2]
	England, Portugal, Spain via New Zealand via Oregon, USA	1995	Tetranychidae	*Tetranychus lintearius* Dufour	Partial
	Portugal	1996	Pyralidae	*Pempelia genistella* (Duponchel)	Not established
	England	2000	Pucciniaceae	*Uromyces pisi* (DC.) Otth f. sp. *europaei* Wilson and Henderson	Not established
Maui pamakani *Ageratina adenophora* (Spreng.) King & H. Rob. (Asteraceae)	Mexico	1945	Tephritidae	*Procecidochares utilis* Stone	Substantial
	Mexico	1955	Tephritidae	*Xanthaciura connexionis* Benjamin	Not established[3]
Prickly pear *Opuntia* spp. (Cactaceae)	Mexico via Australia	1949	Dactylopiidae	*Dactylopius opuntiae* (Cockerell)	Substantial
	Texas, USA	1949	Pyralidae	*Melitara dentata* (Grote)	Not established
	Texas, USA	1949	Pyralidae	*Melitara prodenialis*Walker	Not established
	Texas, USA	1950	Cerambycidae	*Moneilema armatum* LeConte	Not established
	Argentina via Australia	1950	Pyralidae	*Cactoblastis cactorum* (Berg)	Substantial
	Mexico via Australia	1951	Cerambycidae	*Lagocheirus funestus* Thomson	Partial

Target Weed	Agent Origin	First Release	Agent Family	Agent Species	Impact
Koster's curse *Clidemia hirta* (L.) D. Don (Melastomataceae)	Trinidad via Fiji	1953	Phlaeothripidae	*Liothrips urichi* Karny	Partial
	Trinidad; Puerto Rico	1970	Crambidae	*Ategumia matutinalis* Guenée	Ineffective
	Panama	1986	Glomerellaceae	*Colletotrichum gloeosporioides* f. sp. *clidemiae* Trujillo	Partial
	Trinidad	1988	Buprestidae	*Lius poseidon* Napp	Ineffective
	Tobago	1995	Carposinidae	*Carposina bullata* Meyrick	Not established
	Tobago	1995	Coleophoridae	*Mompha trithalama* Meyrick	Partial
	Tobago	1995	Noctuidae	*Antiblemma acclinalis* Hübner	Ineffective
Christmas berry *Schinus terebinthifolius* Raddi (Anacardiaceae)	Brazil	1954	Tortricidae	*Episimus unguiculus* Clarke	Ineffective
	Brazil	1960	Bruchidae	*Lithraeus atronotatus* (Pic)	Ineffective
	Brazil	1961	Gelechiidae	*Crasimorpha infuscata* Hodges	Not established
Firetree *Morella* (= *Myrica*) *faya* (Aiton) Wilbur (Myricaceae)	Florida/Georgia, USA	1956	Tortricidae	*Strepsicrates smithiana* Walsingham	Ineffective
	Azores/Madeira, Portugal	1991	Gracillariidae	*Caloptilia coruscans* (= *C.* sp. nr. *schinella*) (Walsingham)	Ineffective
	North Carolina, USA	1997	Mycosphaerellaceae	*Septoria hodgesii* D.E. Gardner	Uncertain[2]
Sourbush *Pluchea carolinensis* (Jacq.) G. Don (Asteraceae)	Mexico	1957	Gelechiidae	*Dichomeris aenigmatica* (Clarke)	Ineffective
	Guatemala	1959	Tephritidae	*Acinia picturata* (Snow)	Ineffective
Emex *Emex australis* Steinheil *Emex spinosa* (L.) Campd. (Polygonaceae)	South Africa	1957	Brentidae	*Perapion antiquum* (Gyllenhal)	Substantial
	Morocco	1962	Brentidae	*Perapion neofallax* (Warner)	Not established
	Portugal	1962	Brentidae	*Perapion violaceum* (Kirby)	Not established

Target Weed	Agent Origin	First Release	Agent Family	Agent Species	Impact
Asian melastome *Melastoma septemnervium* Lour. (Melastomataceae)	Philippines	1958	Crambidae	*Ategumia fatualis* (Lederer)	Ineffective
	Malaysia	1965	Crambidae	*Ategumia adipalis* (Lederer)	Ineffective
	Malaysia	1965	Noctuidae	*Rhynchopalpus brunellus* (Hampson)	Partial
Elephant's foot *Elephantopus mollis* Kunth (Asteraceae)	Trinidad via Fiji	1961	Tephritidae	*Tetraeuaresta obscuriventris* Loew	Ineffective
Puncture vine *Tribulus cistoides* L. *Tribulus terrestris* L. (Zygophyllaceae)	Italy via Calif./Arizona, USA	1962	Curculionidae	*Microlarinus lareynii* (Jacquelin du Val)	Substantial
	Italy via Calif./Arizona, USA	1963	Curculionidae	*Microlarinus lypriformis* (Wollaston)	Substantial
Florida blackberry *Rubus argutus* Link (Rosaceae)	California, USA	1963	Schreckensteiniidae	*Schreckensteinia festaliella* Hübner	Partial
	Oregon, USA	1963	Sesiidae	*Pennisetia marginata* (Harris)	Not established
	Mexico	1964	Tortricidae	*Croesia zimmermani* Clarke	Partial
	Oregon/California, USA	1966	Tenthridinidae	*Priophorus morio* (Lepeletier)	Ineffective
	Missouri, USA	1969	Chrysomelidae	*Chlamisus gibbosa* (Fabricius)	Not established
Klamath weed *Hypericum perforatum* (Hypericaceae)	France via California, USA via Australia/New Zealand	1965	Cecidomyiidae	*Zeuxidiplosis giardi* (Keiffer)	Substantial
	France via Australia via California, USA	1965	Chrysomelidae	*Chrysolina quadrigemina* (Suffrain)	Substantial
Hamakua pamakani *Ageratina riparia* (Regel) King & H. Rob. (Asteraceae)	Mexico	1973	Pterophoridae	*Oidaematophorus beneficus*Yano & Heppner	Partial
	Mexico	1974	Tephritidae	*Procecidochares alani* Steyskal	Partial
	Jamaica	1975	Entylomataceae	*Entyloma ageratinae* Barreto & Evans	Substantial
Russian thistle *Salsola tragus* L. (Chenopodiaceae)	Pakistan via California, USA	1980	Coleophoridae	*Coleophora klimeschiella* Toll	Not established
	Egypt/Pakistan via California, USA	1980	Coleophoridae	*Coleophora parthenica* Meyrick	Not established

Target Weed	Agent Origin	First Release	Agent Family	Agent Species	Impact
Banana poka *Passiflora tarminiana* Coppens & V.E. Barney (Passifloraceae)	Colombia/ Ecuador	1988	Notodontidae	*Scea* (= *Cyanotricha*) *necyria* (Felder & Rogenhofer)	Not established
	Venezuela	1991	Crambidae	*Pyrausta perelegans* Hampson	Ineffective
	Colombia	1996	Mycosphaerellaceae	*Septoria passiflorae* Syd.	Partial
Ivy gourd *Coccinia grandis* (L.) Voigt (Cucurbitaceae)	Kenya	1996	Sesiidae	*Melittia oedipus* Oberthür	Substantial
	Kenya	1999	Curculionidae	*Acythopeus burkhartorum* O'Brien and Pakaluk	Not established
	Kenya	1999	Curculionidae	*Acythopeus cocciniae* O'Brien and Pakaluk	Partial
Miconia *Miconia calvescens* DC. (Melastomataceae)	Brazil	1997	Glomerellaceae	*Colletotrichum gloeosporioides* (Penz.) f. sp. *miconiae* Killgore et al.	Partial

[1] These early releases failed to establish.

[2] Established, but population and/or distribution limited, and evidence on impact lacking.

[3] Agent apparently was released on both Ageratina spp.