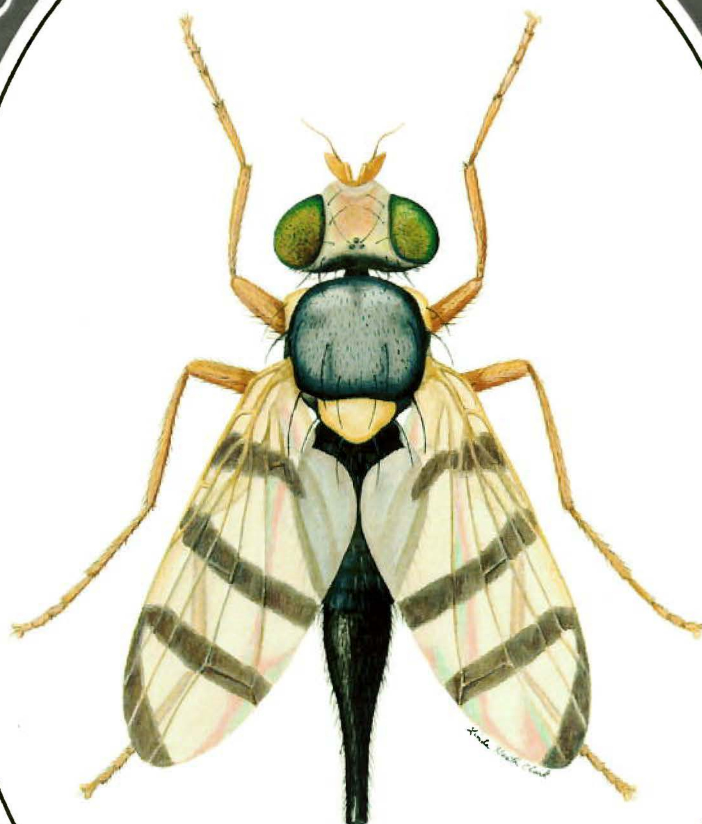
BIOLOGICAL CONTROL PROGRAM



California Department of Food and Agriculture

BIOLOGICAL CONTROL PROGRAM

1996 SUMMARY

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DIVISION OF PLANT INDUSTRY
INTEGRATED PEST CONTROL BRANCH

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The staff would like to thank Linda Heath-Clark for the drawing of *Urophora sirunaseva* and for incorporating it into the cover art.

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Introduction

L. G. Bezark

As we approach the new century, we are surrounded by change. Shrinking budgets have brought together various groups as partners to leverage resources and accomplish what was once being done separately and in some cases independently. Private business has begun to learn how to effectively change to keep current and at the same time reinvent themselves for the future, and the public sector is following suit. More attention is continually focused upon the state of the environment and the need to protect our natural resources from the ravages of pests or even the tools we use to fight them. The effect of some of these changes can be seen in the California Department of Food and Agriculture.

The Department is currently in the process of strategic planning, and developing mission, vision, and value statements that will take us into the next century. Recently crafted legislation mandates that any new requests for general fund dollars by state programs have a Strategic Plan in place that ties their mission to the budget. If biological control activities are to be expanded within the Department, any new proposals would fall under this review process.

The Biological Control Program is part of the ongoing development and integration of functions, budgets and planning within the Department. As an integral part of the department's Pest Prevention Program we implement biological control technologies against an ever increasing array of noxious weeds and insect pests. Using biological control techniques in some cases can be an effective alternative to the use of chemical pesticides. For many years we have engaged in cooperative projects with other Federal, State and local governmental agencies, the University of California, and other research institutions. Through the development and implementation of partnership agreements we formalize our commitment to participation in projects that maximize our resources for the benefit of the people of California.

This past year we participated in a conference designed to " bring to the table" the major participants in biological control in California. Hopefully we all can build on the success of that event and further develop an understanding of what each other does and forge new and better working relationships.

The Biological Control Program places a very high emphasis on obtaining new biological control agents. Maintenance of the importation process, or pipeline, for new agents is critical to the success of our program's ability to rear, release, distribute, and evaluate the impact of introduced agents, on their targets. Program personnel are keenly aware of the need to consider native plant species when pursuing introduction of phytophagous species, in order to mitigate possible harmful effects on these species. It is our goal to maintain a balance between the risk and benefits of all biological control releases. As a result, some additional host-specificity testing of some weed-feeding natural enemies already released elsewhere in the United States is being recommended prior to release in California. Discussions with USDA have led in part to a renewed emphasis in exploring for additional natural enemies of yellow starthistle and in the initiation of foreign exploration for natural enemies of Russian thistle. Research contracts awarded by the Biological Control Program addressed unique aspects of pest and natural enemy biology necessary for the completion of our mission. Research contracts included foreign exploration for natural enemies of Russian thistle, biological studies on cotton aphid parasites required for field release permits, and a study on the interactions between species of parasitoids attacking silverleaf whitefly.

This Annual Report summarizes research activities and implementation efforts performed by the Biological Control Program during 1996, including our many cooperative accomplishments. I would like to personally thank each of our staff members, both permanent and otherwise, for a job well done this past year.

The staff of the Biological Control Program would like to acknowledge the passing of Dr. Charlie Turner in early 1997. Charlie was a valuable partner in many of the weed biological control activities of our program for many years.

Evaluation of *Aphelinus* near *paramali*, an Introduced Parasite of the Cotton Aphid, in the San Joaquin Valley

K. E. Godfrey, J. R. McLaughlin[1], J. R. Brazzle[2], and R. K. Yokomi[3]

The cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae), poses a great threat to cotton production in the San Joaquin Valley. Historically, the cotton aphid was an early season pest, but in recent years has become a mid to late season pest. The increases in late season densities have resulted in loss of profit due to yield reductions and decreased crop value attributable to increased sticky cotton at harvest. Additionally, losses occur due to the cost of additional insecticide applications to prevent anticipated increases in the amount of sticky cotton. These large densities of cotton aphid also place limitations on the insecticides that can be used to control other insect pests of cotton due to the negative impact these chemicals may have on cotton aphid population dynamics. Although insecticides are still effective against the cotton aphid, the length of time the insecticide can keep the aphid densities low is brief due to reinvasion of the fields by alate aphids within days after treatment. Many populations of the cotton aphid in the San Joaquin Valley also have demonstrated resistance to some of the insecticides used in their control. Management of the cotton aphid, therefore, will require the integration of management tactics such as biological, cultural, and chemical control rather than sole reliance on insecticides.

In an attempt to enhance one cotton aphid management tactic, biological control, a cooperative project involving the Biological Control Program, USDA-ARS, and the University of California Cooperative Extension Service was initiated in 1996. The long term goal of this project is to reduce densities of the cotton aphid by constructing a parasite complex for the cotton aphid that has more species richness than currently exists in the San Joaquin Valley. The first candidate for inclusion in this parasite complex is *Aphelinus* near *paramali* (Hymenoptera: Aphelinidae). Five shipments of *Aph.* near *paramali* mummies from the USDA-ARS Horticultural Laboratory in Orlando, Florida, were received at the Biological Control Program between March 7 and September 6, 1996. These individuals were from a colony that had been maintained on green peach aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae). After approximately 6-8 generations of selection in the laboratory, a strain of *Aph.* near *paramali* was produced that prefers the cotton aphid.

Two field studies to evaluate the ability of *Aph.* near *paramali* to reduce densities of the cotton aphid were conducted at Shafter Research Station from July 22 through September 25, 1996. The first field study attempted to measure the maximum mortality that *Aph.* near *paramali* could impose on a population of cotton aphids if other natural enemies were absent. At weekly intervals beginning August 23, 1996, 20 sleeve cages were placed on individual branches along a row of cotton. The plant material within a cage was checked to remove arthropod predators and to be sure it contained an aphid infestation. Five randomly selected cages were harvested at the initiation of a trial and provided an estimate of aphid density before parasite introduction. Five adult *Aph.* near *paramali* were added to each of 10 of the remaining 15 cages. The remaining 5 cages were left undisturbed and served as controls (i.e., no parasites present). The cages were left undisturbed for 10-14 days and then were harvested. The contents of each cage were sorted to determine the number of aphids, mummies, and *Aph.* near *paramali* adults. The trials were replicated 4 times.

Concurrent with the above field study, an attempt was made to measure the mortality that *Aph.* near *paramali* could impose in the presence of other natural enemies using open field releases. From July 23, through September 23, 1996, a total of 1,747 *Aph.* near *paramali* adults were released (Table 1) by attaching a small paper container or vial containing the parasites to the stem of a cotton plant. Each container or vial contained approximately 50 parasite adults. The release areas were left undisturbed for approximately 14 days. The area around a release site (approximately 1 m in all directions) was then sampled in an attempt to recover the parasite.

The results from both field studies were not conclusive in terms of the value of *Aph.* near *paramali* in reducing cotton aphid densities. For the sleeve cage study, no parasite adults or mummies were recovered. The mean density of cotton aphids in each set of sleeve cages (i.e., pre-release count, parasites present, and parasites absent) for each replicate can be found in Table 2. The aphid densities in the cages with and without parasites were compared for each replicate using an one-way ANOVA. For the first replicate (August 28), there were significantly fewer aphids present in cages containing *Aph.* near *paramali* than in those without (Table 2). For the remaining replicates (September 9, 11, and 18), there were no significant differences between treatments (i.e., parasites present versus parasites absent; Table 2). The densities of aphids in cages containing parasites in these replicates tended to be greater than the densities of aphids in cages without parasites, however, there was large variability associated with all estimates. To reduce this variability in future studies, the number of cages used to estimate cotton aphid density for each treatment should be increased. In addition, the experiments should include a larger number of parasites per cage and begin earlier in the season to reduce any effect the phenology of the cotton plant may have on cotton aphid and/or *Aph.* near *paramali* population dynamics.

For open field releases, no *Aph.* near *paramali* adults or mummies were recovered. This lack of recovery suggests that either the parasite is not successful in attacking cotton aphid in the San Joaquin Valley, or it is present in such low numbers that the sampling was not adequate for detection. Sampling of the cotton aphid populations in the area near the release site will continue throughout the next year in an attempt to recover any parasite should they be present.

TABLE 1. The date and number of *Aph.* near *paramali* adults released in open field releases at Shafter Research Station in 1996.

Date of Release	Number Released
July 23 1996	287 adults
July 30 1996	300 adults
August 29 1996	150 adults
September 7 1996	400 adults
September 11 1996	450 adults
September 18-23 1996	160 adults

TABLE 2. The mean density (±std. err.) of cotton aphids for each treatment and F statistics for the one-way ANOVA performed for each replicate of the sleeve cage study. The treatments compared were the parasites present and parasites absent.

Rep.(Date)	Pre-Count	Parasites Present	Parasites Absent	F Statistic[1]	P-value
1 (Aug 28.)	271.6 (± 54.2)	65.1 (± 24.3)	592.4 (± 168.6)	19.4	<0.01
2 (Sept 9.)	288 (± 171.8)	193.7 (± 77.9)	137.8 (± 103.5)	0.18	>0.10
3 (Sept 11.)	22.4 (±7.4)	869.5 (± 34.7)	316 (± 302.1)	1.12	>0.10
4 (Sept 18.)	41.8 (± 18.2)	310 (± 122.8)	13.8 (± 10.7)	0.92	>0.10

[1]degrees of freedom = 1, 13

[1]USDA, ARS, Shafter Research Station
[2]University of California Cooperative Extension, Kern County
[3]USDA, ARS, Horticultural Crop Research Lab

Systematics of *Delphastus* and Their Establishment in California

C. H. Pickett, K. A. Hoelmer[1], and W. J. Roltsch

Delphastus spp. (Coleoptera: Coccinellidae) are important predators of whiteflies (Aleyrodidae) including species of *Bemisia*. Laboratory and greenhouse studies have demonstrated that *Delphastus* larvae consume large numbers of *Bemisia* eggs and nymphs and can play an important role in controlling *Bemisia* on infested poinsettias. These studies and others have used *Delphastus* from a stock culture originating in Florida and identified as "*pusillus*." Recently Robert Gordon published a new key to the species of *Delphastus* in the Western Hemisphere (*Frustula Entomol.* 1994). Based on this new key, voucher specimens used in some of the prior studies were identified as *D. catalinae* (Horn). This species is found in South, Central, and North America, as well as, the Canary Islands and Hawaii. This may be an artificial distribution caused by the movement of cut flowers and fruit on which the beetles could be transported.

While using Gordon's key for species determinations, we learned that a population of *Delphastus* in Arizona previously treated as a synonym for *D. pusillus* is now considered a separate species, *D. sonoricus*. *Delphastus sonoricus* was first collected by George Butler in the greater Phoenix area of Arizona and reported by Gordon (1994). As a result, populations of *D. sonoricus* were collected in the Phoenix region in 1995 and imported into California in an effort to increase the number of specialized predators attacking *Bemisia* in Imperial Valley. The beetle was collected from homesites in Mesa, Arizona during fall 1995 and released at several locations in Imperial Valley. About 100 adults were released at each of three homes in Brawley and at a natural enemy refuge plot at the USDA-ARS Irrigated Desert Research Station. Beetles in the refuge have now survived for over a year and have been collected at one homesite in Brawley, about 1 mile north of the Research Station. The recovery of *D. sonoricus* is especially noteworthy since we released over thirty thousand individuals of *D. catalinae* (previously referred to as *D. pusillus*) in Brawley and El Centro in fall 1993, yet have not recovered any adults since that time.

[1]USDA-APHIS, Phoenix Plant Methods Center

Exotic Natural Enemy Introductions in Imperial Valley to Control Silverleaf Whitefly

W. J. Roltsch, G. S. Simmons[1] J. A. Brown, and K. A. Casanave

The silverleaf whitefly, *Bemisia argentifolii*, Bellows & Perring (Homoptera: Aleyrodidae), has been a severe pest of numerous field and vegetable crops since late 1991 in Imperial Valley. Introductions of non-indigenous natural enemies were initially limited to species present elsewhere in North America. By mid-1994, exotic parasitoid species from numerous worldwide geographic regions became available for field releases. During 1995, the Biological Control Program began mass rearing and releasing exotic whitefly parasites including one species of *Eretmocerus* from Thailand [USDA accession code M94023] and an *Encarsia* species from Brazil [M94056].

During 1996, preparations were made to release large numbers of three *Eretmocerus* and two *Encarsia* species/strains(Table 1). In cooperation with USDA-APHIS and the Imperial County Agricultural Commissioners Office, a home gardener program was initiated. This project sought to utilize home gardens of avid gardeners to expand the availability of suitable habitat for establishing non-indigenous parasitoid species/strains. As a result, parasitoids were released in 18 home gardens and 5 field refuges. The field refuges, consisting of basil, okra, roselle, kenaf and eggplant were approximately 1/4 to 3/4 acre in size. To improve the variety of vegetation at each home site and help to bridge the hot summer period when few plants are generally grown, basil, eggplant and roselle were provided to each home gardener.

Releases were made from late April to mid-November of 1996. Two to three parasitoid species/strains that could be separated either morphologically or through PCR analysis were released a minimum of four times at each site throughout the year. Each parasitoid species was mass reared at the Biological Control Program's greenhouses in Sacramento on hibiscus or at the USDA-APHIS greenhouse facility on eggplant. Parasitoids were delivered to each site as pupae on live plants that were planted in the ground and watered. Table 1 identifies the parasitoid species/strains released and their numbers.

Population monitoring consisted of leaf collections obtained from each plant species in the refuge field plots approximately six times, and one or two collections made at each home garden site. Leaves were collected with a whitefly age structure consisting predominantly of whitefly pupae, whitefly exuviae, and parasite pupae. Whitefly densities were recorded and percent parasitism was estimated during later stages of development. For leaves containing whitefly populations representing a younger age structure, 30 - 50 4th instar whitefly were turned over and inspected for *Eretmocerus* eggs and egg rings, and early to late stage larval *Encarsia*.

A large number of the voucher collections have been evaluated to distinguish exotic species from the often times very abundant native species. Home garden collections for similar releases made in 1995 were negative one year following release, except for one site. That location showed a strong presence of exotic parasite activity which may have been a result of other species released by USDA-APHIS less than one mile away. During 1996, exotic *Eretmocerus* were present in 36% of the samples taken from basil, okra, collard and eggplant in the 5 field refuge plots. Of samples where exotics were recovered, approximately 15% of the total parasite population was composed of exotic species and 85% represented native species.

However, several samples were composed of 50% or greater exotic parasitoids. The exotic, *Encarsia transvena* (Timberlake), was found in small numbers throughout the summer and fall in the refuge field plots, usually on basil, while at one home site, it was common on basil and on broccoli through the winter into April 1997.

TABLE 1. Release species/strains of exotic *Eretmocerus* and *Encarsia* parasitoids of the silverleaf whitefly.

Genus	Accession Code ---(origin)		Number of Shipments Received	Release Period	Number Released
Eretmocerus	M94023	(Sai Noi, Thailand)	15	8/2/95 - 11/15/95	811,500
	M95012	(Multan,Pakistan)	16	3/5/96 - 11/14/96	3,213,058
	M92014	(Murcia,Spain)	5	6/4/96 - 7/22/96	92,424
	M95104	(United Arab Emirates)	5	6/6/96 - 10/14/96	133,470
Encarsia	M94056	(Sete Lagos,Brazil)	32	6/28/95 - 7/1/96	840,085
	M94055	(Sete Kagiasm, Brazil)	3	9/27/96 - 8/1/96	11,896
	M93003	(Murcia,Spain)	9	6/14/96 - 11/16/96	173,188

[1]USDA-APHIS, Western Region

Colonization of Parasites for Biological Control of Silverleaf Whitefly in the San Joaquin Valley, California

C. H. Pickett, J. A. Goolsby[1], W. L. Abel[2], and G. Boyd

The USDA-APHIS Biological Control Center at Mission, Texas, has been actively importing, rearing, and testing new species of silverleaf whitefly parasites for release against the silverleaf whitefly, *Bemisia argentifolii*, Bellows & Perring (Homoptera: Aleyrodidae), over the last four years. Surveys by the Biological Control Program have found only limited populations of three different species of aphelinids associated with silverleaf whitefly infestations in central California. In an effort to increase the diversity of natural enemies attacking this pest, CDFA and the USDA-APHIS PPQ reared and released 29 new species/strains of aphelinids over the last three years in central California. In 1994 and 1995, parasites were released in home gardens in the Bakersfield area of the southern San Joaquin Valley. These served as year round field insectaries or refuges, free of pesticides and untimely cultivation. Sites were selected that contained woody perennial plants susceptible to silverleaf whitefly (e.g. hibiscus, lantana) and had home vegetable gardens. Releases were made so that each site received species combinations that could be separated morphologically or through genetically unique DNA patterns. In 1994, a total of 99,500 parasite pupae were released representing six species/strains; in 1995 a total of 183,714 pupae were released representing 27 species/strains of aphelinids. In 1995, two of the six species/strains released in 1994 were recovered as late as August 1995 at two release sites, both old world *Eretmocerus*. In 1996, exotic *Eretmocerus* were recovered from four of 13 1994/1995 release sites.

During 1996, three different populations of *Eretmocerus* that performed well in laboratory and field tests were released into agricultural settings rather than homesites, (populations from Multan, Pakistan (M95012); Murcia, Spain (M92014); and United Arab Emirates (M95104)). Releases were made in or near agricultural crops in settings that allowed the parasites to overwinter on non-crop weedy vegetation. These included fields of cotton, citrus, small plantings of okra, and weedy areas near these crops. One of the releases was into a citrus orchard on the western side of the valley. Only exotic parasites were recovered in November two months following releases. This finding suggests that native *Eretmocerus* are not plentiful in the area and that one or all three of the strains released is capable of attacking silverleaf whitefly in citrus. PCR techniques will be used to identify which strain(s) were recovered.

[1]USDA-APHIS PPQ, Mission Biological Control Center
[2]USDA-APHIS PPQ

Establishment of Natural Enemies for Biological Control of the Giant Whitefly, *Aleurodicus dugesii*, in San Diego County

C. H. Pickett, D. Kellum[1] and M. Rose[2]

The giant whitefly, *Aleurodicus dugesii* Cockerell, (Homoptera: Aleyrodidae) was first discovered in San Diego, California on October 15, 1992. It has been previously reported from north central Mexico (Zacatecas) and the southern tip of Baja California (Ray Gill, pers. comm.). The original finds in San Diego were mainly from hibiscus but the whitefly has now spread to a broad range of subtropical perennial trees and shrubs and herbaceous monocots. Giant whitefly has been found reproducing on 27 families and 30 genera of plants at the San Diego Zoo, and 32 families and 39 genera of plants in San Diego County. This host list includes the important agricultural crops avocado, citrus, apricot, and prunes. The most commonly reported plants infested with giant whitefly in urban San Diego are hibiscus, bird of paradise, xylosma, avocado, and citrus. Including direct effects to plants, feeding results in sooty mold growth on honeydew excreted by whiteflies. This whitefly may also represent a serious health problem to the general public. The nymphal stages produce long waxy filaments up to four inches long that can break off and float in the air, carrying honeydew with them. Leaves with high densities of giant whitefly are flocked with this white material. In areas with high densities of the pest, clusters of this wax can be seen floating through the air.

Delphastus spp. (Coccinellidae) are arboreal, whitefly specific predators. In an attempt to establish effective natural enemies of giant whitefly, 3000 *Delphastus catalinae* (Horn) (initially identified as *D. pusillus*), were purchased from a local private insectary and released at two different sites in Carlsbad (San Diego County), California, September 29, 1995. They were released onto avocado, citrus, and hibiscus. During subsequent sampling we have observed *D. catalinae* on the avocado tree onto which it was originally released but have never seen this beetle on the two hibiscus plants originally used for release. The beetles were observed for the first time on the original citrus tree release site during our last sample on January 27, 1997. During three minute counts in areas of the avocado tree where releases were made, an average of 2.2 (range 1-3; n=5) adults, and 3.2 (range 0-13) larvae were counted. The beetles have since moved to adjacent avocado and citrus trees at the original release site. Although beetles were never recovered from a second release site of hibiscus, they were found on an adjacent avocado tree infested with giant whitefly, suggesting the beetles have a preference for these trees or an arboreal habitat.

The giant whitefly has also recently invaded and established populations in eastern Texas, Louisiana, Florida, and Arizona. A new species of parasite, *Entedononecremnus krauteri* Zolnerowich and Rose was found in high numbers attacking the giant whitefly in Texas during 1995, suggesting that it may be a specific natural enemy of this pest. Members of the genus *Entedononecremnus* are primary parasites that attack only whiteflies. A total of 3,300 adult parasites were reared in Texas, then shipped to San Diego County for open field releases during October and November 1995. Parasites were released at eight different locations including private homes and public properties (Table 1). Most of the host plants were hibiscus. In June 1996, we released about 4,200 adult parasites into three new sites.

During fall 1996, we recovered *E. krauteri* from two of the 11 1995 release sites and all three of the 1996 release sites. Our results indicate that *E. krauteri* has a preference for hibiscus over xylosma and avocado plants: all recoveries to date have been from hibiscus and 0/3 from xylosma. Although *E. krauteri was observed* March 1996, five months after it was released in avocado, it has not been observed there since. in October 1996 We found adults on hibiscus at our San Diego Zoo release site, up to 100 yards from the original 1995 release site.

TABLE 1. Releases of *Entedononecremnus krauteri* in San Diego County for the biological control of giant whitefly

Date Released	City	# Released	Host	Last Date Examined	adults/pupae of *E. krauteri*
10-18-95	Carlsbad	500	avocado	10-31-96	no
10-18-95	Carlsbad	500	xylosma	10-31-96	no
10-20-95	Bonita	120	hibiscus, lemon	11-25-96	no
10-20-95 10-25-95	Vista	350	hibiscus, geranium, day lily, aratia	12-2-96	no
10-20-95 10-25-95 10-27-95	Vista	500	hibiscus	11-20-96	yes
10-20-95 10-27-95	Vista	400	xylosma	11-20-96	no
10-20-95 10-27-95	Vista	400	citrus	11-20-96	no whiteflies
10-20-95	Oceanside	100	hibiscus	12-2-96	no
10-25-95	San Diego	200	hibiscus	11-20-96	yes
6-19-96	San Diego	200	hibiscus	11-20-96	yes
6-18-96	Carlsbad	200	hibiscus	11-20-96	yes
6-18-96	Carlsbad	500	hibiscus	11-20-96	yes
Total		3970			

[1]Department of Agriculture, San Diego County
[2]Department of Entomology, Montana State University

Colonization of the Tachinid Fly, *Trichopoda pennipes* for the Biological Control of the Squash Bug, *Anasa tristis*

S. E. Schoenig and C. H. Pickett

The squash bug, *Anasa tristis* (DeGeer) (Hemiptera: Coreidae) is a frequent problem for producers of organic squash and pumpkins in California. The squash bug attacks all stages of the plant and is especially damaging to the seedling stage. In California, the only recorded parasite of squash bug is an encyrtid which achieves low levels of parasitism on host eggs. A bio-type of *Trichopoda pennipes* (Fabricius), a nymphal-adult parasite of squash bugs in the eastern United States, has been reported to parasitize up to 84% of overwintering bugs.

Efforts to establish this parasitoid in California were initiated in 1992. This project has two objectives: 1) establish field nurseries for *T. pennipes* in northern California using flies collected by Michael Hoffmann (Cornell University) from upstate New York; 2) measure the impact of released *T. pennipes* on populations of the squash bug.

In 1992 and 1993, *T. pennipes* were field collected in New York and shipped to Sacramento. From 1992 to 1995, the parasite was reared under laboratory and field conditions and released at several small vegetable farms in Yolo, Sacramento, and Placer counties, including the Student Experimental Farm at University of California, Davis. Parasites have now successfully overwintered at five different locations. Of these, two represent continuous establishment for four years.

In summer 1996, we continued to monitor these sites for the presence of *T. pennipes*. We sampled squash bugs and their parasitism by counting during a 15 minute period the total number of adult squash bugs and those with *T. pennipes* eggs on their bodies (Table 1). Counts were usually done in plantings of zucchini, but were also performed in kabocha, Hubbard, and crookneck squash plantings. Counts varied from 0 to 60 in a fifteen minute period with the highest counts in kaboucha squash. Parasitism varied substantially from 0% to 100%, (mean = 59%, for all sample dates) in release sites where parasites have been present for two or more years.

TABLE 1. **The results of fifteen minute counts of parasitized and unparasitized squash bugs in summer 1996. These results are expressed as the total number of adult squash bugs with parasite eggs divided by total number of squash bugs observed.**

Sample date	Yolo Site	Solano Site	UCD, experimental farm	UCD, student gardens	Placer Site
May 31	27/85[1] (zucchini)	4/8 (crook neck) 20/24 (zucchini)			
June 12	59/78[1] (zucchini)	30/30 (zucchini)			11/112[2] (zucchini)
July 1	8/13[1] (zucchini)	33/40 (crook neck) 3/4 (zucchini)	3/3 (crook neck) 36/50 (kabocha)	4/4 (all)	
July 11					17/40 (crook neck) 27/60 (kabocha)
July 26	0/0 (zucchini) 0/0 (kabocha)	21/30 (zucchini) 29/42 (Hubbard)			
August 7	4/26[1] (zucchini) 0/13(kabocha)	1/3 (kabocha)	4/56 (kabocha) 15/78 (crookneck)	0/1 (mixed varieties)	5/24 (zucchini) 17/95 (kabocha)
August 28	17/60 (kabocha)	8/43 (zucchini)		40/52 (Raoul's banana squash	

[1]from three different locations on same farm and representing a total 45 minutes counting time.
[2]from five different locations on same farm and representing a total 75 minutes counting time.

Release of Exotic Natural Enemies for Biological Control of Euonymus Scale

R. K. Wall and C. H. Pickett

Since its accidental introduction into the United States from Asia some 100 years ago, euonymus scale, *Unaspis euonymi* (Comstock) (Homoptera: Diaspididae), has been a problem wherever euonymus and other susceptible host plants grow. Today, euonymus scale is widely spread in the eastern United States. There are no effective native natural enemies of euonymus scale in the United States. Thus, efforts have been made to import natural enemies from Asia: *Cybocephalus* nr. *nipponicus* (Endrody-Younga) (Coleoptera: Nitidulidae), a member of the sap beetle family, and *Chilocorus kuwanae* (Silvestri) (Coleoptera: Coccinellidae), a lady beetle. These two beetles also attack San Jose scale, *Quadraspidiotus perniciosus* (Comstock) and white peach scale, *Pseudaulacaspis pentagona*(Targioni-Tozzetti), two related armored scales which are highly destructive pests of fruit trees throughout the U.S. In 1984, USDA-APHIS introduced *Cy. nipponicus* and *Ch. kuwanae* from Korea to scale-infested euonymus plants at the U.S. National Arboretum in Washington, D.C. Both *Cy. nipponicus* and *Ch. kuwanae* reduced euonymus scale infestations to very low levels. Within six years, both beetles were established in nine eastern states and the District of Columbia due to distribution and release effort by USDA-APHIS.

Euonymus scale is only a problem in a few northern California counties. The effectiveness of the two introduced natural enemies on the East Coast prompted interest in introducing *Cy. nipponicus* and *Ch. kuwanae* into California. From 1993-1995, the Biological Control Program, in conjunction with USDA-APHIS conducted limited releases of *Cy. nipponicus* and *Ch. kuwanae* at sites in Sacramento and Napa counties, releasing 3,047 adult *Cy. nipponicus* and 287 adult *Ch. kuwanae*. In 1995, the USDA-APHIS supplied two newly imported parasitic wasps for release. A total of 2,630 adult *Encarsia* nr. *diaspidicola* and 1,335 *Aphytis* sp. were released at two Sacramento sites. No releases were made in 1996 because the USDA-APHIS Euonymus Scale Project was discontinued.

Monitoring of the release sites was continued in 1996 by the Biological Control Program. A site in William Land Park in Sacramento County had releases of 62 *Ch. kuwanae* adults in January 1994. A thriving population of *Ch. kuwanae* adults and larvae were observed at the release area in 1995 and again in 1996. In 1996, during periodic ten-minute counts throughout the summer, on average 28 (range 24-40, n=4) adults and 21 (range 2-39, n=4) larvae were observed. No releases are scheduled in California in 1997, although detailed monitoring will continue to determine the effectiveness and establishment of the four introduced natural enemies of the euonymus scale.

Survey of Native Parasites of Aphids In Natural Enemy Refuge Plots in Imperial County

K. E. Godfrey and W. J. Roltsch

Natural enemy refugia were established in 1994 in the Imperial Valley to provide suitable overwintering habitat for natural enemies of the silverleaf whitefly, (*Bemisia argentifolii* Bellows and Perring; Homoptera: Aleyrodidae). These refugia also provide habitat for other natural enemies. During studies conducted in the refugia in 1995, it was observed that densities of aphids in cole crops adjacent to the refuge strips were lower than those in separate fields where refuge strips were absent. Such differences in aphid density within the field suggests that either the plants within the refuge are more preferred by aphids than the crop plants, or that natural enemies of the aphids are being harbored in the refugia and are moving into adjacent crop plants. To determine the mechanisms causing differences in aphid densities, the interactions among the aphids and their natural enemies within the system must be elucidated. The first step is to identify the organisms influencing aphid population dynamics. This study was conducted to identify the parasites found attacking aphids in the refugia.

Samples were taken from refuge strips containing either collards or sunflower at two sites in Imperial County, Bornt Farms, El Centro, and the USDA field station, Brawley. Samples were taken in collards from January 23 through June 10 1996, and in sunflower, from January 23 until March 13 1996. The difference in the length of sampling of each plant species was due to differences in the availability of host plants through time. On each sample date, 10 leaves of each plant that contained aphids were harvested. The aphids on the samples were then screened for parasites in the laboratory.

For both sites, collards had a greater number of species of aphids and parasites than sunflower (Table 1). The predominant aphids found in collards were cabbage aphid (*Brevicoryne brassicae* (L.)), and green peach aphid (*Myzus persicae* (Sulzer)). The cotton aphid (*Aphis gossypii* Glover: Homoptera; Aphididae) was also found in collards, but only in low numbers in the January sample (Table 1). In sunflower, only cotton aphid was found (Table 1). As expected, the primary parasites attacking these aphids were also more diverse in collards than in sunflower. In collards, primary parasites belonging to the genera *Diaeretiella*, *Lysiphlebus*, and *Aphidius* (Hymenoptera: Aphidiidae) were found (Table 1). In sunflower, the only primary parasite found belonged to the genus *Lysiphlebus* (Table 1). Low numbers of secondary parasites were found at all sites. In collards, the secondary parasites recovered belonged to the genera *Asaphes*, *Pachyneuron* (Hymenoptera: Pteromalidae), and *Alloxysta* (Hymenoptera: Cynipidae), and in sunflower, only secondary parasites belonging to the genus *Alloxysta* were recovered (Table 1).

TABLE 1. The aphids and total number and genera of parasites found in samples taken from natural enemy refuge plots in Imperial County in 1996.

Site and Date	Aphids Present[1]	No. and Genus of Primary Parasites[2]	No. and Genus of Secondary Parasites[3]
Bornt Collards			
23 January	CA, GPA	28 Dia	-
15 February	CBA, GPA	33 Dia	-
13 March	GPA	24 Dia, 1 Ly	-
17 April	CBA, GPA	21 Dia, 3 Apd	5 Pach
8 May	CBA, GPA	-	-
Bornt Sunflower			
23 January	CA	-	-
15 February	CA	36 Ly	9 All
13 March	CA	1 Ly	-
USDA Collards			
23 January	CA, GPA	4 Dia, 1 Ly, 1 Apd	-
15 February	GPA	17 Dia, 1 Apd	1 Pach
13 March	GPA	23 Dia	2 Pach, 1 As
22 April	CBA	11 Dia	1 Pach
9 May	CBA	-	-
10 June	CBA	6 Dia	1 All
USDA Sunflower			
23 January	CA	-	-
15 February	CA	45 Ly	4 All

[1]CA = cotton aphid; GPA = green peach aphid; CBA = cabbage aphid
[2]Dia = *Diaeretiella*; Ly = *Lysiphlebus*; Apd = *Aphidius*
[3]Pach = *Pachyneuron*; As = *Asaphes*; All = *Alloxysta*

Survey of Native Parasites of the Cotton Aphid, *Aphis gossypii*, in the San Joaquin Valley

K. E. Godfrey and J. R. Brazzle[1]

The cotton aphid is considered the most widespread insect pest affecting cotton growers in the approximately 1.25 million acres of cotton planted annually in the San Joaquin Valley. Mid to late season increases in density of the aphid result in yield reductions, yield quality losses, and decreased profits due to the cost of additional insecticide applications for the cotton aphid. One solution proposed that would reduce pest pressure from the cotton aphid is classical biological control. However, prior to the introduction of exotic parasites, a survey to identify the native parasites attacking cotton aphid is required. This survey of native parasites was initiated in the fall of 1995 in Kern County and has continued through 1996.

The native parasites attacking cotton aphid were surveyed at 11 sites that were established in October 1995. In May 1996, an additional site was added to the survey. The sites represent a variety of habitats occupied by the cotton aphid and include cotton, citrus, melons, cole crops, and non-crop plants such as cheeseweed (*Malva parviflora*). These sites were visited monthly and samples taken when both the cotton aphid and host plants of the cotton aphid were present.

The results of this survey demonstrate that the cotton aphid and its associated parasites are present nearly year-round in the San Joaquin Valley (Table 1). The aphid appears to move from non-crop host plants in the winter and early spring to cotton and melons in the late spring and summer. In the late summer and through the fall, the aphids can be found moving from the senescing cotton to citrus and non-crop habitats.

Primary and secondary parasites are associated with the cotton aphid in all habitats sampled. Three genera of primary parasites, *Aphidius*, *Lysiphlebus* (Hymenoptera: Aphidiidae), and *Aphelinus* (Hymenoptera: Aphelinidae), were recovered nearly year-round and from all the habitats sampled (Table 1). Secondary parasites belonging to the genera *Asaphes*, *Pachyneuron* (Hymenoptera: Pteromalidae), *Alloxysta*, and *Phaenoglyphis* (Hymenoptera: Cynipidae) were recovered in small numbers and only from cheeseweed and cotton habitats (Table 1). To determine if the patterns of parasite distribution through space and time are indicative of the general pattern of cotton aphid parasite distribution in the San Joaquin Valley, the survey will continue through 1997.

TABLE 1. **The plants harboring cotton aphid, the total number and genera of primary and secondary parasites, and the plants harboring both aphids and parasites in Kern County in 1996.**

Date	Host plants with aphids[a]	No. and genus of primary parasites[b]	No. and genus of secondary parasites[c]	Host plants with aphids and parasites[a]
Jan. 18	MA, SN	3Ly	-	MA
Feb. 15	CR, MA, SN	3Apd, 1Ly, 1Aph	-	MA
Mar. 14	MA, SN	3Apd	2As, 1Phan, 1Al	MA
Apr. 10	CR, MA	-	-	-
May 8	CR, MA, ML, CT	3Ly	-	CT
Jul. 23	ML, CT	2Ly	-	ML, CT
Aug. 27	CT	1Apd, 1Ly	-	CT
Sep. 18	CR, CT	1Apd, 14Ly	-	CR, CT
Oct. 17	CR, CT	3Ly	4Pach	CR, CT
Nov. 13	CR, CT	86Ly	2Pach	CR, CT

[a]MA = cheeseweed; SN = sunflower; CR = citrus; CT = cotton; ML = melons
[b]Apd = *Aphidius* spp.; Aph = *Aphelinus* spp.; Ly = *Lysiphlebus* spp.
[c]As = *Asaphes* spp.; Pach = *Pachyneuron* spp.; Al = *Alloxysta* spp.; Phan = *Phaenoglyphis* spp.

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Field Cage Evaluations of Non-indigenous, Silverleaf Whitefly, *Bemisia argentifolii*, Parasitoids on Desert Crop Plants

W. J. Roltsch and J. A. Goolsby[1]

Five species/strains of autoparasitic *Encarsia* (Hymenoptera: Aphelinidae) have been evaluated on several crop plant species in Imperial Valley. These studies were done in tandem with those conducted by Kim Hoelmer (USDA-APHIS), who was evaluating species of *Eretmocerus* and uniparental *Encarsia.* All parasite species/strains except one were provided by the Mission Biological Control Center, USDA-APHIS, Mission, TX. Accession M92018 was provided by Greg Simmons, USDA-APHIS, Brawley, CA.

Field cages, (2 m x 1.5 m x 2 m in size, constructed of 52x52 mesh Lumite screen) were set up to house transplanted greenhouse grown seedlings. Three cages were established as replicates for each species/strain evaluated, as well as for a control [i.e., only receiving whitefly]. Whiteflies were introduced into each cage (approx. 200 females per cage for broccoli, 80 for cantaloupe, and 200 for cotton) 9-14 days following transplanting. When early fourth instar whiteflies were present, 50 female parasites were released into each cage with 10 males. After approximately 14 days, when early stage parasite pupae were present, 20 additional females along with 2-5 males were introduced into each cage. This was repeated one week later. Second and third introductions are done in order to de-synchronize the parasite generations within each cage to facilitate continual male and female production. Assessment of F1 production was accomplished by collecting half leaf samples when emergence of the F1 generation first occurred. The number of parasite pupae of the target species were counted separately as well as other occasionally detected immature life stages and contaminant species.

Morphologically indistinguishable strains of *Encarsia transvena* (Timberlake) [M93003 (Spain), M94041(Thailand) and M94047 (Malaysia)] were evaluated simultaneously in broccoli and cantaloupe. In each instance, M93003 produced the greatest number of F1 offspring. F2 production by M93003 in broccoli was weak, with densities declining from F1 counts. F2 production on cantaloupe yielded a modest increase of approximately 6 fold for M93003 and M94041.

Cotton tests in 1996 included M93003, *E. transvena* M95107 (Pakistan) and *Encarsia* sp. M92018 (*strenua* group, India). On cotton, M93003 gave a response similar to that on cantaloupe. Also, M93003 and M92018 yielded a modest increase in F2's that was highly variable among cages. In contrast, M95107 produced numerous F1 in two cages and an extraordinary number in the third cage. F2 production of M95107 was very good in all three cages. The test on cotton occurred during a very hot July and August period.

The same three cultures were tested on broccoli during the fall of 1996. M93003 performance was nearly identical to that on broccoli in 1995. The performance of one replicate of M95107 was similar to the mean performance of M93003, however there were few F1 M95107 progeny produced in the remaining two replicates. M92018 performed poorly in all cages.

In summary, M93003 was the most consistent performing accession tested in this group. Accession M95107 produced striking results on cotton, however it did not do as well as M93003 on broccoli. As a result of these cage evaluation results, M93003 was massed produced at CDFA greenhouse facilities in Sacramento and released in Imperial Valley during late summer and fall of 1996. Currently, we are initiating recovery studies to determine the overwintering success of parasites released in 1996.

TABLE 1. First generation production by autoparasitic *Encarsia* on the silverleaf whitefly in field cages in Imperial Valley.

Crop	Period	Accession Number	F1 Mean Fecundity Per Female	Range of Fecundity Among 3-Cage Replicates
Broccoli	Fall 1995	M93003	12.9 a	10.3 - 15.5
		M94041	4.1 b	2.7 - 4.8
		M94047	6.1 b	4.2 - 7.5
Cantaloupe	Spr. 1996	M93003	17.6 a	10.6 - 24.7
		M94041	14.8 a	9.2 - 22.7
		M94047	1.6 b	0.3 - 2.4
Cotton	Sum.1997	M93003	17.7	9.0 - 40.3
		M95107	78.5	20.3 - 185.2
		M92018	9.9	6.9 - 8.1
Broccoli	Fall 1997	M93003	12.8	9.8 - 15.6
		M95107	5.0	2.0 - 11.4
		M92018	1.1	.3 - 1.7

Within test period means followed by the same letter are not significantly different ($P<0.05$, Waller-Duncan [1969] preceded by a one-way ANOVA). Analyses for summer and fall periods are not yet completed.

[1] USDA-APHIS-PPQ, Mission Biological Control Center

Screening of Perennial Arid Landscape Plants for Silverleaf Whitefly Parasite Refuges

W. J. Roltsch, C. H. Pickett, and J. A. Brown

Perennial species of plants native to the desert southwest along with other low maintenance landscape plants are being screened as potential refuge plants for parasitoids of the silverleaf whitefly, (*Bemisia argentifolii* Bellows and Perring; Homoptera: Aleyrodidae). Once established, perennial plant systems could provide a stable habitat for source populations of parasitoids needed during the spring months to maintain whitefly densities at low levels in nearby whitefly susceptible commercial field plantings. Such plants must support a high proportion of parasitized whitefly, survive high summer temperatures and occasional winter frosts, grow in alkaline soils and over a broad range of soil moisture conditions, and have few special management needs.

Plant species under evaluation were mostly obtained at nurseries specializing in low maintenance landscape plants for moderately arid to desert regions of California. Non-desert plants were generally obtained at locations where the silverleaf whitefly is rare. These plants were put through a prescreening test in Sacramento to assess their whitefly host-plant potential. Desert plants were obtained from nurseries in southern California where the silverleaf whitefly is common, especially during fall months. The plants were selected from on-site observations at nurseries and botanical gardens identifying them as silverleaf whitefly hosts. In searching for whitefly host-plants, particular attention was given to members of the families Acanthaceae, Euphorbiaceae and Malvaceae.

At an organic farm in Imperial County, a bed next to an annual refuge planting has been dedicated to testing perennials for their season-long whitefly and parasitoid relationships. Each plant species was randomly assigned to two, six foot long mini plots over the length of the bed. Samples were taken five or more times throughout the year to monitor the seasonal activity of whitefly, and species of *Eretmocerus*. and *Encarsia*. parasitoids. Approximately ten leaves were collected at each "mini-plot." For each leaf, 0.92 sq. cm sections were inspected for late stage immature whitefly, exuviae, and parasitoid pupae.

Results to date are preliminary (Table 1). The potential of each plant species to grow in the desert climate under field conditions with moderately alkaline soil is identified according to a four point scale (poor *, fair **, good ***, excellent****). In addition, the affinity of whitefly and each genus of parasitoid (*Eretmocerus* and *Encarsia*) is tentatively identified. Monitoring will continue for at least 18 more months over which time the plants will become considerably larger.

Few plant species are both able to support whitefly and parasitoids at suitable levels and able to survive under the high summer temperatures. Soil salinity in the Imperial Valley is also a restrictive factor in finding suitable refuge plant candidates. Three species have been selected for their potential usefulness based on early results, and have recently been planted into larger blocks for evaluation. These include a desert species (*Justicia californica*), and two other perennial, landscape/garden plants (*Lavatera thuringiaca* and *Ruta graveolens*).

TABLE 1. Perennial plant evaluation list as of March 1997

FAMILY	SPECIES	COMMON NAME	Plant growth potential	Affinity of Whiteflies to Plant	Affinity of Parasitoids to Plant
Acanthaceae	*Justicia californica*	chuparosa	***	**	*** [a]
	Justicia carnea	Brazilian plume			
	Justicia ovata	red justicia	*	***	*** [a]
	Justicia spicegera	Mexican honeysuckle	*	***	*** [a]
	Ruellia californica		****	*	*** [a]
	Ruellia peninsularis		***	*	*** [a]
Bignoniaceae	*Tecoma stans stans*		***	**	*** [a]
Asteraceae	*Echinacea purpurea*	purple coneflower	newly started		
	Rudbeckia hirta gloriosa	gloriosa daisy	newly started		
Curcurbitacae	*Curcurbita foetidissima*	wild gourd	*		
	Curcurbita palmata	coyote melon	*		
Euphorbiaceae	*Euphorbia xantii*		*	**	*** [a,b]
Malvaceae	*Anisodontea [tara's choice]*	Tara's mallow	**	*	*** [a]
	Hibiscus californica	California hibiscus	**	**	*** [a]
	Hibiscus sabdariffa	roselle	***	**	**** [a,b]
	Hibiscus esculentus	okra [Clemson spineless]	****	****	**** [a,b]
	Hibiscus rosa-sinensis	Chinese hibiscus	***	***	**** [a,b]
	Lavatera bicolor	tree mallow	***	*	
	Lavatera thuringiaca	lavatera	**	***	*** [a]
	Althaea rosea	hollyhock	**	***	*** [a]
Rutaceae	*Ruta graveolens*	Rue	***	**	*** [a,b]
Solanaceae	*Datura discolor* [1]	jimsonweed	*		
	Datura meteloides	jimsonweed	*	*	** [a]
		purple potato vine			
	Nicotiana glauca		****	*	*** [a,b]
	Nicotiana trigonophylla	tobacco bush	**	*	*** [a]
Verbenaceae	*Verbena peruviana*	St. Paul's verbena	newly started		

Performance rating: poor *, fair **, good ***, excellent ****.
1 = annual species of *Datura*
Letters in brackets signify whether *Eretmocerus*[a], *Encarcia* [b], or both are common on each plant type.

Insect Natural Enemies Mass Reared for Research and Colonization Projects

K. A. Casanave, J. A. Brown, and C. H. Pickett

Each year one or more insect natural enemies are mass reared for a variety of projects conducted by the Biological Control Program or other state and federal agencies. These research or colonization projects may not be reported elsewhere in our annual summary. Below we list these projects, the agency primarily involved in the work, and a description of the project goals. This past year all natural enemies were reared for control of silverleaf whitefly, *Bemisia argentifolii* Bellows and Perring (Homoptera: Aleyrodidae). The DNA "banding patterns" reported below are from a PCR fingerprinting technique developed by the USDA-APHIS, PPQ, Biological Control Center at Mission, Texas. The patterns are considered unique to strains or species of parasites that have not been described or identified using traditional morphological techniques.

Natural Enemy	DNA banding pattern	Agency receiving shipments	Project description	stage delivered	Total insects delivered
Eretmocerus M95012 (Multan, Pakistan)	ERET-10	CDFA, Imperial Co.	field, urban releases	pupae[1]	3,121,000
		USDA-APHIS-PPQ, Imperial Co.	augmentation studies in Imperial County	pupae	594,000
		CDFA	field, urban releases, San Joaquin Valley	pupae	782,000
Encarsia nr. pergandiella M94055 (Sete Lagas, Brazil)	EN-15	USDA-APHIS PPQ, Mission, Texas	field releases	pupae	9,000
Eretmocerus M93005 (Thirumala, India)	ERET-2	USDA-APHIS PPQ, Mission, Texas	maintenance culture	adults pupae	500
Encarsia nr. hispida M94056 (Sete Lagos, Brazil)	ENC-16	USDA-APHIS, Imperial Co.	field, urban releases	pupae	58,622
		CDFA, Imperial Co.	field, urban releases	adults	318,000
		USDA-APHIS, Mission, Texas	field releases	adults	9,000
		Univ. Florida (D. Schuster)	initiate culture	adults	2,000
		USDA-APHIS PPQ Phoenix (D. Gerling)	experimental studies	adults	50
Encarsia transvena M93003 (Mursia, Spain)	EN-7	USDA-APHIS PPQ, Imperial Valley	field, urban releases	adults	34,810
		CDFA, Imperial Co.	cage studies, field release	adults pupae	126,700
Eretmocerus M94120 (Golan Ma'Aleh Gamla, Israel)	ERET-1	USDA-APHIS, Imperial Co.	field, urban releases	adults pupae	600[2]
		CDFA, Imperial Co.	field, urban releases	adults pupae	136,000[3]

[1]pupae delivered on hibiscus leaves or whole plants
[2]Contaminated with M95012
[3]Contaminated with M93003

Survey of Parasites of Native Gracillariidae: A Possible Source of Parasites for Citrus Leafminer

K. E. Godfrey, J. M. Heraty[1], N. J. Smith[2], and D. Haines[3]

Citrus leafminer, *Phyllocnistis citrella* Stainton; (Lepidoptera: Gracillariidae) is a small lepidopterous pest that is poised to invade California citrus. Currently, citrus leafminer is found in Florida, Alabama, Louisiana, Texas, Mexico, and southward through Central America. Within a year of its detection in Florida, native parasites belonging to the genera *Pnigalio*, *Sympiesis*, *Zagrammosoma*, *Closterocerus*, *Horismenus*, and *Elasmus* (Hymenoptera: Eulophidae) were found attacking citrus leafminer. These native parasites moved from their native hosts (other leafmining insects including other Lepidoptera and Diptera) to the citrus leafminer. In California, there are representatives of each of these genera attacking various native leafminers. It is possible that once citrus leafminer enters California some of these native parasites will move from their native hosts to citrus leafminer just as their counterparts did in Florida. Therefore, a survey was initiated to identify the parasites attacking native gracillariids in Fresno and Tulare counties.

The native parasites attacking gracillariid leafminers were surveyed at four sites, two in Fresno County and two in Tulare County. Each site had a stand of oak located near a citrus grove and a stream or waterway. Samples were collected monthly beginning on May 7, 1996, in Fresno County and on July 10, 1996 in Tulare County and continued until November 11, 1996. In Fresno County, blue oak (*Quercus douglasii*) and interior live oak (*Q. wislizenii*) were sampled at the Greenleaf Farms and Bailey Farms sites. In Tulare County, blue oak was sampled at both sites. At each site on each sampling date, leaves containing mines were collected. The leaves were then held individually at 25°C (70% relative humidity) for the emergence of the parasite or leafminer adult.

Parasites were recovered from samples taken at both sites in Fresno County and from one site in Tulare County. In Fresno County, parasites were recovered from each site on the following dates: Greenleaf Farms - June 4, nine eulophids from leafminers on blue oak and two eulophids from leafminers on interior live oak; Bailey Farms - May 7 - one eulophid from leafminers on blue oak; July 10 - one pteromalid from leafminers on blue oak. In Tulare County, two eulophids were recovered from leafminers on blue oak from the November 11 sample. Identification of all parasites is pending. No adult leafminers were recovered from any of the samples.

The survey will be continued at these sites beginning in March 1997. An attempt will be made to collect leafminers from more host plants than just the oaks. In addition, if leafminers are abundant, some may be dissected in an attempt to get a better estimate of parasitism.

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[2]Department of Agriculture, Fresno County
[3]Department of Agriculture, Tulare County

Phenology of Vine Mealybug on Grapevines in the Coachella Valley

J. C. Ball, K. E. Godfrey, D. A. Powell[1], E. L. Reeves[2], D. Gonzalez[1], and S. V. Triapitsyn[1]

The vine mealybug, *Planococcus ficus* (Signoret) (Homoptera: Pseudococcidae), is an economic pest of grapevines in the Mediterranean region, South Africa, Pakistan and Argentina. Although known from the eastern United States since the 1950's, *P. ficus* was first reported in California in 1994 on grapevines in the Coachella Valley, Riverside County. With discovery of vine mealybug, Riverside County initiated a delimitation survey in the Coachella Valley, and found it infesting approximately 6,000 acres, indicating that it had been around for several years. Although vine mealybug is not known to be established elsewhere in the state, it now appears to be present in most vineyards in the Coachella Valley. Elsewhere in the world, *P. ficus* attacks several other agricultural hosts such as figs, avocado, mango, and pomegranate, but it has only been recovered from grapes in the Coachella Valley.

Since November 1994, the Biological Control Program, along with the University of California, Riverside, and the Riverside County Agricultural Commissioner's Office has worked cooperatively on a survey of native parasites of vine mealybug in Coachella Valley vineyards. That survey was completed and reported in the 1995 annual summary.

In 1996, while continuing to monitor native and introduced natural enemies, we set out to determine the seasonal activity of vine mealybug on the grapevine. The study was conducted in a certified organic block of Superior Seedless grapes. Population growth of vine mealybug was followed on the same pre-selected vines for the duration of the one year study. Sampling was at monthly intervals beginning in May and every other month after November. We attempted to monitor vine mealybug population densities through direct inspection of the roots, trunk, canes, leaves, and fruit clusters, and monitor activity using sticky traps. Sticky traps, made of double-coated tape encircling the arms and canes of selected vines, were placed in a manner we hoped would indicate both activity and direction of movement. This was done by specifying the position (proximal, middle, distal) on an arm or cane where the trap was located. On other vines (ones sampled throughout the study), loose bark was removed from the trunk, a 250 cm^2 exposed area marked, and then either wrapped with a layer of burlap or left bare. On the "wrapped" vines, a section of root was exposed, sandwiched between a sheet of plastic, and reburied. The intention of these manipulations was to delimit specific areas on the vine for return sampling, providing physical protection, yet access for mealybugs and ants.

The greatest number of vine mealybug caught on sticky traps during the year was in the period from May through June. In July, counts dropped to 3% of the annual peak, but increased slightly between August and October to about 8% of this peak. Lowest seasonal counts were recorded in October and November. The majority of mealybugs trapped were crawlers, but later instars were also present. Direct counts on the trunk generally followed the seasonal pattern exhibited on the sticky-traps. Mealybug numbers both on leaves and fruit clusters, however, remained low and showed no trends through time. We feel that manipulations on the trunk and roots interfered with normal vine mealybug activity in these micro-habitats. The burlap wraps on the trunk sheltered earwigs, crickets, spiders, etc., that could cause direct mortality or prevent settling of vine mealybug. Plastic around the roots appeared to maintain a moist environment that may have been unattractive to the mealybugs.

We cannot determine from our data whether there are directional movements from one part of the vine to another (root to trunk to cane) depending on season. We recovered very few predators and no parasites in our samples, which we feel was a consequence of the low vine mealybug densities on our sample vines. The study next year will focus on known infested vines which may give us higher population densities to monitor.

TABLE I. Vine Mealybug Dispersion Along Cordons and Canes; Sticky-trap Collections

	Total Mealybugs Trapped[1]					
	Cordon			Cane		
Month	Proximal	Medial	Distal	Proximal	Medial	Distal
May-June	2,769	2,315	1,555	89	22	0
Jun.-July	114	39	62	9	8	9
July-Aug.	42	38	22	10	6	8
Aug.-Sep.	275	244	180	5	17	1
Sep.-Oct.	193	97	89	13	7	16
Oct.-Nov.	5	4	0	0	0	0
Nov.-Jan.	0	0	0	-	-	-

[1]Based on 12 traps per position. Mealybugs counted as small, medium, or large which generally corresponded to 1st, 2nd, and 3rd instars. Mealybugs ensnared on traps in June were 86% to 96% small, those trapped in July 54% to 83% small, in August 63% to 75% small, in September 96% to 100% small, and October 72% to 93% small.

TABLE II. Vine Mealybug Densities on Various Parts of the Vine; Coachella Valley, 1996

	Trunk[1]				
Month	Wrapped	Exposed	Root[2]	Leaves[3]	Clusters[4]
Apr.-May	8.5	2.4	0.0	0.01	1.04
May-June	0.33	0.08	0.0	0.0	1.12
June-July	0.17	0.0	0.0	0.01	1.08
July-Aug.	0.08	0.08	0.08	0.0	-
Aug.-Sep.	1.08	0.0	0.92	0.01	-
Sep.-Oct.	5.92	0.08	0.42	0.01	-
Oct.-Nov.	0.08	0.08	0.75	0.02	-
Nov.-Jan.	0.25	0.17	0.67	-	-

[1]250 cm² surface area counted. Means for 12 trunks. [2]Mean for 12 roots. Counts "in situ". [3]Mean for 96 leaves. [4]Mean derived from intensity ratings of infestations in 24 clusters (ratings 1-5; 1= no infestation, 5= 75% of fruit in cluster infested).

[1]Department of Entomology, University of California, Riverside.
[2]Department of Agriculture, Riverside County (retired)

Releases and Establishment of Two *Chaetorellia* Flies for the Biological Control of Yellow Starthistle in California

B. Villegas, J. Balciunas[1] and C. E. Turner[2]

During 1996, two similar looking seedhead flies, the peacock fly, *Chaetorellia australis* Hering and the seedhead fly, *Chaetorellia succinea* (Costa) (Diptera: Tephritidae), were found well established in northern California and southwestern Oregon on yellow starthistle, *Centaurea solstitialis* L. and cornflower (bachelor button), *Centaurea cyanus* L. (Asteraceae). The identity of the two flies was discovered after submitting voucher specimens of *Chaetorellia* to Mr. Louis Blanc (Biosystematist CDFA, retired) and Dr. Eric Fisher (Biosystematist, CDFA Plant Pest Diagnostics Laboratory, Sacramento) for routine species confirmation. The identity of *C. succinea* was later confirmed by Dr. Ian White (Biosystematist, British Museum of Natural History, England) from specimens sent to him.

A thorough review of the quarantine shipping records at the USDA, ARS facility in Albany, California, helped us develop the following probable scenario for the introduction of *C. succinea.* In 1991, a contaminated sample of yellow starthistle seedheads was received from Greece, and the flies reared from this sample were mistakenly identified as all *C. australis* although voucher specimens kept from this shipment consisted of both species. The flies were subsequently released in the Merlin area of southern Oregon approximately 61 miles north of the California border. It appears that both species of flies were able to colonize and establish at this site. Later, both flies moved on their own into northern California with *C. succinea* moving up to 200 miles from the original release site. *C. australis*, on the other hand, was found about 100 miles south of the Merlin area in areas of northern California that have naturalized infestations of cornflower.

The peacock fly, is one of five biocontrol agents that were introduced from Greece into California, Oregon, and Washington for control of yellow starthistle. In California these flies were released from 1988-1994 at six sites in Contra Costa, Mariposa, Napa, Nevada, Plumas and Shasta counties by the USDA-ARS, Biological Control of Weeds Project in cooperation with the Biological Control Program and the California Agricultural Commissioners and Sealers Association (Table 1). Establishment of the peacock fly was observed in Oregon and Washington in 1993, but neither colonization nor establishment was confirmed at any of the California sites. The failure to establish was blamed on asynchrony between the early spring emergence of adult flies and the availability of susceptible seedheads of yellow starthistle at the release sites. At sites where *C. australis* had become established in Oregon and Washington, cornflower, an alternate host of this fly, was widely spread among the yellow starthistle. At these sites, it was thought that the early blooming cornflower seedheads acted as a bridge between the early emerging peacock flies and the later blooming yellow starthistle. In 1994, a final release of flies imported directly from Greece and one small release of flies collected from Merlin in southern Oregon were made at El Portal in Mariposa County. This site had naturalized cornflower in close proximity to yellow starthistle. During subsequent surveys of the release site, signs of possible colonization of the flies were detected on yellow starthistle seedheads, but the numbers were very small. It was then thought that larger numbers of flies would be needed to ensure establishment.

In 1995 and 1996, the Biological Control Program made releases of large numbers of peacock flies from Oregon at several sites in California. Sites containing both cornflower and yellow starthistle in close proximity were given the highest priority, with second priority given to sites with early blooming yellow starthistle. Through this renewed effort, large collections of yellow starthistle seedheads infested with what was thought to be *C. australis* were made from Merlin, Oregon from April through June, 1995-1996. The earliest collected material was placed in cold storage in order to synchronize fly emergence with susceptible yellow starthistle seedheads at release sites in California. Once field plots of yellow starthistle had developed to a susceptible stage, the seedheads were transferred to sleeve cages and fly emergence monitored daily. Emergence generally started within a week after the seedheads were taken out of cold storage and continued for approximately three weeks.

The 1995 releases occurred from May 12 through June 21, in Amador, Mariposa, Placer, San Luis Obispo, Sacramento, Shasta, and Siskiyou counties. It should be noted that one of the releases made on June 21, was made from F_1 flies emerging from infested seedheads from *C. cyanus* collected in mid June. These flies, presumed to be *C. australis*, were released at a site in Fall River Mills area of Shasta County that contained a large naturalized stand of *C. cyanus* among the yellow starthistle infestation. In 1996, 3,420 flies were released from May 21 through June 1, in Contra Costa, El Dorado, Fresno, Madera, Marin, Santa Barbara, Sutter, and Tulare counties (Figure 1). In addition, 1,950 flies were field collected as adults near Merlin and released in Glenn, Napa, Shasta and Yolo counties on May 1, 2, 3, and 31, 1996

TABLE 1: Releases of the Seedhead Flies, *Chaetorellia* spp. (*C. australis* Hering and *C. succinea* (Costa)) on Yellow Starthistle in California 1988-96.

	1988-91	1994	1995	1996	TOTAL
# Counties	6	1	7	12	20
# Individual Releases	7	1	10	15	33
# Flies Released	770[a]	122[a] 53[b]	4,040 [b]	5,370[b]	10,355

[a]Colonization releases with European material.
[b]Colonization releases with Oregon material.

With the discovery of a second species of *Chaetorellia* in California and Oregon, a complete survey of all previous *Chaetorellia* release sites was made during the remainder of 1996. Adult flies were collected by sweeping flowering yellow starthistle or cornflower plants and, if no flies were collected, seedhead samples were collected for subsequent rearing in the laboratory. Recoveries of *Chaetorellia* occurred at all 1994-1996 release sites where flies from southern Oregon were released, but no recoveries were made at any of the sites where releases took place from 1988 through 1991 (Table 2). *C. australis* appears to need cornflower for colonization as it was recovered from sites with cornflower in close proximity to yellow starthistle (e.g., El Portal, Mariposa County; Yountville, Napa County; Fall River Mills, Shasta County; and Yreka, Siskiyou County). *C. succinea*, on the other hand, does not appear to need cornflower for colonization and establishment as it was reared only from yellow starthistle seedheads.

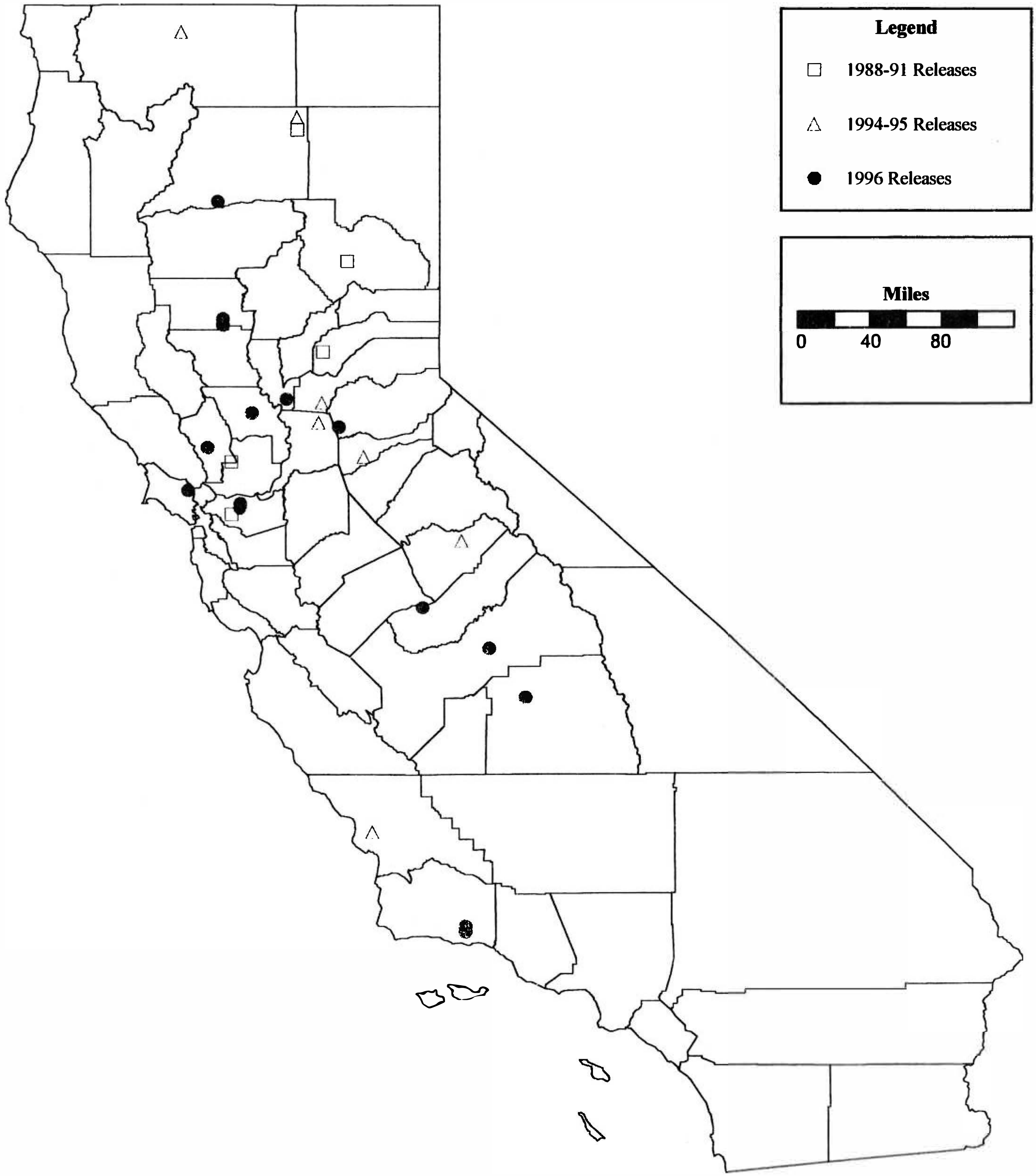
TABLE 2: Recoveries of *Chaetorellia* Flies at Previous Release Sites in California during 1996

County	City	Year Released	Flies Released	Target Host	Established
Amador	Jackson	1995	164	YST	*C. succinea*
Contra Costa	Lafayette	1988	200	YST	None
Contra Costa	Concord	1996	300	YST	*C. succinea*
Contra Costa	Concord	1996	300	YST	*C. succinea*
El Dorado	Latrobe	1996	300	YST	*C. succinea*
Fresno	Fresno	1996	400	YST	*C. succinea*
Glenn	Willows	1996	250	YST	*C. succinea*
Glenn	Willows	1996	500	YST	*C. succinea*
Madera	Chowchilla	1996	200	YST	*C. succinea*
Marin	Novato	1996	320	YST	*C. succinea*
Mariposa	El Portal	1994-95	1,151	YST/Cornflower	both
Napa	Mankas Corner	1989	120	YST	None
Napa	Yountville	1996	500	YST/Cornflower	both
Nevada	Penn Valley	1989-90	322	YST	*C. succinea*
Placer	Loomis	1995	460	YST	*C. succinea*
Plumas	Quincy	1989	42	YST	None
Sacramento	Folsom	1995	972	YST	*C. succinea*
San Luis Obispo	San Luis Obispo	1995	560	YST	*C. succinea*
Santa Barbara	Santa Barbara	1996	460	YST	*C. succinea*
Santa Barbara	Santa Barbara	1996	410	YST	*C. succinea*
Shasta	Fall River Mills	1991	86	YST/Cornflower	None
Shasta	Fall River Mills	1995	408	YST/Cornflower	*C. australis*
Shasta	Anderson	1996	300	YST	*C. succinea*
Siskiyou	Yreka	1995	500	YST/Cornflower	both
Sutter	Pleasant Grove	1996	300	YST	*C. succinea*
Tulare	Farmersville	1996	430	YST	*C. succinea*
Yolo	Woodland	1996	400	YST	*C. succinea*

[1]USDA, ARS, Western Regional Research Center
[2]USDA, ARS, Purdue University, (deceased)

Figure 1: Releases of Chaetorellia Seedhead Flies in California in 1988-96

Biological Control Program, CDFA



Biological Control of Purple Loosestrife, *Lythrum salicariae*

D. B. Joley, B. Villegas, M. J. Pitcairn, H. D. Riley[1], and J. V. Albright[2]

Purple loosestrife, *Lythrum salicariae* L. (Lythraceae), a serious invasive weed of wetlands in the northern U.S., is limited to relatively small acreages in northern California. In 1996, the Biological Control Program made its initial release of a biocontrol agent on purple loosestrife in California. Specifically, 323 eggs of *Hylobius transversovittatus* Goeze (Coleoptera: Curculionidae), a root boring weevil, were placed in depressions bored into the pith of cut loosestrife stems in Butte County. An additional 511 eggs were placed in cut stems near Fall River Mills in Shasta County (Table 1). Follow-up examination of stems indicated a strong possibility that larvae survived at least long enough to mine into the roots at the Butte County site, but failed to survive at the Shasta County site. Both release sites have experienced difficulties this first season. In Shasta County, cocoons of parasitic Hymenoptera were found next to the end of larval mines of *Hylobius* in stems above the junction with the roots, suggesting that they attacked the larvae. Also, plants at the Shasta County site had been trampled by cattle sometime after the release, and few of the infested stems remained intact. Both areas were subjected to high water during winter, potentially drowning larvae.

TABLE 1. Numbers of eggs of *Hylobius transversovittatus* deposited in cut stems of purple loosestrife in California during 1996.

Location	Date	Number of Eggs
Butte County	June 19	323
Shasta County	June 27	511

[1]Department of Agriculture, Butte County
[2]Department of Agriculture, Shasta County

An Update on the Release and Establishment of Natural Enemies for the Biological Control of Spotted Knapweed, *Centaurea maculosa* in California

D. M. Woods and D. B. Joley

Spotted knapweed, *Centaurea maculosa* Lamarck (Asteraceae), is currently under eradication in most of California. One location in the Big Bend area of Shasta County however, is too large and remote for effective eradication. The Biological Control Program has been attempting to implement a 'classical' biological control program in the core of this relatively remote and persistent infestation.

Five natural enemies have been intentionally released at the infestation in the Big Bend area over the past four years (Table 1). In addition, one insect, *Urophora quadrifasciata* (Meigen) (Diptera: Tephritidae), appears to have migrated to the site on its own, presumably from the nearest populations at the California/Oregon border. Establishment of the gall fly, *U. quadrifasciata,* was confirmed this year by collection of galls in seedheads and rearing adult flies in the laboratory. In 1996, one natural enemy was re-released; *Terellia virens* (Loew) (Diptera: Tephritidae). An adult *Agapeta zoegana* L. (Lepidoptera: Cochylidae) was recovered for the first time. Measurements of spotted knapweed population and seedhead densities for evaluation of combined impact of the biological control agents were made during 1994 through 1996,

TABLE 1. Biocontrol agents released on spotted knapweed in Shasta County and their status

Biocontrol agent	Total Released	Years Released	Status December 1996
Urophora affinis	327	1993	Established
Agapeta zoegana	578	1993, 1994, 1995	Recovered in 1996
Cyphocleonus achates	210	1993, 1994, 1995	No recoveries
Terellia virens	597	1995, 1996	Successfully infested seedheads in 1996
Larinus minutus	800	1995	Established

Biological Control of Diffuse Knapweed, *Centaurea diffusa*

D. B. Joley and D. M. Woods

Diffuse knapweed, *Centaurea diffusa* Lamarck (Asteraceae), primarily occurs in California as single plants or small patches, presumably originating as a contaminate on products from nearby western states. It is under eradication in most areas of the state except in Trinity County, where spraying with pesticides is not allowed. The Biological Control Program has an ongoing project to release available biocontrol agents on diffuse knapweed in Trinity County.

At least five biocontrol agents now appear to be established on diffuse knapweed in Trinity County. *Urophora affinis* Frauenfield (Diptera: Tephritidae), first released in 1976, still infests only a small percentage of heads (10-15%), compared to much higher levels observed elsewhere in the U.S. and Canada. The root beetle, *Sphenoptera jugoslavica* Obenberger (Coleoptera: Buprestidae), released in 1980, was not recognized as established until recently. In a field evaluation in 1996, nearly 80% of the roots were found to be infested. More recent introductions, *Bangasternus fausti* (Reitter) (Coleoptera: Curculionidae), released in 1994 and 1995, and *Larinus minutus* Gyllenhal (Coleoptera: Curculionidae), first released in 1995 both appear to be established. A sample of seedheads, collected from the release sites in November 1996 showed that 16% and 7% of the heads were infested with *B. fausti* and *L. minutus*, respectively.

The pathogen, *Puccinia jaceae* (Otth.) (Uredinales), an immigrant from Canada, continues to infect diffuse knapweed plants in Trinity County at low levels. Another immigrant from Canada, *Urophora quadrifasciata* (Meigen) (Diptera: Tephritidae), was found (single specimen) in 1995, but was not detected in 1996.

TABLE 1. Biocontrol agents currently infesting diffuse knapweed in Trinity County

Biocontrol Agent	Date of Initial Release	Means of Introduction	Current Status
Urophora affinis	1976	Inoculative release	Established
Sphenoptera jugoslavica	1980	Inoculative release	Established
Bangasternus fausti	1994	Inoculative release	Established
Larinus minutus	1995	Inoculative release	Established
Puccinia jaceae	?	Natural immigration	Established

Attempts to Establish Insects for the Biological Control of Squarrose Knapweed, *Centaurea squarrosa*

D. M. Woods, B. Villegas and D. B. Joley

Infestations of squarrose knapweed, *Centaurea squarrosa* Willd (Asteraceae), exist in several counties in California, and are usually confined to disturbed roadsides. A few infestations occur in the state that may be too large to eradicate. The Biological Control Program has initiated an effort to test currently available knapweed biological control insects as potential controls for squarrose knapweed.

There are currently no biocontrol agents that were specifically selected and tested against this weed host. However, several agents currently available for diffuse and spotted knapweeds may have potential for use on squarrose knapweed. One of the knapweed gall flies, *U. quadrifasciata* Meigen (Diptera: Tephritidae), appears to have immigrated to California through Oregon and is established on squarrose knapweed near the Oregon border. Two other natural enemies have been released on field populations of squarrose knapweed. In 1995, a shipment of *Cyphocleonus achates* (Fahraeus) (Coleoptera: Curculionidae), a root-boring weevil, was released, while in 1996 a release was made of *Bangasternus fausti* (Reitter) (Coleoptera: Curculionidae) obtained from the Oregon Department of Agriculture (Table 1). A total of 217 heads were dissected at the end of the growing season but there was no evidence of establishment. Also, no eggs were detected in the field. Unfortunately, the seasonal phenology of squarrose knapweed may be out of synchrony with the source of the weevils and it will be difficult to establish the weevils. Alternatively, squarrose knapweed may just be a poor host for the tested insect species.

TABLE 1. Biological control insects released on squarrose knapweed in California

Biocontrol Agent	Total Released	Year Released	Status December 1996
Cyphocleonus achates	100	1995	No recoveries
Bangasternus fausti	200	1996	No recoveries

Recovery of *Urophora stylata* on Bull Thistle, *Cirsium vulgare* in California

B. Villegas, D. B. Joley, K. Chan[1], and E. Coombs[2]

Bull thistle, *Cirsium vulgare* (Savi) (Asteraceae), is a widespread exotic biennial weed that is usually associated with a high degree of disturbance, such as overgrazed permanent pasture and woodland clearings. One host specific biological control agent, the bull thistle gall fly, *Urophora stylata* (Fabricius) (Diptera: Tephritidae), was released at six sites in California during 1994 and 1995.

U. stylata has one generation per year. The adult flies emerge from overwintering seedhead galls from late May through early July. The adult flies may live up to two months. Oviposition occurs on top of developing flower buds, and the eggs hatch after about one week. After hatching, the larvae migrate to the receptacle where they induce gall tissue formation which the larvae feed on. A multi-chambered gall forms on the receptacle of the seedhead with individual larvae occupying separate chambers of the gall. Each gall may contain from five to 20 larvae. Seedheads infested with the gall flies produce less seed due to the limited amount of receptacle area for seed production.

No releases were made during 1996 as efforts on this project were directed toward surveying previous release sites in order to determine establishment. To date, we have only recovered flies or recorded the presence of galls from two sites. The first site is located in Marin County and the second site is located in Mendocino County. No establishment has occurred at the other sites.

[1]USDA, ARS, Western Regional Research Center
[2]Oregon Department of Agriculture

Weed Biological Control Workshops

B. Villegas

The Biological Control Program maintains an active distribution program for weed biocontrol agents. The distribution program operates primarily through a series of workshops. Workshops are conducted at field nursery sites or at centralized locations by the Biological Control Program and are designed to train county biologists in the identification, collection and release of established biological control agents. Based on the training at the workshop, county biologists field collect available biological control agents, then return to their own county and attempt to establish their own nursery sites for further distribution.

Twelve sessions of the distribution workshop system were held during 1996 for the distribution of biological control agents on yellow starthistle (Table 1). All workshops were devoted to *Eustenopus villosus.* No workshops were held for *Bangasternus orientalis* or *Urophora sirunaseva* as these two species have been widely distributed and are widely established.

TABLE 1: List of workshops held in 1996 for the distribution of yellow starthistle biological control agents

WORKSHOP SUBJECT	LOCATION	DATE	COUNTY PARTICIPATION
Eustenopus villosus	El Dorado	7/15/96	2 counties
Eustenopus villosus	Placer	6/19/96	1 county
Eustenopus villosus	Sacramento	6/10/96	5 counties
Eustenopus villosus	Sacramento	6/19/96	4 counties
Eustenopus villosus	Sacramento	6/20/96	4 counties
Eustenopus villosus	Sacramento	6/25/96	5 counties
Eustenopus villosus	Sacramento	6/26/96	4 counties
Eustenopus villosus	Sacramento	6/27/96	4 counties
Eustenopus villosus	Sacramento	7/1/96	1 county
Eustenopus villosus	Shasta	6/24/96	2 counties
Eustenopus villosus	Shasta	7/2/96	4 counties
Eustenopus villosus	Shasta	7/9/96	8 counties

Distribution of the Hairy Weevil, *Eustenopus villosus,* in California for the Biological Control of Yellow Starthistle

B. Villegas

The hairy weevil, *Eustenopus villosus* (Boheman) (Coleoptera: Curculionidae), was introduced from Greece for the biological control of yellow starthistle, *Centaurea solstitialis* L. (Asteraceae). The USDA-ARS, in cooperation with the Biological Control Program and the County Agricultural Commissioners, established the first colonies in Nevada and El Dorado counties in 1990 and Napa, Mendocino, and Shasta counties in 1991. Populations were so well established in El Dorado and Nevada counties in 1992 that the hairy weevil distribution was made to Sacramento and Placer counties. The following year the same sites served as sources of weevils for 12 releases in ten counties. From 1994 through 1996, the Biological Control Program's distribution program rapidly expanded (Table 1; Figure 1). To date, some 111,172 hairy weevils have been released in 440 separate releases (427 sites) in 48 counties in California.

Eustenopus villosus has one generation per year, emerging in May, mating and ovipositing eggs inserted inside closed flowerhead buds in June. Larvae feed on receptacle tissue and on developing seeds. Unlike other yellow starthistle natural enemies, hairy weevil adults also cause extensive damage by feeding on young closed buds. Adult feeding damage can be very extensive at release sites three years and older visibly reducing the total bloom in the stand.

In 1996, five sites were used for holding the county workshops. These sites were located in Sacramento, El Dorado, Placer and Shasta counties. From these sites a total of 64,420 hairy weevils were collected and released at 228 locations in 37 counties (Table 1). Four counties, El Dorado, Glenn, Placer and Shasta, made their own in-county releases, totaling 11,195 weevils.

TABLE 1: Releases of *Eustenopus villosus* on yellow starthistle in California 1990-96

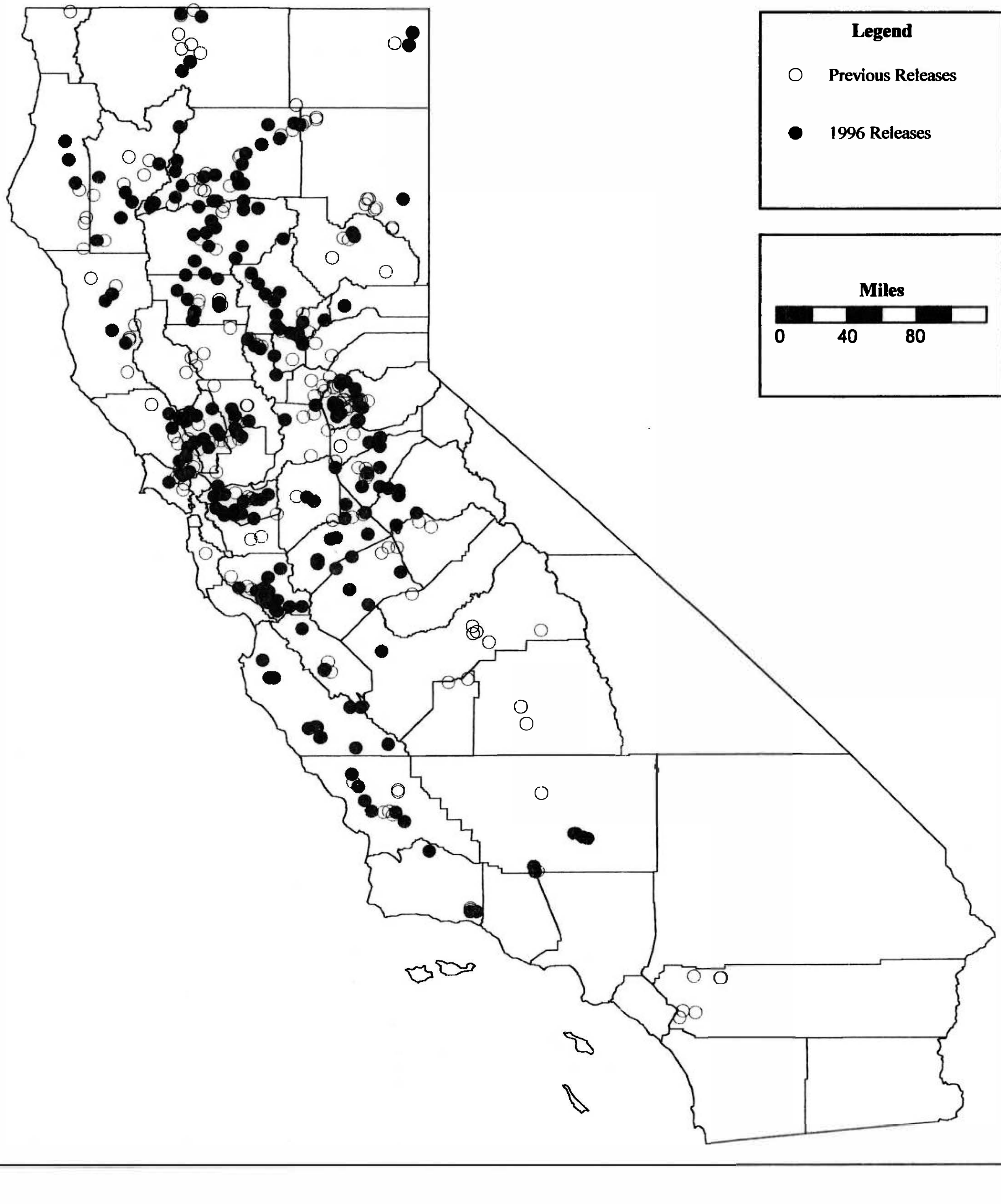
	1990	1991	1992	1993	1994	1995	1996	Total
# Counties	2	3	2	10	43	41	37	48
# Individual Releases	2	4	2	12	84	108	228	440
# Weevils	431[a]	1,014[a]	230[b]	3,150[b]	18,770[b]	23,157[b]	64,420[b]	111,172

[a]Colonization releases with European material.
[b]Distribution releases with domestic material.

The hairy weevil has become established in 47 of the counties where it had been released. Through 1996, a total of 135 different sites in 47 counties were visited and establishment was noted. The best establishment was noted in Butte, Calaveras, El Dorado, Glenn, Nevada, Placer, San Mateo, Shasta, Trinity, Tulare, and Yolo counties. These preliminary survey data also indicate that the hairy weevil establishes readily in most areas of California, but prefers the hotter interior parts of the State. The weevil appears not to have established well in coastal areas of California that are affected by fog and persistent cool temperatures nor in areas where yellow starthistle persists over a long period of time due to the high water tables.

Figure 1: Releases of Eustenopus villosus Weevils in California in 1990-96

Biological Control Program, CDFA



Distribution of the Gall Fly, *Urophora sirunaseva,* in California for the Biological Control of Yellow Starthistle

B. Villegas

The gall *fly, Urophora sirunaseva* (Hering) (Diptera: Tephritidae), was introduced from Greece into California for the biological control of yellow starthistle, *Centaurea solstitialis* L (Asteraceae). The USDA-ARS, in cooperation with the Biological Control Program and the County Agricultural Commissioners, established the first colonies of the fly in Loomis (Placer County) in 1984-1985, and near Orinda (Contra Costa), Mankas Corner (Napa County), Ukiah (Mendocino County), and Hornbrook (Siskiyou County) in 1990-1991. Populations were well established in Placer County by 1992, and the gall fly was made available for statewide distribution. The distribution information through 1996 is summarized in Table 1.

Urophora sirunaseva has two generations per year. In the Sacramento Valley, adult flies emerge from overwintering seedhead galls from mid-April through May while adults of the first generation emerge from late June to mid-July. Oviposition occurs on intermediate, closed flowerhead buds. After hatching, larvae migrate to the receptacle of the yellow starthistle bud. Gall formation around developing larvae is induced, and there is one fly larva per gall. Up to 12 galls have been found in galled seedheads. Galls induced by the fly larvae are woody with those from the overwintering generation being stronger than those induced by the first generation larvae. Buds infested with the gall flies are believed to produce less seed due to the reduced amount of receptacle area for seed production.

In 1996, no formal distribution workshops were held for the gall fly as it appears to be widely distributed in California. A total of 2,210 gall flies were released in conjunction with research releases of *Chaetorellia* seedhead flies. These flies were released at five sites in four counties (Figure 1).

TABLE 1: Releases of the gall fly, *Urophora sirunaseva* on yellow starthistle in California 1984-96

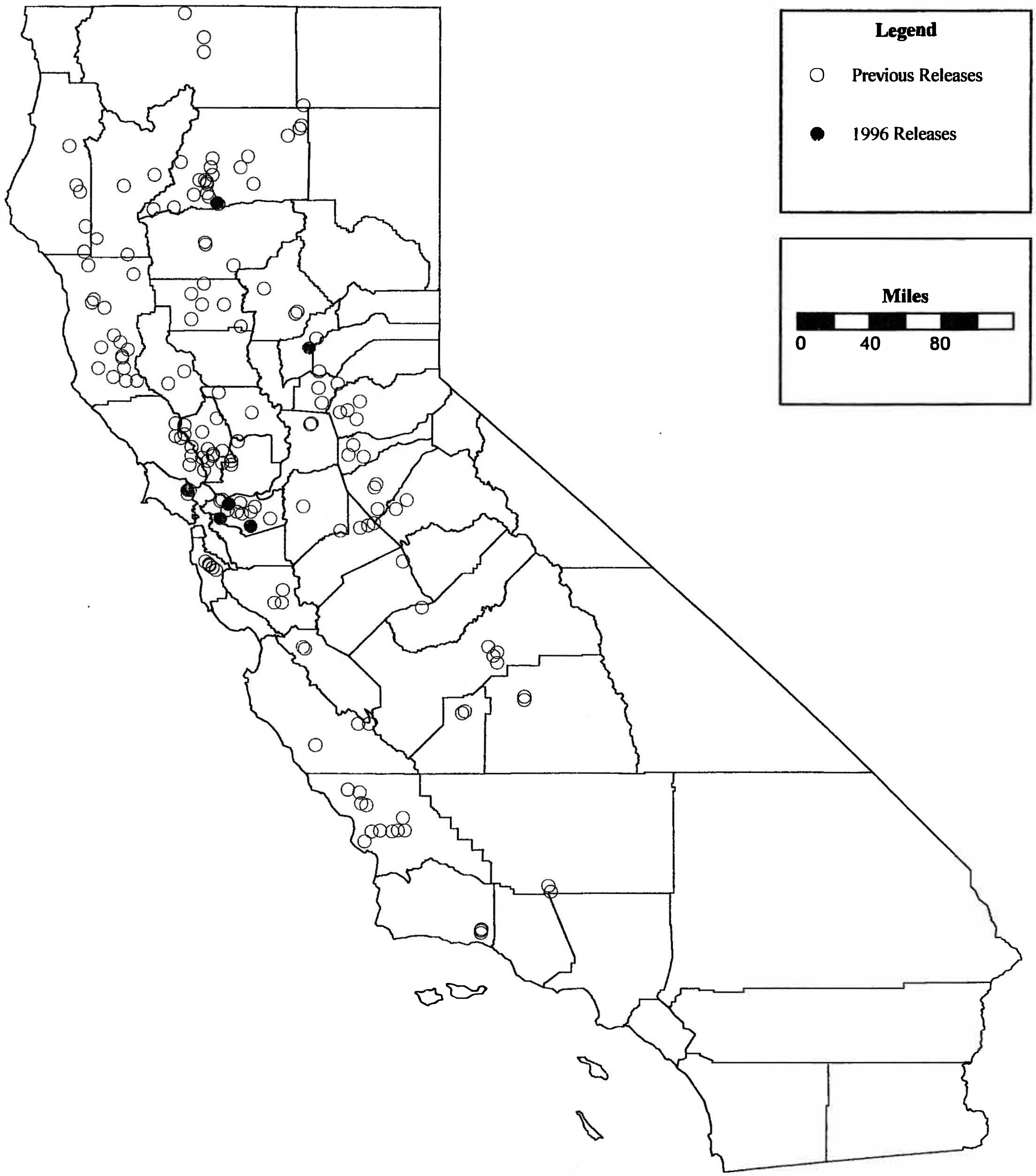
	1984-85	1990	1991	1992	1993	1994	1995	1996	Total
# Counties	2	3	3	13	30	25	10	4	38
# Individual Releases	3	3	3	16	63	64	34	5	191
# Flies Released	244[a]	998[b]	756[b]	2,755[b]	9,526[b]	17,595[b]	8,964[b]	2,210[b]	43,048

[a]Colonization releases with European material.
[b]Distribution releases with domestic material.

Urophora sirunaseva has become widely established in California due to the efforts of all the counties participating in its distribution. The gall fly appears to be most abundant in and around the western foothills of the Sierra Nevada, and in Siskiyou and Mendocino counties.

Figure 1: Releases of Urophora sirunaseva Gall Flies in California in 1984-96

Biological Control Program, CDFA



Distribution of the Bud Weevil, *Bangasternus orientalis,* in California for the Biological Control of Yellow Starthistle

B. Villegas

The bud weevil, *Bangasternus orientalis* (Capiomont) (Coleoptera: Curculionidae), was introduced from Greece into California for the biological control of yellow starthistle, *Centaurea solstitialis* L. (Asteraceae). The USDA-ARS, in cooperation with the Biological Control Program and the County Agricultural Commissioners, established the first colonies of this weevil near Lincoln (Placer County), Montague (Siskiyou County) and Rumsey (Yolo County) in 1985. Additional releases were made in Loomis (Placer County), Orinda (Contra Costa County), Santa Rosa (Sonoma County), Lotus (El Dorado County), and again at the Rumsey site in 1986-1988. *Bangasternus orientalis* appeared to be well established at the Placer and Siskiyou sites by 1988, when it was made available to the County Agricultural Commissioners for statewide distribution. The distribution information through 1996 is summarized in Table 1.

Bangasternus orientalis has one generation per year. Adult weevils emerge from overwintering sites from mid-April through May and find bolting yellow starthistle plants. After mating, female weevils start laying eggs on terminal leaflets and bases of young flower buds. When the female weevil lays an egg, she covers it with a mucous substance, combined with fecal particles and plant hairs. As the mucous mixture hardens, it forms a characteristic tear-shaped black protective cap. The eggs hatch within two weeks after oviposition and each larva burrows its way into the stem and up into the flower bud. There, the weevil larva feeds on the receptacle tissue as well as directly on the developing seeds. Larval development generally occurs from early May through mid to late July, followed by the pupal stage in late July and August. Adult weevils emerge through a visible hole in top of the seed head. These adult weevils presumably aestivate through the rest of the summer and fall, and overwinter in the duff and debris near the yellow starthistle plants.

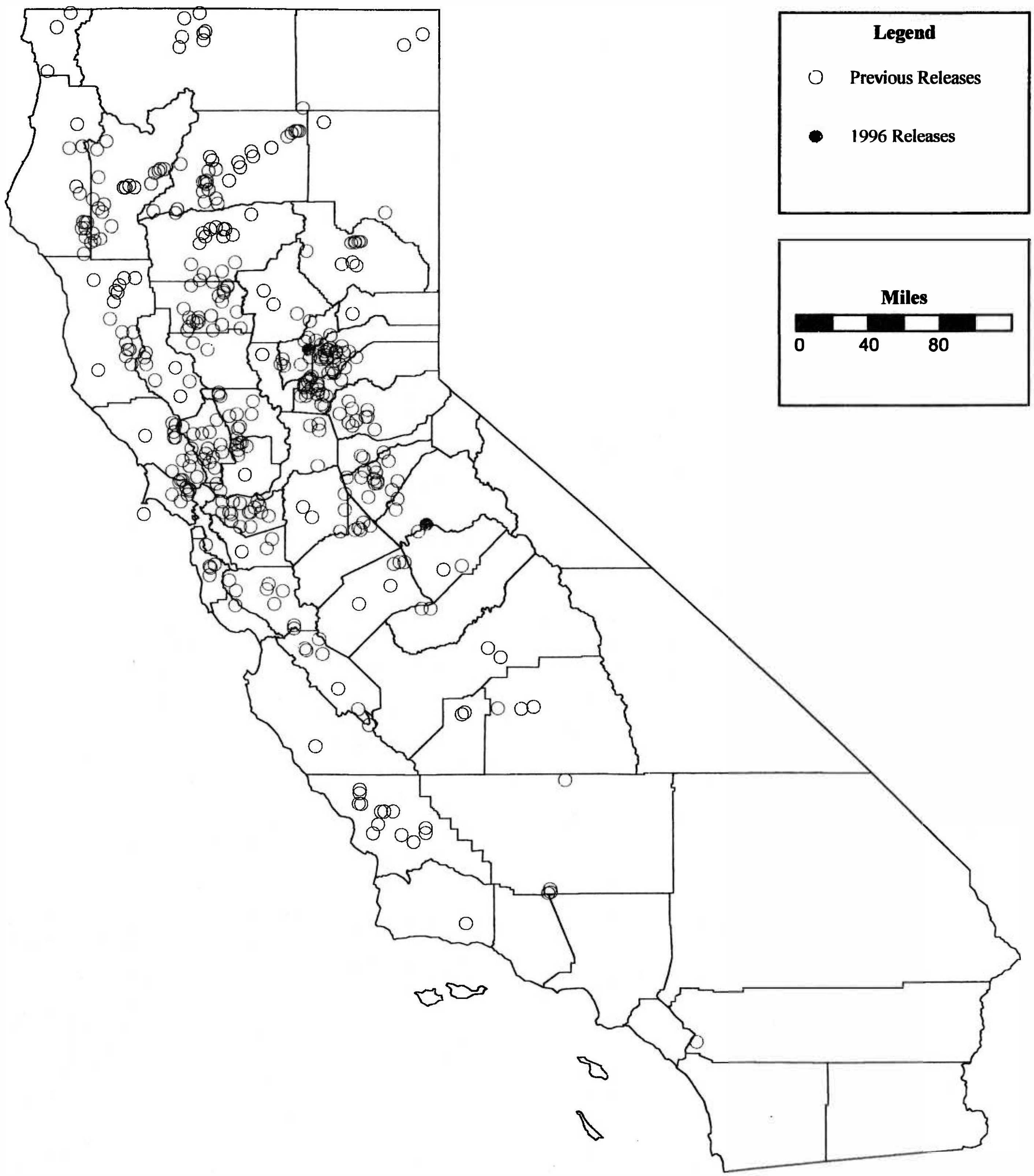
In 1996, no formal distribution workshops were held on the bud weevil as it has been widely distributed in 49 counties from 1988-1995 (Figure 1). However, two releases totaling 400 bud weevils were released in conjunction with educational and research demonstrations at two sites in two counties.

TABLE 1: Releases of bud weevil, *Bangasternus orientalis* on yellow starthistle in California 1985-96

	1985-95	1996	Total
# Counties	49	2	49
# Individual Releases	426	2	428
# Weevils Released	80,761	400	81,161

Figure 1: Releases of Bangasternus orientalis Weevils in California in 1985-96

Biological Control Program, CDFA



Ascochyta Seedling Disease of Yellow Starthistle, *Centaurea solstitialis*: Inoculation Techniques

D. M. Woods and V. Popescu

A seedling disease naturally occurring in California on yellow starthistle, *Centaurea solstitialis* L.(Asteraceae), has been shown to cause significant mortality in growth chamber experiments. An apparently new species of the fungus, *Ascochyta,* has been shown to be the causal agent. Preliminary pathogenicity tests were performed using a root soaking technique in which three day old seedlings were root soaked in a suspension of spores prior to planting. More practical inoculation techniques are needed to evaluate the fungus as a potential biological control agent for yellow starthistle.

We have been unable to reproduce the disease with foliar inoculations either by spraying a spore suspension on mature plant foliage or soaking leaf material in a spore suspension. The disease appears to be exclusively a root pathogen, so additional attempts to inoculate the roots in more practical manners were made.

Soil incorporation of agar or plant material colonized by a fungus is a commonly utilized method for inoculation with root pathogens. Clean agar and agar supporting colonies of *Ascochyta* were incorporated into soil in various proportions in order to inoculate yellow starthistle. Three day old seedlings were planted into the infested soil and monitored for disease development (Table 1). This technique proved effective in reproducing disease in growth chamber experiments

TABLE 1. Effect of mixing *Ascochyta* infested agar in the soil on the growth and survival of yellow starthistle seedlings.

	Control	Proportion of Clean agar: *Ascochyta* agar			
	No agar	4:0	2:2	1:3	0:4
Survival, % of Control	100	92	61	42	36
Growth, % of Control	100	90	82	75	60

Preparing a field trial requires an even more manageable form of inoculum, so *Ascochyta* was grown on autoclaved wheat grains, then mixed into soil for testing pathogenicity. Yellow starthistle seeds and three day old seedlings were planted into the amended mix in a growth chamber. This technique appears to work under these conditions as well as previous methods of root inoculation (Table 2), and is a potential method for field inoculation.

TABLE 2. Effect of mixing clean or *Ascochyta* infested wheat grains into the soil on the survival of yellow starthistle seedlings. Total number of surviving plants divided by the number planted.

	Planted as Seedlings	Planted as Seeds
Survival in Control Soil (Clean Grain)	16/20	20/20
Survival in Infested Soil (*Ascochyta* Grain)	7/20	9/20

Unfortunately, complete evaluation of the fungus has been hampered by the development of an apparent reduction in virulence. The isolate utilized in our experiments appears to have lost some pathogenicity during repeated laboratory culture. Experiments conducted in the previous years demonstrated a mortality of yellow starthistle seedlings as great as 90% in controlled experiments. Similar experiments this year had seedling mortality as low as 20-30%. Additional field collections of the *Ascochyta* fungus are needed to regain the high level of virulence.

Yellow Starthistle: Survey of Statewide Distribution

M. J. Pitcairn, R. A. O'Connell[1], and J. M. Gendron[1]

The California Department of Food and Agriculture maintains several eradication and control programs for noxious and exotic weeds. The recent creation of a Geographic Information System Laboratory and a weed management database provides an opportunity for improved efficiency and efficacy of all weed management efforts. In 1996, the Biological Control and the Weed and Vertebrate Control Programs initiated a cooperative effort to document the statewide distribution of several widespread weeds. The first of these is yellow starthistle, *Centaurea solstitialis* L., (Asteraceae).

Yellow starthistle was first recovered in Alameda County in 1869 and has quickly spread throughout northern and central California. Previous estimates of yellow starthistle have shown an exponential increase in abundance over time. Given this trend, its current range of infestation may triple its last estimate of 7.9 million acres in 1985 by Maddox and Mayfield (California Agriculture, vol. 39, no. 11-12). The Biological Control Program maintains an active distribution program for three biological control agents on yellow starthistle throughout the state. It is critical to know where yellow starthistle is located to ensure that all infested regions are covered with biological control agents and to identify any areas lacking these agents. Also, the level of success in lowering yellow starthistle abundance may not be similar among the various climatic and geographic regions of California. Establishment of a monitoring program to assess impact of biological control agents on yellow starthistle statewide is dependent on knowing where yellow starthistle is found.

Because yellow starthistle is widespread, distribution information was recorded on commercial county maps using the grid of legal townships. A township is a square block 6 mi x 6 mi (36 sq. miles). The maps were marked so that the abundance of yellow starthistle in every township was given a score of 0 for no plants, 1 for low abundance, 2 for high abundance, or left blank if unknown. Any rating of yellow starthistle abundance is necessarily subjective because of the large sample area, however, the following guidelines were provided:

Low abundance:

- a. Only a single plant was found in the township.
- b. The only plants found were scattered plants confined to the roadsides.
- c. Plants were scattered throughout the township, but didn't occur in high densities.
- d. No dense patches or few, small dense patches (<10 acres) were observed.

High abundance:

- a. Plants occurred primarily along roadsides and were quite dense for several miles.
- b. Plants not confined to roadsides, but observed throughout neighboring fields.
- c. Dense patches of plants >10 acres found in at least three sections.
- d. Everywhere you looked you saw yellow starthistle plants.

Despite the subjective nature of the rating system, this information should provide a good qualitative estimate of how widespread yellow starthistle has become and indicate areas of its highest abundance.

Commercial county maps with the township grid were distributed in May, 1996, to Weed and Vertebrate Control Program district staff*. Some maps were completed by the biologists themselves, whereas others distributed the maps to the county biologists in their district. All maps were returned to the Biological Control Program and the information transferred into a GIS database. A preliminary map of the 1996 survey is shown on the following page. Follow-up surveys of "unknown" areas will occur in Summer, 1997, and a finished map should be produced by Fall, 1997.

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[1]CDFA, Integrated Pest Control Branch

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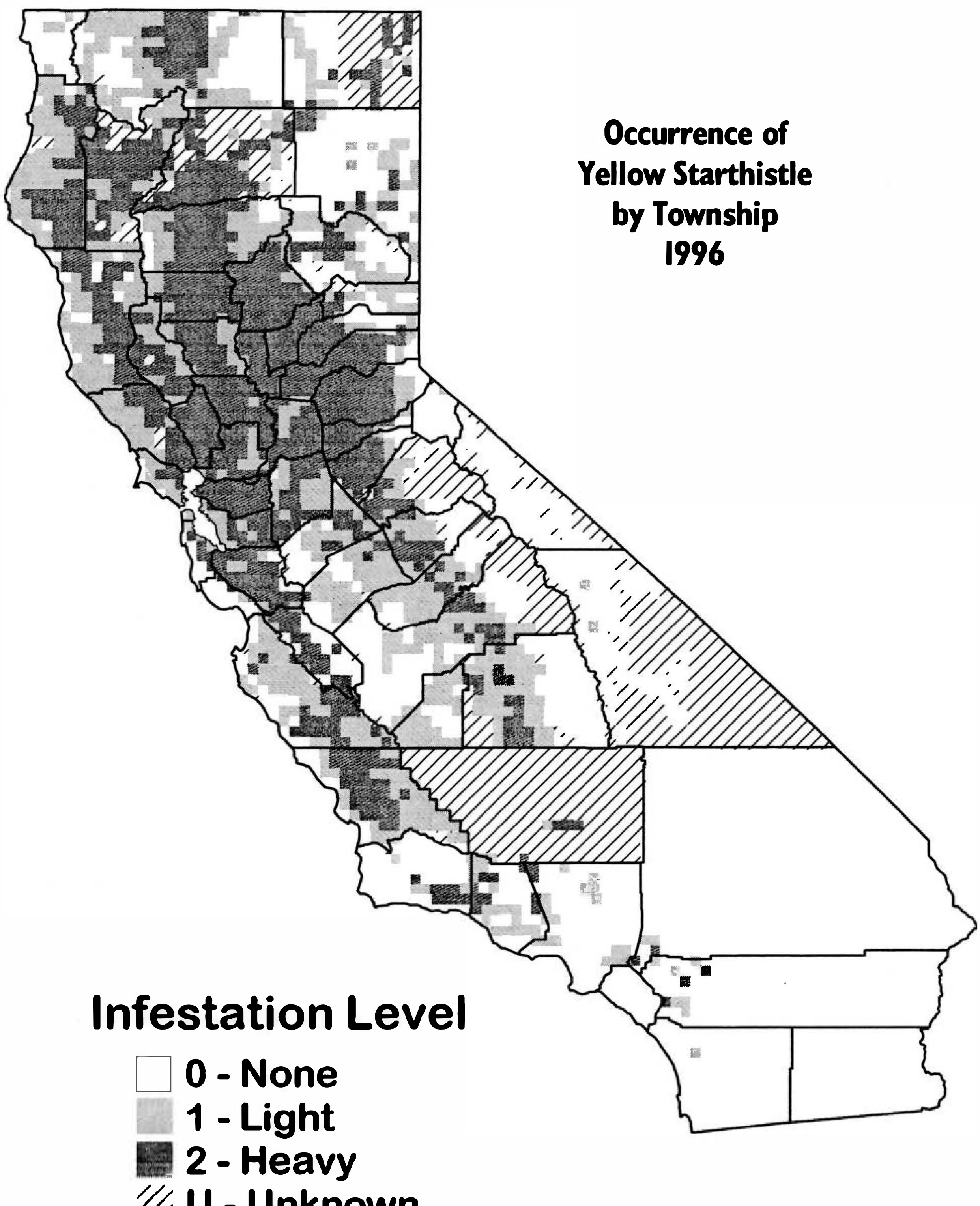
Ed Finley
Denis Griffin
Rick Keck
Rod Kerr
Butch Kreps
Tom Patrick
David Quimayousie

California Department of Food & Agriculture
Integrated Pest Control Noxious Weed Information System



Yellow Starthistle: Identification of Biotypes in the Western United States and Location of Source Populations in Europe and Asia

M. J. Pitcairn

The USDA, Biological Control of Weeds Project, and the Biological Control Program are currently pursuing biological control of yellow starthistle, *Centaurea solstitialis* L. (Asteraceae), in California. To date, six insects have been introduced into the western United States; five insects have become established and three are widespread. This effort is ongoing and more agents are expected within the next three years. In obtaining natural enemies overseas, it is critical to know what biotypes of yellow starthistle exist in the western United States. Insects collected from biotypes different from those in the United States may experience poor survivorship and produce little control of the new host biotype. For example, during biological control efforts of leafy spurge in Montana, success was possible only after researchers discovered that the target plant was a complex of several subspecies and the appropriate biotypes of the biological control agents were obtained. Early ecological studies in the 1970's showed morphological and phenological differences among yellow starthistle populations in California and suggested that several biotypes may exist. It is believed that California experienced multiple introductions of yellow starthistle from different regions over several decades. Identification of the overseas sources of yellow starthistle is critical as these sources should harbor biological control agents that will most closely match yellow starthistle in western North America.

Recently, Mei Sun, a plant biologist from the University of Hong Kong, performed isozyme electrophoretic surveys for 22 populations of yellow starthistle in California (n=15), Washington (n=4), and Idaho (n=3). Initial results indicated that the genetic diversity within populations was very high and similar to that observed between populations. Also, genetic differentiation at the isozyme level was low among most of the populations examined. This survey, however, consisted primarily of yellow starthistle populations near Davis, CA and within the Sacramento Valley. It was thought that a survey of yellow starthistle in different climatic regions may show some genetic differences. Also, a survey of yellow starthistle overseas needed to be initiated.

A team of interested scientists was organized consisting of Mei Sun, University of Hong Kong, Joseph Balciunas, USDA, ARS, Albany, Joseph DiTomaso, University of California, Davis, Michael Pitcairn, CDFA, Sacramento, and Fred Ryan, USDA, ARS, Fresno. It was decided that yellow starthistle populations in 13 regions of California would be sampled for genetic analysis. These regions consist of Siskiyou, Shasta, Humboldt, Placer, Marin, Calaveras, Fresno, Kern (2 populations), Riverside, San Diego, Monterey, and San Luis Obispo counties. The sampling protocol consisted of sampling 40 plants from each population. Each plant needed to be at least 10 meters away from any other sampled plant to prevent the collection of related individuals. All heads removed from a plant were combined into one container and each plant kept separate from the others. Usually 8-10 heads from each plant were collected to ensure enough seeds were obtained. During Fall, 1996, yellow starthistle populations in nine of the 13 counties were sampled and sent to the Biological Control Program for processing. Processing involves removing seeds from the seed heads, packaging and labeling, and shipment to Mei Sun for genetic analysis. The remaining four regions will be sampled in Summer, 1997.

Survey of yellow starthistle populations overseas will be coordinated by Joe Balciunas. Some seed was obtained from seed heads received in quarantine shipments of biological control agents in 1995 and 1996 from Turkey, Uzbekistan, and Italy. A preliminary screening of these seeds by Mei Sun showed that seeds from Turkey contained a very high level of isozyme variation, much higher than seeds from Uzbekistan and Italy. Also, the Turkey populations may contain all the alleles found in North America. A survey of European and Asian yellow starthistle populations using the sampling protocol outlined above will begin in 1997.

Impact of Plant Density on Yellow Starthistle Seedhead Production

M. J. Pitcairn, D. B. Joley and D. M. Woods

Yellow starthistle, *Centaurea solstitialis* L., is an exotic annual from southern Europe and central Asia that has become one of California's worst weeds. To date, six exotic insects have been introduced from its region of origin for biological control of this weed. In order to evaluate the progress made in this biological control effort, it is necessary to measure the impact of the established bioagents on yellow starthistle reproduction and recruitment. Field studies were performed to measure the impact of each of the three widespread biological control agents and the data are currently being evaluated. In each of these studies, seed production for infested and uninfested plants will be compared and the difference will estimate the impact of the bioagents on seed production by individual plants. However, these estimates are only part of the answer. Field observations indicate that yellow starthistle generally over-recruits, as more plants are recruited from seed than can be sustained to maturity. Thus, a reduction in seed production may not result in fewer plants next year as the reduced amount of seeds may still exceed the carrying capacity of the environment. In addition, yellow starthistle has a compensatory growth response to changes in density, so that at low densities, plants become larger and their *per capita* seed production increases ten fold. The target of the biological control effort, then, is to reduce seed production to a level where the population can no longer produce the amount of seed needed to compensate for the seed loss.

In 1995, a study was performed to examine the relationship between density and seed head production at a field site in Solano County near Davis. Previous field observations have shown that the strongest correlation of plant size and seed production is the number of seed heads produced by a plant. Thus, seed production in this study was estimated using the number of seed heads per plant and seed heads produced per area. Seed head production was examined as a function of two factors: 1) without other competing plant species present (only intraspecific competition) and 2) with other competing plant species present (intra- and interspecific competition combined). For factor 1, eight densities were examined: 1, 4, 12, 24, 48, 100, 200, and 400 plants per square meter. Five replicates were used at all densities except the one plant per square meter density where 10 replicates were used. For factor 2, five densities were used: 4, 24, 100, 200, and 400. Five replicates were used at all densities for this factor. These plant densities were chosen because population monitoring at this field site indicated that, for most years, the maximum sustainable plant density is approximately 200 plants per square meter.

The individual replicates were one square meter plots laid out in a 4 x 21 row grid, with each plot separated by three meters. Not all plots on the grid were useable because of the presence of tree stumps, rocks, bottles, etc., so these were excluded. A total of 70 plots were used in this study. Treatments were assigned in a randomized complete-block design with the replicate blocks formed among consecutive rows: 1-6, 6-10, 10-13, 13-15, 16-21. All plots contained yellow starthistle seedlings at densities greater than 400 plants per square meter. The desired density levels were created by removing plants by hand in late February - mid March when the plants were in 4-10 leaf stage. The plots were examined approximately monthly following the initial thinning to remove any new plants until mid June. After June, the plots were not examined until harvest on September 14, 1995. At harvest, the plants in a square, .25 x .25 meter, located in the center of each plot were cut at ground level and removed. All mature seedheads were counted and recorded.

Interestingly, no mortality occurred among plants for any of the treatment densities, despite the expectation for some mortality at the highest densities. This may have been due to the occurrence of a very wet spring, as substantial rainfall occurred in March, April, and May. The results clearly show the plastic response of yellow starthistle to density. The number of seedheads per plant decreased exponentially with increasing density (Figure 1a). Yield is the product of seedheads per plant and density and is shown in Figure 1b. The results show that yellow starthistle expresses the classic density-yield response observed in a wide range of other plants and described by the "law of constant final yield." In plots without other competing plant species, seedhead production per square meter increased with increasing plant density until resources set the limit to yield, regardless of plant density (Figure 1b). At densities below 400 plants per square meter, yellow starthistle plants experiencing competition from other plant species consistently produced fewer seedheads than those experiencing only intraspecific competition. However, yield was equivalent for both competition factors at the treatment density of 400 plants per square meter.

It appears that increasing stress (in this study due to interspecific competition) lowers the rate at which yield increases with increasing density, which is illustrated by the shift in the yield-density response curve to the right. The significance of this shift with regard to biological control is that, in the absence of interspecific competition, a decline in plant abundance will not occur until recruitment is reduced to less than 100 plants per square meter. However, in the presence of interspecific competition, population decline may occur at recruitment levels below 400 plants per square meter, a level four times higher. This illustrates the significance of interspecific competition for successful biological control of yellow starthistle.

Any factor that can decrease the rate that yellow starthistle can compensate for seed loss will increase the impact of the seedhead insects. Two new bioagents are currently being examined by the USDA-ARS for future introduction: a rust disease, *Puccinia jaceae* Otth. (Uredinales) and a root weevil, *Ceratapion brassicorne* L. (Coleoptera: Apionidae). Both agents reduce seed production by stressing their host. Thus, in addition to their direct impact, their presence in California may also significantly increase the impact of the guild of seedhead insects currently established.

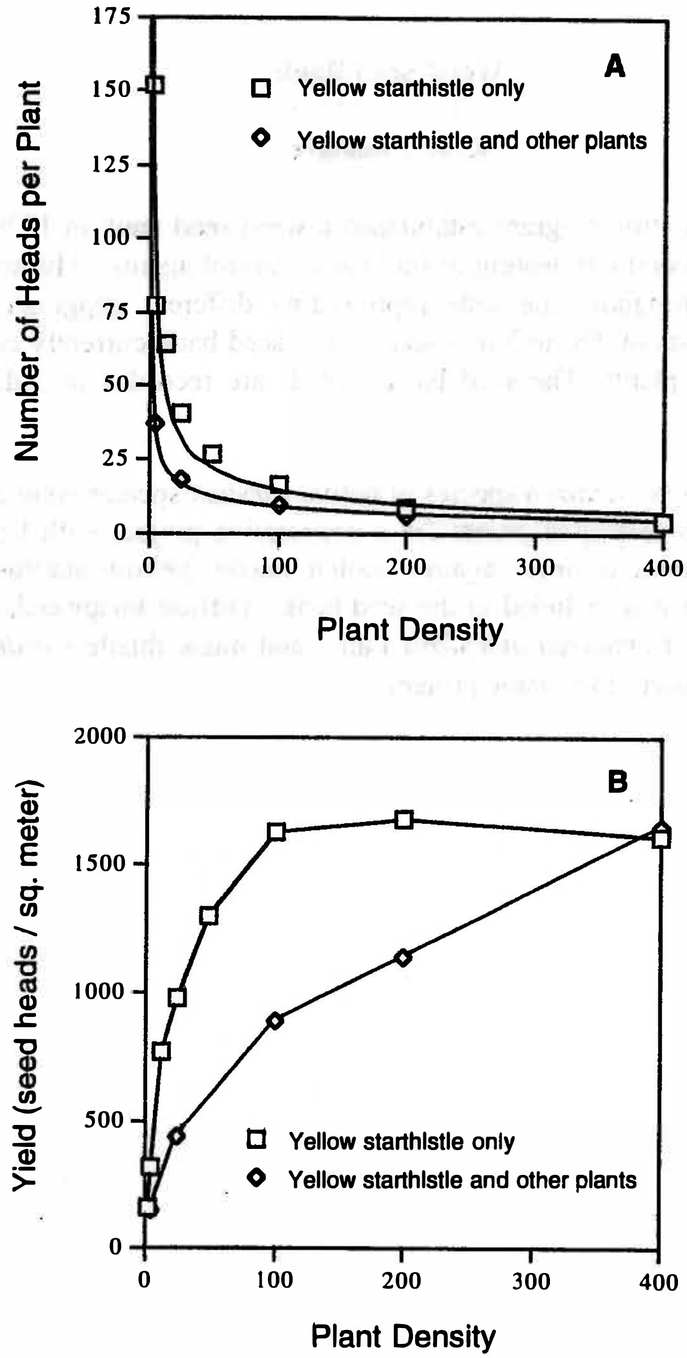


Figure 1. Seed head production by yellow starthistle as affected by density and interspecific competition: A. Number of seed heads per plant as a function of density; the curves presented were fitted using standard linear regression methods on transformed data; yellow starthistle only: $y=202.86x^{(0.584)}$ $r^2=0.95$; yellow starthistle and other plants: $y=76.46x^{(0.481)}$ $r^2=0.99$; B. Yield (number of seed heads per square meter) as a function of density.

Weed Seed Bank

K. A. Casanave

The Biological Control Program established a weed seed bank in 1979 to provide seeds and host plants for host specificity testing of biological control agents. The seeds were gathered from several regions throughout the state representing different geographic regions. Each collection typically consists of 200 to 3,000 seeds. The seed bank currently contains 212 lots of seed from 50 species of plants. The seed bank records are recorded in a database. A list is available upon request

In 1996, seeds of over a dozen species of native *Cirsium* species were collected. Most of the seed is being used to propagate plants for a cooperative project with USDA-ARS in host specificity testing of natural enemies against scotch thistle, yellow starthistle and artichoke thistle. The seed not used was included in the seed bank. Diffuse knapweed, *Centaurea diffusa* Lam., spotted knapweed, *Centaurea maculosa* Lam., and musk thistle *Carduus nutans* L., are also being propagated as part of the same project.

A Geographical Information System and Database for Noxious Weeds and the Control Activities Conducted Against Them in California

S. E. Schoenig, R. P. Akers[1], J. M. Gendron[1] G. H. Miller[1]

Introduced noxious weeds cause millions of dollars worth of losses to agriculture in California due to crop yield reductions, weed control activities, and injury to livestock. Additionally, noxious weeds cause immense harm to the integrity of native plant and animal communities and to the aesthetic value of private and recreational lands. CDFA's Integrated Pest Control Branch works through the Weed and Vertebrate Control Program and the Biological Control Program in concert with the County Agriculture Department's staff to eradicate incipient weed infestations and to establish biological control agents on widespread infestations beyond eradication. The creation of a Noxious Weed Information System has been initiated to aid in the management of these biocontrol and eradication projects.

The Noxious Weed Information System will keep track of detailed information on the location and attributes and control activities against targeted weed populations. The Noxious Weed Information System is comprised of a Geographical Database (MapInfo) and a general attribute database (Microsoft Access 7.0) . A Global Positioning System is being used to collect location data. Both field and management staff will have access to the database over the internet and will be able to generate reports and maps at offices throughout the state.

In 1996, the system was under preliminary development, including procurement and modification of hardware and software and development of data protocols. A pilot project will be initiated in early 1997 to collect data for eight counties in California. Later in 1997, data collection will be widened to include the whole state.

[1]CDFA, Integrated Pest Control Branch

Contracted Research

Title: Illustrated Color Key for Identifying *Eretmocerus* species (Hymenoptera: Aphelinidae) in North America

Principal investigators: Mike Rose, Entomology, Biological Control, Montana State University, Bozeman MT and Greg Zolnerowich, Biological Control Laboratory, Department of Entomology, Texas A&M University, College Station, TX

A simple-to-use taxonomic key with color photos and line drawings was developed into a laminated brochure. The key will aid parasystematists and others working on control of the *Bemisia tabaci* species complex (Homoptera: Aleyrodidae). The brochure includes summary discussions of the systematics and taxonomic status of *Eretmocerus*, a genus of parasites attacking *Bemisia* whiteflies in the United States. A key to 10 species of *Eretmocerus* in the United States is provided, aided by line drawings of key features. The key includes three new species reared from *Bemisia* (*tabaci* complex) collected in Arizona, California, and Texas. A key to other parasite genera is included, as are color and scanning electron microscope photos, and line drawings of pertinent, discriminating features of the parasites. The biology of *Eretmocerus* is presented, as well as figures showing developmental stages and biological clues to help discriminate between the immature stages of *Eretmocerus* and *Encarsia*. The historical use of *Eretmocerus* in biological control and their potential for further use are discussed. The brochure is available upon request by writing to the Integrated Control Branch, CDFA, 1220 N Street, Sacramento, CA 95814.

Contracted Research

Curation and Archiving of Biological Control Research Vouchers and Development of Identification Expertise

Principle Investigator: Steve Heydon
Address: Department of Entomology, University of California, Davis CA

Additions of specimens to the voucher database during 1996 were from CDFA Project 6, The Biological Control of Yellow Starthistle, *Centaurea solstitialis*, and CDFA Project 9, The Biocontrol of *Bemesia argentifolii*. A total of 413 specimens in 9 taxa were mounted, identified, and added to the voucher collection. Further identifications were made on some specimens from earlier lots. The bethylid wasp that was collected from Italian thistle heads in CDFA Project 12, Italian Thistle Biocontrol and yellow starthistle seedheads in CDFA Project 6 were both identified as specimens of *Plastonoxus incompletus* Evans. This species was previously recorded from anobiids in composite seedheads. The eulophid from CDFA Project 6, Lot Number 95061 was identified as *Pronotalia carlinarum* Szelenyi and Erdos. *Pronotalia carlinarum* is known from Tephritidae in flowerheads of *Cirsium* and *Centaurea* spp. in Europe, where it was first described. A paper describing a new species of *Stenoselma* is being prepared. This new species is apparently a parasite of *Urophora sirunaseva*, a gall fly that attacks the seedheads of yellow starthistle.

Contracted Research

Title: Search for and Obtain Natural Enemies of Russian Thistle, *Salsola australis* in Europe and Asia

Principle Investigators: L. Knutson, R. Sobhian, G. Campobasso, L. Fornasari and J. Kashefi
Address: USDA-ARS European Biological Control Laboratory, Monpellier, France

Russian thistle, *Salsola australis* R. Brown (Chenopodiaceae), is a very disruptive exotic pest plant in California. Economic damage results from the tumbling mature plants which pile up against fences and buildings, clog irrigation canals, or become a road hazard. Also, Russian thistle is a good host to the beet leafhopper which is the primary vector of curly top virus, an extremely serious gemini virus infecting several hundred varieties of ornamentals and commercial crops including sugar beets, tomatoes, melons, cucumbers, peppers, squash, spinach, and beans. The seriousness of the problem has resulted in annual abatement efforts by the California Department of Food and Agriculture's Integrated Pest Control Branch. In addition to the beet leafhopper, three other plant pests, Say's stink bug, *Chlorochroa sayi* Stal, and two *Lygus* spp. (especially *Lygus hesperus* Knight), use Russian thistle as an alternate host. Recent observations of *Lygus* and stink bug activities show that their populations can increase in density on Russian thistle and disseminate to commercial vegetable and field crops in late spring and early summer. Reports from growers indicate that in fields near foothill and riparian areas where Russian thistle is common, as much as 60% of tomatoes and peppers may be damaged by stink bug feeding.

In 1995, the Biological Control Program awarded a research contract to the United States Department of Agriculture's European Biological Control Laboratory (EBCL) to search for natural enemies of Russian thistle in Europe and Asia. The following are summaries of collections and activities during several exploration trips made by EBCL scientists, R. Sobian, L. Fornasari, and G. Campobasso, in 1996. This information was taken from Trip Reports submitted to the Biological Control Program.

Turkey May 16-25, 1996, R. Sobhian
Many specimens of *Lixus salsolae* Becker (Coleoptera: Curculionidae) were collected at several sites in southwest Turkey. Host specificity tests of *L. salsolae* and *Aceria salsolae* (Acari: Eriophyidae) were initiated in cooperation with Prof. Tunc at the University of Antalya. *A. salsolae* is a new mite species recently described by DeLillo and Sobhian (1996, Entomologica, Bari, vol. 30:91-98).

China June 3-18, 1996, R. Sobhian
The most important discovery was a root-boring weevil that forms galls on the roots. This natural enemy was abundant at several locations. Also, *Lixus* sp. (probably *L. salsolae* also found in Turkey) was common. Other potential new natural enemies were a lepidopteran similar to *Gymnancella canella* Hubner, an undetermined chrysomelid beetle, and an undetermined weevil collected on the foliage. Some specimens of *Piesma sp.* (probably *P. salsolae*) (Hemiptera: Piesmatidae) were also collected.

Uzbekistan June 24 - July 6, 1996, R. Sobhian
The most important natural enemies found were:
a. The mite, *Aceria salsolae*.
b. The gall midge, *Desertovelum stackelbergi* Mamae (Diptera: Cecidomyiidae), was common. Approximately 2,000 galls were hand-carried to France to be used for testing their attraction to *Salsola australis* from California.
c. An unidentified root weevil.
d. A rust
e. The stem borer, *Lixus salsolae*.

Turkey July 30 - August 13, 1996, R. Sobhian
Many specimens of *Lixus salsolae* and *Aceria salsolae* were collected at several sites in southwest Turkey. The host specificity tests being performed by Prof. Tunc at the University of Antalya were examined during this trip.

Uzbekistan September 15-30, 1996, R. Sobhian
Russian thistle plants heavily attacked by *Aceria salsolae*. An agreement was made with a technician at the Plant Protection Station in Ultarma to grow *Salsola australis* from California in a field plot in Spring, 1997, to test their susceptibility to the gall midge, *Desertovelum stackelbergi*.

Kazakhstan September 20 - October 2, 1996, L. Fornasari
During this trip the following observations were made:
a. *Salsola* prob. *orientalis* with stems deformed by pathogen (looked like cancer)
b. *Salsola kali* attacked and killed by a pathogen. Attacked stems are black. Several plants completely black.
c. *Salsola* sp. common is clumps. Plants attacked by a rust. Larvae of Noctuids were found at the base of the plants. Adult flea beetles found on big plants of *Salsola kali*.

Italy September, 1996, G. Campobasso
Collected many specimens of an apionid weevil feeding on *Salsola kali* in southern Italy. The weevil appears to cause substantial damage to the main and secondary stems of its host.

Contracted Research

Title: Biotypes of Russian thistle, *Salsola australis*, in California Determined by Isoenzymic Analysis

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Genetic variation in the widespread alien plant Russian Thistle or tumbleweed (*Salsola australis*) R. Brown (Chenopodiaceae), is being investigated using isoenzymes and the random amplified polymorphic DNA (RAPD) assay. Plants from California will be compared to those from Europe and Asia, using the same markers, to determine the extent of similarity among accessions from within the state and abroad.

Analysis of plants from Northern California collected during 1995 indicated limited genetic variation in these populations. The area surveyed during the past year was increased; some sites were re-sampled. In addition, a large number of samples were collected at a single site, in order to detect rare biotypes that might be present in the populations. Only enzymatic analyses were conducted during this period; biotype was assigned from the patterns of aspartate aminotransferase and 6-phosphogluconate dehydrogenase after non-denaturing electrophoresis on polyacrylamide gels. These isozymes were the only ones which showed polymorphism in earlier work.

Between March and December, 1996, plants were collected in the southern San Joaquin valley from Santa Nella to Bakersfield, in the western Mojave desert, at the University of California campuses at Irvine and Riverside, as well as other sites in Southern California. The total numbers of plants sampled in 1996 and the distribution of biotypes is given in Table 1. Of the plants sampled in both years, 64.5% were of biotype A and 24.0% were of biotype B, and the distribution of biotypes was generally uneven. One group of plants in the vicinity of Bakersfield showed an anomalous enzymatic phenotype with multiple bands for each of the two isoenzymes examined. This site was sampled in May and September with comparable results; flowers were not present at the latter sampling date precluding conclusive identification. The plants had a more robust appearance than *S. australis* in general and may be *S. paulsenii*.

Sites which were re-sampled in 1996 were: Cameron Park-Hacienda and Yuba City-Site 1. Samples in 1996 were taken in the spring, whereas in the previous year, sampling was in late summer. In 1996, the Cameron Park-Hacienda site had only biotype A (20 plants) although previously a similar sample had contained individuals of three minor biotypes. Likewise, in 1996, the Yuba City-Site 1 contained only biotype B (20 plants), although the previous collection had biotype B and C. This strongly suggests that the minor biotypes may be environmentally induced.

Intensive sampling was conducted in a field off West Barstow Avenue in Fresno. An area of approximately 75,000 m^2, heavily infested with the plant, was sampled: the biotype of 101 samples from throughout the area was determined and all were biotype A. In all plants examined in both years, there was no instance of independent sorting of the two polymorphic isozymes which suggests that either they are closely linked or the expected sexual reproduction is not occurring. These results must be examined closely, especially since sulfonyl-urea resistant plants are reported to have appeared in Idaho and California.

TABLE 1 Collections of *Salsola australis* during 1996.

Site and time of collection	Number on individuals of Biotype A	B	C	D	E	F
Cameron Park - Hacienda, Spring 1996	20	-	-	-	-	-
El Dorado Hills (Raley's), Spring 1996	3	-	-	1	2	-
Yuba City - Site 1, Spring 1996	-	20	-	-	-	-
Southern San Joaquin Valley, Ridgecrest & Lancaster, May 1996	31	5	-	1	2	-
Bakersfield (resampled in September), May 1996	-	-	-	-	-	10(10)
UC Irvine, May 1996	7	-	-	-	-	-
Rancho Cucamonga, May 1996	7	-	-	-	-	-
Highway 152, Casa de Fruta to Highway 99, July 1996	8	1	-	-	-	-
West Barstow Avenue, Fresno, August 1996	101	-	-	-	-	-
Santa Nella, August 1996	3	4	-	-	-	-
Highway 152 at I-5, August 1996	8	-	-	-	-	-
Highway 65, 10 miles north of 99, Sept. 1996	2	8	-	-	-	-
Marty Ave at Santa Fe RR, Fresno, Sept. 1996	5	5	-	-	-	-
UC Riverside and Coachella Valley, December 1996	7	2	-	-	-	-
Total for 1996	202	45	-	2	4	10(10)
% of total (1996)	76.8	17.1	-	0.8	1.5	3.8
% of Total (1995 and 1996)	64.5	24.0	1.1	3.0	3.2	2.1