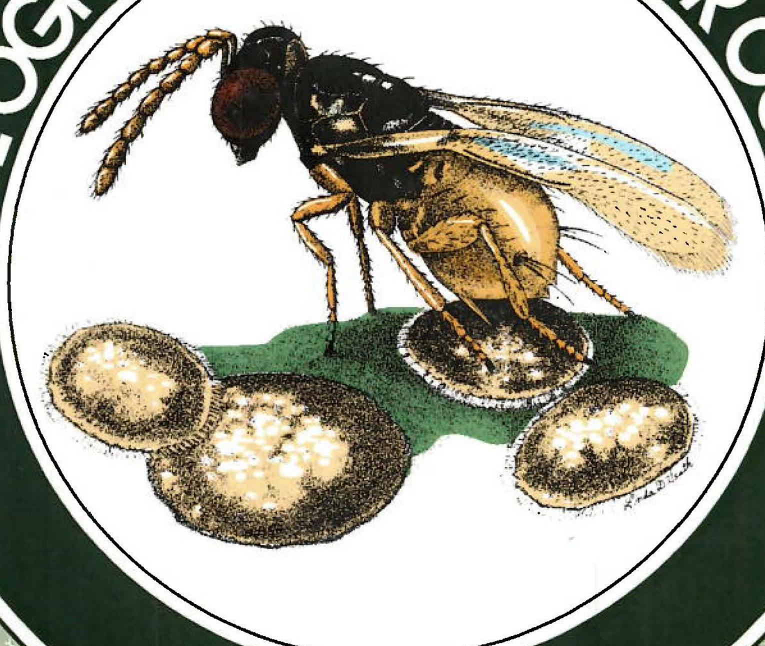
BIOLOGICAL CONTROL PROGRAM



1994

California Department of Food and Agriculture

BIOLOGICAL CONTROL PROGRAM

1993 SUMMARY

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CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE
DIVISION OF PLANT INDUSTRY
INTEGRATED PEST CONTROL BRANCH

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Introduction

L. G. Bezark

The primary objective of the Biological Control Program is to find, introduce, distribute and evaluate new natural enemies for insect and weed pests in California. The establishment of effective, new biological control agents can often serve as an alternative to pesticides, providing less costly control strategies to growers and the environment. The Biological Control Program meets this goal through the following activities:

- Assessing the State's immediate and long range needs for established natural enemies and candidates for importation

- Establishing natural enemy nursery sites and facilitating the state-wide distribution of new and established natural enemies

- Rearing, releasing and evaluating new biological control agents

- Developing new sampling and evaluation techniques

- Developing contracts with other state and federal agencies to conduct needed basic research and foreign exploration

- Serving as an information resource to the Department and other agencies

The Biological Control Program began operations in 1973/74 as part of the Control and Eradication Branch to combat pests that were beyond eradication such as skeletonweed and western grapeleaf skeletonizer. In 1977 the Program was transferred to the newly formed Division of Pest Management, Environmental Protection and Worker Safety. In 1991, the Program was transferred back to the Department of Food and Agriculture where it currently resides in the Integrated Pest Control Branch, formerly Control and Eradication.

To facilitate the distribution of new and established natural enemies, the Program initiated a working relationship with the County Agricultural Commissioners and Sealers Association (CACASA). (In California each county has an agricultural commissioner primarily to serve as the local pesticide and quarantine regulatory authority). In December 1987, the County Agricultural Commissioners and Sealers Association established a Biological Control Subcommittee under CACASA's Pest Prevention Committee. The subcommittee's first meeting was on February 8, 1988. During 1988, this committee evolved into a Special Committee of CACASA entitled the Biological Control Committee. The major purposes of the Committee are to provide more direct input to the Department on county biological control needs, to assist the Department in prioritizing its biological control activities, to improve the efficiency of dissemination of biological control agents throughout California, and to promote the use of biological control as an alternative to other forms of pest control.

The new system for distributing available biological control agents involving county cooperation was tested on two different weed pests -- puncturevine and Russian thistle. It entails the assistance of CACASA's Biological Control Committee, active participation by the counties taking part in the distribution of biological control agents for the targeted pests, and training of county participants through workshops held at field nursery sites by Biological Control Program personnel. The early success of this system resulted in its expanded use by the Biological Control Program against additional pests such as yellow starthistle, Italian thistle, Klamath weed, waterhyacinth, and ash whitefly.

The Program is structured as follows: under the supervision of Larry Bezark, there are two working groups, one that deals with insect pests headed by Charles Pickett, and one that deals with weed pests, headed by Mike Pitcairn. Steve Schoenig provides statistical support for the program (Figure 1).

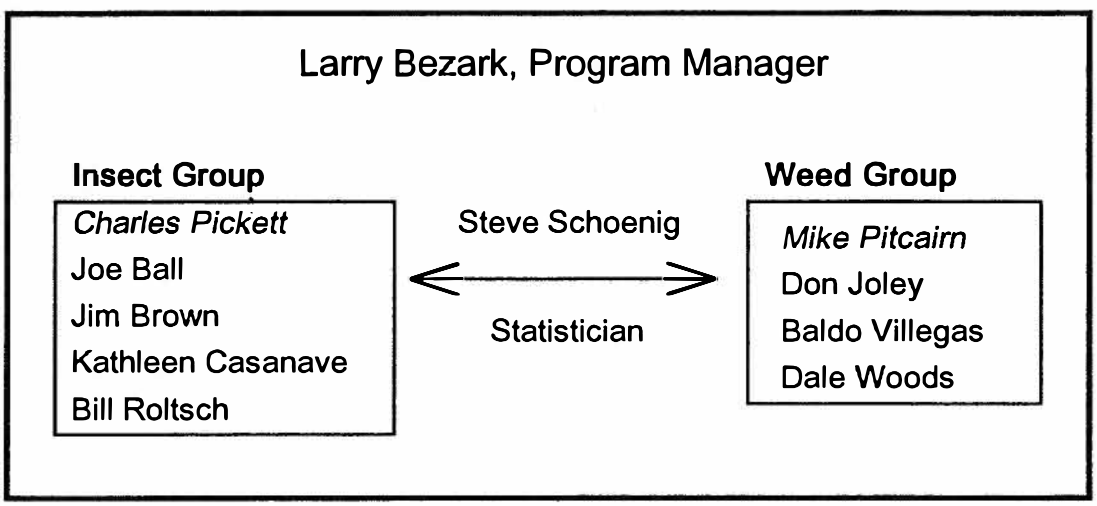

Figure 1. Organizational structure of the Biological Control Program.

This report details Program activities during 1993 and includes cooperative work with a number of other governmental agencies involved in biological control projects.

Establishment of the Ash Whitefly Parasite, *Encarsia inaron* (Walker)

C. H. Pickett, J. C. Ball, K. A. Casanave, and L. G. Bezark

The first North American record for the ash whitefly, *Siphoninus phillyreae* (Haliday) was in Los Angeles County, California on 18 August 1988. By October 1991 the whitefly had been reported from throughout the state, 46 of 58 counties. Foreign exploration for this parasite was initiated in 1989. Two populations of *Encarsia inaron (Walker)* were obtained, an Italian strain collected by L. Bezark in Italy, and an Israeli strain sent by Dr. Gerling to Dr. Tom Bellows of the University of California (UC), Riverside. Both strains were mass reared, some at the UC Riverside campus and the remainder at the Department of Food & Agriculture's Biological Control Facility in Sacramento. *E. inaron* was released into a total of 43 counties from 1990 to 1992. The Israeli population was released into all counties but San Diego which received the Italian population. Two hundred and fifty parasites were released into each of at least four nursery sites per county. Most sites were located in major urban areas where high densities of ash whitefly susceptible host trees were present, i.e. ash, ornamental and flowering pear, and pomegranate. *E. inaron* was released into 13 counties in 1990 (of which 7 were experimental sites and not treated in our analysis), 27 in 1991 and 3 in 1992.

On only two occasions were ash whitefly found parasitized at the time *E. inaron* were first released (most likely migrants from other releases). No other species of parasitoids were recorded emerging from ash whitefly. Parasitoids successfully overwintered at all release sites. Of the central California counties receiving parasites in 1990, the density of ash whitefly averaged over the year dropped from a high of 13.06 per cm^2 leaf area measured in 1991 to 1.04 per cm^2 leaf area in 1992. The drop in whiteflies is associated with a rapid establishment and high levels of parasitism by *E. inaron*. Within two years of release, average levels of parasitism at individual nursery sites in September were above 90%. One year after releases, regional differences were detected for whitefly densities but not parasitism. Regions designated as foothills or coastal had significantly higher numbers of whiteflies than others, however in all areas whitefly numbers during the last months of monitoring in 1992 were difficult to detect. Only minor differences were detected among host plants in ash whitefly densities; no significant differences were detected in parasitism. Hawthorn had the highest overall densities of ash whitefly one year after releases of *E. inaron*. Reduction in whitefly numbers was greatest on pomegranate, which had the lowest number of whiteflies of all host plants examined during the last four months of sampling. Superparasitism increased with increasing levels of parasitism. The percentage of dissected whiteflies with two or more *E. inaron* increased from 5.3% to 20% from 1991 to 1992.

Productivity of Ash Whitefly, *Siphoninus phillyreae* (Haliday), and Its Parasitoid, *Encarsia inaron* (Walker) in northern California

M. J. Pitcairn and C. H. Pickett

Since its introduction in 1990, *Encarsia inaron* (Walker) has shown an impressive ability to control the ash whitefly, *Siphoninus phillyreae* (Haliday). In 1991, a field study was initiated to document the increase in parasitism and concurrent decrease in ash whitefly density following release of this parasitoid. On three ornamental pear trees (*Pyrus kawakamii* Hayata) located at Davis, Yolo County, 360 leaves (30 leaves on each of 4 branches per tree) were tagged and observed weekly (twice monthly during the winter) from August 2, 1991 through October 30, 1992 for pupal cases of either emerged ash whitefly or *E. inaron* adults. All pupal cases were counted and then removed from the leaf to prevent them from being recounted in subsequent observations.

The data show that prior to introduction, ash whitefly productivity peaked at 1.8 adults per leaf per week. After approximately 40 days from noting the first parasitoid pupal case, ash whitefly productivity was reduced to less that 0.03 adults per leaf per week, a 60-fold reduction in productivity. In 1992, ash whitefly productivity peaked at 0.02 adults per leaf per week during June and remained below this value for the duration of the study.

Leaf samples were also removed weekly at the time of observation and a sample of fourth instar ash whitefly nymphs was dissected for occurrence of the parasitoid. At peak parasitoid productivity in 1991, percent parasitism exceeded 95%. In 1992, percent parasitism consistently exceeded 80% through the season. This study was terminated October 30, 1992. Analysis of data will be completed in 1994.

Biological Control of the Silverleaf Whitefly, *Bemisia argentifolii* Bellows & Perring, Using Early Season Releases of *Delphastus pusillus* LeConte

J. R. Brazzle[1], K. M. Heinz[1], C. H. Pickett, K. A. Casanave, and M. P. Parrella[1]

The silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, is reported on at least 420 plant species representing 18 families. The sweetpotato whitefly has been a problem on a variety of crops in Imperial County since 1975, reaching very high numbers in 1975, 1977, and 1981. These outbreaks have been attributed to mild winters, the introduction of pyrethroid insecticides (Ray Gill, pers. comm.), and displacement of the indigenous strain by a new and more virulent one. Populations of this whitefly in 1991 reached catastrophic levels never before reported in Imperial County and probably in the world.

Alternatives to conventional chemical control are needed due to considerable resistance to pesticides in sweetpotato whitefly populations. A biological alternative to pesticides is inoculative releases of the coccinellid, *Delphastus pusillus* (LeConte), a predator with a high degree of specificity for whiteflies. The beetle is indigenous to the southern United States and has been recently re-introduced to California for establishment in Imperial County. Early season releases of *D. pusillus* can potentially augment local populations of natural enemies at relatively low whitefly numbers decreasing the need for late season applications of insecticides. Any decrease in pesticide usage will also allow for emigration into fields of indigenous natural enemies that otherwise would be eliminated due to frequent pesticide applications.

A cooperative effort between CDFA's Biological Control Program and the University of California (UC), Davis was initiated in March 1992 to jointly determine whether early season releases of *D. pusillus* can prevent sweetpotato whitefly populations infesting cotton from reaching economically damaging levels in mid and late season. A study site was established at the University of California Desert Research and Extension Center in El Centro in May 1992. Eight one-half acre plots of cotton (var. DPL5461) were planted in 1992 and 1993, half for releases of beetles. The efficacy of *D. pusillus* releases was examined under conditions in which whitefly migration was absent by using exclusion cages, and under conditions where migration was present, i.e. uncaged field cotton. Four cotton plots and four cages received weekly releases of *D. pusillus* during summers 1992 and 1993. In the open field analyses of whitefly densities no significant differences between the release and non-release treatments were detected using ANOVA in 1992 ($F-0.01$, $df=1,6$; $P<0.9449$) and 1993 ($F=0.04$, $df=1,6$; $P<0.08485$). The late date of releases in 1992 and the magnitude of whitefly immigration in 1993 appeared to negate any suppressive impact of the beetles. Results from cage studies show significant reductions in whiteflies by beetles both in 1992 ($F = 14.0$, $df = 1,6$; $P<0.0096$) and 1993 ($F=2.47$, $df = 1,6$; $P< 0.0309$). Whitefly densities were suppressed by 55% and 67% in 1992 and 1993, respectively. No significant differences were detected in predation of parasitized whiteflies (*Eretmocerus* and *Encarsia*) vs. nonparasitized in field plots. These results show that *D. pusillus* can survive, reproduce, and suppress sweetpotato whitefly during summer months in Imperial Valley. Under the current outbreak population levels of sweetpotato whitefly, however, this beetle is unable to provide significant control in cotton.

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Survey of Silverleaf Whitefly Parasitoids in the Desert Valleys of California in 1993

J. C. Ball and R. C. Weddle[1]

The devastating appearance of the silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, on crops in the desert valleys in 1991, prompted an effort by the Biological Control Unit to identify and evaluate the "resident" parasitoids on this species. The work reported represents the second year of a contract with the Imperial County Agricultural Commissioner to provide personnel to monitor the populations. Dr. Richard Weddle (Plant Pathologist/Entomologist, Imp. Co.) provided supervision and Jolene Carson (Agricultural Biologist II), Licia Mecate (Agricultural Biologist II). Phyllis Cason (Agricultural Biologist III) collected and processed the samples. The objective of the study was to evaluate the ability of the native parasitoids to control the whitefly. Ornamental plants in urban areas were sampled in order to provide continuity between the whitefly and its parasitoids and also eliminate the disruptive impact of insecticidal treatments. In 1992, three plant species were used as hosts in the study: hibiscus (*Hibiscus rosa-sinensis* L.), snail vine (*Vinga caracalla* (L.)), and orchid tree (*Bauhinia* spp). These species were relatively common in the study area and retained their leaves throughout winter, thus providing the desired continuity in habitat. In 1993, sampling of snail vine and orchid tree was discontinued in favor of increased replication using hibiscus. Samples consisted of 20 leaves collected from hibiscus at each of 16 locations. Leaves were brought back to the lab, the whiteflies counted, nymphs dissected, and then the leaves were held in pint ice cream cartons for parasitoid emergence. Rodney Mendes (Assoc. Econ. Entomologist, IPC) sampled silverleaf whitefly parasitoids in the Blyth and Coachella areas of Riverside County.

Silverleaf whitefly population development on hibiscus in the Imperial Valley in 1993 was similar to trends observed in 1992. The lowest populations were in the spring and early summer with less than one per leaf through mid-July. Pupal populations peaked in September (that occurred in October in 1992), averaging 20 to 30 pupae per leaf. As in 1992, three species of parasitoids accounted for the observed parasitism: *Eretmocerus* nr. *californicus*, *Encarsia luteola* Howard, and *E. meritoria* Gahan (Aphelinidae). *E.* nr. *californicus* represented approximately 72% of the parasitoids recovered in the samples. In the spring, mean parasitization varied from 0% to 83%. Between August and October, as the silverleaf whitefly population was rapidly growing, mean parasitization was around 35%. From October on (as the whitefly population was dropping), mean parasitization varied from 17% to 70%.

[1]Imperial County Agricultural Commissioner's Office, El Centro, CA

Survey for Resident Parasitoids of the Silverleaf Whitefly and the Release of Natural Enemies in Kern County

J. C. Ball and K. A. Casanave

The silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, has become locally abundant in late summer and fall at several locations in the San Joaquin Valley, particularly in Kern County. A survey for native parasitoids of silverleaf whitefly was conducted at urban properties between August 12 and October 1, 1993. Various plant hosts were sampled at 15 locations in and around Bakersfield. Whitefly populations varied between location and plant host. Parasitization varied widely, ranging from 0% to 43%. Two species of *Encarsia* and possibly two *Eretmocerus* species were recovered. In these samples, *Eretmocerus* represented 16% of the parasites.

The coccinellid predator *Delphastus pusillus* (LeConte) was released at four sites in the Bakersfield area between August 12 and September 1, 1993. Between 400 and 1500 adults were released at a site for a total of 2900 individuals. Beetles were released on egg plant, okra, or poinsettia. No beetles were recovered in samples taken when three of the sites were revisited approximately one month later.

Eretmocerus nr. *californicus* was released at three properties around Bakersfield on September 30, 1993, approximately 100 adults per site. Half the adults were placed in sleeve cages on plants and half released unconfined. All releases were on egg plant. The sites will be revisited to determine recovery.

Survey of Kern County Cotton to Determine Abundance of the Silverleaf Whitefly, *Bemisia argentifolii* Bellows & Perring

L.G. Bezark, C. Hodson[1], D. Keaveny[1], and J.C. Ball

The silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, has caused well over 100 million dollars in economic damage in the Imperial Valley during the last two years. In 1991, this whitefly was recorded in the lower part of the San Joaquin Valley, where it successfully overwintered in Kern County on poinsettia, *Euphoria pulcherrima* Willd. ex Kl., in homeowner gardens. This pest has also been recorded in Fresno, Kings, Tulare, Merced, and Sutter counties in the northern part of the state.

Since the whitefly overwintered in Bakersfield on ornamentals, we wanted to determine the extent of this whitefly in cotton in Kern County, late in the season as whitefly populations were increasing. In October of 1992, utilizing the Pink Bollworm Project work force already in place, 477 sites were sampled for the presence of the silverleaf whitefly. Other species of whiteflies were not included in this survey. Leaf samples were collected, taken back to the laboratory and scored using a scale of four categories (0, 1 to 5, 6 to 49, and greater than 50 per leaf) to rank the abundance of immature whiteflies. After the leaves were scored for whiteflies, they were held in paper bags to await emergence of parasitoids.

Results indicated that 38.8% of all sites were infested with whiteflies. Of those sites, only 3.8% had large numbers (more than 50 immatures per leaf) of whiteflies. Additionally, the distribution of whiteflies in cotton appeared to be centered around the city of Bakersfield where whiteflies had previously overwintered. A very small number of parasitoids representing two genera of aphelinids emerged from bagged leaf samples. In 1993, a second survey will include Fresno and Visalia as well as Bakersfield and a small sample of other cotton fields in the San Joaquin Valley.

Also participating in the project were Ray Gill, CDFA Analysis and Identification Laboratory, Robert Staten, USDA, APHIS, Methods Development, Phoenix, Arizona, and Tom Palmer who supervises C. Hodson and D. Keaveny.

[1]Pink Bollworm Project, CDFA, Bakersfield, CA 93308

Development of a Regional Computer Model for the Silverleaf Whitefly, *Bemisia argentifolii* Bellows & Perring, in Imperial County

L. Wilhoit[1], S. Schoenig, D. Supkoff[1] and B. Johnson[1]

The silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, a serious pest of many crops, has inflicted over 100 million dollars in damage in the Imperial Valley of California during 1991-1993. Although the less polyphagous and damaging sweetpotato whitefly, *B. tabaci*, has been present in Imperial County since the 1920's, the recent devastation is the result of the silverleaf whitefly. High populations of the silverleaf whitefly build up throughout the season on cotton and other summer crops and inflict particularly severe damage in the fall on seedling melons and lettuce. The silverfleaf whitefly is highly mobile through wind driven, passive dispersal, and especially tends to spread at the time of crop harvest or senescence. The timing of crop cultural activities and crop rotations has been at the forefront in the search for a set of management strategies to combat the silverleaf whitefly.

A joint project was initiated to create a regional computer model of sweetpotato whitefly movement and population dynamics by the Department of Pesticide Regulation (CDPR) (Pest Management and Analysis Program) and the Department of Food and Agriculture (CDFA) (Biological Control Program) to more fully understand the implications and outcomes of proposed management strategies. A "C' computer language program has been completed which tracks silverleaf whitefly populations on 18 crop categories in square mile sections on a week by week basis. A 48 by 42 square mile grid was created to represent most of the major growing areas in the Imperial Valley north of Mexico. Realistic crop profiles were compiled for each section using data from the 1991 Pesticide Use Report (CDPR). In the model, realistic silverleaf whitefly densities are assigned to appropriate crops at the beginning of the calendar year and then growth of immatures and movement of adult whiteflies during subsequent weeks is calculated and displayed in a multi-color grid overlaid on a map of Imperial County. Computer data files are also created on a weekly basis to allow analysis of population levels on the crops throughout the season. The coarse geographic scale of information in the model and the many simplifications of the biologies of the organisms, does not allow the model to make precise and accurate predictions of population levels on a field by field basis. However, the model should suggest ways of reducing both the movement and growth of silverleaf whitefly populations.

Analysis of the model has suggested that alfalfa is the most critical crop in understanding the regional dynamics of the whitefly. It is very important to further investigate whitefly growth on alfalfa. One strategy suggested by the model is a combination summer alfalfa dry down, early cotton harvest, and late fall melon planting which could theoretically result in a 90% reduction in whiteflies throughout the region.

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[1]California Department of Pesticide Regulation, Sacramento

Use of Refugia for Enhancing the Biological Control of the Silverleaf Whitefly in Imperial Valley

W. J. Roltsch, C. H. Pickett, and M. Rose[1]

Natural enemy refugia are presently being evaluated in the Imperial Valley for their potential in building and maintaining populations of silverleaf whitefly, *Bemisia argentifolii* Bellows & Perring, natural enemies, including parasites and generalist predators. Plots consist of two rows of refuge plants (interplanted sunflower, kale, and collards) alternating with 20 rows of crop (melon, cotton or broccoli). Two refuge plots (2 acres each) and corresponding check sites are being evaluated at the USDA-ARS Field Station in Brawley, California whereas one refuge plot (5 acres) and check site are present at a second farm site (organic) in Imperial County. Currently, refugia are intended for use throughout the year.

Eretmocerus nr. californicus, and Encarsia luteola Howard are two native parasite species that were found at low levels in newly created refugia and associated cotton crop during spring. *Encarsia* parasitism was generally low throughout the year, rarely exceeding 10% on any whitefly host plant included in the evaluations. *Eretmocerus* parasitism on sunflower has been as high as 80%, however it was disrupted by the presence of a lace bug (Hemiptera: Tingidae) which causes increased damage to leaves of sequential plantings of sunflower as the season progresses. Sunflower lasts for 2-3 months and must be replanted. The native *Eretmocerus* seldom parasitized whitefly on kale and collards from May to September, with parasitism seldom exceeding 4%. During October, parasitism increased to 20% on collards (2% on kale). Several predators including, *Geocoris* spp. (Hemiptera: Lygaeidae) and *Hippodamia convergens* Guérin-Méneville (Coleoptera: Coccinellidae) were very common on sunflower throughout the year. On crop plants, both species were common on cotton, and *Geocoris* spp. were common in organic cantaloupe fields during the spring, causing upwards of 35% whitefly nymphal mortality.

An additional plant is currently being considered for refuges. Kenaf can sustain high levels of whitefly parasitism (75%) by *Eretmocerus.* With this long season plant, it is conceivable that refuge strips could be planted in early spring and provide effective natural enemy habitats through October, thereby minimizing replanting costs and inconvenience.

The low levels of whitefly parasitism on cole crops throughout the year in our refuge plantings and in commercial plantings (conventional and organic farms combined) clearly indicates the need to introduce new parasite species capable of performing well on cruciferus plant species. To this end we are introducing *Eretmocerus nr. californicus* from Texas where high levels of parasitism on cabbage have been observed.

In 1994 we are evaluating a spring refuge planting composed of collard, sunflower, kenaf, and low densities of kale. Kenaf is capable of supporting large populations of *Eretmocerus* from mid-summer into the fall. This is crucial since sunflower is a fast growing, but short term plant whose use is restricted to spring and early summer periods, and can be easily grown again in mid-September.

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Biological Control of the Silverleaf Whitefly in Imperial County:
***Delphastus pusillus* Area-Wide Release And Evaluation**

W. J. Roltsch, C. H. Pickett, and K. A. Casanave

An area-wide release of *Delphastus pusillus* (LeConte) was conducted in Imperial County and Mexicali, Mexico during August and September of 1993. Beetles were mass reared at the California Department of Food and Agriculture's greenhouses in Sacramento and mailed on a weekly basis for release into urban and rural homesites selected for their presence of whitefly host plants and year around existence of ornamental vegetation, especially hibiscus. One thousand adult beetles (1:1 sex ratio) were released at each of 13 rural home-sites, 10 urban home-sites in the communities of Brawley and El Centro, and 4 home-sites in Mexicali, Mexico. A second release of one thousand beetles was made several weeks later at six of the sites. Sleeve cages containing 100 beetles for seven days were used to evaluate initial release survivorship. Subsequently, each site has been sampled for late stage larvae, adults, and exuviae (old skins) of older larvae and pupae on a 4 to 5 week basis. Throughout the remainder of the fall, evidence of reproduction was recorded in nearly all sites. During January 1994, both adult beetles and whiteflies were recorded at low numbers.

Survey of Sunflower Head Moth, *Homeosoma electellum* (Hulst), Parasitoids

D. M. Woods

The sunflower head moth, *Homeosoma electellum* (Hulst), is one the world's most important insect pests of sunflower. It is the only sunflower pest in California that warrants consistent pesticide applications. Biological control scientists from CDFA, USDA-ARS in North Dakota, and entomologists in Hungary have begun survey efforts for parasitoids of this pest in the hope that they may eventually be shared, thus contributing to control of the head moth.

Mature sunflower heads from commercial sunflower seed fields were collected in Northern California during 1992 as part of this process. Infested sunflower heads were sent to Dr. Laurence D. Charlet, Research Entomologist, USDA-ARS, Fargo, North Dakota for evaluation. A total of 490 larvae were extracted and reared on artificial diet. Parasitoids emerging from larvae were identified this year and included Hymenoptera (Ichneumonidae and Braconidae) and Diptera (Tachinidae).

Importation of the Tachinid Fly, *Trichopoda pennipes* (Fabricius) for the Biological Control of the Squash Bug, *Anasa tristis* (De Geer)

S. Schoenig, C. H. Pickett , M. Hoffmann[1]

The squash bug, *Anasa tristis* (De Geer) 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. Squash bug may transmit diseases during feeding such as cucurbit wilt disease. In California the only recorded parasitoid of squash bug is an encyrtid egg parasite which achieves low levels of parasitism. A bio-type of *Trichopoda pennipes* (Fabricius), a nymphal-adult parasite of squash bugs, occurs in the eastern United States and 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 Dr. Michael Hoffmann (Cornell University) from upstate New York; and 2) measure the impact of released *T. pennipes* on populations of the squash bug.

In 1992 significant progress was made in both objectives. A total of 2350 adult squash bugs were collected in New York from June through August and held in the laboratory for parasitoid larval emergence. From these, a total of 590 larvae successfully emerged and pupated and were shipped to our Sacramento facility. Of the 590 pupae received, 335 successfully produced adult flies. There was no evidence of either hyperparasitism or disease in the flies. Three nursery sites with high squash bug populations were chosen in Yolo County; one large garden near Davis, an organic farm near Winters and an organic farm in the Capay Valley. A total of 243 adult flies were released at these sites. Also 947 adult squash bugs were parasitized at our facility in Sacramento and then released at the nursery sites.

Intensive sampling of squash bug population densities was carried out from June 16 to August 20, 1992 at the Capay Valley site to give an indication of pre-release levels of the bugs. Bugs attained high levels at all sites and caused a crop failure at the Winters site.

In 1993 parasites were recovered at the Winters site and the small garden near Davis. By September parasites had moved into a new squash site in Winters and parasitism was approaching 20%. A total of 151 flies were received from New York and were used to oviposit on a total of 2700 squash bugs collected in Yolo County. Of these 2440 were released at a new nursery site established at the Student Experimental Farm (SEF) at the University of California, Davis. The remainder were released at an organic farm in Sacramento County. Intensive sampling of squash bug population densities was carried out in 1993 to measure the impact of the parasite releases.

In 1994 the nursery site at the SEF and the Winters site will be the source of parasites for movement to new establishment sites. Reintroduction to the Capay Valley site will be undertaken. Sampling will continue through the season.

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Prune Trees as Refuges for the Grape Leafhopper Parasite, *Anagrus epos* Girault

B. Murphy[1], J. Rosenheim[1], and C. H. Pickett

Vineyards planted near riparian habitats in central California seldom require control measures for grape leafhopper, *Erythroneura elegantula* Osborn, an important pest of grapes in central and northern California. *Anagrus epos* Girault, considered largely responsible for preventing late season buildup of grape leafhoppers, overwinters on the blackberry leafhopper, *Dikrella californica* (Lawson), associated with wild blackberry bushes (*Rubus spp.*) in riparian habitat. Attempts to enhance the biological control of grape leafhoppers by planting blackberry bushes next to vineyards distant from riparian habitats have largely failed. Prune leafhoppers associated with French prune trees can also serve as overwintering hosts of *A. epos*. Preliminary, single site studies in the San Joaquin Valley suggest that prune trees planted next to vineyards can reduce grape leafhopper numbers. The early season establishment of *A. epos* in a vineyard adjacent to prunes was earlier in 1987, and more rapid in 1987 and 1988, than in a nearby isolated vineyard. Studies in 1990 showed that early season mortality of grape leafhoppers caused by *A. epos* parasitism in a vineyard next to prune trees was higher than in a nearby, control vineyard lacking trees. In 1991 and 1992 an intensive region-wide study was conducted to compare the impact of prune trees adjacent to vineyards. Twelve to 15 paired vineyards were examined, one with and one without a prune refuge. Grape leafhopper egg parasitism was monitored from May through October. Significant differences in egg parasitism rates among prune and non-prune vineyards was found for all three leafhopper generations. The largest difference occurred during the first leafhopper generation where parasitism was 70 percent greater in refuge vineyards and 22 percent greater for both the second and third generations. Results were similar across all viticultural growing regions. An analysis of the impact of refuges on leafhopper nymph populations is in progress.

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Biological Control of the Western Grapeleaf Skeletonizer in Siskiyou County

B. Villegas

The western grapeleaf skeletonizer (WGLS), *Harrisina brillians* Barnes and McDunnough, is a pest of commercial and backyard grape plantings. Larvae of this zygaenid moth feed on the soft leaf tissues, leaving only the veins intact and when populations are high they feed on the grape clusters as well. Two natural enemies, the braconid wasp, *Glyptapanteles harrisinae* (Muesebeck), and the tachinid fly, *Ametadoria misella* (Wulp) and a granulosis virus (HbGV) have been available for the biological control of WGLS.

In 1993 the Siskiyou County WGLS infestation was monitored along with the level of parasitism by the tachinid fly, *Ametadoria misella*, released at four sites in September 1992. Moth emergence was monitored with two types of traps baited with commercially available WGLS pheromone[1] placed at the four 1992 natural enemy release sites and checked at least once monthly. Parasitoid activity was monitored through larval collections at the four release sites as well as monitoring sites near the release sites.

It is still too early to show any impact of the parasitoid on the WGLS population within the infested area. A total of 16 larval samples were taken from the four release sites and from five monitoring sites during the two WGLS generations recorded for Siskiyou County during 1993. The tachinid fly was recovered at low levels from seven samples collected from both WGLS generations from one release site and from three monitoring sites along the Klamath and Shasta Rivers. It is hoped that the parasitization level will increase during 1994 since it appears that the fly was able to overwinter and move from the release sites to the monitoring sites during the 1993 season.

It should also be noted that on October 14-15, 1993 a special survey of the infested area was made in order to collect larvae that could be tested for the WGLS granulosis virus (HbGV). Numerous samples of leaves containing colonies of second through fourth instar larvae were collected and transported to the University of California at Berkeley. Samples of these larvae were subjected to a serological technique (ELISA) which employs antibodies to detect granulosis viruses. All the larvae tested were negative for the granulosis virus.

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[1]Myerson, J., W. F. Hadden, and E. L. Soderstrom. 1982. Sec-butyl-(Z)-7-tetradecenoate. A novel sex pheromone component from the western grapeleaf skeletonizer, *Harrisina brillians*. Tetrahedron Lett. 23:2757-2760.

Development of an Enzyme-Linked Immunosorbent Assay (ELISA) for the Western Grapeleaf Skeletonizer Granulosis Virus

D. M. Stark[1], A. H. Purcell[1], and M. J. Pitcairn

The western grapeleaf skeletonizer (WGLS), *Harrisina brillians* Barnes and McDunnough, is a serious defoliating pest of table, raisin and wine grapes, backyard grapevines, and native wild grapes throughout California. WGLS larvae feed on both leaves and fruit, causing extensive damage if left uncontrolled. A naturally occurring granulosis virus (HbGV) has demonstrated potential as a biological control agent for WGLS. In order to study and evaluate the impact of HbGV on WGLS populations, a serological assay, based on ELISA technology was developed to provide for rapid assessment of HbGV incidence in WGLS larvae.

An aliquot of dried, pulverized HbGV-infected WGLS larvae (supplied by Dr. Vern Stern, U. C. Riverside) was used to inoculate a colony of WGLS in the laboratory. Infected insects were frozen before death, and virus was isolated at 4^{o}C by rate zonal and isopycnic centrifugation. Purified virus was examined by light and electron microscopy to insure that the preparation was free of microbial and particulate contamination. Examination of the purified virus by electron microscopy revealed particles whose shape, size, and morphology corresponds to those of other known granulosis viruses. However, a small number (approximately 1/10,000) of unusually shaped particles were observed. We believe that these are aberrant HbGV particles, a phenomena reported for other granulosis viruses. The alkali soluble proteins of HbGV were separated using polyacrylamide gel electrophoresis to confirm the identity of the virus and determine the purity of the virus preparation. The major protein on the electrophoresis profile corresponded to the reported molecular weight of the viral coat protein "granulin." This strongly indicates that the virus isolate is a granulosis virus. The infectivity of purified virus was demonstrated by successfully reinfecting healthy WGLS larvae.

Two forms of HbGV antigen, whole virus and viral coat protein (i.e. granulin), were prepared and injected into mice to produce acites fluid. Several ascites collections form an HbGV inoculated mouse bound purified virus at high titres (>1:10,000). These collections were pooled and used to develop the assay. Ascites fluid from mice inoculated with HbGV-granulin bound virus at low titres and was not used. Production of antisera was done at the U.C. Berkeley Monoclonal Facility in Albany under the supervision of Dr. Alexander Karu.

Initial tests of the assay systems are encouraging. The ELISA has been used to detect sub-microgram quantities of purified virus. A total of 51 larvae have been tested. All positive and negative ELISA readings were corroborated by examination of stained viral granules under a microscope or were from known virus-inoculated insects. Sensitivity, reliability, and cross-reactivity with other available baculoviruses are now being assessed.

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Introduction and Colonization Attempt of *Encarsia variegata* Howard, a Parasite of the Nesting Whitefly

J. C. Ball

The nesting whitefly (NWF), *Paraleyrodes minei* Iaccarino, was discovered in San Diego in 1985 and has since spread to Los Angeles, Orange, and San Bernardino counties. It attacks avocados, citrus, and several ornamental plant species. Joe Ball (Assoc. Envir. Res. Scientist) traveled to Florida in October 1993 to collect parasitoids of this whitefly. He collected samples infested with NWF from 10 locations in 5 counties. Citrus was the main host plant searched, but samples from hibiscus and sea grape (*Coccoloba* spp.) were collected at two locations. While in Florida, Dr. Harold W. Browning (University of Florida, IFAS, CREC) accompanied Joe on several trips and provided space in his lab at Lake Alfred to process the samples.

Approximately 100 NWF mummies were brought back to Sacramento and held in quarantine for parasite emergence. From this material, 70 *Encarsia variegata* Howard emerged between October 18 and November 4, 1993. These parasites were released at 5 sites in San Diego County on citrus, avocado, and hibiscus infested with NWF and the giant whitefly, *Aleurodicus dugesii* Cockerell. In January 1994, the release sites were inspected to determine recovery. No evidence of parasitism was found at that time.

Biological Control of Euonymus Scale

P. S. Pao and C. H. Pickett

Euonymus scale, *Unaspis euonymi* (Comstock) (Homoptera: Diaspididae), has been a problem to the nursery industry ever since its accidental introduction into the United States from Asia probably some 100 years ago. The scale spread rapidly throughout the United States and the world, with the exception of Australia. Today, *U. euonymi* is found wherever euonymus and other susceptible host plants grow.

There are no effective natural enemies of euonymus scale in the United States. Two Asian beetles have been imported to control euonymus scale: *Cybocephalus* nr. *nipponicus* Endrody-Younga (Nitidulidae), a member of the sap beetle family, and *Chilocorus kuwanae* (Silvestri) (Coccinellidae), a lady beetle. These two beetles also attack San Jose scale and white peach scale, highly destructive pests of fruit trees.

In 1984, USDA-APHIS introduced *C. nipponicus* and *Chilocorus kuwanae,* both collected in Korea, to scale-infested euonymus plants at the United States National Arboretum in Washington D.C. Both *C. nipponicus* and *C. kuwanae* are responsible for the great reduction of euonymus scale to very low levels at the Washington D.C. site--the larger *Chilocorus* possibly responsible for effectiveness at reducing high levels of scale while the smaller *Cybocephalus* responsible for controlling or regulating this scale at low densities. Within six years (1984-1989) beetles were established in nine states and the District of Columbia.

The seriousness of *U. euonymi* in the eastern United States has not translated across to California although it has been reported to occur in three of its counties. Its presence in the Sacramento area has in the past caused homeowners to remove euonymus plants from their properties and some nurseries in the county have halted their propagation of euonymus. The effectiveness of the two promising natural enemies on the east coast has prompted interest in controlling California's euonymus scale problem.

The Biological Control Program of the California Department of Food and Agriculture in conjunction with the USDA-APHIS's national program is conducting limited releases of euonymus scale natural enemies *Chilocorus kuwanae* and *Cybocephalus* nr. *nipponicus* in northern California. Releases of 1,905 adult *Cybocephalus* nr. *nipponicus* and 187 adult *Chilocorus kuwanae* have been made at two nursery sites, one in the William Land Park, Sacramento and the second at the Decia Nursery in Napa County. Scale and natural enemy populations will be monitored over the next two years.

Population Dynamics of Yellow Starthistle:
A Pre-release Study for Biocontrol Agents

M. J. Pitcairn, D. M. Supkoff[1], D. B. Joley, and D. M. Woods

Yellow starthistle (*Centaurea solstitialis* L.), one of California's worst weeds, is a target for biological control. Both the Departments of Food and Agriculture and Pesticide Regulation have funded research by the USDA-ARS for the exploration and host testing of exotic arthropods and diseases for biological control of yellow starthistle.

A three year field study was initiated in 1990 at the University of California, Putah Creek Preserve, Solano County, to obtain information on yellow starthistle population dynamics before the release of natural enemies. Various components of the population dynamics of yellow starthistle are being studied, including variability in seed production, the temporal dynamics of seeds in the soil, plant spatial pattern, and plant survivorship as affected by abiotic and biotic factors. This information will be used as baseline data to measure the impact of introduced biological control agents. This study is being carried out collaboratively with the Department of Pesticide Regulation.

The field study employs four sites, each 20 by 20 m, set in areas heavily infested with yellow starthistle. Within each site, fifty permanent quadrats (0.5 by 0.5 m) were established using a restricted randomization procedure for sequential observation of the density and survivorship of seedlings, density and number of mature seed heads per plant and percent cover of all species of the plant community. Soil cores are extracted before and after seed rain in 50 other quadrats per site, and the number of viable yellow starthistle seeds counted. Also, four transects are located along each side of a site. Forty plants along each transect (those plants closest to 40 random points) are monitored throughout the season by bagging seed heads to determine the flowering phenology and estimate seed production. When mature, plants are harvested to evaluate plant biomass and count seeds produced.

In 1992, a site located in the Sierra foothills near Newcastle in Placer County was added to this study. In addition to the information on plant population dynamics listed above, data on the seed head weevil, *Bangasternus orientalis* Capiomont, are being collected to determine its level of infestation and impact on seed production. A second beetle, *Lasioderma haemorrhoidale* (Illiger), was found infesting seed heads at Putah Creek Preserve and Newcastle and data are being collected to measure its impact on seed production.

Data now have been obtained for three years at Putah Creek Preserve and two years at Newcastle. At Newcastle, the study will continue as described above for one more year. At Putah Creek Preserve, estimates of seed, seedling, and mature plant densities will continue but estimates of the seed production of individual plants will no longer be monitored. The results to date suggest that there are substantial differences in plant cover, density, and reproductive output of yellow starthistle and carryover of seeds in soil between years. Further analysis of the data will continue.

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Regional Surveys Of Noxious Weed Abundance Using Aerial Imaging Technologies

J. F. Paris and M. J. Pitcairn

In order to obtain successful control of weeds using biological agents, it is necessary to accurately assess the impact of these agents on the target pest species. For annual and biennial weeds, natural enemy impact can be measured on individual plants by noting the decrease in seed production or on small plant communities by noting stand decline in small plots. These observations, however, do not provide information on the regional impact of natural enemies. Current methods for monitoring plant densities on the ground are labor-intensive, time-consuming and impractical for large areas. Remote sensing (e.g. aerial photography, aerial videography, and digital images from electro-optical scanners on Earth satellites) may provide information that can be used to estimate plant abundance over large areas. With modern digital image processing techniques, technicians may extract useful information from remotely sensed images and re-sample this information to conform to a defined geographic frame of reference (i.e. a map coordinate system). Such rectified image information can then be stored in a geographic information system (GIS) for further analysis. The combined application of these three technologies, remote sensing, digital image processing, and GIS, may provide the means for monitoring noxious weed abundance over large areas.

In 1992, aerial photographs from a fixed-wing aircraft were acquired May 21, June 11, and July 8 at three sites (Putah Creek Preserve, Solano County; Shingle Springs, El Dorado County; Loomis, Placer County) heavily infested with yellow starthistle, *Centaurea solstitialis* L. These photographs were scanned to produce separate red, green, and blue digital image files. Using the observed brightness of calibration panels located at each site, the digital value was converted to reflectance factor (%) values. This conversion puts the image data on a firm physical basis for subsequent transformation to biophysical indices and measures (e.g. percent plant cover). A computer algorithm was developed that combined the reflectance factors of the three primary colors of the multispectral image and successfully produced a map indicating percent cover of yellow starthistle.

In 1993, aerial photographs from a fixed-wing aircraft were acquired on June 24 at Putah Creek Preserve in Solano County and Woodland in Yolo County, and on July 14 at Shingle Springs in El Dorado County. Comparisons between ground and aerial estimates of percent cover along two transects at Putah Creek Preserve were good (r = .79 and .71). Additional comparisons between ground and aerial estimates are proceeding at the other sites. In 1994, further efforts to test the accuracy of this method will continue.

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Impact of Exotic Insects Utilized for Biological Control of Yellow Starthistle (*Centaurea solstitialis L.*)

D. M. Woods, M. J. Pitcairn, D. B. Joley, D. M. Supkoff [1] and C. E. Turner[2]

Five exotic insects have been imported into California in an effort to establish enduring biological control of yellow starthistle. Three of the insects have established sufficient populations to initiate field studies of their impact. In 1993, field plots were selected based on several factors, including stable accessible populations of starthistle, high numbers of the bioagent, and apparent absence of other biological control agents. All three agents are known to be seedhead feeders so field studies were centered around determining the impact on seed production. At each plot, 160 plants were monitored throughout the season, seedheads were bagged to estimate infestation and impact on seed production. Mature plants were harvested and evaluated at the end of the season.

The seedhead weevil, *Bangasternus orientalis* Capiomont, is being studied at a site in the Sierra foothills near Newcastle in Placer County. Field evaluations began in 1992 and continued in 1993. At least one additional year is anticipated at this site. Level of infestation, impact on seed production, as well as host plant dynamics are being studied at this site. This study is being carried out collaboratively with the Department of Pesticide Regulation.

The seedhead gall fly, *Urophora siruneseva* (Hering), has been successfully established in many areas of the state, however, most of these areas also include other bioagents. A field plot was established in 1993 near Ukiah, in Mendocino County where *U. siruneseva* has been successfully established in relative isolation. Field observations suggest that adult flies are active during most of the host plant's flowering cycle. Additional years and additional research sites are anticipated. This study is being carried out collaboratively with the USDA-ARS, Biological Control of Weeds Laboratory.

A site was established in 1993 near Grass Valley in Nevada County to study the hairy weevil, *Eustenopus villosus* (Boheman). Adult feeding on immature flower buds appears to destroy nearly half of the plant's reproductive potential. Oviposition and larval feeding within surviving seedheads destroys an additional large percentage of seeds. Preliminary evaluations suggest that this weevil may exert a significant impact on seed production of yellow starthistle. Additional years and additional research sites are anticipated. This study is being carried out collaboratively with the USDA-ARS, Bioloigcal Control of Weeds Laboratory.

[1]California Department of Pesticide Regulation, Sacramento
[2]USDA-ARS, Western Regional Research Center, Albany

Yellow Starthistle, *Centaurea solstitialis* L., Seed Germination Study: Effect of Light, Temperature, Storage and Seed Type

D. B. Joley

Yellow starthistle (*Centaurea solstitialis* L.) depends solely on seeds for reproduction. Two kinds of seeds are produced in each seed head. Seeds in the central portion bear bristles (plumed) and are usually disseminated at maturity during summer. Peripherally-borne seeds are usually without bristles (non-plumed) and are retained in the heads until the bracts are dislodged by wind, rain, or mechanical disturbance, usually in late fall.

The measurement of impact of natural enemies (especially seed-feeding insects) imported for the biological control of yellow starthistle in California must consider the bioagent's effect on viability of seeds produced by the infested plant. One way to measure viability is to germinate seeds under ideal conditions. For this, it is important to understand the major factors that regulate germination response, such as seed type, light, temperature, and after-ripening effects.

In 1993 laboratory studies were set up to examine the role of light and other factors in the germination response of the two kinds of seeds. Seeds were collected plants located at the Putah Creek Preserve, Solano County, on various dates from July through December (unfilled or poorly filled seeds were eliminated). All seeds were either germinated immediately or stored dry at 20^{o}C or -15^{o}C for several months and then germinated.

Although, this study is not yet complete, there are some general observations that can be discussed. Studies clearly show an after-ripening period to be present and that storage at -15^{o}C inhibits after-ripening and storage at 20^{o}C promotes it. Also, it appears that the two seed types differ in their response to light. The non-plumed seeds appear to require a longer exposure to light than the plumed seeds for comparable germination rates. In one study with red and far-red light, results implicated phytochrome as a triggering mechanism in germination in yellow starthistle seeds. This response of the seeds to red and far-red light may help explain an apparent anomaly in the study of yellow starthistle biology at Putah Creek Preserve and Newcastle. A 1:1 or 2:1 ratio of non-plumed seeds to plumed seeds have been recovered from soil cores extracted from the surface 1" of soil in the spring. This is after winter rains have occurred to initiate germination and before seed rain from summer seed production. This seed ratio is in contrast to the 1:3 ratio of non-plumed to plumed seeds produced in the seedheads. These conflicting observations may be explained as follows. The plumed seeds fall to the ground before the onset of autumn rains. Many of these seeds germinate soon after the first significant rainfall of the season, thus decreasing the number remaining in the soil. The non-plumed seeds fall to the soil well after the onset of rainfall in autumn and after the growth of plants. It is well known that sunlight passing through a canopy of plants is rich in far-red light. This acts to "turn off" germination of yellow starthistle.

Release of Cold-Hardy Weevils for Control of Puncturevine (*Tribulus terrestris* L.)

C. E. Turner[1] and B. Villegas

Puncturevine, *Tribulus terrestris* L., is a noxious weed of Mediterranean origin infesting roadside and croplands throughout California. It was first reported in California in 1903 and was considered a pest by 1912. Puncturevine produces seeds in spiny burrs (fruits) which cause injury to the mouths and intestinal tracts of grazing animals. The presence of its burrs devalues alfalfa hay and wool. Puncturevine is also an extreme nuisance around homes, orchards, and recreational areas.

In 1961, a seed-feeding weevil, *Microlarinus lareynii* (Jacquelin du Val) and a stem-boring weevil, *Microlarinus lypriformis (Wollaston)*, were introduced into California from Italy by personnel at the University of California, Berkeley, and the USDA-ARS. Both weevils are now widespread throughout California and have successfully reduced puncturevine abundance throughout much of the state.

The success of these biological control agents, however, has not been consistent. Despite numerous releases, the weevils were not able to get established and control puncturevine in the higher elevation areas of northern California. Cold winter temperatures appear to reduce the overwintering weevil populations, but do not kill the seeds, which germinate the following season. As a result, efforts were directed toward obtaining cold-hardy strains of *M. lareynii* and *M. lypriformis* for release in northern California. Several releases of cold-hardy stem and seed weevils from southeastern Colorado and southwestern Kansas were made in the past on infestations in northern California, but there were no recoveries in follow-up surveys at any of the release sites.

In 1993, the USDA-ARS European Biological Control Laboratory collected several hundred stem and seed weevils from the Abruzzi Mountains in central Italy. These were shipped to the USDA-ARS quarantine facility at Albany, California. The Biological Control Program contacted the agricultural commissioner's offices of all high elevation counties known to have puncturevine infestations and surveyed potential release sites in Calaveras, El Dorado, Inyo, Modoc, Nevada, Shasta, Siskiyou, and Tuolumne Counties. In August, a total of 171 stem weevils were released at one site in Siskiyou County. No releases of the seed weevil were made due to the presence of *Nosema* sp., a debilitating protozoan found in the gut of some of the seed weevils that arrived from Italy. Efforts to obtain cold-hardy puncturevine weevils from several areas in Europe and Asia will continue in 1994.

[1]USDA-ARS, Western Regional Research Center, Albany

Weed Seed Bank

Kathleen Casanave

The Biological Control Program established a weed seed bank in 1979 for the purpose of having seeds available for propagation as host plants for biological control agents. The collection currently contains 190 lots of seed from 50 species of plants. They were collected from several regions throughout the state representing different geographic and climatic conditions. Each collection typically consists of between 200 to 3,000 seeds. The seeds are used by the Biological Control Program and by other researchers and cooperators who screen natural enemies for host specificity. In this way, potential biological control agents identified for release into California are tested against local biotypes of the target plant species. In 1993, approximately 1000 skeletonweed (*Chondrilla juncea* L.) seeds were collected from Placer and San Luis Obispo (by San Luis Obispo Agricultural Commissioner's Office) Counties and sent to S. Hasan (USDA-ARS) at Montpellier, France. Dr. Hasan is working with several biotypes of the skeletonweed rust, *Puccinia chondrillina*, and needed specimens of California skeletonweed for host specificity and genetic studies.

The seed bank records have recently been entered into a computer database. A listing of weed species whose seeds are in storage is available.

Endemic Pathogens in Weed Biocontrol

D. M. Woods

Plant pathogens are an integral part of the natural enemy complex that maintains effective biological control of many plant species. Regulatory issues currently prevent the large-scale introduction of exotic plant pathogens to control exotic weeds, however, endemic pathogens or accidental introductions may contribute to biocontrol of exotic weed species. Currently three weeds are being studied in order to evaluate he impact of plant pathogens naturally occurring in California. A rust fungus collected in northern California is being cultured on diffuse knapweed (*Centaurea diffusa* Lamark) in the greenhouse for future studies on impact as well as complete taxonomic evaluation. Three soil-borne fungi isolated from decaying roots of yellow starthistle (*Centaurea solstitialis L.*) have been shown to significantly reduce root-shoot ratios of inoculated seedlings. Finally, a powdery mildew on field bindweed (*Convolvulus arvensis* L.) is being studied. These studies will be enlarged this year.

Spotted knapweed, *Centaurea maculosa* Lamarck, and Bull thistle, *Cirsium vulgare* (Savi) Ten.: Initiation of Two New Weed Biocontrol Projects

D. M. Woods, D. B. Joley, and C. E. Turner[1]

In 1993, two new weed biocontrol projects were initiated with the introduction and release of three natural enemies on spotted knapweed (*Centaurea maculosa* Lamarck): *Urophora affinis* Frauenfeld a seedhead gall fly, *Agapeta zoegana* L. a root-boring moth, and *Cyphocleonus achates* (Fahr.) a root-boring weevil; and the release of one natural enemy on bull thistle (*Cirsium vulgare* (Savi)): *Urophora stylata* (Fabr), a seedhead gall fly. The release of bioagents on spotted knapweed was located in the Big Bend area of the Pit River in Shasta County and is focused on the core area of the infestation (gravel bars of the river), currently not being treated chemically. Future releases will include larger numbers of these three insects and possibly one or more new bioagents. It is hoped that some degree of reduction in knapweed density can be achieved biologically, but if not, then at least a significant decrease in seed production sufficient to limit re-infestation of nearby areas that are under eradication.

The release of *U. stylata* occurred on bull thistle located at the University of California, Blodgett Forest Research Station, in El Dorado County. Galls containing larvae were found in a limited number of heads at the release site in early fall, but many of the primary heads had been chewed off, presumably by cattle (the research station uses cattle among other experimental methods to control weeds in forest clear cuts), and we suspect that at least some larvae were destroyed. Part of the area will be fenced in 1994 prior to release of additional flies to allow the insect to establish and increase. *U. stylata* will be released on bull thistle at additional sites in California in 1994.

[1]USDA-ARS, Western Regional Research Center, Albany

Biological Control of Weeds Workshops

B. Villegas and L. G. Bezark

In December 1987, the County Agricultural Commissioners and Sealers Association (CACASA) established a Biological Control Subcommittee under CACASA's Pest Prevention Committee. The subcommittee's first meeting was on February 8, 1988. During 1988, this committee evolved into a Special Committee of CACASA entitled the Biological Control Committee. The major purposes of the Committee are to provide more direct input to the Department Food and Agriculture on the counties' biological control needs, to assist in prioritizing biological control activities, to improve the efficiency of dissemination of biological control agents throughout California, and to promote the use of biological controls as alternatives to other forms of pest control.

As part of these cooperative efforts, a new system for distributing available biological control agents was tested on two different weed pests -- puncturevine and Russian thistle. The new system consists of assistance from CACASA's Biological Control Committee, active participation by the counties taking part in the distributions of biological control agents for the targeted pests, and training of county participants through workshops held at field nursery sites by Biological Control Program. This new system was effective in achieving its objective. Since then it has been fine-tuned and its use expanded by the Biological Control Program for redistributing new natural enemies on yellow starthistle, Italian thistle, Klamath weed, musk thistle, puncturevine, waterhyacinth, and ash whitefly.

In 1993, releases of natural enemies through the CACASA Biological Control Committee county workshop system were made in 31 different counties from San Diego to Siskiyou Counties. Some nine different natural enemies were released to aid in the control of three weed species: musk thistle, waterhyacinth, and yellow starthistle. Individual accounts of the pests and natural enemy releases follow.

Redistributions of *Rhinocyllus conicus* Froelich on Musk Thistle

Musk thistle, *Carduus nutans* L., is widely distributed in the United States and limited to very few areas in northern California. Along the California-Nevada state border, seed from adjoining infestations in Nevada repeatedly invade California. In 1993 musk thistle seedhead weevils (musk thistle biotype), *Rhinocyllus conicus* Froelich, were collected on June 8, 1993 from the Mount Shasta area of Siskiyou County and released on June 10, 1993 at one site in Sierra County and at four sites in adjoining Washoe County, Nevada. The releases in the State of Nevada were made with the permission of the Nevada State Department of Agriculture. Surveys of the release areas during August, 1993, showed that the seedhead weevils successfully oviposited on the musk seedheads. At each of the sites, at least one seedhead was dissected showing numerous weevil pupae in the receptacle area of the seedhead.

Releases of *Rhinocyllus conicus* Froelich on Musk Thistle during 1993		
County	**Release Sites**	**Weevils Released**
Sierra	1	500
Washoe, NV	4	1,050
GRAND TOTAL:	5	1,550

Redistribution Releases of the Mottled Waterhyacinth Weevil, *Neochetina eichhorniae* Warner, on Waterhyacinth

Waterhyacinth, *Eichhornia crassipes* (C. Martius) Solms-Laubach, is a rapidly growing aquatic plant in the Pontederiaceae or pickerelweed family. It is a serious pest in that, through the weed's prolific growth, it clogs lakes and ponds and chokes off water flow in slow moving rivers and streams as well as in canals and irrigation ditches. It can also plug water pumps used in irrigation.

In 1982, an integrated pest management program was begun to combat a large-scale waterhyacinth infestation in the San Joaquin River delta in central California. In the delta, the weed impacts recreational, agricultural, and residential water uses. As a part of the management program, three biological control agents were introduced into California from the southeast United States by the Army Corps of Engineers in cooperation with the USDA-ARS and the Biological Control Program. The bioagents were two species of waterhyacinth weevils, the chevroned waterhyacinth weevil, *Neochetina bruchi* Hustache, and the mottled waterhyacinth weevil, *Neochetina eichhorniae* Warner, and one species of waterhyacinth moth, *Sameodes albiguttalis* (Warren). To date, only the mottled waterhyacith weevil is known to be established in California.

In 1993 a total of 1000 mottled waterhyacinth weevils were collected on August 23, 1993 from White's Slough in San Joaquin County. The weevils were then transported to Los Angeles County where they were released on August 25, 1993 at two ponds in the Tujunga Wash, located within the Los Angeles Wildlife Sanctuary operated by the Los Angeles County Department Parks and Recreation. The two ponds had a total surface area infestation of waterhyacinth of about 14.5 acres.

Biological Control Workshops and Colonization Releases of Yellow Starthistle Biological Control Agents

Yellow starthistle (YST), *Centaurea solstitialis* L., is an annual Eurasian weed which currently infests an estimated 7.9 million acres in California. Its importance as a weed pest arises from its interference with agricultural productivity, particularly in rangeland, and its implication in a physiological chewing disorder in horses. The USDA-ARS, Biological Control of Weeds Laboratory, in cooperation with the Biological Control Program, has released five natural enemies against yellow starthistle. These natural enemies comprise two tephritid flies, *Urophora sirunaseva* (Hering) and *Chaetorellia australis* Hering and three weevils, *Bangasternus orientalis* (Capiomont), *Eustenopus villosus* (Boheman), and *Larinus curtus* (Hochhuth).

The first natural enemy, the seedhead gall fly, *Urophora sirunaseva* (Hering) was released in Placer County in 1984-85 and again in 1990-91 in Contra Costa, Napa, Mendocino, and Siskiyou Counties. Beginning in 1992, the gall fly was made available to county personnel for county nursery sites. In 1993, the gall fly was made available mainly as overwintering larvae inside YST seedheads mass collected on March 30, 1993 and separated into allotments of 1000 YST seedheads. County personnel were invited to participate in three training workshops held in Sacramento on April 7, Fresno on April 14, and Redding on April 21. At the workshops each participating county was given one carton containing approximately 1000 YST seedheads. Twelve cartons were kept by the Biological Control Program to monitor adult emergence. Fly emergence started on May 1, 1993 and continued through mid June. An average emergence of about 100 flies per container was documented. A small number of adult flies was also made available to counties for release. These were collected either from sleeve cages containing YST seedheads infested with overwintering fly larvae or as part of other ongoing workshops in Placer and Siskiyou Counties. Approximately 9,426 seedhead gall flies were released at 57 sites in 31 counties (see attached table). To date *U. sirunaseva* has become established in Siskiyou, Mendocino, Napa, and Sacramento Counties. In areas of Siskiyou and Placer Counties, the fly has become widely distributed on its own.

The bud weevil, *Bangasternus orientalis* (Capiomont), was the second natural enemy released in California. Two nursery sites, one in Placer and the other in Siskiyou County, received the first imported shipments of *B. orientalis* in 1985. These sites were selected to approximately match the climatic regions from which the weevils were collected in Greece in order to improve chances of establishment. A collaborative USDA-ARS-Biological Control Program research study was initiated to monitor the population increase and impact of the weevil on local YST populations. In 1988, the weevil was made available for county redistribution and since then over 52,000 weevils have been released by county, USDA-ARS, and Biological Control Program personnel at over 250 different sites in 47 counties from Siskiyou County in the north to Riverside County in the south. In 1993 a total of 19 counties (see table) made releases of the bud weevil. Collections of this weevil were made through two workshops held in Placer County and one workshop held in Siskiyou County. Through these workshops a total of 10,660 weevils were collected and released at 50 sites in 15 counties. In addition four counties (Merced, Nevada, Plumas, and Yuba) released 3,760 weevils at 20 sites from their own nursery sites. The bud weevil is now established in all counties where it was released through the 1992 season. High population densities of *B. orientalis* are located in the Sierra Nevada foothills from Merced County, northward, and in the mountainous areas of northern California. In the San Joaquin Valley and parts of the Sacramento Valley, the weevil exists in low populations.

The third natural enemy to be released in California was the peacock fly, *Chaetorellia australis* Hering. One release of this fly was made in 1988 and additional releases in 1989-1991. The peacock flies were imported from Greece. To date, *C. australis* has not become established at any of the California release sites. According to the Dr. Charles Turner, USDA-ARS, Biological Control of Weeds Laboratory, the peacock fly was recovered during the 1993 season from release sites in Oregon and Washington.

The hairy weevil, *Eustenopus villosus*, was the next biological control agent introduced into California from Greece. In 1990, two releases were made in Nevada and El Dorado Counties, with additional releases continuing in 1991 in Mendocino, Napa, and Shasta Counties. In 1992, the hairy weevils appeared to be well established at the El Dorado County site. In June, 1992, several hundred *E. villosus* adults were collected El Dorado County and released at two lower elevation sites located near Folsom Lake in Sacramento and Placer Counties. In 1993, a total of 3200 hairy weevils were collected from El Dorado and Nevada Counties and released at 11 sites located in 10 counties (see table).

The last biological control agent to be released by the USDA-ARS was the flower weevil, *Larinus curtus*. The first release of this bioagent was made in the Sutter Buttes of Sutter County in 1992. During 1993, two additional releases of 200 weevils each were made in Amador and Yolo Counties. No further releases were made in 1993 due to the discovery of the protozoan organism, *Nosema* sp., in the gut of weevils from the second shipment that arrived from Greece. The Biological Control Program provided support to these releases by securing and surveying prospective release sites identified by the agricultural commissioner's offices from several counties.

RELEASES OF YST BIOLOGICAL CONTROL AGENTS IN CALIFORNIA DURING 1993

COUNTY	*Bangasternus orientalis* Weevils	*Urophora sirunaseva* Gall Flies	*Eustenopus villosus* Weevils	*Larinus curtus* Weevils
Amador		100 (1)		200 (1)
Butte		200 (2)	220 (1)	
Calaveras		200 (2)	124 (1)	
Contra Costa	800 (4)	1500 (7)	207 (1)	
El Dorado	300 (1)			
Fresno		100 (1)		
Glenn	1100 (5)	100 (1)	350 (2)	
Humboldt	650 (2)	100 (1)		
Kern		100 (1)		
Kings		100 (1)		
Lake		200 (2)		
Madera		100 (1)		
Marin		200 (2)		
Mendocino		450 (3)		
Merced*	60 (1)	100 (1)		
Monterey		100 (1)		
Napa		500 (5)	829 (2)	
Nevada*	1400 (7)	100 (1)		
Placer		700 (1)	350 (1)	
Plumas*	1200 (6)			
San Joaquin	300 (1)	200 (1)		
San Luis Obispo	900 (3)	100 (1)	310 (1)	
San Mateo	635 (3)			
Santa Barbara		100 (1)		
Santa Clara	460 (2)	200 (2)		
Shasta	2360 (12)	1450 (8)	300 (1)	
Siskiyou		200 (2)		
Solano	465 (3)	1026 (5)		
Sonoma	475 (3)	200 (1)	200 (1)	
Stanislaus*	300 (2)			
Tehama	865 (5)	200 (1)		

RELEASES OF YST BIOLOGICAL CONTROL AGENTS IN CALIFORNIA DURING 1993				
COUNTY	*Bangasternus orientalis* Weevils	*Urophora sirunaseva* Gall Flies	*Eustenopus villosus* Weevils	*Larinus curtus* Weevils
Trinity	1000 (5)	100 (1)		
Tulare		100 (1)		
Tuolumne		100 (1)		
Yolo	800 (3)	400 (2)	310 (1)	200 (1)
Yuba*	350 (2)			
GRAND TOTAL:	14,420 (70)	9,426 (63)	3,200 (12)	400 (2)

NOTE: Numbers in parenthesis are the number of releases made in the counties; Counties marked with an ansterisk (*) represent those counties that made their own in-county releases from nursery sites.