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IN THIS ISSUE

OLIVE FLY TRAPPING SURVEYS IN SOUTHERN CALIFORNIA
Phil A. Phillips, UCCE, Ventura County, and Richard E. Rice, U. C. Kearney Agricultural Center

The olive fly, *Bactrocera oleae* (Gmelin), is native to the Mediterranean area. It is considered the most damaging pest of olives in southern Europe, North Africa and the Middle East. The first infestation of this fruit fly in North America was observed in landscape olive trees in Los Angeles County in October 1998. Detection surveys through June 2000 showed olive flies generally infesting coastal areas from the Mexican border north to San Luis Obispo County. Widespread infestations were subsequently found by late summer 2000 throughout Kern, Tulare, Fresno, and Madera counties in the San Joaquin Valley, and in Central Coast counties to Monterey and Santa Cruz. Santa Clara, Alameda, and San Joaquin counties were also generally infested by December 2000, as were Sutter, Butte, Yuba, and Tehama counties in the northern Sacramento Valley. Numerous olive flies were also trapped in 2000 in Baja California Norte, and the Caborca area of Sonora, Mexico. State and Federal regulatory officials thus concluded that it was not possible to eradicate olive fly from California. Consequently, there is great potential for damage to the commercial table olive and oil industries throughout California growing districts. Olives grown by homeowners for home curing and oil are equally at risk. Once established in commercial or backyard trees, expensive control procedures may be required to prevent significant losses from fruit damage or decreased quality of oil.

Olive fly larvae are the only stage causing damage and feed exclusively in olive fruits. Newly emerged or overwintered female

flies lay eggs in unharvested olive fruits in late winter or spring. Female flies from this generation then attack mature olives or young fruit as they develop in June through August. Depending on the area of California, three or more generations may be produced each year. Because the olive fly is such a new pest, its seasonal phenology has never been documented in North America. Consequently, trapping studies were initiated in April 2000 in heavily infested areas of southern California to begin developing a data base for olive fly behavior and biology.

In southern California, development appears to be nearly continuous as long as fruit are present on the tree or ground. This is based on our observations of olive fly since April 2000 at four coastal locations, two in Santa Barbara County (mature olive trees in irrigated landscape) and two in Ventura County (olive trees in dry, roadside sites). At each of these locations a ChamP® yellow sticky panel trap was placed in an open space in the mid-tree canopy, parallel to the trunk at a location 20-40 inches in from the outer canopy. Each trap was baited with a male sex attractant capsule (spiroketal pheromone) and an ammonium bicarbonate food bait packet. The traps and pheromone were changed every four weeks while the bait packet was changed every three weeks. Thus the traps have three attractive components, visual (yellow foliar mimic), pheromone (male sex attractant), and feeding (ammonium bait packet).

Adult olive flies were identified on the ChamP traps by their yellow or white scutellum and the distinct, single black spot at the tip of each wing. The wings have dark veins and no other markings. Other fruit flies, such as walnut husk fly, apple maggot, and Med fly all have typical broad, dark colored bands across their wings. Except for the difference in wing banding, olive fly appears quite similar to walnut husk fly. The generally brownish olive flies also have black bands on the abdomen and stripes on the thorax.

In this first year of continuous trapping, collection records indicate there is a general decline in adult fly populations in early spring when good quality olive fruits are not readily available. In the irrigated Santa Barbara sites (Figure 1), the number of flies trapped per day steadily declined from April through mid-July. This period of fly activity was very low relative to the flies trapped in these sites from mid-July through the end of December. In contrast to the Santa Barbara traps, only one half the number of flies were trapped per day in the non-irrigated sites in Ventura County (Figure 2). Here

again, however, the numbers of flies trapped from April through mid-July were generally lower than those trapped the remainder of the year. During periods of the year when fruit is not available, female olive flies do not get the nutrients necessary for oviposition that they normally would acquire by feeding on fruit exudates from oviposition punctures. Female flies start to lay eggs in new crop fruit as soon as the olive pits begin to harden. Adult flies from these early season fruit infestations result in increased trap catches beginning in mid-July.

While fluctuations in trap activity are similar between the Santa Barbara and Ventura sites, there is clearly an increase in olive fly populations at the irrigated (SB) versus the non-irrigated (V) sites (figure 3). The reduction in activity during October at the Santa Barbara sites is puzzling. The data represent an average of four sample dates at each of the two sites in each county and are representative for at least the 2000 season. Although preliminary, the season-long trapping data from Ventura and Santa Barbara are quite similar to olive fly trap collections observed in olive production areas of Mediterranean Europe and North Africa. The numbers of flies collected on a daily basis, particularly in irrigated locations, are an indication of the population pressures that olive growers will experience in many of the more temperate climates in California. In many instances, olive growers in southern California reported their 2000 crop year olives 100% infested by early September, long before fruit were ready for harvest.

OLFF Adult Activity
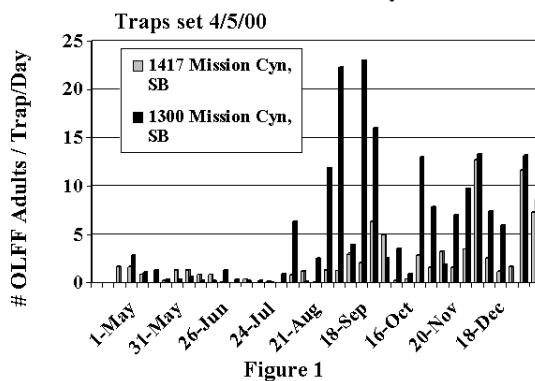### Santa Barbara County, 2000

Traps set 4/5/00

Figure 1

OLFF Adult Activity
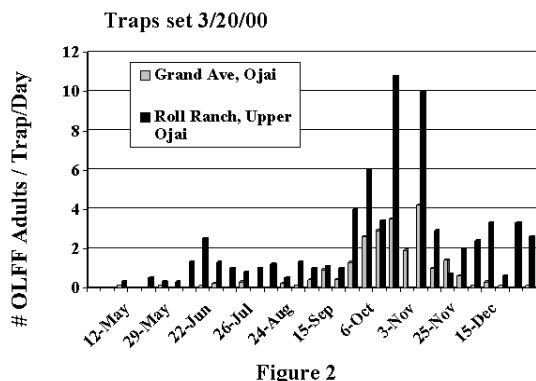### Ventura County, 2000

Traps set 3/20/00

Figure 2

Monthly OLFF Adult Activity
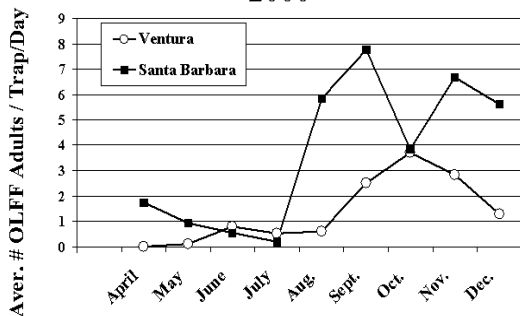### Ventura and Santa Barbara Counties 2000

Figure 3

COLLECTION AND CHARACTERIZATION OF *BOTRYOSPHAERIA DOTHIDEA* FROM VARIOUS HOSTS AND PATHOGENICITY STUDIES ON PISTACHIO

Themis J. Michailides, David P. Morgan, and Dan Felts, U. C. Kearney Agricultural Center

Summary

During 2000 we continued examining shoots blighted by *Botryosphaeria dothidea* (Moug. ex Fr.) Ces. & de Not. from pistachio, *Pistacia vera* L. and other hosts with the ultimate goal of determining whether the pathogen produces pseudothecia in pistachio and any other hosts occurring close to pistachio orchards. A second objective was to determine whether isolates of *B. dothidea* from other hosts could serve as inoculum for infection of pistachio and vice versa. Sixty samples were collected from a number of different plant species from different locations, representing counties where pistachios are grown. The samples were examined with a dissecting and a compound microscope for the presence of reproductive structures of *B. dothidea*. Of the samples, 77% had mature pycnidia of *B. dothidea*; single spore isolates were stored in our *Botryosphaeria* fungal collection.

Pseudothecia of *B. dothidea* were found in pyracantha (*Pyracantha* sp.) and olive (*Olea europaea*) in 1999 and in olive, Incense cedar (*Calocedrus decurrens*), and blackberry (*Rubus ursinus*) in 2000. However, only pseudothecia in blackberry were mature and produced large numbers of ascospores that were used in pathogenicity experiments. Mature ascospores from blackberry infected pistachio fruit and leaves in the laboratory and ascosporic isolates caused typical Botryosphaeria blight in the field. Therefore, pycnidiospores and ascospores produced in these hosts can serve as inoculum for Botryosphaeria blight in pistachio found in close proximity, or at a great distance from these hosts. At least blackberry vines next to pistachio orchards should be considered problematic, especially since this host might support development of both pycnidia and pseudothecia of *B. dothidea* and serve as a major spore inoculum source. The fact that colonies produced from ascosporic isolates infected pistachio shoots and caused typical blight in the field could suggest that an infection, which would initiate from an ascospore, could be able to produce pycnidia that eventually provide inoculum for multiple infection cycles of pistachio.

Results in 2000 confirmed that *B. dothidea* isolates from other hosts could infect pistachio trees in the field causing typical Botryosphaeria blight symptoms. These findings strongly support the hypothesis that these hosts can serve as inoculum sources for Botryosphaeria panicle and shoot blight of pistachio. Furthermore, for the first time, we showed that *B. dothidea* obtained from pistachio infected at least giant sequoia (*Sequoiadendron giganteum*), and interestingly, it produced pseudothecia in this host. Results of another of our studies showed that there are no significant differences among isolates from pistachio and other hosts, supporting the hypothesis that the population of *B. dothidea* in pistachio and other hosts is very uniform, if not the same.

Introduction

In 1966 *Botryosphaeria dothidea* was reported in California almond (*Prunus dulcis* 'Nonpareil'), causing a band-like canker on the trunk or scaffolds of vigorous young trees. In 1984, *B. dothidea* was isolated and identified for the first time from blighted shoots and panicles of California pistachio trees. In 1986, *B.*

dothidea isolates were recovered from shoots of French prune (*Prunus domestica* L. 'French'), causing small shoot cankers; maple (*Acer* sp.), causing blighted shoots; sycamore maple (*Acer pseudoplatanus* L.) from dead branches on trees; and pecan (*Carya illinoensis*), causing blighted shoots. In 1986, both the pycnidial and the pseudothecial (ascocarpic) stages of *B. dothidea* were reported on giant sequoia (*Sequoiadendron giganteum*) and coastal redwood (*Sequoia sempervirens*) in California, causing twig and branch dieback (Worrall et al., 1986). Thus, by 1986, pistachio, prune, maple, sycamore maple, pecan, coastal redwood, and giant sequoia were considered as new hosts for *B. dothidea* in California.

During 1986 to 2000 we continued examining shoots blighted by *B. dothidea* from both pistachio and other hosts with the ultimate goal of determining whether the pathogen produces pseudothecia in pistachio and in any of the other hosts occurring close to pistachio orchards, and whether isolates of *B. dothidea* from other hosts could serve as inoculum for infection of pistachio.

In 1999, we reported more than 30 different plant species where pycnidia of *B. dothidea* were discovered. Occasionally pseudothecia (ascocarps) intermingled with pycnidia of *B. dothidea* were found, but only in olive and pyracantha collected in northern California. Pseudothecia and pycnidia were embedded in various amounts of stroma. *Stroma* is a melanized (black) layer of fungal mycelia where spore producing structures such pycnidia or ascocarps are produced. The presence of pseudothecia in only two out of 36 other host plants with *B. dothidea* suggests that, although ascospores of *B. dothidea* may be found in low levels in the air, pycnidiospores by far are the more common reproductive spore structure of this pathogen. However, ascospores, which are airborne, may be important for spread of the pathogen over long distances.

In 1999, we inoculated detached pistachio fruit with most of the isolates of *B. dothidea* collected from other hosts. All 80 isolates of *B. dothidea* from other hosts infected detached pistachio fruit and reproduced by producing pycnidia on the surface of the fruit. In addition, all 46 isolates from other hosts caused shoot blight when inoculated on shoots in an experimental pistachio orchard at KAC. Infection levels ranged from 15 to 72%, and all reproduced by producing pycnidia along the base of the inoculated shoots. Similarly, *B. dothidea* isolates from pistachio caused 15 to 86% infection levels when inoculated on pistachio shoots in the field, and all reproduced by producing pycnidia. The

1999 results confirmed and expanded the results of inoculations done in 1986, and strongly suggest that isolates of *B. dothidea* from other hosts can easily infect pistachio trees and thus, these other hosts can serve as another source of *B. dothidea* inoculum. Presence of pseudothecia of *B. dothidea* in other plants close to pistachio orchards could be of major importance for the initiation of the disease cycle.

The objectives of this study were 1) to continue collecting isolates of *B. dothidea* from other hosts at different geographic areas in California and simultaneously searching for the ascocarpic stage of the pathogen. 2) to determine whether ascospores and ascosporic isolates of *B. dothidea* recovered from other hosts can infect pistachio. And 3) to determine whether isolates of *B. dothidea* from pistachio can infect other plants.

Procedures

Collection of *B. dothidea* isolates and search for pseudothecia. In 2000, we collected 60 different samples of blighted or dead shoots or canes from various hosts at different times and from different locations throughout the state. Samples were collected from trees or vines from riparian areas next to pistachio orchards, along freeways, farm roads, city streets, and backyards of private houses. All samples were brought to the laboratory and examined for the presence of pycnidia or pseudothecia with a dissecting and a compound microscope. Most of the isolates were stored as single-spore colonies in our *Botryopshaeria* fungal collection for the identification of the population structure of these isolates.

Obtain ascosporic isolates. To obtain ascosporic isolates, blackberry canes with mature pseudothecia were sectioned longitudinally, attached in the inner surface of the cover of a Petri plate so that the outer surface of the cane was suspended over the surface of acidified potato dextrose agar (APDA), but without touching the surface of the agar. The plates with the covers bearing the blackberry sections were incubated on a laboratory bench overnight (temperature 23 ± 1° C). The next day, single, germinating ascospores were recovered from the surface of the agar and cultured on APDA plates. Some of these single ascospore isolates produced colonies bearing numerous pycnidia, characteristic of the *Fusicoccum* sexual stage of *B. dothidea*. These colonies then were used to inoculate pistachio trees in an experimental pistachio orchard at KAC.

In another experiment, blackberry sections prepared as above were attached in the inner surface of a plastic container cover above healthy 'Kerman' pistachio fruit and leaflets; and above leaflets from male 'Peters' trees. The fruit and leaflets were placed on top of wire screens and the containers were kept on a laboratory bench at 25º C for 2.5 weeks, when disease was recorded. Both the incidence of infection and production of pycnidia were recorded.

Infection of pistachio with ascosporic isolates of *B. dothidea*. Four sets of ascosporic isolates were used in these experiments. Two inoculation procedures were used, 1) mycelial-plug and 2) spray inoculation. For the mycelial-plug inoculation, inoculum sources included: a) a culture initiated from a pseudothecium from olive (collected in Glenn County); b) a culture formed from shooting ascospores from pseudothecia from olive (Glenn County); and c) a culture developed from shooting ascospores from blackberry (two isolates) (Glenn County). Seven current season shoots each were inoculated with each of the above described isolates by inserting a 5-mm mycelial plug in a wound created with a 7-mm diameter cork borer and wrapped with Parafilm to prevent dehydration. For the spray inoculation procedure, three different sources of pycnidiospore suspensions or pycnidiospore suspensions and mycelial fragments originated from an ascosporic isolate from blackberry were used. After spraying the spore suspension on the shoot, each shoot was enclosed in a plastic bag inside and a paper bag outside to increase relative humidity and prevent sunburn, respectively. All these inoculations were performed on 11 May 2000. The bags were removed in the morning of the day following inoculation. Disease recording was done 1 and 2 weeks and 1 month after inoculation by recording the incidence of shoots killed. Shoots were collected in January 2001 to determine presence of pycnidia development.

In addition, in early October 2000 a suspension prepared from pycnidiospores and mycelial fragments of a third ascosporic colony from blackberry (Glenn County) was used to inoculate an entire male, potted pistachio tree. After spraying the foliage with the above suspension to run off, the tree was covered with a plastic bag for 4 days. Leaf blight symptoms were recorded 1 and 2 weeks after inoculation.

To confirm for a second year that isolates of *B. dothidea* from other hosts can infect pistachio and are as virulent as the pistachio isolates, 10 different isolates of *B. dothidea*, four conidial isolates each from blackberry and willow (*Salix lasiolepis*), and two from walnut (*Juglans regia*) were used as inoculum to inoculate each of five shoots of 'Kerman' pistachio in an experimental orchard. To compare infection rates, 10 conidial isolates from pistachio (representing three different locations) were also inoculated each onto five shoots of pistachio in the same experimental orchard. Results represent evaluations 6 weeks after inoculation. The shoots were collected in late January 2001 to determine size of cankers developed and presence of pycnidia.

Inoculation of *B. dothidea* from pistachio into other hosts. Ten potted plants, of each incense cedar, coastal redwood (*S. sempervirens* 'Aptos Blue'), and Giant Sequoia were obtained from a commercial nursery. It was in late August when we were able to secure these plants. A spore suspension of 50,000 spores of *B. dothidea*/ml obtained from infected pistachio fruit (Glenn County) was sprayed on the foliage of these trees. The inoculated trees were covered with a plastic bag for about 12 hours to create conditions favorable for infection. Disease was evaluated 2 weeks and 2 months after inoculation.

Results and Discussion

Collection of *B. dothidea* isolates and search for pseudothecia. Of the 60 samples collected in 2000, 77% had pycnidia typical of *B. dothidea*, suggesting that this pathogen is very common among native and introduced trees, as well as blackberry vines. Hosts with *B. dothidea* in 2000 included: apple (*Malus domestica*), blackberry, cedar, cottonwood (*Populus* sp.), elderberry (*Sambucus caerulea*), Euonymus (*Euonymus japonicus*), eucalyptus (*Eucalyptus* sp.), giant sequoia, juniper (*Juniperus* sp.), olive, orange (*Citrus aurantium* var. *sinensis*), persimmon (*Diospyros virginiana*), redbud (*Cercis occidentalis*), redwood, walnut, and willow (Table 1). Locations where these samples were collected included Parlier, Fowler, Reedley, Del Rey, Kingsburg, Selma, Fresno, Clovis, Yuba City, Turlock, Modesto, Stockton, Madera, Orland, Colusa, Sacramento, Atwater, Winton, Escalon, Williams, Los Banos, and Chico (Table 1). Pseudothecia were discovered in blackberry (from two locations), one sample from an incense cedar tree in Chico, and two samples of olive from Orland. However, only the pseudothecia from blackberry were sufficiently mature to shoot ascospores allowing us to obtain ascosporic isolates for inoculation of pistachio. Pseudothecia from olive had only a few mature asci and they were used directly to obtain conidial isolates.

Obtain ascosporic isolates. Using the method of shooting ascospores on the surface of agar, we were very successful in obtaining single ascosporic isolates. A total of 100 isolates were stored for further studies (i.e., pathogenicity tests, sensitivity to fungicides, and variability among isolates).

Ascospores infected pistachio fruit and leaflets from male and female pistachio trees within a week from the initiation of the experiment. After 2.5 weeks, the majority of the fruit and all the leaflets were infected (Table 2). All infected fruit and leaves bore exuding (mature) pycnidia of *B. dothidea*. Similar results were recorded in the second trial of this experiment (Table 2). Although this experiment represents laboratory trials, it clearly indicates that ascospores can cause Botryosphaeria blight on pistachio resulting in symptoms very similar to those observed in the field. We plan to use ascospores as inoculum in 2001 and inoculate pistachio shoots of trees in the field.

Infection of pistachio with ascosporic isolates of *B. dothidea*. For mycelial-plug inoculations, 1 week after inoculation 14 to 71% of the shoots were blighted only by the pseudothecial isolates obtained from olive (Table 3). By the second week all inoculation sets showed blighted shoots. One month after inoculation, 100% of the inoculated shoots were blighted (Table 3). However, the spore suspension inoculations were not as successful in the field. Temperatures in May 2000 were unusually high at Parlier and perhaps shoots became extremely hot when were enclosed in the plastic bags. This may have prevented infection from occurring. These experiments need to be repeated. However, inoculation in October of a male potted pistachio tree using a suspension of pycnidiospores and mycelial fragments from an ascosporic isolate from blackberry resulted in 100% leaf blight 2 weeks after inoculation (Table 3).

Infection of pistachio with conidial isolates of *B. dothidea* from other hosts. One and a half months after inoculation of pistachio, nine of ten isolates from other hosts caused blight of pistachio shoots at 20 to 80% levels. Seven of 10 pistachio isolates caused shoot blight varying from 20 to 60%. These results suggest that more isolates from hosts other than pistachio caused blight, and specifically, one isolate from willow caused even greater incidence of shoot blight than any isolate from pistachio. These results confirmed last year's results in which we showed that a number of isolates from other hosts were able to infect pistachio and cause typical Botryosphaeria blight symptoms in the field. Presence of *B. dothidea* in other hosts located close to pistachio

orchards can explain why these orchards have experienced severe Botryosphaeria panicle and shoot blight. We also noticed that sometimes the disease diminished with increasing distance from the riparian areas. In other cases, we noticed that disease started from the side of the orchard where elderberry plants were present and infections started from bird damaged nuts. Birds may feed on elderberry berries initially and later on move into the pistachio orchard when nuts mature. In previous research, we repeatedly showed that bird-damaged nuts were infected with *B. dothidea* at a time when other symptoms of the disease were not present in orchards.

Inoculation of *B. dothidea* from pistachio into other host plants. Symptoms of infection were obvious 2 weeks after inoculation only on the giant sequoia, which were severely infected. Nine of the ten plants were killed after 2 months, and the tenth plant showed large shoot blights. None of the coastal redwood or the incense cedar trees were infected by this time. We cannot explain why these latter species of trees were not infected, because we find natural Botryosphaeria blight to be very common in these hosts. One possibility could be that these tree species show some resistance to *B. dothidea* isolates from pistachio. However, before making any definite conclusions, this experiment needs to be repeated.

Approximately 2.5 months after inoculation, examination of infected and killed giant sequoia revealed that their shoots were covered with pseudothecia, which contained mature asci and ascospores (figure 1). This is the first time we were able to produce the pseudothecial stage of *B. dothidea* from isolates obtained from pistachio. Single ascosporic isolates have been recovered for further studies. Interestingly, the pseudothecial stage of *B. dothidea* was also reported on this same host by Worrall et al. (1986). At this moment, we do not know why giant sequoia supported the production of pseudothecia. The reason may be that the inoculum we used to inoculate these trees had the right mating strains of *B. dothidea* for this event to happen.

Conclusions and Practical Application

1) These studies strongly suggest that a number of native, introduced, and ornamental trees and blackberry vines can be hosts of *B. dothidea*. The pseudothecial (sexual) stage of this pathogen can occasionally occur in some of these hosts. Therefore, pycnidiospores and ascospores produced in these hosts can serve as

inoculum for Botryosphaeria blight in pistachio orchards in close proximity or at further distances, respectively.

2) Blackberry canes borepseudothecia that had mature ascospores at a time when other hosts such as olive and pyracantha had immature pseudothecia. The presence of blackberry next to pistachio orchards should be considered problematic, especially since this host can serve as a major spore inoculum source for both pycnidiospores and ascospores.

3) Ascospores infected fruit and leaves of pistachio causing symptoms typical of Botryosphaeria blight (laboratory trials). This is the first time that it was shown that ascospores of *B. dothidea* could infect pistachio, although this phenomenon may occur in nature more frequently than has been suspected.

4) Colonies produced from ascosporic isolates infected pistachio shoots and caused typical blight in the field. This finding suggests that an infection, which started from an ascospore, is able to produce pycnidia that eventually provide inoculum for additional infection of pistachio.

5) We also confirmed that *B. dothidea* isolates from various hosts could infect pistachio in the field, causing typical Botryosphaeria blight symptoms. Results of two years strongly support the hypothesis that *B. dothidea* from other hosts can infect pistachio.

6) Isolates of *B. dothidea* obtained from pistachio infected at least giant sequoia, and interestingly, produced pseudothecia in this host. Results from another study showed that there are no significant differences between isolates from pistachio and other hosts, which also support the hypothesis that the population of *B. dothidea* is very uniform (Michailides et al., 2001). This uniformity may indicate that ascospores are rarely produced in nature, or it may indicate that infections from ascospores only occur in rare years when conditions are conducive to their development and spread.

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Table 1. Various hosts and locations of sample collection in which *Botryosphaeria dothidea* was isolated in 2000.

Host	Location
Apple	Orland
Blackberry**	Atwater, Chico, Orland, Winton
Cedar*	Chico, Clovis, Fresno, Fowler, Modesto, Parlier, Reedley, Sanger, Selma, Winton, Yuba City
Cottonwood	Atwater
Elderberry	Williams
Euonymus	Parlier
Eucalyptus	Clovis, Orland, Sacramento
Giant Sequoia	Fresno, Parlier, Reedley, Turlock
Juniper	Modesto, Reedley
Olive*	Orland
Orange	Del Rey, Reedley
Persimmon	Orland
Redbud	Orland
Redwood	Chico, Colusa, Orland, Reedley, Selma
Walnut	Colusa, Del Rey, Los Banos, Orland, Stockton, Tulare
Willow	Atwater, Madera, Orland

* Samples with pseudothecia of *B. dothidea*
** Mature pseudothecia

Table 2. Infection of pistachio fruit and leaves with ascospores from *Botryosphaeria dothidea* pseudothecia in blackberry.

Infection site[1]	Infection (%)[4]		Presence of pycnidia (%)[5]	
	Trial 1	Trial 2	Trial 1	Trial 2
Fruit[2]	75.0	43.7	100	80
Leaflets (female tree)[3]	100.0	80.0	100	100
Leaflets (male tree)[3]	----	91.7	----	100

[1] Fruit and leaves were placed directly beneath pseudothecia which actively released ascospores.
[2] Three replications of 34 to 56 fruit per replication.
[3] Three replications with 4 to 6 leaflets each.
[4] Disease was recorded 2.5 weeks after the initiation of the experiment; first symptoms of infection were noted 1 week after ascospore shooting was initiated.
[5] Numbers of pycnidia with exuding mature pycnidiospores.

Table 3. Infection of pistachio by pseudothecial and ascosporic isolates of *Botryosphaeria dothidea* in an experimental pistachio orchard.

Inoculation method and inoculum source	Blighted shoots (%)		
	1 week	2 weeks	1 month
Mycelia-plug inoculation			
Blackberry, ascosporic isolate	0	43	100
Blackberry, ascosporic isolate[1]	0	100	100
Olive, pseudothecial isolate[1]	14	100	100
Olive, ascosporic isolate[1]	71	100	100
Spray-inoculation			
Blackberry, pycnidiospore suspension from ascosporic isolate[2]	NI[4]	NI	NI
Blackberry, pycnidiospore mycelial fragments of ascosporic isolate[2]	NI	NI	NI
Blackberry, pycnidiospore and mycelial fragments of ascosporic isolate[3]	50	100	----

[1] Seven shoots were inoculated on 11 May 2000.
[2] Seven shoots were sprayed with the above suspension on 11 May 2000.
[3] One potted male pistachio was sprayed in early October 2000.
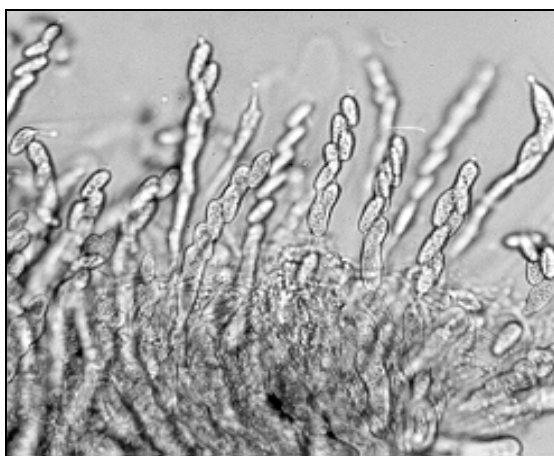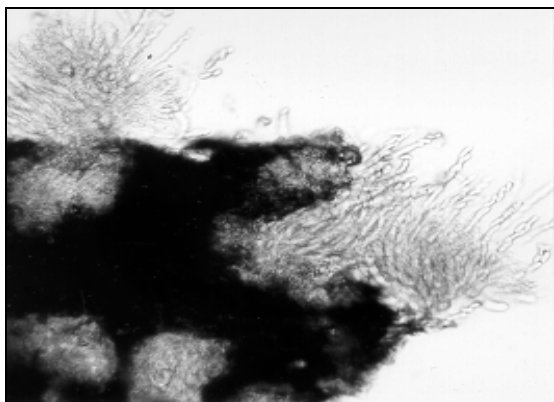[4] NI= Not infected.

Figure 1. A, Sectioned pseudothecia showing mature asci (magnification 100×), and **B,** Asci and mature ascospores of *Botryosphaeria dothidea* (magnification 250×).

MANAGING LYGUS IN THE LANDSCAPE[1]
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Lygus bug (*Lygus hesperus* Knight*)* is a major pest on many crops including alfalfa seed, dry and fresh beans, cotton, strawberries, apples, pears and cool season vegetables. In addition, this mirid has a wide host range that includes many common weeds and crops. Lygus is well adapted to the western landscape. In the Central Valley, lygus populations build throughout the year, moving from plants that become unsuitable to those that can provide habitat for the next generation. Thus, the movement of lygus into a farmer's field usually is not a result of current management practices, but rather a threat external to the management of the recipient crop.

There is no "*silver bullet*" solution to lygus. However, across the country, research efforts are providing new knowledge and developing new approaches to managing lygus, including host plant resistance, biological control, insecticide management strategies and cultural management alternatives. No single approach will solve the problem in an individual field; they must all be brought to bear on the problem. To succeed, the context of the large region surrounding individual fields must be considered. Professor Vern Stern, the eminent entomologist from UC Riverside, recognized this fact in 1967 when he wrote:

> "The grower, faced with rising production costs at all levels must decide if he will rely completely on insecticides to fight *Lygus* and accept the financial burden or if he will look for another method of control….." and "In attacking the *Lygus* problem, chemicals are used when absolutely necessary; but first a major change must be made in farm practices to keep *Lygus* out of cotton"

Dr. Stern and his students made invaluable contributions to our understanding of lygus in a regional context (Stern, 1969). They realized that managing lygus on a large scale required understanding of the crops that acted as sources and which ones became sinks for lygus. Prevention of movement into susceptible crops required one of two general approaches; managing the habitat from which lygus originated or providing alternative, preferred habitats into which they could move. Several specific strategies included:

- habitat diversification through the interplanting of alfalfa strips in cotton fields

- habitat preservation in alfalfa hay by retaining uncut strips
- prevention of lygus movement from safflower by timing insecticides based on insect phenology.

Interest in regional approaches for management of lygus is increasing. For example, in the southern US, as boll weevil has been eradicated in many states, the heliothine complex is controlled with transgenic cotton, and plant bugs are becoming the key pest in their cotton systems. Area-wide management, so successful in taming boll weevil, is seriously being considered (Nordlund, in press) as a viable management approach for tarnished plant bug (*Lygus lineolaris* Palisot & Beauvois) in this area. Key to this approach is the destruction of host plants that provide important habitat for lygus population development.

California, and especially the Central Valley, has a wide diversity of cultivated and wild plants that serve as sources of lygus throughout the year. Informal and community-based programs have successful managed insect pests in the San Joaquin Valley. In the Tulare Lake bottom area of Kings County, farmers worked together to time insecticide treatments against lygus on safflower (Sevacharian et al. 1977), coordinating both timing and insecticide choice. This approach provided some uniformity in seeking to minimize the need for duplicate treatments in a field while not requiring centralized authority. In northwestern Fresno County, almond growers were unwittingly driving lygus into cotton fields through poor timing of mowing their orchard floors. Consultants and extension advisors facilitated meetings between cotton and almond growers to develop an acceptable strategy that limited the population development of lygus. By mowing alternate orchard middles more frequently in those orchards that bordered cotton, lygus hosts were limited in their growth and lygus population buildup was minimized.

Many control tactics helpful to the implementation areawide management have been developed and modified over the years. The use of interplanting crops to draw lygus away from the primary crop was proposed (Stern et al, 1969). While this approach was used on large farms in the 1960s, it was abandoned shortly thereafter, primarily due to the incompatibility between cotton and alfalfa production practices. Other examples of trap cropping utilize the primary crop as the trap. For example, Pima cotton (*Gossypium barbadense*) is considered more attractive to lygus than Acala cotton varieties (*G. hirsutum*). Large strips of Pima were interplanted within Acala fields to draw and concentrate lygus. The same idea was employed when strips within a cotton field were maintained in a more vigorous state of growth. These strips were considered more attractive to lygus and concentrated the population. In both approaches, insecticides were focused on the trap area while the larger area of the field was left untreated. While only limited demonstration trials have been conducted to evaluate the performance of these approaches, practical experience indicates the results are of limited use.

California blackeye beans (*Vigna sinensis*) have been found to be more attractive to lygus than is cotton (Goodell and Eckert, 1998) (figure 1). The advantage of blackeye beans is their compatibility with cotton production. Beans can be sown with the same planters and at the same time as cotton. It is managed similarly and is not overly stressed when its irrigation schedule is dictated by cotton. The beans, planted on the edge of a cotton field, act as a buffer slowing the movement of lygus into the cotton. Such buffer strips could provide a killing zone into which lygus could be drawn and treated with insecticides. This approach would concentrate the lygus, reduce the overall amount of insecticides applied, and preserve natural enemies on the majority of the cotton field. The concept was demonstrated on fields in the west side of Fresno County with some success. The principal problem was lygus movement into the field from all directions. If the buffer strip was encountered, lygus settled. However, lygus will not search for buffer strips, and there are practical limitations to the amount of acreage that can be committed to non-productive areas. There is a breakeven point between loss of yield (and profit) due to lygus damage and that due to reduction in cotton acreage to accommodate buffer or trap crops and management costs.

In many areas of the Valley, alfalfa forage plays a key role in providing stable, preferred habitat for lygus. Modified harvesting patterns have been suggested for over 30 years as a strategy for maintaining habitat and reducing the movement of lygus from alfalfa to more susceptible crops, especially cotton. This technique was articulated by van den Bosch and Stern (1969) and Stern et al. (1967), but has not been accepted due to crop management issues. Demonstration trials in 1998 and 1999 (Goodell et al. 2000) have rekindled an interest in maintaining alfalfa as alternative habitat. There are two viable approaches; first leaving smaller, uncut strips in fields (Summers 1976), and second modifying the approach of Stern to ensure that vigorously growing alfalfa is available to absorb lygus displaced from harvested areas.

Following up on observations of Summers (1976) that smaller, uncut alfalfa strips will retain lygus, on-farm demonstrations were initiated in 1998 (Goodell et al. 2000). The three demonstration fields bordered cotton fields. Two, three, and eight strips were left uncut in three fields, representing 5%, 7%, and 18% of the total area. All three alfalfa fields retained lygus equally well. In contrasting the neighboring cotton to alfalfa strips, there was a 30-fold population difference in lygus density (figure 2). In another demonstration, hand moved sprinkler lines were not removed prior to hay cutting, providing a four-foot wide strip of uncut alfalfa. This approach provided labor savings for the grower, while providing habitat throughout the field for lygus.

While there are still questions concerning the minimal amount of uncut alfalfa that is required to hold sufficient lygus, general guidelines suggest leaving end strips and several strips through the field. It is not well understood how far lygus will travel to a strip or how much of the population remains in the field. Further studies utilizing mark and recapture methods (Hagler, 1992) are planned.

The forage hay industry has expressed concern about the impact of quality when 28-day and 56-day (uncut strip from previous harvest) hay are mixed. Summers (1976) found no difference in quality but changes in variety since 1976 and current market pressures require that this concern be further examined. Experiments are underway to evaluate mixtures of old and new hay using both qualitative and quantitative measures.

The concept of splitting hay fields and staggering harvests is a valid, but unacceptable approach for farmers. However, in many locations alfalfa is produced on sufficient acreage that existing harvest schedules may provide adequate habitat. For example, in the San Joaquin Valley, hay is cut on an approximate 28-day cycle. In any given area, it is estimated that 25% of the fields are harvested and curing, 25% are getting the first irrigation since cutting, 25% are vigorously growing and 25% are being prepared for harvest. Thus, about 75% of the acreage in an area might be receptive to attracting and holding lygus. In 1998 and 1999, large-scale, on-farm trials demonstrated that alfalfa could provide adequate habitat and be managed to avoid lygus movement into cotton (Goodell et al, 2000). Cotton in close proximity to alfalfa resulted in lower lygus populations in those fields than in situations in which there was no alfalfa nearby (figure 3).

Regional management issues come into focus when questions about the relationships between crops need to be addressed. What proportion of an area is required for alfalfa to be an effective sink for lygus rather than a source? What are the spatial relations between alfalfa and cotton? How close to each other do they have to be? How close do alfalfa fields have to be from each other? These questions require spatial analytical techniques such as those offered by geographical information systems (GIS) and ecological landscape integration tools (Berry et al, 1998). Efforts are currently underway to investigate the usefulness of these landscape analysis approaches.

Piecing it together

The development of regional management strategies will not be easy. Successful programs have generally been imposed and involved some governmental or quasi-governmental organization to conduct the program. While lygus is a key pest in some crops most years, it does not represent the threat that exotic pest introductions often do. Thus, the driving need to organize and work together is not compelling.

Since lygus does not threaten everyone every year, what is the motivation to work together? Several factors actually encourage the development of community-based, regional management programs:
1. Farm economics are driving the search for ways to reduce cost; i.e. avoiding insecticide costs
2. Many of the cultural control techniques can be implemented and become almost transparent in normal production practices
3. Multiple tactics will lead to a general decrease in population density, while no tactic will solve the entire problem
4. The entire area may not have to be committed; suppression and management of the population is the goal, not eradication

A successful regional management program might result in the overall reduction in lygus population. This in turn could result in reduced movement into susceptible crops, fewer broad-spectrum insecticides required for lygus management, less secondary disruptions and improved stability in field and fruit crops. Such a program would have two pillars supporting it; first, having adequate knowledge of lygus biology at the ecological landscape level, and second, willingness of the community to implement such a program.

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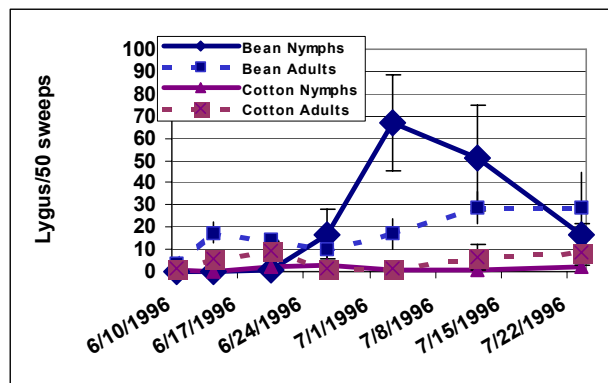

Figure 1. Lygus densities in adjacent, replicated small plots from blackeye beans and cotton. Kearney Research and Extension Center, 1996.
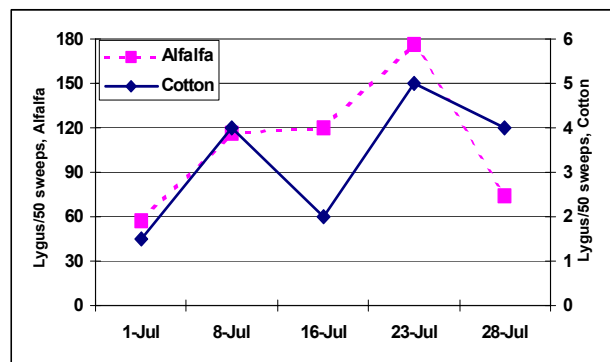

Figure 2. Lygus densities from adjacent alfalfa and cotton fields, Tulare Co. 1999. Note the difference in scale between cotton and alfalfa axes.
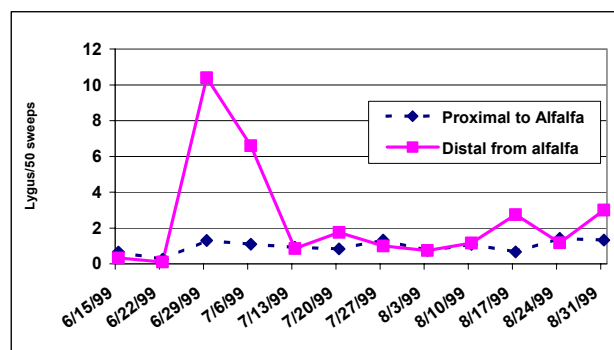

Figure 3. Lygus densities from cotton near alfalfa or distant from alfalfa, Fresno County 1998.