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BIOLOGICAL CONTROL OF ORIENTAL FRUIT MOTH, *Grapholitha molesta* (Busck). *Walter Bentley, Susan B. Mallek and Andrew Molinar, University of California Kearney Agricultural Center*

Key words. Oriental fruit moth, biological control, *Macrocentrus ancyliivorus*

Abstract

Macrocentrus ancyliivorus Roh., a parasitoid of Oriental fruit moth (OFM), *Grapholitha molesta* (Busck), was released at intervals in three consecutive plantings of sunflower at the UC Kearney Research and Extension Center (KREC) in both 2003 and 2004. Because *Macrocentrus* does not overwinter on OFM, the sunflower moth, *Homeosoma electellum* (Hulst) was targeted to serve as an alternate overwintering host. Sunflower was planted adjacent to a three-acre orchard of Crimson Lady peaches. Laboratory-reared *M. ancyliivorus* were obtained from the Colorado State Division of Agriculture, Biological Control Unit, in Palisade, Colorado. Parasitoid pupae were allowed to develop in the laboratory at KREC then collected for release in the sunflower fields when they emerged. Each planting (ca. 1/6 acre) was artificially infested with 1,000 *M. ancyliivorus* once sunflower moth larvae were detected in the seed heads. Sunflower heads were caged before and after parasitoid release to monitor the level of parasitism by *M. ancyliivorus*. Sixty sunflower heads were collected in October 2003 and showed no emergence of either sunflower moth or *M. ancyliivorus* in the spring of 2004. Heads collected in early September 2004 for overwintering survival of the parasitoid resulted in successful overwintering on sunflower moth larvae (41% emergence in spring 2005). Uncaged sunflower, in 2004, indicated a steady increase in parasitism levels through late season, achieving 100% in our sample populations.

As the plantings were consecutive, so were the *Macrocentrus* releases, resulting in a high degree of parasitism even in our control population. These results confirmed similar findings from 2003 that showed an increase in parasitism of sunflower moth with each consecutive planting.

Introduction

On September 30, 1942, G. V. House collected a small, pink larva from a peach tree in Yorba Linda, CA (Mackie, 1944). It was identified as Oriental fruit moth (OFM), which subsequently spread throughout the state and quickly became the key peach pest in California. Control of OFM has been one of the driving forces for the continued use of broad spectrum pesticides in stone fruit in the San Joaquin Valley. Initially, DDT and later parathion were widely used for control prior to their prohibition due to environmental and human health concerns. Currently, organophosphates, carbamates, and pyrethroids are used in conjunction with mating disruption to manage OFM, particularly in late-harvested peach and nectarine varieties. The use of mating disruption has been a successful management technique for OFM, but infestation has continued to occur in varieties harvested after August, necessitating use of the insecticides. These insecticides are now targeted for either restriction in use or removal from registration because of surface water contamination of rivers and streams, and pesticide movement away from the target site. Fortunately, however, the development and success of mating disruption techniques has allowed the inclusion of other management protocols and subsequently, a truly integrated pest management program. An example of this approach is work currently being done with *Macrocentrus ancyliivorus*, an important parasitoid of OFM.

Macrocentrus ancyliivorus has been used in Colorado since 1946 in a biological control program for OFM. Because *M. ancyliivorus* does not overwinter on OFM, millions of parasitoids are reared and given to peach growers each year for release in their orchards. For the OFM larvae to be parasitized, they must be within reach of the *M. ancyliivorus* ovipositor, which is inserted through the tunnel entrance into the twigs (Philips and Proctor 1970). As the larvae tunnel into the twigs, the leaves at the terminal end of the shoot wilt and die, producing the characteristic flagging or shoot strike that can be a sign of OFM infestation. After laying eggs in the OFM larvae, the parasitoid larvae eclose from the egg and begin to consume the host. First and second instar OFM appear to be the most heavily parasitized. As

the larvae move from shoot to shoot, they are subject to parasitism in later instars as well. Though the current study involves early-harvested varieties, an attempt is underway to eventually integrate this parasitoid into OFM mating disruption orchards that are harvested after August. These late-harvested varieties are more prone to infestation, even when mating disruption is used. Because *Macrocentrus* does not overwinter on OFM, experiments were conducted to test suitability of an alternate overwintering host, the sunflower moth, *Homeosoma electellum*, with the goals of providing higher populations of the parasitoid earlier in the season and keeping OFM populations at lower levels. Then, as mating disruption is most effective on the first two generations, parasitism by *Macrocentrus* can be incorporated to achieve successful control of late season infestations, particularly where no additional hangings of mating disruption dispensers are made.

Methods and Materials

Trials were conducted from spring through fall of both 2003 and 2004 to determine the levels of parasitism in OFM and the sunflower moth by *M. ancyliivorus*. A proprietary line of sunflower seed (R line, Vaccaro Seed) was planted at KREC in three consecutive plantings beginning in May and concluding in July of both years. The field was adjacent to an unsprayed peach (cv. Crimson Lady) orchard.

Parasitism of sunflower moth. The original plan was to infest the sunflower with *H. electellum* imported from northern California. However, in 10 sunflower heads collected from each of the plantings on three dates in 2003, 33, 78, and 31 sunflower moth larvae were recovered. This appeared to be a natural infestation of sunflower and indicated the presence of an acceptable population for our experiments. Approximately 4,000 laboratory-reared *M. ancyliivorus* were obtained from the Colorado State Division of Agriculture, Biological Control Unit in Palisade, Colorado. Pupae were allowed to eclose in the laboratory, then they were collected for field infestation of sunflower heads. In the third planting, 20 sunflower heads were individually caged in the field inside 5 gal. paint strainer bags, secured with twist ties. Five adult female *Macrocentrus* were released inside each bag. Twenty heads were also caged without *Macrocentrus* to act as controls. After two weeks, all caged heads were removed from the field and placed in emergence cages constructed of one gal. cylindrical cardboard containers with lids. Holes were cut in the lids and clear plastic funnels with clear plastic vials attached were secured over the openings. Observations on

emergence were recorded on a daily basis. One month later, cages were opened and counts of sunflower moths and *Macrocentrus* were taken.

In 2004, sunflowers were again planted in the same field as in 2003, in three consecutive plantings and on approximately the same dates. Sampling protocol was the same for each planting. At the first sign of frass and webbing on the maturing sunflower heads, 20 heads were collected. These were dissected for evidence and recovery of sunflower moth larvae. Larvae were placed on an OFM nutrient medium, capped and left to await emergence. Immediately following the initial sampling, 20 heads in the field were caged individually inside paint strainer bags. At the same time, 1,000 of the laboratory-reared *Macrocentrus* (again obtained from Colorado) were released into the field. After two weeks, the caged sunflower heads were cut. These heads functioned as the non-infested control heads. Twenty additional heads were bagged and cut as the exposed heads. All heads remained inside the cages, which were placed in a greenhouse at approximately 72° F to await emergence. After one month, cages were opened and a final count of moths and *Macrocentrus* was conducted.

Overwintering behavior. In October 2003, 60 senescing sunflower heads were cut from plants in the same KREC field and placed, 20 each, in three vinyl and mesh emergence cages ('Bug dorm', BioQuip, Inc.) inside a larger tent in a fallow field at KREC. These remained outdoors until June 2004 and were monitored regularly throughout the winter and spring for insect emergence. Additionally in October, 24 senescing sunflower heads were cut from the last planting and placed inside eight 'Bug dorm' cages in the laboratory. Each cage contained three sunflower heads. One hundred *Macrocentrus* pupae were placed in an open Petri dish in each of four emergence cages. These four served as the treated; the remaining four cages served as controls and did not receive pupae. Cages were observed throughout the winter and spring for emergence.

In addition, 60 senescing sunflower heads were cut from the final planting in 2004. Heads were cut earlier than the previous year, with considerable green tissue still in evidence but with florets faded. As in 2003, 20 heads were placed inside each of three 'Bug dorms' inside the larger tent outdoors at KREC. However, in 2004 the heads were placed on a bed of sand in a 2 in. deep tray inside each 'Bug dorm'. The bed of sand provided a medium in which the pupae of the sunflower moth could overwinter. Cages were again examined for emergence throughout winter 2004 and into spring 2005.

Parasitism of OFM. Pheromone traps (Trécé, Inc.) for OFM were placed in the Crimson Lady peaches and in a block of mixed stone fruit 3/4 mile away at KREC. The Crimson Lady had not been managed with mating disruption for the past four years. The mixed fruit block had never been part of a mating disruption program and all were early harvested varieties (late May). Traps were monitored weekly from February through October (Figure 1). Following the peak of each OFM flight as indicated by the trap counts, flagging shoots from each orchard were cut and opened to retrieve larvae. These were then placed on the OFM nutrient media to await emergence. Fruit was also sampled at harvest for OFM damage. Five hundred fruit of each of two varieties in the mixed fruit block were sampled, for a total of one thousand. One thousand fruit were also sampled in the Crimson Lady peaches.

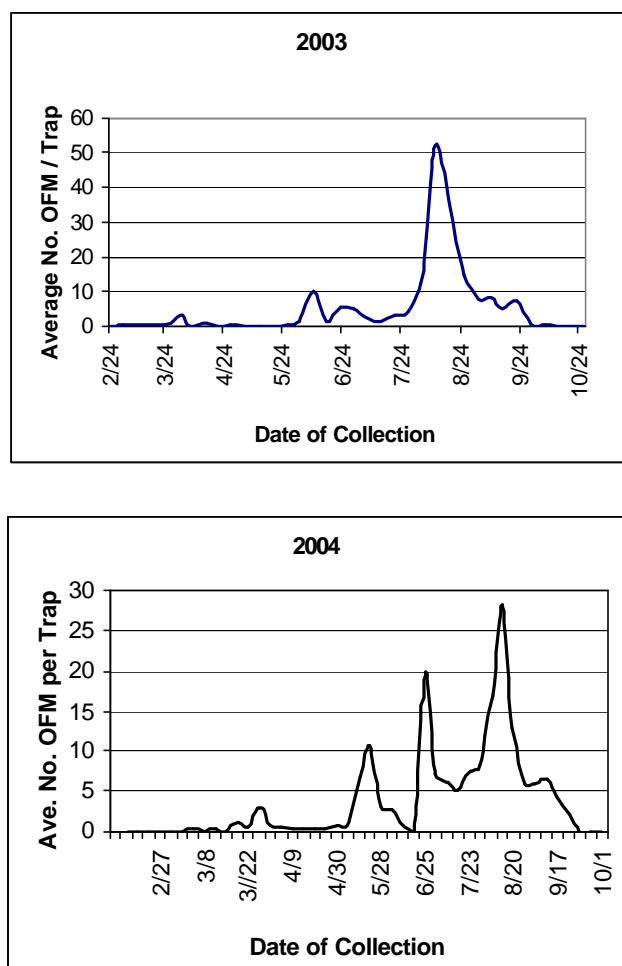


Fig. 1. Seasonal flight activity of Oriental fruit moth (*Grapholitha molesta*) in Crimson Lady peaches at KREC, 2003 and 2004.

Results and Discussion

Parasitism of sunflower moth. In September and October 2003, emergence of *Macrocentrus* from caged sunflower heads exposed to female *Macrocentrus* was significantly greater ($P < 0.05$, Fisher's Protected LSD) than from the non-exposed heads. From a total of 236 insects emerged from 20 heads, 129 were sunflower moths, and 89 were *Macrocentrus*. This amounted to a parasitism rate of 38% following the first exposure of the moth larvae to the parasitoid. Even in the non-exposed heads, 195 sunflower moths and 36 *Macrocentrus* emerged from 20 heads, a level of 15% parasitism. While total insect emergence from exposed and non-exposed heads was approximately equal, the proportion of *Macrocentrus* to moths was much higher in the exposed heads, implying successful parasitism.

Initial sampling of each sunflower planting in 2004 indicated a steady increase in parasitism through late season, until parasitoid emergence was almost double moth emergence in our late season sample. As the plantings were consecutive, so were the parasitoid releases for the caged trial, resulting in a high degree of parasitism even in our control population (Figure 2). As expected, the first planting produced no *Macrocentrus* from the control sunflower heads while six *Macrocentrus* emerged from the exposed heads. Moth emergence numbered 17 and 33, respectively. The second planting produced eight *Macrocentrus* from both the control and the exposed heads, but far fewer sunflower moths (49) in the exposed heads than in the control (84), demonstrating a much smaller moth population in the exposed heads than in the control. These results confirmed our preliminary findings from 2003. By the time of the third planting, no sunflower moths emerged from the control or the exposed heads, but 59 and 2 *Macrocentrus* emerged from the two categories, respectively. A 100% parasitism rate in our sample population was achieved.

Early sunflower moth larvae prefer to feed primarily on florets and pollen of the sunflower, tunneling into the seeds during the third instar (Rogers 1978). Thus, the time of exposure of the larva to the female *Macrocentrus* is limited. Once the larvae are outside the reach of *Macrocentrus* ovipositors, they are less vulnerable, although they may wander after feeding, increasing the chances for parasitism of later instars.

Overwintering behavior. No sunflower moths or *Macrocentrus* emerged from the overwintering sunflower heads in 2003. This was probably a result of

harvesting the sunflower heads too late in the season. The heads had begun to dry out and any larvae present most likely had left to pupate in the soil. Carlson (1967) and Riemann (1991) found that *H. electellum* prefers to pupate in the soil, so the sunflower heads were first overwintered without a soil medium to confirm that pupation was not occurring in the heads. Additionally, no *Macrocentrus* emerged from the pupae maintained in the lab. Subsequent dissection revealed the pupae to contain intact but non-viable *Macrocentrus*.

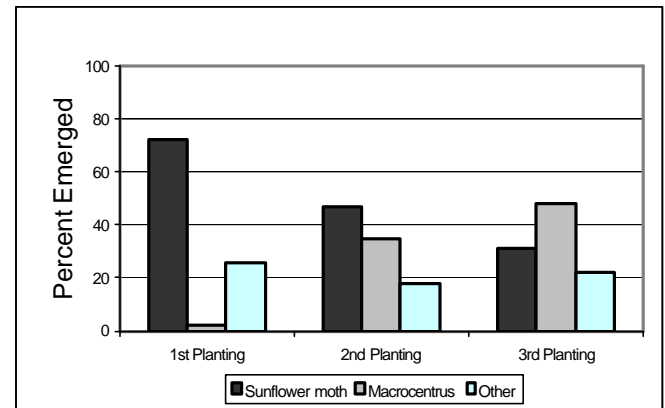


Fig. 2. Parasitism of sunflower moth by *M. ancylicivorus* as a percentage of total emergence from caged sunflower heads at KREC in 2004

Preliminary evaluation of the overwintered sunflower heads from 2004 revealed live *Macrocentrus* and sunflower moths emerging in late March 2005, and continuing through the late April. Most *Macrocentrus* emergence occurred over the first two weeks, but moths continued to emerge on an almost daily basis (41% parasitism). The addition of the bed of sand under the 2004 overwintering heads appeared to have provided the necessary site for the overwintering pupae once they left the heads. A brief survey detected several sunflower moth pupae in the sand in late fall.

Parasitism of OFM. Both orchards were harvested in late May and sustained little or no fruit damage from OFM. Of the larvae collected from shoot strikes in 2004, a significant number of *Macrocentrus* emerged from both the Crimson Lady and the mixed fruit. Percent parasitism is shown for three generations of OFM (Figure 3); of 89 larvae in Crimson Lady shoots, 34 produced *Macrocentrus* and 20 produced Oriental fruit moth. In the mixed fruit block 34 *Macrocentrus* and 50 moths emerged from 102 larvae. Larval collection began in May and ended in mid-September, and so was representative of the entire season. The remainder of the larvae did not complete development. Parasitism at the end of generation one was 50% and 13% for the

Crimson Lady and mixed fruit blocks, respectively. Parasitism at the end of the second generation was 17% and 41%, and for the last generation was 91% and 59% for the same blocks, respectively. With these results, it is expected that an established population of parasitoids may continue to build in both the Crimson Lady and the mixed fruit blocks over the next two years.

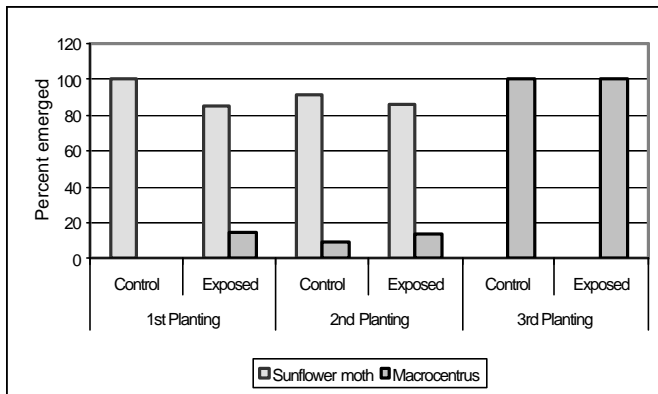


Fig. 3. Parasitism of oriental fruit moth by *M. ancylicivorus* in two orchards at KREC in 2004.

Mating disruption for management of OFM is most effective on the first two generations. The early harvested varieties tested had virtually no damage in 2003 and 2004 due to OFM. However, monitoring of shoot strikes in these orchards and extraction of OFM larvae revealed a growing population of the pest later in the season that could result in an increase in damaged fruit for later harvested varieties when mating disruption alone is used. Introduction of the parasitoid *M. ancylicivorus* over the 2003 and 2004 growing seasons resulted in significant parasitism of OFM late in the season. It is important to note that *Macrocentrus* was introduced only into the sunflower fields and not directly into the stone fruit orchards.

Current data have revealed that *Macrocentrus* overwintered in pupae of the sunflower moth in 2005. Investigation into sunflower moth as an alternate host of *Macrocentrus*, and subsequent parasitism of OFM, will continue through 2005. Plans are to forgo artificial infestation of the sunflower and monitor natural presence of the parasitoid in sunflower and in the two stone fruit orchards. Additionally, a comparison will be made between parasitism levels of commercial orchards, with and without a history of mating disruption.

The spring emergence of *Macrocentrus* from the sunflower moth pupae, coupled with the late-season presence of *Macrocentrus*, have provided evidence that parasitism is active in the early-harvested orchards at KREC. The evidence encourages expansion of this

biocontrol effort to late-harvested varieties of peaches and nectarines. There is reason to anticipate that parasitism by *M. ancylicivorus* may have a place when used in tandem with early-season mating disruption for biological control of OFM.

Based on the results of this study, we plan to implement the release of *M. ancylicivorus* in infested sunflower plantings next to commercial peach orchards. We have shown the high level of natural infestation of sunflower by sunflower moth. Because of the natural abundance of sunflower moth, we feel that plantings need to be approximately 1/6 to 1/3 acre. We believe that the high level of fall OFM parasitism will result in low survival in subsequent years, making mating disruption even more effective.

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Field experimental site.



Macrocentrus ancyliworus, parasite of Oriental fruit moth and sunflower moth.



Sunflower head infested with sunflower moth.

PINK BIOTYPE OF THE PEA APHID FOUND IN CALIFORNIA. Charles G. Summers, Department of Entomology, University of California, Davis and Kearney Agricultural Center, Parlier

Key Words: Pea Aphid, *Acyrtosiphon pisum*, pink biotype

The pink biotype of the pea aphid, *Acyrtosiphon pisum* (Harris), has been established in Europe for many years (Harper et al. 1978). It was first reported in U.S. from New York State in 1979 (Gyrisco and Smith 1979) and was later found in Maryland, Ohio, Michigan, and Washington (Kugler and Ratcliffe 1983). It is also present in Missouri (Ben Puttler, Personal Communication) and probably several other states. On 13 May 2005 the pink biotype of the pea aphid (Fig. 1) was discovered in an alfalfa field at the Kearney Research and Extension Center, Parlier, Fresno County, California. This is the first report of its occurrence in California. Its identity as *A. pisum* was confirmed by John Sorensen, California Department of Food and Agriculture. The pink biotype is identical in appearance to the green biotype except for the color. Another "pink" aphid associated with alfalfa, *Macrosiphum creelii* Davis, but generally considered rare, has been reported from several western states and British Columbia (Blackman and Eastop 1984, Pike et al. 2003). However, it has not been found in the desert southwest, including California (Pike et al. 2003). In addition to alfalfa, the pink biotype has been found on several species of clover in other parts of the U.S. and thus clover in California may also become infested. In some cases, clover appears to be a better host than is alfalfa.

The pink biotype apparently differs from the green biotype in a number of important ways. Several studies have suggested that the pink biotype shows signs of partial resistance to the parasitoid *Aphidius ervi* Haliday (Li et al. 2002). Similar results were found by Michaud and Mackauer (1994) working with pink and green biotypes of *M. creelii* and *A. pisum*. Females of *A. ervi*, *A. pisivorus* Smith and *A. smithi* Sharma and Subba Rao selected hosts by sight and showed a preference for the green biotype over the pink biotype. The pink biotype may also circumvent some of the pea aphid resistance bred into many alfalfa cultivars. Kugler and Ratcliffe (1983) found that the pink (red) biotype of *A. pisum* introduced into the U.S. from Europe easily overcame resistance in a number of U.S. cultivars with the exception of CUF 101.

The pink biotype was readily recovered in surveys conducted in Fresno, Kings, and Tulare Counties. It has also been reported from Yolo and Sacramento Counties (Rachael Long, Jodi Azulai: Personal Communication). The pink biotype appears predominate in all three San Joaquin Valley counties over the course of the late spring and early summer (Table 1). The sample taken in Fresno County (KAC) on 18 July showed no pink biotypes but there were only two pea aphids in the 10 sweep sample. Temperatures during the preceding week exceeded 106°F for most of the week, far in excess of what pea aphid can usually tolerate. With the advent of cooler fall weather, surveys will be conducted statewide.

The significance of the pink biotype to California alfalfa, its distribution in California, and its pest potential remain to be seen. Further evaluations are needed. I

would appreciate hearing from any Farm Advisors or PCAs statewide if you find the pink biotype in alfalfa or clover. Please contact me at chasum@uckac.edu.

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Table 1. Percentage of pink and green biotype of the pea aphid collected in three southern San Joaquin Valley Counties in 2005. Each collection represents 10 sweeps.

Sample Date	Fresno County		Kings County		Tulare County	
	% Pink	% Green	% Pink	% Green	% Pink	% Green
16 May	43	57	-	-	-	-
23 May	-	-	93	7	-	-
24 May					62	38
25 May	-	-	-	-	73	27
1 June	-	-	88	12	77	13
9 June	64	36	-	-	-	-
22 June	-	-	45	55	50	50
30 June	30	70	-	-	-	-
7 July	50	50	83	17	-	-
18 July	0	100	-	-	-	-



Fig. 1. Pink biotype of the pea aphid, *Acyrtosiphon pisum* (Harris). Photo by Jack Kelly Clark.

VERTICILLIUM WILT IN YOUNG *PRUNUS* SPP. James J. Stapleton, University of California Kearney Agricultural Center

There have been a number of reports of Verticillium wilt in newly-planted *Prunus* orchards this year, particularly in San Joaquin Valley almond plantings. These reports are not surprising, given the cool, wet weather conditions during spring which favored disease development (Stapleton, 1997), and the re-planting of old *Prunus* orchards or establishment of new orchards in fields which were previously planted to wilt-susceptible crops, such as cotton or tomato. Fields which have been infested with *Verticillium*-susceptible weeds are also at risk. Verticillium wilt, caused by the soilborne fungus *Verticillium dahliae* (Epstein et al, 2003), is a sporadic problem in *Prunus*, usually not appearing in epiphytic proportions unless favorable weather conditions are present (Stapleton & Duncan, 2000). Symptoms of the disease begin with chlorosis and wilting (often on only one side of the tree), then may progress to death of scaffolds, shoots, and sometimes entire trees. Vascular discoloration (“blackheart”) is usually present in the wood of affected trees, even if no foliar symptoms are apparent. Young trees, less than 4-6 years old, are most severely affected. Foliar symptoms begin to disappear as trees mature, although tree growth and yield may remain depressed (Stapleton, 1997). Cumulative economic damage of \$3,600-4,400 per acre has been reported in severely-infected orchards, and losses may accrue even in infected trees which never exhibit foliar symptoms (Asai & Stapleton, 1995; Stapleton & Duncan, 2000).

Pre-establishment (and pre-replant) disease management strategies include monitoring to avoid infested fields, root removal, fallow, soil solarization, and soil fumigation with materials such as methyl bromide/chloropicrin. Note that methyl bromide usage now must be allowed under critical use exemption. Check with county agricultural commissioners for permitting details (Gubler et al, 2005; Stapleton, 1997; Stapleton & Duncan, 1999)

For more comprehensive information on this problem, the review article on the biology and management of Verticillium wilt in *Prunus* referred to above was published in 2000 in the UCPPQ, and is available on-line using this link: <http://www.uckac.edu/ppq/PDF/00april.pdf>



Fig. 1. In almonds, a Verticillium wilt infection usually becomes apparent when leaves on one or more branches suddenly wilt, turn light tan, and die. Dead leaves generally remain on the tree throughout the growing season.



Fig. 2. Verticillium wilt damages plants' vascular tissue; peeling back the bark on newly infected branches may reveal dark stains following the grain, as seen on this almond wood.

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