two counties is quite diverse, consisting of a cool coastal zone, a warm southern zone, and a mild midpeninsula zone. Data for 10 locations throughout the two counties during November through February 1975-78 were processed using daily maximum and minimum temperatures obtained from National Oceanic and Atmospheric Administration Climatology Reports. Results show a large range in chill-hour estimates, from 150 hours in San Francisco in 1975-76 to 1,403 in Woodside in 1977-78 (table 2).

The chill-hour map constructed from these values shows that chilling is greatest in the hot-summer/cool-winter, south peninsula zone (approximately 900 to 1,200 hours). The cool-summer/mild-winter coastal zone had the lowest number of chill hours (200 to 600), while the midpeninsula zone had an intermediate number of chill hours (600 to 800). Both the midpeninsula and south peninsula zones can be considered climatically closer to the inland locations of Davis and Blackwell's Corner than to the coastal sites of Santa Maria and Watsonville. Therefore, the values calculated using the Aron equation should be a reliable indication of actual chill hours received. However, values calculated for the coastal zone may not closely reflect the amount of chilling received: they are likely to be somewhat less than actual values. These estimates are an indication, nonetheless, that chilling hours in this coast zone are probably not sufficient to meet the requirements of high-chill fruit species.

The estimated value for the city of San Mateo also appears low in comparison with Burlingame and Redwood City. However, since the thermograph for San Mateo was adjacent to a wall, heat from the wall may have increased night temperatures and resulted in the low chill-hour estimate. A more likely value for San Mateo is suggested to be between 800 and 900 hours.

In conclusion, this equation offers a quick, economical means of estimating chill hours for inland areas, and can be used to construct a chill-hour map. Such a map can be useful when evaluating an area for either commercial or home fruit, nut, and berry production. Varieties can be selected for areas in which they will receive adequate chilling, and those with high-chill requirements can be avoided in zones with low chilling.

Laurence R. Costello is Farm Advisor, University of California Cooperative Extension, San Mateo County. *The author thanks Ellen Gates, Statistician, and Richard Snyder, Bioclimatologist, both with UC Cooperative Extension, for their assistance.*

Previously imported parasite may control invading whitefly

Mike Rose □ James B. Woolley

During urban grid surveys in September 1982, San Diego County biologists discovered a new invading whitefly on avocado. Ray Gill, insect taxonomist for the California Department of Food and Agriculture (CDFA), identified the new invader as *Tetraleurodes* sp. Steve Nakahara of the United States National Museum then confirmed both the identification and the fact that the whitefly was new to California. Gill and Nakahara agree that this whitefly is the same undescribed species known from the Caribbean, Central America, Florida, and Mexico.

The whitefly

The adults of both sexes of the invading *Tetraleurodes* sp. bear red wing patterns, prompting the common name, red-banded whitefly.

Wing patterns of adult give red-banded whitefly its common name. Also shown here is black fourth-stage larva.

Adult female *Cales noacki* wasp parasitizes both red-banded and woolly whitefly.

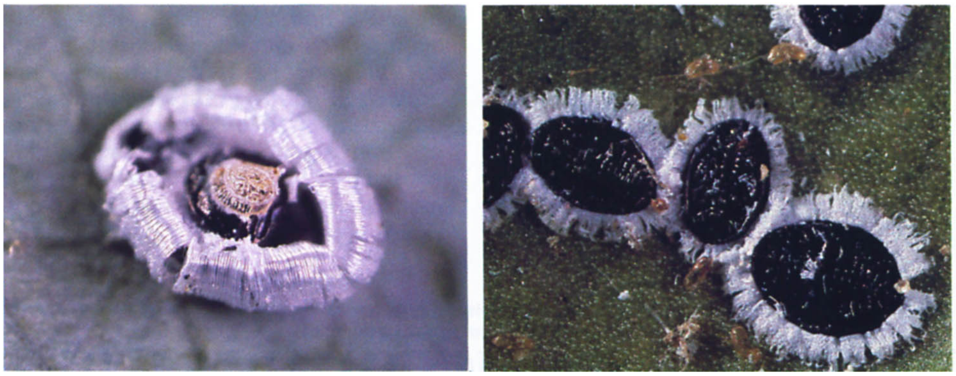
Several other species of *Tetraleurodes* are found in southern California, including the mulberry whitefly, *T. mori* (Quaintance), acacia whitefly, *T. acaciae* (Quaintance), and Stanford whitefly, *T. stanfordi* (Bemis). The red-banded whitefly can be distinguished from these three species in southern California by both adult and larval characters. The red patterns on the wings are unique to the red-banded whitefly and are readily visible. Late larval stages of all four species are a characteristic jet black, surrounded by a white marginal fringe. However, red-banded whitefly larvae, which develop on the undersides of maturing avocado leaves, produce a copious white marginal fringe that curls up and partially covers the dorsum. The white fringe of mulberry, acacia, and Stanford whitefly larvae generally lies flat on the leaf surface and is not as prominent.

Additionally, of the three named species of *Tetraleurodes* previously in southern California, only mulberry whitefly has been recorded from avocado. Therefore, host plant association is a partially reliable means of identifying the red-banded whitefly.

History

Following the original detections in San Diego, we were asked to examine the newly discovered infestations. A preliminary search indicated that the red-banded whitefly infestation was more widespread than had been known. A subsequent survey of avocado trees by the County Department of Agriculture showed some 100 square miles infested in southern San Diego County.

The extent of infestation in California and plant host range are as yet unknown. The California Department of Food and Agriculture has determined that eradication programs against other whitefly species have generally failed. Thus, attaining biological control is critical, particularly because avocado growers rely extensively or completely



White curly fringe that partially covers dorsum characterizes late-stage red-banded whitefly larva. Fringes of late-stage mulberry whitefly larvae lie nearly flat.

Jack Kelly Clark

Exit hole on red-banded larva at left indicates parasitization by *Cales noacki.*

on natural enemies to control other pests. Pesticide applications against an invading foliar pest on avocado could create secondary outbreaks of mites, Lepidoptera, scale, and mealybug, all of which are usually under complete biological control.

Initial searches for evidence of hymenopterous parasites attacking the red-banded whitefly in San Diego were negative. Parasites of red-banded whitefly are known to exist in Mexico, however, where this species had previously been observed. In Uruapan, Michoacan, Mexico, the red-banded whitefly recently attained pest status on avocado, apparently as a result of a pesticide-induced upset. The avocado treehopper, *Metcalfiella monogramma* (German), has been treated with a pyrethroid insecticide in Michoacan for the past several years and new pest problems, including *Tetraleurodes* sp., have occurred during this period. Untreated avocado groves in Uruapan were found to be nearly free of the red-banded whitefly because three species of parasites — two *Encarsia* spp. and an *Eretmocerus* sp. — were maintaining satisfactory biological control.

Fortuitous biological control

California has been invaded three other times by exotic whitefly species since the early 1900s. The citrus whitefly, *Dialeurodes citri* Ashmead, was the first of these to be discovered when it was found in Marysville in 1906 (see *California Agriculture*, July-August 1981). Woolly whitefly, *Aleurothrixus floccosus* (Maskell), was detected 60 years later in nearly the same areas of San Diego County that now harbor the red-banded whitefly (*California Agriculture*, May 1976). The bayberry whitefly, *Parabemisia myricae* (Kuwana), was found in California in 1978 (*California Agriculture*, March-April 1981). All of these whitefly species attack citrus and have been subjects of biological control research, during which effective natural enemies (parasites) have been discovered, imported, and established in southern California.

Of the many parasites imported during the biological control project on woolly whitefly, *Amitus spiniferus* Brethes and *Cales noacki* Howard are now established and have proved very effective. The tiny wasp *C. noacki* is now the most abundant woolly whitefly parasite in southern California.

Over the past several years, we have found that *C. noacki* successfully parasitizes both mulberry whitefly and acacia whitefly. Although no evidence of parasitization of the red-banded whitefly by *C. noacki* was found initially in San Diego, there was a good probability that it would occur because of the demonstrated ability of *C. noacki* to parasitize two other *Tetraleurodes* spp.

Parasite recovery samples were collected throughout the known infested area in San Diego to determine if *C. noacki* would parasitize the red-banded whitefly. During November 1982, we selected several varieties of avocado trees for study in a small grove harboring the largest observed populations of red-banded whitefly in San Diego. We began preliminary analyses of the biology, behavior, and phenology of the new whitefly, along with determination of mortality imposed by any naturally occurring parasites on this site. The information was needed to plan a biological control research project that would stress parasite importations from Mexico, followed by rapid field colonization, establishment, and measurement of the effect of the imported natural enemies on red-banded whitefly populations.

Although it was no great surprise to find *C. noacki* parasitizing the red-banded whitefly during November 1982, it was surprising to find that rates of parasitization very rapidly reached nearly 50 percent on the study site within three weeks. Rates of parasitization by *C. noacki* reached 82 percent on this site by mid-January 1983. These high rates of parasitization during the winter resulted in an overall red-banded whitefly mortality of about 92 percent.

These trends proved to be widespread. Our continuing field searches and parasite recovery samples all showed evidence of *C. noacki*. San Diego County biologists provided 27 parasite recovery samples collected from avocado on nine sites throughout the infested area from November 24, 1982, to February 17, 1983. *Cales noacki* was recovered in 25 of the 27 samples. Most importantly, *C. noacki* was found to be active, and rates of parasitization were high (from about 50 percent to nearly 100 percent in all 25 samples from all sites), even though red-banded whitefly populations were very small (averaging 3 to 15 larvae per sample leaf). Sample leaves were those which bore larvae of the red-banded whitefly.

Conclusion

Cales noacki has rapidly achieved high rates of parasitization resulting in substantial mortality to overwintering populations of the invading red-banded whitefly, *Tetraleurodes* sp. in San Diego County. Such high rates of parasitization when red-banded whitefly populations were low indicate that complete biological control may be occurring throughout the known infested area and that importation of additional parasite species may not be required. Additionally, the rate of dispersal of the red-banded whitefly to uninfested areas has undoubtedly greatly decreased as a result of population regulation by *C. noacki*.

Mike Rose and James B. Woolley, formerly with the Division of Biological Control, Department of Entomology, University of California, Riverside, are now Staff Research Associate and Assistant Professor of Entomology, respectively, Texas A & M University, College Station, Texas. Ray Gill, California Department of Food and Agriculture, provided taxonomic information and the photograph of the adult red-banded whitefly. George Opel, San Diego County Department of Agriculture, provided parasite recovery samples. The authors especially thank Paul DeBach, Division of Biological Control, UC Riverside.