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Variegated leafhopper

Long-term control of variegated leafhopper in grape IPM programs will depend on finding, rearing, and releasing effective natural enemies

Biological control of variegated leafhopper in grapes

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The single highest preharvest production cost for California grape growers is control of pests and diseases, including mildew. In 1986, total insect/mite control costs on Thompson Seedless grapes grown for raisins or wine and on wine variety grapes in the San Joaquin Valley were estimated at $113 and $137 per acre, or 22 and 26 percent, respectively, of total production costs.

In recent years, a new insect pest, the variegated grape leafhopper (VLH), *Erythroneura variabilis*, has invaded the San Joaquin Valley and threatens to cause increasingly costly and serious damage to vineyards. The destructive potential of this pest is due in part to its feeding on foliage, which affects fruit quality and quantity. There is evidence that VLH is developing resistance to insecticides, indicating that a long-term reliance on chemical control is neither technically nor economically feasible. The use of insecticides against this pest is also causing problems with spider mites by increasing their resistance to chemicals and destroying their natural enemies.

A biological control program as part of an overall integrated pest management (IPM) strategy has the potential to lower VLH populations, reducing plant feeding and associated losses in yield and quality. The components of such a grape IPM strategy are: (1) foreign exploration, importation, and development of mass-rearing procedures for improved species and/or biotypes (races) of VLH parasites; (2) mass-rearing and colonization (subsequent field release) of potentially effective parasites to reduce damaging and overwintering VLH populations; (3) field evaluation to determine permanent parasite establishment and effectiveness; (4) establishment of economic thresholds for VLH by plant growth stages, adjusted for parasite effectiveness by grape growing district, grape variety, and intended market; and (5) development of a season-long grape management program beginning with a pilot project to validate all proposed procedures and recommendations.

The potential for biological control of leafhoppers on grapes in an IPM program is suggested by the numerous, diverse candidate parasite species and biotypes for use in a managed biological control scheme (table 1), as well as the grapevine's apparent tolerance of relatively high numbers of variegated leafhoppers. This tolerance may allow VLH populations to increase while parasites also increase. One study (by co-author L. T. Wilson, unpublished data) has shown that the grapevine can tolerate up to 30 VLH nymphs per leaf, plus uncounted accompanying adults, without measurable yield reduction. M. Kliewer (Viticulture and Enology Department, UC Davis) reported that up to 25 percent removal of Thompson Seedless leaves caused no significant reduction in dry weights of canes, trunk, and roots, regardless of the time of defoliation. In Hermosillo, Mexico, up to 50 percent of grape leaves removed in October caused no significant yield or quality reduction the following year.

In seeking to develop a variegated leafhopper IPM program, we are actively involved in exploration and importation of potential parasites, have developed preliminary procedures for mass-rearing, and are collaborating in preliminary field-cage screening of selected populations of the parasitic wasp *Anagrus*. In this report, we discuss our progress in exploration, mass-rearing, and preliminary parasite colonizations.

TABLE 1. Locations of parasite collections from leafhopper eggs in grape leaves and of leafhopper species (1985-86)

	Parasite spp.*				Leafhopper spp.			
Locality	*Paracentrobia*	*Epoligosita*†	*Anagrus*	Near *Ittys*†	*E. variabilis* (variegated LH)	*E. elegantula* (grape LH)	*Dikrella cockerelli* (blackberry LH)	*E. ziczac*
USA:								
California								
Coachella			X		X			
Colorado								
Grand Jnctn‡			X					X
New Mexico								
Deming			X	X		X	X	
Las Cruces			X			X	X	
Utah								
Provo			X					X
MEXICO:								
Baja Calif.			X		X	X		
Sonora	X		X	X	X			
Chihuahua			X	X			X	X
Coahuila	X	X	X	X			X	X

* Detailed host and locality data available in shipping and receiving records at the Division of Biological Control, University of California, Riverside.
† New species records.
‡ Host leafhopper species *E. vulnerata* also found in Grand Junction.

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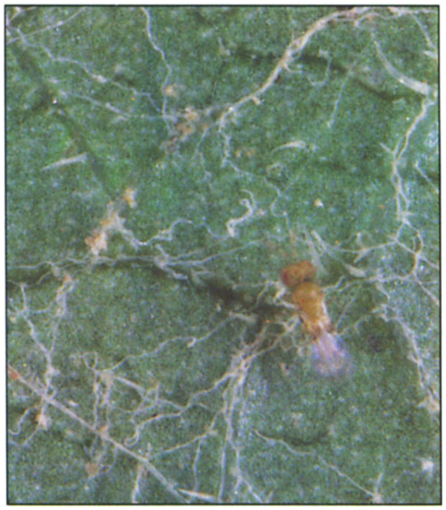

Near-*Ittys*, a parasite of variegated grape leafhopper eggs discovered in Mexico, could complement the *Anagrus* wasp in biological control programs.

Out-of-state exploration

Our priorities have been to search for VLH and its natural enemies outside California in all directions from the reference areas of Yavapai and Coconino counties, around Flagstaff, in northern Arizona. VLH was first collected in 1927 from wild grapes in the mountain canyons of those areas.

We have focused on commercial grape plantings in climates comparable to that of California's San Joaquin Valley. So far, the search has been primarily toward the south into Mexico almost to Mexico City, including grape plantings in the Mexican states of Aquascalientes, Baja California Norte, Baja California Sur, Chihuahua, Coahuila, Queretaro, Sonora, and Zacatecas. The initial emphasis was on Mexico, where there were more small farms having a variety of crops and little or no use of insecticides, thus presenting greater opportunity to find parasites. We have also made collections from Grand Junction, Colorado.

Based on the literature on geographical distribution of VLH, we have searched in 1985-86 in less than half of the available major commercial grape plantings in different climatic areas. Results to date indicate that variegated leafhopper has a wide geographic range. It has been found in locations with distinct wild and cultivated grape hosts, which are abundant and varied in some areas and limited in others (Sonora, Mexico). Climates are diverse, some characterized by hot summers and cold winters, others by moderate temperatures.

In this study, all confirmed VLH specimens were taken west of the Continental Divide: the Rocky Mountains in the United States and the Sierra Madre Occidental in Mexico. Otherwise, however, the distribution information available is much too variable and more sites are needed before the "native home" of VLH can be determined. The native home is important, because that is where the pest has been exposed the longest to environmental interactions and, consequently, where there is a higher probability of finding its most effective natural enemies.

Although we did not find variegated leafhopper east of the Continental Divide, other leafhoppers (*Dikrella cockerelli* and *Erythroneura ziczac*), which were parasitized, were abundant in commercial grapes. With regard to biological control, these two leafhoppers and VLH have a salient difference—the manner in which they deposit their eggs in grape leaves. VLH eggs are deposited deep inside the grape leaf tissue, where they are difficult to see and do not bulge out from the leaf surface. The eggs of most other leafhopper species on grapes found in our survey, including those of the grape leafhopper, *Erythroneura elegantula*, bulge out from the grape leaf surface. *Dikrella* inserts eggs in the main veins. We assume that the eggs deep inside leaves are more difficult for some parasites to find. Therefore, our first priority now is to collect, evaluate, and release parasites only from areas having VLH. Future parasite collections will be from grapevines west of the Continental Divide.

VLH egg parasites

The VLH egg parasites found to date are promising. We have eight populations of *Anagrus* and three of near-*Ittys* (N-*Ittys*).

At least four of the *Anagrus* populations appear to differ appreciably from the others. The population from Grand Junction, Colorado, and the one from Parras, Coahuila, are nearly all females. The Grand Junction females prefer VLH over grape leafhopper and survive in hot summers and cold winters. The population from Coachella, California, parasitizes more VLH eggs than does the native San Joaquin Valley *Anagrus*. The *Anagrus* from Hermosillo, Sonora, comes from vineyards in the otherwise barren Sonoran desert, where there are no other known alternative plant or leafhopper hosts. These findings indicate that, among the *Anagrus* populations collected, there are clear differences or potential differences in host preference, sex ratio, egg searching and killing, and adaptation to climate and alternative hosts.

The N-*Ittys* populations represent a previously unstudied genus within the family Trichogrammatidae. Since we have concentrated on the more widespread, better known *Anagrus*, we have had little experience with N-*Ittys* in the insectary. Two characteristics, however, are cause for optimism. First, N-*Ittys* may be faced with little competition. This group was abundant earlier in the season than was *Anagrus* and so might complement rather than compete with *Anagrus*. Also, because we have found N-*Ittys* only in Mexico, it may have few or no competitors early in the season in a new area. Second, N-*Ittys* appears to be hardier than *Anagrus*. Individuals live longer and survive in much greater numbers under a variety of handling and shipping conditions.

As is the case with *Anagrus*, N-*Ittys* has been found in several localities having different habitats and climatic patterns. For N-*Ittys*, those localities are Caborca, Guaymas, and Hermosillo, Sonora. Temperature patterns, especially, differ greatly among these areas; Caborca has below-freezing temperatures from November through March, and Hermosillo seldom, if at all, has freezing temperatures. Of the three localities, Caborca has an abundance of fruit trees that may provide ample alternative leafhopper egg hosts; in contrast, there are no fruit trees anywhere within 20 miles of the Guaymas vineyards. These differences among the source localities increase the probability that the N-*Ittys* from each of these sites will differ from one another in one or more characteristics affecting their biological control potential against VLH, as has already been shown with some of the *Anagrus* populations.

We found two other parasite species, *Epoligosita* sp. and *Paracentrobia* sp., on leafhopper eggs collected in this study. *Epoligosita*, like N-*Ittys*, is a new species. Specimens of both *Epoligosita* and *Paracentrobia* represent new records of these parasites found in eggs of leafhoppers on grape leaves. We consider these two parasites of far less priority than *Anagrus* and N-*Ittys*, because relatively few specimens were collected in few areas.

Few leafhoppers and no parasites were found in vineyards in Baja California Sur, or in Aquascalientes, Guanajuato, Queretaro, and Zacatecas. Heavy summer rainfall is common in all of these areas except Baja California Sur, where, as in Guaymas, the summers are extremely hot and dry. Baja California Sur has few vineyards and no alternative host plants for other leafhoppers.

Mass-rearing and release

Preliminary results of our studies confirm the feasibility of mass-rearing *Anagrus*. Additional trials are needed, however, before we can produce large numbers for mass releases as part of either a full-scale colonization or an augmentation biological control program.

Under a colonization program, the offspring of the parasites would increase over a long period and progressively reduce pest levels, eliminating or greatly reducing the need for insecticide treatments. Depending on several variables, it may be three to six years before effective evaluation of parasite releases under field conditions will be possible. We base this estimate on our previous experience with aphid parasites in alfalfa. Variables affecting parasite establishment and success include effectiveness, quality, and numbers of parasites released, synchronization with hosts in time and place, adaptability to the new environment including weather and alternative leafhopper hosts, and interference from insecticide applications directly or from drift.

In the second method of releasing parasites, augmentation programs, the principal impact is from the individuals being released. Results are expected within a short time, as they would be from an insecticide application. Ideally, large numbers of parasites would be released in selected vineyards, timed to coincide with the first and second peaks of VLH egg-laying to reduce VLH numbers before they reached damaging levels. Large numbers of parasites would also be released to coincide with the last peak of VLH egg-laying during a season, to reduce the numbers surviving over the winter.

Colonization of parasites

We have begun pilot colonization releases, mostly at the Kearney Agricultural Center, and at the West Side Field Station (table 2) in conjunction with field-cage preliminary parasite screenings. *Anagrus* has made up 88 percent of the releases to date, principally in Fresno County, where 80 percent of the total releases occurred. Of the *Anagrus* released, 80 percent were from Hermosillo, Grand Junction, or Coachella.

For future priorities, we have arbitrarily set 50 emerged, mated, and fed female parasites as the minimum for a colonization effort at any given time and place. On this basis, probably too few *Anagrus* from Torreon and Caborca and N-*Ittys* from Caborca were released for establishment.

Releases of N-*Ittys* were made in September and October. There are relatively few VLH eggs on grapes that late, and the probabilities for parasite establishment accordingly much less than at higher egg densities.

We are cautious in any expectations of success in the parasite-release program thus far. First, the releases were made under less than optimal conditions in field cages. Second, until the surveys can be completed, the releases have been based on limited parasite findings to date; that is, they represent fewer than half of the parasite populations potentially available for release.

Conclusions

A long-term grape IPM pest management program including biological control of variegated leafhopper will depend on finding, mass-rearing, and releasing the most effective natural enemies. A priority is completion of the VLH parasite survey in the areas north, east, and west of those where VLH was originally collected, including cultivated and wild grapes in various climates and habitats of northern Arizona, southern Utah, southwestern Colorado, and northwestern New Mexico. The survey would add to available data on the geographic, climatic, and habitat range of the VLH and its natural enemies. The potential parasites include new and different populations of *Anagrus* and N-*Ittys* and of other species.

Based on present findings, techniques are needed for mass-rearing *Anagrus* and N-*Ittys*. There are at least two phases in these procedures. In the case of N-*Ittys*, initial trials would determine the technical feasibility of this approach. Then, with both parasites, economically viable rearing techniques would be needed to support production and field-release of large numbers of high-quality parasites. Releases would be made at different times of the season corresponding to differences in VLH density, temperature patterns (day/night, summer/winter), and abundance of alternative plant and leafhopper hosts.

After preliminary colonization releases, three to six parasite populations would be selected for mass-rearing and release and, subsequently, evaluation for efficacy in either colonization or augmentation programs. The selection would be based on: preliminary insectary trials on host preference, sex ratio, robustness, activity in searching for and attacking VLH eggs, survival (especially over the winter), and developmental rates at several temperatures; similar trials in field cages; and habitat, climate, synchronization of parasite abundance with VLH and other parasites, and other pertinent data from each locality.

Optimal releases of parasite species and numbers should be integrated with all grape management practices at defined grape growth stages. The usefulness of our results should be validated in a season-long evaluation to determine priorities, the most effective management practices, and interactions or conflicts among those practices.

TABLE 2. Variegated leafhopper parasite releases in the San Joaquin Valley, 1985-86

Parasite	Origin	Release County	Release Numbers
1985	**MEXICO**		
Anagrus epos	Hermosillo, Son.	Madera	27
(mymarid)	Parras, Coah.	Fresno	236
	Santo Tomás, B.C.	Fresno	69
	Torreon, Coah.	Fresno*	8
1986	**USA**		
Anagrus epos	Coachella, CA	Fresno*	382
		Tulare	118
	Grand Junction, CO	Fresno*	368
		Tulare	372
	MEXICO		
	Caborca, Son.	Fresno*	16
	Hermosillo, Son.	Fresno*	640
nr. *Ittys*	Caborca, Son.	Fresno*	24
(trichogrammatid)	Hermosillo, Son.	Fresno*	274

*68% of total releases were at Kearney Agricultural Center, Parlier, or West Side Field Station, Five Points, in collaboration with L.T. Wilson's preliminary field-cage screening of leafhopper parasites.

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