POPULATION DYNAMICS OF VINE MEALYBUG AND ITS NATURAL ENEMIES IN THE COACHELLA AND SAN JOAQUIN VALLEYS

Raksha Malakar-Kuenen, Kent M. Daane, Kris E. Godfrey, Joe C. Ball, Walter J. Bentley, Glenn Y. Yokota, Lee Marvin, Dan González.

ABSTRACT

The vine mealybug (VMB) was first identified as a new pest in the Coachella Valley (CV) and shortly thereafter moved north into the San Joaquin Valley (SJV). We report on VMB population dynamics and parasitoid effectiveness in these two different regions. In CV vineyards, VMB density followed a well-known pattern, increasing from spring through early summer, followed by a dramatic decline in May and June. Two parasitoids were recovered – *Anagyrus pseudococci* and *Leptomastidea abnormis*. Both parasitoids increased with VMB densities, however – *Anagyrus* appeared before *Leptomastidea*. In SJV vineyards, VMB similarly concentrated on the lower trunk and roots in winter and progressively moved from these protected areas during spring. However, comparison of CV and SJV data showed important differences in VMB seasonal abundance, distribution, and parasitism. In CV, there were 2 distinct adult VMB peaks, while 3 occurred in SJV – with adult and crawler densities highest in June. In SJV there were also all VMB life stages found on roots, trunk, canes, leaves and fruit in summer and fall samples. Factors leading to VMB decline most sharply contrast the 2 regions. In SJV samples, *Anagyrus* killed >80% of exposed VMB by August, resulting in lower VMB densities (*Leptomastidea* was not recovered). Parasitism in the CV never exceeded 25%, and VMB decline came 2 months earlier and was more clearly associated with increasing temperatures than parasitism. The more exposed locations of VMB (e.g., leaves) in the SJV may have resulted in higher parasitism. Laboratory studies on VMB and parasitoid biology are being conducted.

OBJECTIVES:

1. To study the biology and ecology of the vine mealybug (VMB).

2. To evaluate the impact of parasitoids on VMB in the San Joaquin and Coachella Valleys.

PROCEDURES:

Coachella Valley. To evaluate the impact of parasitoids on the vine mealybug, *Planococcus ficus* (Signoret) (Homoptera: Pseudococcidae), and to elucidate changes in age structure through space and time, studies were conducted from February through November 2000, in a certified organic vineyard near Thermal (Riverside County), California. Imported parasitoids (*Leptomastidea abnormis* and *Anagyrus pseudococci*) had been previously released in this block (see González 1998). In February, 270 vines with active VMB infestations were selected and randomly assigned to one of three groups of 200, 50, or 20 vines each, to be used, respectively, in one of three sampling methodologies: "refuge site," "field counts," and "trapping" (this study was conducted by CDFA personnel).

Refuge Site Sampling: The group of 200 vines was used to investigate the amount of parasitism on VMB using the "refuge site" sampling method. Each vine within the group was assigned at random to one of ten subgroups of 20 vines and the subgroup allocated to a different sampling date. A month before a subgroup's sample date, the loose bark was removed from an area of the trunk and cordon and the refuge wraps put in place. Two refuge sites (one on the trunk and one on the cordon) were established on each vine and were comprised of a two-inch band of bubble wrap affixed over the exposed section of vine. The bubble wrap bands were left undisturbed for 4 weeks. The bands were then removed, returned to the laboratory, and the number and developmental stage of VMB, and the number of parasitized VMB (mummies) were recorded. The VMB and mummies were then held for parasitoid emergence and identification.

Field Count Sampling: The second group of vines (50 vines) was used to investigate changes in the VMB population age structure on different parts of the vine through time. At the beginning of the study, each vine within the group was assigned at random to one of ten subgroups (5 vines) to be used on one sample date. At 4-week intervals, the 5 vines in one subgroup were examined for VMB on the trunk, cordon, and roots. The VMB and mummies were collected, taken to the laboratory for counting, and held for parasitoid emergence and identification. The number and developmental stage of VMB, and the number of mummies and parasitoid species found at the various locations on the vine were recorded.

Trap Sampling: The third group of vines (20 vines total) was used to investigate VMB movement through space and time, and to determine the general pattern of activity of VMB males and parasitoids. For each vine, the loose bark was removed from portions of the trunk and cordon in February. The exposed areas were then wrapped with duct tape and a single width (1.91 cm) of double-sided sticky tape placed on top of the duct tape. There was one tape placed on the trunk, and one on the cordon. In the canopy of each vine, a 7.6 cm × 12.7 cm yellow sticky card was hung. The sticky tapes and cards were replaced every 4 weeks and returned to the laboratory to record the number of each stage of VMB and the number of each parasitoid species.

A second study was begun to better determine VMB seasonal abundance and movement throughout the vine. Samples were taken to determine the effect of management practices and environmental factors on VMB densities. Eight vineyards were surveyed for VMB to locate suitable sites to experimentally manipulate VMB densities and follow resident natural enemies (this study was conducted by UC personnel).

San Joaquin Valley. A series of field and laboratory studies were begun in the SJV. To evaluate VMB age structure and parasitoid impact through space (e.g., where on the vine) and time (e.g., when during the season). Field studies were conducted from May to the present in Thompson Seedless cv. raisin vineyards near Sanger (Fresno County), California.

In a 6-year-old block with canes trained to an overhead trellis system for dried-on-the-vine (DOV) raisins, 30 vines were randomly selected from a block of 237 vines. All 30-vines were examined weekly with non-destructive techniques. This means, in contrast to the CV study, the same vines were searched repeatedly for VMB – removing only mummies and dead VMB. Since we found all stages of VMB from root through the trunk and canes, we modified our sampling technique slightly from the non-destructive sampling method developed for grape mealybugs (Geiger & Daane 2001). Each vine was divided into 7 different sections – ground (included a section about 5 cm below the ground level to about 30 cm above), trunk, armpit, old cane, new cane, leaf and grape bunch (when present). On each weekly sample, we spent 3 minutes per section searching for VMB on each of the 30 vines. All the VMB present outside the bark as well as those underneath the loose bark (lifting the bark gently caused only a minimum disturbance to the mealybugs) were recorded by development stage. The old mummies, when present, were counted and removed, and the new mummies (e.g., live, unemerged parasitoid) were taken to the laboratory, placed individually in gelatin capsules, and held for parasitoid emergence. Parasitoids were identified to species or genus and percentage parasitism was evaluated by a weekly mummy count (e.g., old mummies were removed) compared to live VMB (this is a more conservative measure of parasitism than that used in CV samples.)

In July, we destructively sampled six vines in the DOV raisin blocks. This means that we removed all the leaves, canes, and bark from the trunk, separated by the 7 sections (lower- mid- and upper-trunk, canes, spurs, leaves and fruit) and brought the collected material to the laboratory for dissection. All VMB and their natural enemies found were recorded. All live material was placed in emergence boxes and held for 1 month for parasitoid emergence.

At harvest time, economic damage for each of the 30 DOV vines was rated using a 0—3 scale: 0 means no mealybug damage, 1 means honeydew present but the bunch is salvageable, 2 means honeydew and mealybugs present but at least part of the bunch is salvageable, and 3 means a total loss. Since we knew that there were higher rates of mealybug infestations on bunches touching the wood (Geiger et al. 2001), we chose only those bunches that touched the wood: 3 from the mid section of the vine (just above the main trunk) and 3 each from the left and right hand side arm.

Additional destructive samples (similar to work in CV) were taken to evaluate VMB distribution on the vine, seasonal abundance, age structure and resident parasitism. Two Thompson Seedless raisin vineyards were sampled during the summer period. Both were 30-40 year-old vines, which naturally had a larger trunk structure than the younger DOV vines. This becomes important because the vine structure and pruning system more closely resembled that found in the table grape block sampled in the CV. In each block, 50 leaves with VMB (about 100 individuals) were collected weekly and taken to the Kearney Agricultural Center insectary (where they were quarantined). We also made monthly collections (May – January) of 50 later-stage mealybugs found under the loose bark of the trunk and cordon. Finally, in November we began bi-weekly collections of 50 later-stage VMB from the roots. All mealybugs collected were removed from the leaves, trunk, bark or root sections with a paintbrush and placed individually in gelatin capsules where they were held for 1 month. All the parasitoids that emerged were recorded by species and sex (as well as mealybug stage attacked).

The data generated from both non-destructive and destructive samples were analyzed to determine patterns in VMB age structure and parasitism. Similarly, the percent parasitism, parasitoid species composition, parasitoid sex allocation according to the size of the host were calculated and presented in graphs. Data presented are means (± SEM) from each vineyard block. After more samples are collected, distribution will be measured in two ways. First, means and variances of mealybug populations will be used to perform a Taylor's Power Law analysis (Taylor 1961). Then, spatial distribution will be examined visually by measuring mealybug populations in 2 separate vineyard blocks of ~100 vines.

Laboratory Studies. A colony of VMB was started from 5 ovipositing females collected from vineyards near Sanger (Fresno County), California. These individuals initially were reared on sprouted potatoes enclosed in glass jars, the mouth of each jar was tightly sealed with muslin cloth. Females were watched every day until they finished laying eggs and died naturally. Crawlers established themselves on sprouting potatoes. For next generation of VMB, we placed clean potatoes on the top of each jar and provided a small opening for VMB crawlers to move onto new potatoes or squash. In this manner we were able to establish same age cohorts (e.g., VMB of similar size and developmental stage) for laboratory studies.

On 7/21/2000, four containers (with a total of 12 females) were placed in an incubator set at 27 ± 2^0C and another four containers were placed at 21 ± 2^0C. Mealybugs were monitored everyday to determine VMB density, age structure, number of developmental stages and development time. This work will be expanded in 2001 to investigate the influence of different temperatures on VMB, establishing temperature thresholds and degree-day development models.

Using some of these laboratory VMB colonies, we have begun studies of *Anagyrus pseudococci* biology. Note here that the parasitoid used was collected in August in the SJV, not from imported material (González 1998). *Anagyrus pseudococci* was field collected in August 2000 as mummies, which were held individually in gelatin capsules until the parasitoids emerged. Ten pairs of male and female *A. pseudococci* were placed with a mixture of third and pre-ovipositional VMB in a plastic container with mesh-lid. A few drops of honey were smeared on the rearing container's inner wall as a supplementary food for *A. pseudococci*. The fecundity and longevity of these parasitoids were recorded. We have also begun studies of *Anagyrus* and *Leptomastidea* interactions to determine which combination of parasitoids may be most effective (note here that the real tests comes from field studies, as are being conducted in the CV).

RESULTS:

Coachella Valley. *Refuge Site Sampling*: All life stages were found under the wraps with large and medium VMB predominating. On the trunk, the density of VMB peaked in May with a second, smaller peak in late August (Fig. 1). On the cordon, the peak in VMB density occurred in April through May with a second, smaller peak in late August (Fig. 2). The reason for the smaller peak in August is not clear, but may be an artifact of sample size. In 11 of the 20 wraps, no VMB were found.

Parasitoids were found in VMB that used the wraps as refugia. Adult *A. pseudococci* and *L. abnormis* emerged from VMB mummies collected in the March through June and November sampling dates (Table 1). In July, August, and October, the densities of VMB under the wraps was much lower than earlier in the season, despite the small increase in the VMB density in August (Figs. 1 and 2).

Field Count Sampling: The seasonal population dynamics of VMB found on the trunks and cordons of 5 vines, revealed using the field count method, was similar to that seen in the refuge site study (compare Figs. 1 & 2 to 3 & 4). There was a peak in density in April and May, with a second peak in August. For the August peak, 3 out of the 5 vines had very large densities of VMB, and 2 vines had no VMB. The reason for this dichotomy in VMB populations is not immediately clear, although it may be related to small sample sizes and the clumped nature of the distribution of VMB within a vineyard.

VMB was found only sporadically on root samples (Table 2). In May and August when substantial numbers of VMB were recovered on roots, these individuals were found on one or two heavily infested vines and were not evenly distributed throughout the sample. In general, VMB does inhabit the roots of grapes, but the extent of its habitation is influenced by many factors such as ant activity, soil texture, temperature and irrigation regimes.

Mummies and/or parasitoids were recovered from February through October from samples collected on the trunk and cordon sections (Table 2). Both introduced parasitoids were recovered with *A. pseudococci* being recovered a few months prior to *L. abnormis*. It is not known if recovered *A. pseudococci* represent individuals that are progeny of the introduced or the native population. No parasitoids were recovered from the VMB found on the roots.

Trap Sampling: The seasonal dynamics of the VMB populations determined from trap collections on the trunks and cordons differed slightly than the seasonal dynamics revealed using the other sampling methods. On the trunk, the densities of small and medium VMB peaked in June, and decreased dramatically in July (Fig. 5). The densities of large VMB and male VMB are not shown because very few were collected on the tapes. The few that were found were collected in June, July, October, and November.

On the cordon sticky tape traps, the peak in density of small VMB occurred in May, and the peak in medium VMB in June (Fig. 6). For the small VMB, this peak is one month earlier than that seen on the trunk. This suggests that either the larger VMB are moving out on to the cordon from February through April, or there is a resident VMB population on the cordons year-round. Combining the data from this sampling method with that from the others, there appears to be a small resident population on the cordons in early spring that is reinforced by movement of other VMB from the trunk (compare Figs. 1-6). All life stages of VMB on the cordon traps decreased in July. On the cordon tape traps, a few mummies and a parasitoid were collected (June sampling date – 5 mummies and 1 *A. pseudococci*; August sampling date – 2 mummies). It is interesting to note that there is no increase in VMB density in August on the tape trap samples as was seen with the other sampling methods. The reason for this lack of increase is not known.

The seasonal dynamics of male VMB on the yellow sticky cards was consistent with the seasonal dynamics of other life stages. The peak male VMB density occurred in June with a smaller, second peak in October and November (Fig. 7). The second peak was most likely the result of the increase in density of VMB immatures in August (compare with Figs. 1-4). The peaks in VMB male trap catches should be offset in time from the peaks in the immature stages of VMB because time is needed for VMB to complete development.

The pattern of trap catches of adult parasitoids was also consistent with the other data (Fig. 7). The parasitoid, *A. pseudococci*, was captured in low numbers in March and April with a peak in density in June. There was a slight increase in density in October and November (Fig. 7). For the other parasitoid, *L. abnormis*, the densities did not begin increasing until May with a peak density occurring in July. As with the other parasitoid, there was a slight increase in density in October and November (Fig. 7). Combining this data with the data from the other studies suggests that *A. pseudococci* begins parasitizing VMB a little earlier in the season than *L. abnormis*. In addition, there appears to be resident populations of both parasitoids in this vineyard. We note that augmentation of 1,000s of parasitoids was conducted at a neighboring block and some of these adults may have moved into our sample block.

San Joaquin Valley. While there were similarities in VMB seasonal abundance and distribution between CV and SJV, it is the differences that might better explain VMB pest status. In SJV vineyards, we observed three distinct peaks of adult VMB during the summer and fall seasons (Fig. 8a). Our sampling began in May and we believe that there was a prior generation (or 2) that winter and spring. We are continuing to take samples throughout the winter (2001) and will be able to answer these questions next year. What is surprising is that more adult peaks were found in the SJV than the CV. Combined with other field observations suggests that VMB may have upper temperature thresholds at which either development slows or VMB mortality is so much higher that individual generations are hidden during the summer months as the population density declines.

The VMB seasonal abundance pattern did have some similarities between CV and SJV vineyards. The adult population in June was higher than that of August and September-October generations (Fig. 8a). Adults were present in November and December, but they are in very low numbers and most were located on the roots. Crawlers remained visible during late spring, summer and early fall; they slowly disappeared after harvest (Fig. 8b). Crawler density typically increased 3-4 weeks following each adult peak.

VMB were present in all ground samples (including the roots about 5 cm below the soil surface) throughout the season. Unlike CV samples, VMB density on the trunk near or below the soil surface remained high even when there were leaves and fruits present (Fig. 11). Movement or transition of VMB from trunk to leaves occurred in mid June and then to bunches about a week later (once the berry diameter was ca. 1.5 cm or larger). Throughout the growing season, a significant proportion of VMB remained on the canes. After harvest, VMB density declined; although a low number of VMB were always present during the winter, most were found on the roots or the trunk section near the soil surface. We found similar distribution patterns of VMB on the older vines (used in destructive sampling). During the growing season, VMB (2nd instars through ovipositing females) were present throughout on the truck region and roots. Especially on older vines, VMB were present underneath a thick layer of bark (in trunk region). One new refuge site found was the feeding holes of some lepidopteran larvae, which bored into the truck section. VMB were often found inside the small, protected spaces, adding another layer of protection from abiotic (e.g., weather) and biotic (e.g., natural enemies) mortality factors.

In all samples, we found a dramatic VMB reduction in August and September (Fig 9). This reduction came much later than that observed in the CV and was not accompanied by an increase in summer temperatures. In fact, VMB of all stages were found throughout the summer feeding on leaves and canes in exposed locations – suggesting that SJV temperatures had little affect on VMB densities. In contrast to CV, we found a much later (e.g., beginning in August) and greater level of parasitoid activity, which may be responsible for VMB's decline in fall.

Perhaps the most significant difference between CV and SJV was the level or resident parasitoid activity. First, we note that the SJV sample sites have never had VMB parasitoids released into them. Further, these sites are maintained by cooperative growers that have used extensive chemical controls in all blocks bordering the sample plots in order to prevent further spread of VMB in the SJV. Therefore, any parasitoids that reach the plot most likely came from citrus mealybug in backyard plantings (the vineyard sites are not near citrus orchards) and had to cross treated blocks without VMB to reach the unsprayed plots. With that as background, we found that parasitism of exposed VMB was > 80% by August (Fig 11) resulting in a pre-harvest reduction of VMB. Two parasitoid species were recovered, *A. pseudococci* was the dominant parasitoid, attacking 2nd instars through adults, and an *Allotropa* (a presumed hyperparasite) species was present. *Anagyrus pseudococci* was first observed in the first week of August. By mid August percentage parasitism rose from 2 to 80%. Afterwards, parasitoid activity remained high on all VMB on leaves and canes. Mealybugs collected in December and January are still in the process of rearing and no parasitoids from these VMB have emerged to date. Further, these mealybugs were collected from the deep pockets (feeding holes of moth larvae) underneath the barks or roots.

Laboratory studies. There was a prominent effect of temperature on VMB development time. Development time of mealybug was slowed down by 50% when the rearing temperature went down from 27 to 21^{0}C. The time (days) required to complete each instar stage at both temperature regimes are shown below. We did not count the number of eggs per ovisac from these laboratory reared mealybugs, however, we counted the number of eggs per ovisac from field collected mealybugs (n = 10) in May 2000. We found a range of 300 - 450 eggs/ovisac.

We were successful in rearing both VMB and *A. pseudococci* in our laboratory. We produced one generation of VMB per 4 weeks and *A. pseudococci* per ca. 3 weeks. This research is currently being conducted (during winter and spring) and we are in the process of separating the colonies into different controlled-temperature cabinets.

From this work, age-specific mortality will be compared between temperature regimes. Mean body size and mean instar will be plotted against time for each treatment, and compared between temperatures. Development rates (1/days to maturity) will be plotted against temperature for each species. Lower temperature thresholds for development will then be estimated using linear extrapolation and upper temperature thresholds will be estimated using nonlinear curve-fitting.

Degree-day stadial time will be calculated for each species and instar. Total fecundity and mean egg size (or first instar size for longtailed mealybug) will be compared between temperature treatments and between species using multiple ANOVA.

At 27±2^{0}C

Date (days)	**Mealybug stage**	**Total number**
FIRST GENERATION		
7/21/00 (0)	Eggs (near to hatch stage)	12 ovisacs
7/24/00 (3)	Crawlers	
7/31/00 (7)	1st instars (settled)	
8/4/00 (4)	2nd instars	
8/8/00 (4)	3rd instars	
8/15/00 (7)	Preadults	
8/21/00 (6)	Ovipositing females	539
SECOND GENERATION		
8/21/00 (0)	Eggs	12
8/30/00 (9)	Crawlers	
9/5/00 (6)	1st instars (settled)	
9/8/00 (3)	2nd instars	
9/12/00 (4)	3rd instars	
9/19/00 (7)	Preadults	
9/26/00 (7)	Ovipositing females	612

At 21±2^{0}C

Date (days)	**Mealybug stage**	**Total number**
7/21/00 (0)	Eggs (near to hatch stage)	12 ovisacs
7/24/00 (3)	Crawlers	
8/8/00 (15)	1st instars (settled)	
8/15/00 (7)	2nd instars	
8/24/00 (9)	3rd instars	
9/10/00 (17)	Preadults	
9/18/00 (8)	Ovipositing females	516

CONCLUSIONS:

Work conducted in the organic block in the CV show a peak in VMB density in mid to late spring followed by a dramatic decline in mid summer. The data were consistent with the idea that there was a resident population of VMB on all parts of the vine throughout the year. The dramatic increases in density in the spring were most likely the result of increased reproduction and movement of the VMB throughout the vine. The role of the VMB on the roots in overall seasonal dynamics requires further study because many factors may impact that role. The two parasitoids, *A. pseudococci* and *L. abnormis* appeared to have established resident populations within this vineyard. The densities of both parasitoids responded to changes in VMB density and *A. pseudococci*, appeared to be active earlier in the season than *L. abnormis*.

Our most important contribution in the 2000 season was the contrast between VMB seasonal abundance and parasitism between CV and SJV regions. There was a similar movement from the roots and lower trunk sections in winter to the upper trunk and grape bunches as the season progressed. However, the timing of this migration and the build-up of the population were different. As expected, peak adult abundance began later in the SJV (probably due to lower spring temperatures). However, in the SJV there were more spring and summer adult "peaks." We are still collecting data on VMB development to determine the cause of these peaks. Also, in the SJV the VMB remained exposed on leaves and canes for all of the summer and into the fall season. It may be this exposure that led to higher levels of VMB parasitism. While no parasitoids have ever been released in or near these vineyards for VMB control, percentage parasitism was between 80-95% for exposed VMB collected in August through October. Data are still being analyzed on the effectiveness of parasitoids on VMB underneath the bark and on the roots and during the winter months. Initial data collection indicates a steep decline in parasitoid effectiveness in these vine regions.

Contrasting the grape mealybug the VMB shows why this new pest is potentially more damaging. The grape mealybug overwinters most commonly under the bark on the upper third of the grape vine trunk (often on the spurs) as eggs or crawlers (see Geiger et al. 2001). They boil out from under the bark during the first few weeks of warm weather, just before bud break, and settle around the new buds, often under the bud scale or in adjacent bark crevices. After bud break, a few moved up onto the new foliage and canes, but most stayed at the base of the cane to complete development. The first grape mealybug generation reaches the adult stages in late May/June and then move back to the protected bark to lay their eggs. The next generation of crawlers begin emerging in late June. These crawlers settle primarily on the spurs, with some moving into the bunches by late July. There they develop rapidly and begin laying eggs in late August, continuing through September and October for the third, overwintering generation. This pattern shows fewer grape mealybug generations, a slower population increase, and a population that is established higher on the vine canopy. All these factors may better enable parasitoids to suppress grape mealybug populations before harvest.

The northern spread of VMB and development of control programs must be taken seriously in order to protect the billion-dollar grape industry. The research is timely because of complementary research efforts proposed or currently underway, which include the use of pheromones for mealybug sampling (J. Millar), effects of cover cropping on ants (W. Bentley), parasitoid augmentation (D. Gonzalez), ant control (J. Klotz and D. Gonzalez) and insecticide controls (W. Bentley). Our research will provide information on pest and natural enemy ecology that is complementary to each of these VMB research programs. A description of seasonal VMB age structure or resident parasitoid activity is essential to both of these programs. Research in Coachella has determined that of the imported parasitoids, *A. pseudococci* and *L. abnormis* appear to be the most effective (Gonzalez 1998) and are currently being tested in mass-release programs in the Coachella Valley (Griffith et al. 2000). Because we found resident *A. pseudococci* to be so effective in the SJV, we believe that studies using methodology from molecular biology need to be performed to determine differences between the native and imported parasitoid populations. In both CV and SJV studies, parasitoid specimens have been stored for later molecular analyses.

BUDGET SUMMARY:

UC – A total of $49,286 was contributed for UC research at the KAC laboratory and SJV and CV field sites. Salary positions include a post-doctoral (Raksha Malakar-Kuenen) appointment at 50% (ca. $19,000 w/ benefits), an SRA III (Glenn Yokota) at 10% (ca. $5,750 w/ benefits), and two seasonal Laboratory Assistants (ca. $15,000 w/ benefits). Travel costs include five trips to the Coachella Valley with hotel accommodation (ca. $3,000), shared car rental for a "lab vehicle at KAC (ca. $3,000), and shared travel cost reimbursement for KMD (Berkeley to Fresno) (ca. $2,000). Supplies included minor field equipment (pruning shears, paper and plastic bags, etc.) and insectary supplies (squash, potatoes and cages) (ca. $2,000)

CDFA - A total of $7,036 was contributed for CDFA directed research. The money was used to defer the cost of travel for Drs. Godfrey and Ball. A total of 9 trips were made to the Coachella Valley. The cost for each trip was as follows: air fare – Sacramento to Ontario - $320 ($160/person); car rental - $120 ($40/day for 3 days); and per diem - $600 ($300/person; $100/day/person for 3 days.) Total cost of all trips $9,360. Contribution from CTGC - $7,036; Contribution from CDFA - $2,360.

REFERENCES:

Geiger, C. A. and K. M. Daane. 2001. Seasonal movement and sampling of the grape mealybug, *Pseudococcus maritimus* (Ehrhorn) (Homoptera: Pseudococcidae) in San Joaquin Valley vineyards. J. Econ. Entomol. (in press – Jan Feb issue)

Geiger, C. A., K. M. Daane, and W. J. Bentley. (2001) Development of a sampling program for improved management of the grape mealybug. Calif. Agricul. (Accepted August 2000).

González, D. 1998. Biological control of the vine mealybug in the Coachella Valley. Calif. Table Grape Comm. Ann. Rep. Vol.. Vol. 26: 4 pages

Griffiths, H. Barcinas, J., González, D. and J. Klotz. 2000. Mass release of parasites of vine mealybug (vmb) colonization or augmentation strategies. Calif. Table Grape Comm. Ann. Rep. Vol. 28: 12 pages.

Table 1. The total number of emerged mummies and adult parasitoids, and percent parasitism found in 20 wraps in the refuge site study in the Coachella Valley in 2000.

	Trunk Wraps		Cordon Wraps	
Date	Number[a]	% Parasitism	Number[a]	% Parasitism
3/26	1 EM	T - 3.3	0	-
4/24	0	-	1 Ap	Ap – 2.5
5/23[b]	4 AP; 1La	Ap – 4; La – 1 T - 4.95	1 EM, 1 Ap	Ap – 3.3 T - 6.25
6/22	3 EM, 2 Ap	Ap – 9.1 T - 22.7	1 Em, 1 Ap 1 La	Ap – 6.3, La – 6.3 T - 18.8
7/24	0	-	0	-
8/31	0	-	0	-
10/5[c]	0	-	0	-
11/7	1 EM	-[d]	0	-

[a]EM = emerged mummy; Ap = *A. pseudococci*; La = *L. abnormis*; T = Total
[b]Extra leaf sample taken – 1 Ap and 1 La emerged
[c]Extra brown cane sample taken – 3 Ap emerged
[d]For the 20 trunk wraps, only 1 emerged mummy and 1 large VMB were found.

Table 2. The total number of intact mummies, emerged mummies, and adult parasitoids from the trunk and cordon, and the total number of each life stage of VMB found on the roots in the field count study in the Coachella Valley in 2000.

	Trunk[a]		Cordon[a]		Roots[a]
Date	Mummies	Parasitoid	Mummies	Parasitoid	VMB
2/24	0	0	1 MU	1 Ap	1 L
3/28	1 MU	0	2 EM	0	0
4/25	1 EM	0	0	1 Ap	1 L
5/24	1 MU	2Ap & 1 La	1 EM & 3 MU	8 Ap	15S, 5M, 15L, E
6/22	2 EM, 1 MU	6 Ap	4 EM & 6 MU	0[b]	0
7/25	0	0	2 Mum	0	0
8/31[c]	3 MU	0	2 Mum	0	17S, 14M, 42L, E
10/3[d]	0	0	0	0	0
11/7	0	0	0	0	0

[a]MU = mummy, EM = emerged mummy, Ap = *Anagyrus pseudococci*, La = *Leptomastidea abnormis*, S = small VMB, M = medium VMB, L = large VMB, E = VMB eggs
[b]*Chartocerus* spp. reared from mummies. These are hyperparasitoids.
[c]Extra samples taken: Trunk below soil line (but not on roots) – 7S, 2M, 50L, Eggs – no parasitoids recovered; Brown cane – 45S, 51M, 5L, 1 EM, 1Mum – reared out 1 Ap and 1 La; Green cane – 21S, 31M, 38L, 3 Mum – reared out 2 Ap and 2 La
[d]Extra sample taken: Grape cluster – 24M, 56L, 4 Mum, numerous small VMB and eggs reared – 40 Ap and 1 La.

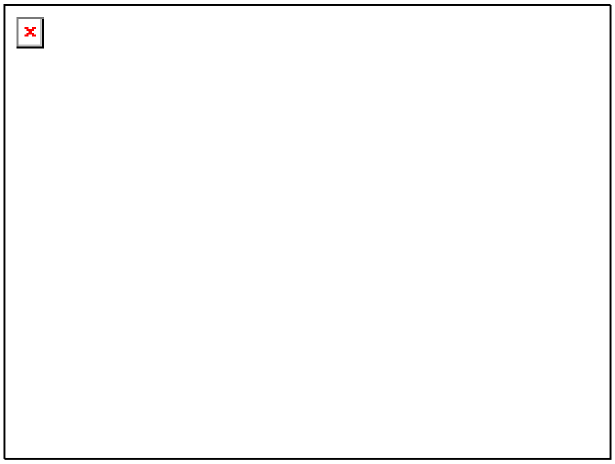

Figure 1. The total number of all life stages of VMB found under the wraps on the trunk used in the refuge site study in the Coachella Valley in 2000.

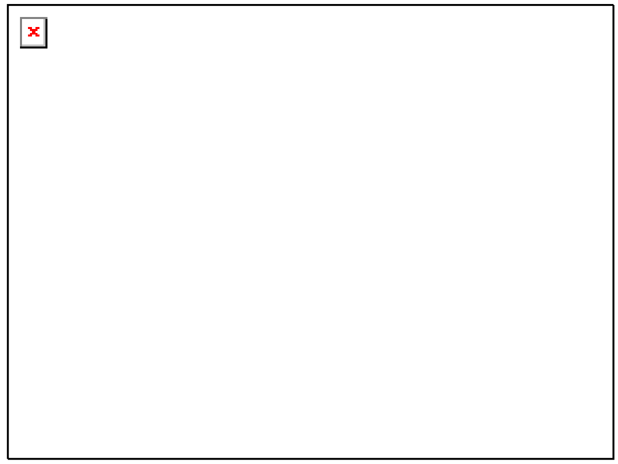

Figure 2. The total number of each life stage of VMB found under 20 wraps on the cordon in the refuge site study in the Coachella Valley in 2000.

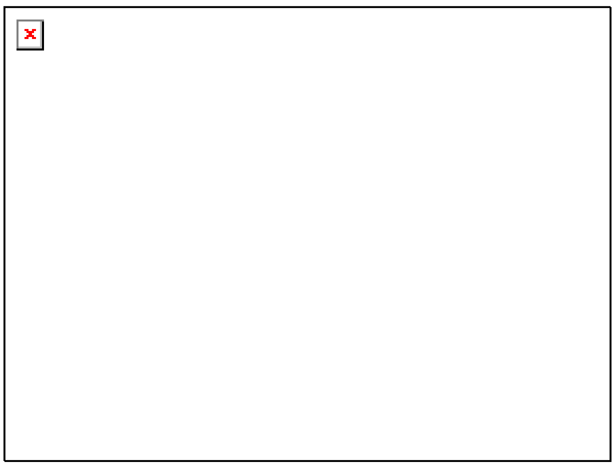

Figure 3. The total number of each life stage of VMB found on the trunks of 5 vines in the field count study in the Coachella Valley in 2000.

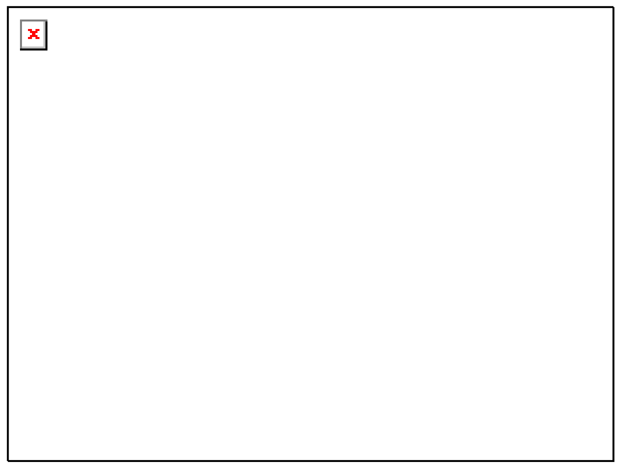

Figure 4. The total number of each life stage of VMB found on the cordon on 5 vines in the field count study in the Coachella Valley in 2000.

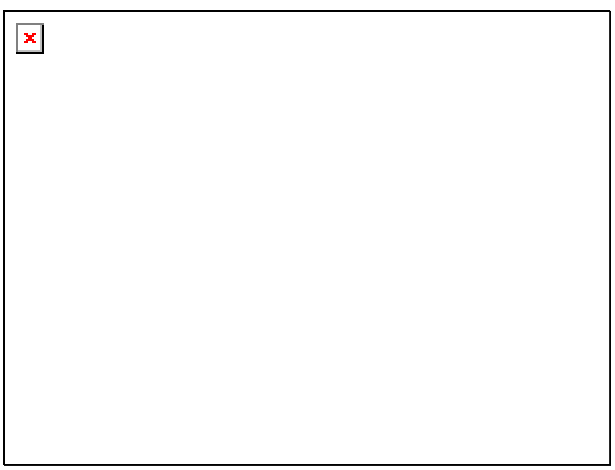

Figure 5. The total number of small and medium VMB per sq. cm of sticky tape trap found on trunks in the Coachella Valley in 2000.

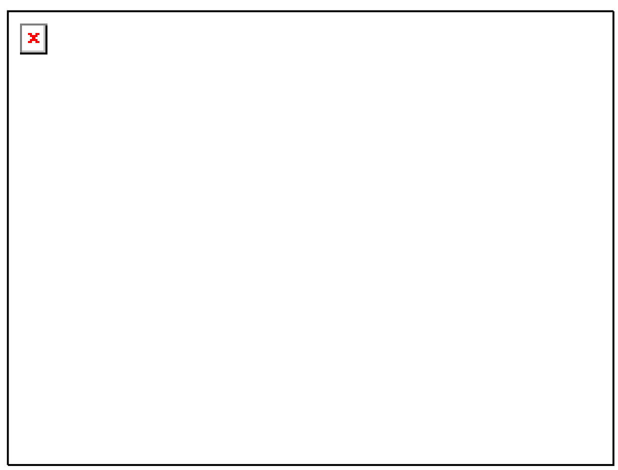

Figure 6. The total number of each life stage of VMB per sq. cm of sticky tape trap found on cordons in the Coachella Valley in 2000.

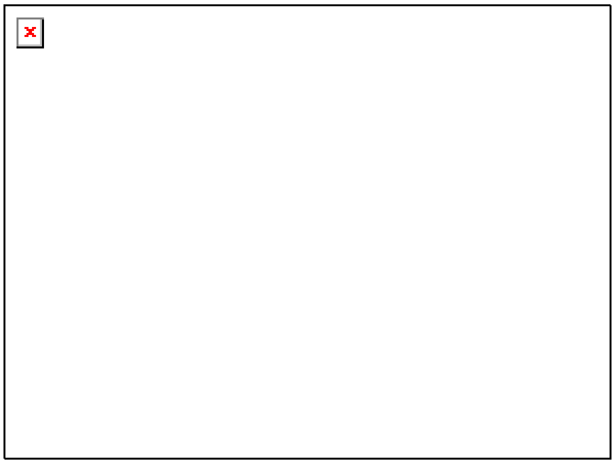

Figure 7. The total number of VMB males and parasitoid adults found per yellow card placed in the grape canopy in the Coachella Valley in 2000.

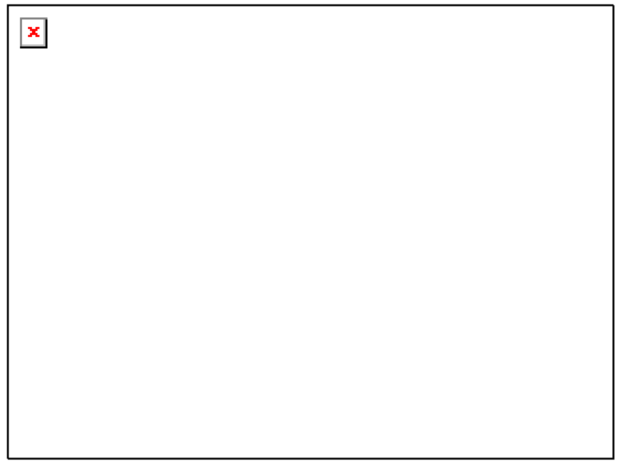

Figure 8. Vine mealybug (A) adult and (B) crawler density as measured from weekly, nondestructive samples of 30 vines in a raisin vineyard. Del Rey, CA, 2000.

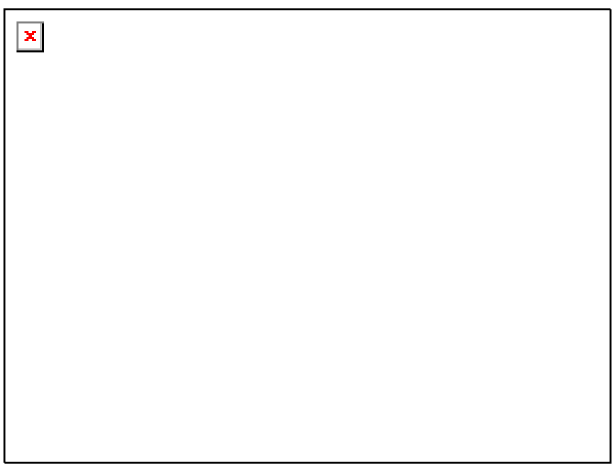

Figure 9. Total number of vine mealybugs as measured from weekly, nondestructive samples of 30 vines in a raisin vineyard. Del Rey, CA, 2000.

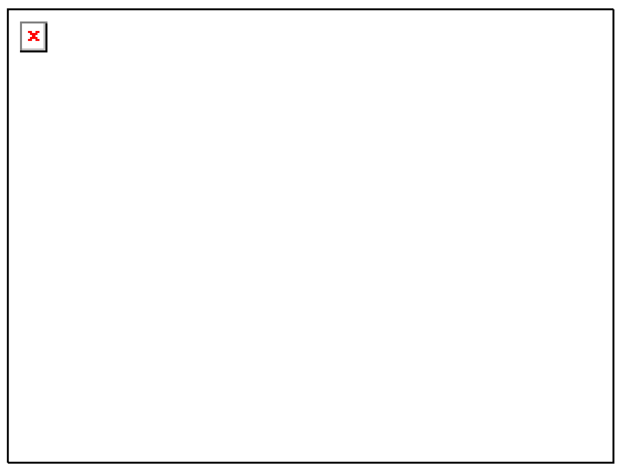

Figure 10. Percentage parasitism of vine mealybug shows high parasitoid activity after August. Over 95% of the parasitoids recovered were *Anagyrus pseudococci*. The increase in parasitism corresponded to a dramatic decrease in vine mealybug density. Del Rey, CA, 2000.

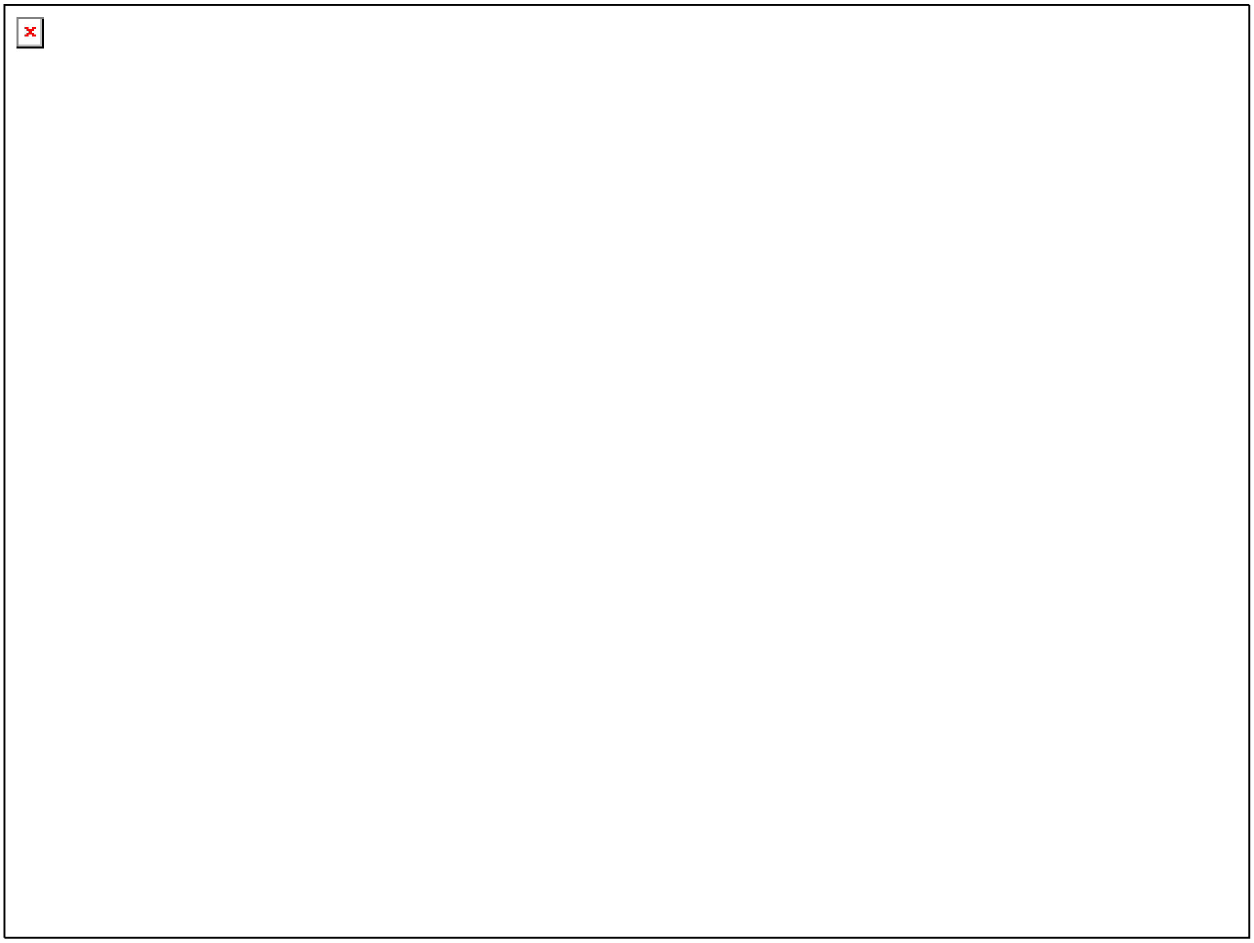

Figure 11. Vine mealybug population distribution (%) throughout the vine shows a continual presence of mealybugs on the trunk and on or under ground. Data collected from nondestructive samples of 30 vines in a raisin vineyard. Del Rey, CA, 2000.