

Biology and Control of the Grape Bud Beetle, *Glyptoscelis squamulata* (Coleoptera: Chrysomelidae), in Southern California Table Grapes

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J. Econ. Entomol. 77: 1327-1334 (1984)

ABSTRACT *Glyptoscelis squamulata*, often called the grape bud beetle (GBB), is indigenous to North America. During the 1920's and into the late 1940's this univoltine species was considered the major pest of fresh table grapes in the Coachella Valley of southern California. Adult beetles feed on emerging buds and eat the immature leaves and flower cluster primordia. The larval stages are spent in the soil feeding on roots. The beetle has reappeared recently as a major pest of grapes. Adult emergence from the soil was monitored in five Coachella Valley vineyards. Peak emergence occurs in the last three weeks of March. Early-budding varieties such as 'Perlette,' 'Cardinal,' and 'Beauty Seedless' may suffer less damage than the late-developing 'Thompson Seedless.' Adults are active at night, making detection difficult with a flashlight. We found that the beetles glow a bright silver blue under ultraviolet light; detection can be made in seconds. Feeding and oviposition studies were conducted. Phosmet, azinphosmethyl, and dimethoate were applied for control of adult beetles at 1.41, 1.41, and 2.25 kg (AI)/ha, respectively. They gave statistically similar results and caused significantly higher mortality than diazinon and carbaryl, which were both applied at 1.80 kg (AI)/ha.

Glyptoscelis squamulata Crotch (Coleoptera: Chrysomelidae), often called the grape bud beetle (GBB), is indigenous to North America and occurs throughout the western United States (Krauss 1937). In 1922, adults were found causing serious damage to new buds in the Las Vegas Valley vineyards, Clark County, Nev. (Creel 1922). The following year the beetle was discovered in Coachella Valley vineyards in southern California (Bottel 1925). Later reports mentioned adult beetles causing damage to vineyards in the Imperial Valley (Urbahns 1926) and San Joaquin Valley, Calif. (Donohoe 1936). However, the most serious damage occurred in the Coachella Valley, where some vineyards suffered 80% crop loss (Ebeling 1939).

Very little is known about the biology and phenology of this univoltine species. The larval stages are spent in the soil feeding on roots. Adults feed on the foliage of a variety of native and introduced plants in addition to grapevines (Krauss 1937, Ebeling 1939). Egg clusters are deposited in cracks in and under the grape bark. On hatching, the larvae drop to the ground and immediately enter the soil. Larvae have been found 60 to 90 cm below the soil surface (Quayle 1938) but more often at 30 to 40 cm. Stafford and Doult (1974) commented that the larvae do not seem to cause any noticeable loss in vine vitality, but there are no published data to substantiate this.

Adult beetles cause fruit loss by feeding on opening buds and eating the bud center, which contains the immature leaves and flower cluster

primordia. One or both lateral growing points of the bud are often left intact, but these are usually sterile (Winkler et al. 1974). Once new shoots are 2 to 3 cm long, damage due to feeding is negligible.

Ebeling (1939) published the last work containing new information on the grape bud beetle. This report mainly concerned controlling bud damage. Control measures included treatment with lead and calcium arsenate, and the use of barriers, either sticky banding material or paper bags, to keep the beetles away from the opening buds.

The GBB was no longer considered an important pest of grapes in the Coachella Valley by the early 1950's, although occasional damage was reported (State of California 1959, 1963). Many current grape growers and pest-control advisors had not seen the GBB until recently. The marked decrease in GBB abundance may have been due to the early-season use of DDT to control a leafhopper, *Erythroneura variabilis* Beamer, and citrus thrips, *Scirtothrips citri* (Moulton). Also, a nematocide, triadimefon (1,2-dibromo-chloropropane) (DBCP), may have been effective in keeping the soil-inhabiting larvae at low levels.

While the GBB is considered to be a minor pest of grapes in most of California, growers in the Coachella Valley have recently noticed increased damage due to the beetle. The withdrawal of DDT for use on grapes in 1972 and DBCP on all crops in the United States in 1977 may be responsible for the increase. In order to understand and man-

age this potentially serious pest better, we conducted a study of its biology, phenology, and control.

Methods and Materials

Adult Emergence, Activity, and Dispersal. Pink bollworm emergence cages (Reynolds and Leigh 1967) were used to monitor adult GBB emergence from the soil. The cone-shaped aluminum screen cages were 0.92 by 0.92 m at the base and 0.92 m tall. A 473-ml Kerr mason jar, 7.5 cm in diameter and 10.5 cm deep, containing a small, cone-shaped, wire screen trap, was placed on top of each cage. Soil was packed around the base of each cage to prevent beetle escape.

To determine the efficiency of the emergence cages in trapping GBB adults, three cages were set up on bare ground in 1982. Twenty, 30, and 40 adults were dropped into separate cages. Twenty-four hours later, 90% of the beetles were found in the mason jar traps; 100% were found after 36 h.

Adult emergence from five Coachella Valley vineyards was monitored from February to April 1983. There were two 'Thompson Seedless' vineyards and one each of the 'Perlette,' 'Cardinal,' and 'Beauty Seedless' varieties. Ten to 15 emergence cages were placed under the trellis in different vine rows in each vineyard. All cages were monitored twice weekly and the number of beetles counted and recorded.

Observations of adult activity were made in several Coachella Valley vineyards during the day and at night. Both white and ultraviolet light were used for night observations.

Movement of adults between early- and late-budding grape varieties was studied by marking adults with fluorescent dust. In this paper, bud break is defined as the stage of bud development when green tissue becomes visible. A bright yellow dust pigment, Type 2267 (USR Optonix, Inc., Hackettstown, N.J.), was found to persist well on GBB adults marked in the laboratory. The two vineyards selected were the 'Perlette' and 'Thompson Seedless' (1) vineyards used in the adult emergence studies. The two vineyards were separated by a 9.2-m wide dirt road. At the time of the study, the 'Perlette' vineyard had completed bud break while the 'Thompson Seedless' had ca. 20% open buds.

During the day in the last week of February 1983, ca. 2,000 to 2,500 adult GBB that could be found hiding in the space between the grape stakes and crossarms or in cracks in the wooden supports in the 'Perlette' vineyard were marked with fluorescent dust pigment Type 2267 as described by Stern and Mueller (1968). The marked adults were in a 200-by-100-m area adjacent to the 'Thompson Seedless' (1) vineyard. The following week, a handheld, portable, long-wavelength, ultraviolet lamp was used to search out marked beetles in both vineyards.

Adult Feeding and Damage. To determine the extent of leaf damage caused by adults feeding after bud break, 5, 10, and 15 beetles were confined on three different grape shoots. Organdy bags, 53.3 cm long and 25.4 cm wide, were placed around each shoot, and the beetles added to the bags. Each shoot was ca. 46 cm long with a single floral cluster. The bags were examined 8 days later. The number of live beetles was recorded and the extent of leaf loss was estimated for each bag.

Ovarian Development, Oviposition, and Egg Development. All adults used in laboratory experiments were collected from field emergence cages in the 'Perlette' vineyard. No reliable method of sexing the adults was found. Therefore, females were selected from copulating pairs. Because males often remained astride females for long periods of time without copulating, only pairs actually in copulo were used in the experiments.

All adults present in the mason-jar traps in the 'Perlette' vineyard emergence cages were removed 28 March. Twenty-four hours later, the cages were again inspected and the newly emerged adults were collected and brought into the laboratory. Eleven females were placed in a 5-cm-deep, 9-cm-in-diameter, 237-ml cardboard container. Three males were added in case any original mating was not completed. Folded cardboard strips with their open ends stapled were provided for oviposition sites. The container was held at 15.5°C. Another container with 12 females was set up in an identical manner and held at 21.1°C. Small, fresh leaves of Boston ivy, *Parthenocissus tricuspidata*, were provided daily for food and moisture. Oviposition strips in each container were examined daily and any eggs were removed and counted. Every 3 to 4 days, two females from each container were removed and dissected.

The following scale was used to rate ovarian development for each dissected female. In stage I ovaries, eggs were pale or not seen at all. Stage II ovaries had yellow eggs, ca. half the size of mature eggs which are ca. 2 mm long and 0.5 mm wide. Stage III ovaries contained mature or nearly mature eggs, remaining in individual ovarioles. In stage IV ovaries, all or nearly all eggs were in the egg-calyx, while stage V ovaries had only a few eggs in the egg-calyx and no mature eggs in ovarioles, indicating recent oviposition.

Recently emerged adults were held at 15.5°C for 9 days. Five copulating pairs were placed in each of two 237-ml cardboard containers. Two other containers were prepared, each containing five mated females but no males. One container of paired beetles and one of isolated females were held at 15.5°C; the other containers were kept at 21.1°C. Food and oviposition sites were provided as in the above experiment. The containers were examined daily at first, and any eggs removed and counted. Later, the containers were examined twice weekly. All eggs were held in petri dishes for development.

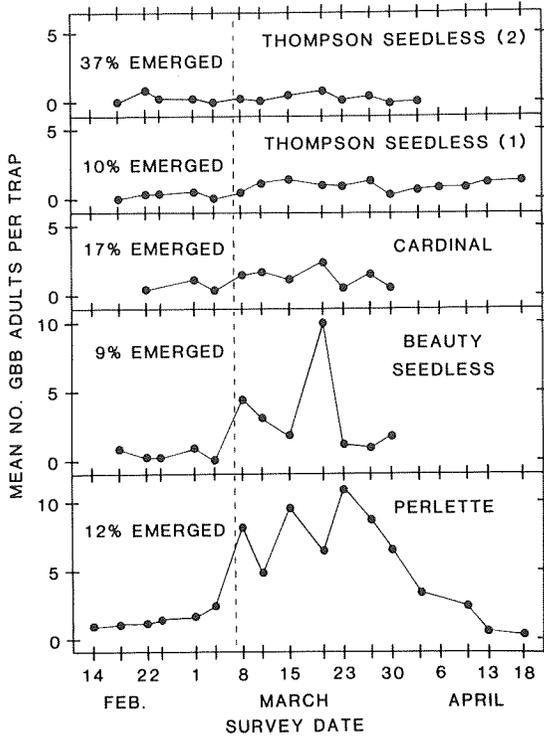


Fig. 1. Emergence of grape bud beetles from five Coachella Valley, Calif. vineyards, 1983.

Eggs laid in the two preceding experiments were used to determine developmental rates at different temperatures. Newly laid eggs were placed on moist filter paper in small plastic petri dishes. Dishes were held at 15.5, 21.1, 26.7, and 32.2°C. The eggs were examined daily and the filter paper was moistened when necessary. The number of eggs hatching on each day was recorded. A temperature threshold for egg development was determined by regression analysis.

Chemical Field Trials. Two field trials were conducted in 1983 to evaluate the effect of five different insecticides on adult GBB. In the first trial, azinphosmethyl, phosmet, diazinon, and carbaryl were applied from 1900 to 2100 hours on 31 March in a 'Beauty Seedless' vineyard. Dosages were 1.41, 1.41, 1.80, and 1.80 kg (AI)/ha, respectively. Each treatment consisted of four replicates of five vines each in a randomized block design.

In the second trial, azinphosmethyl, phosmet, and dimethoate were applied on 12 April in a 'Thompson Seedless' vineyard. Dosages were 1.41, 1.41, and 2.25 kg (AI)/ha, respectively. Dimethoate was evaluated in this test because dead GBB adults were noted beneath vines treated with dimethoate for citrus thrips, *S. citri* (Moulton), control. Eight replicates of five vines each were used per treatment in a randomized block design. The

materials in both trials were applied with a hand gun at 14.06 kg/cm² and the vines sprayed until spray ran off with a dosage of 568 liters/ha.

At the time of treatment, vine foliage was well developed and shoot length was ca. 60 to 90 cm. The actual or relative number of live beetles present on the vines could not be determined by any practical method. Because pre- and posttreatment counts of live beetles could not be obtained, the percentage of beetle mortality could not be used to evaluate insecticide effectiveness.

There was no ground cover in either of the two test vineyards. Pretreatment examination showed only an occasional dead beetle on the ground in the treatment plots. No dead beetles were found under untreated vines after treatment. Dead beetles under treatment vines were assumed to have been killed by the insecticide applied. Therefore, the numbers of dead beetles underneath treatment vines were used to compare the effectiveness of insecticides.

Counts were made 18 and 36 h after treatment in the first trial, and 24 and 72 h after treatment in the second. Dead beetles were not removed, making counts cumulative. Counts were discontinued after the second count in both trials due to violent dust storms which covered up or blew away the dead beetles. Analysis of variance was performed on log-transformed data, and Duncan's (1951) multiple range test was used to separate significantly different treatments.

Results and Discussion

Adult Emergence, Activity, and Dispersal. In 1983, adult beetles were first detected on 25 January when a 3-h visual search of the 'Perlette' vineyard used for adult emergence (Fig. 1) showed two beetles hiding in the space between the grape stake and crossarms. The average number of adult beetles collected per trap (Fig. 1) varied considerably between the five vineyards monitored. The emergence cages were removed from three of the vineyards after 30 March because of pending French plowing operations and decline of beetle emergence. The 'Perlette' and 'Beauty Seedless' vineyards showed a peak in beetle emergence during the last 3 weeks of March. In the two 'Thompson Seedless' and 'Cardinal' vineyards, beetle numbers were generally too low to show any peak in beetle emergence. However, beetles were present in all five vineyards on each sampling date.

The difference in the numbers of emerging adults between the monitored vineyards may have been due to the frequency and timing of past chemical treatments rather than a preference by the beetles for a particular grape variety. Treatment schedules are affected by the relative time that buds break for each variety. Of the four varieties monitored, buds break first in 'Beauty Seedless' and 'Perlette,' and in 'Cardinal' vines ca. 10

to 14 days later. 'Thompson Seedless' buds begin to break ca. 3 to 4 weeks after the 'Beauty Seedless' and 'Perlette.'

Early bud-break varieties are often past the critical bud development stage well before peak beetle emergence. Later-developing varieties, such as 'Thompson Seedless,' are more susceptible to beetle damage when a greater proportion of the adult GBB population has emerged. In 1983, the 'Perlette,' 'Beauty Seedless,' and 'Cardinal' buds had broken by 7 March and were no longer susceptible to beetle damage. At this time, 70% of the 'Thompson Seedless' vines had reached the bud-break stage and were still susceptible. In all the vineyards, the proportion of trapped adults emerging before 7 March (Fig. 1) was relatively low (9–37%). Because the 'Thompson Seedless' vineyards were the only ones still susceptible after this time, they were the most likely to sustain damage and receive treatment.

Treatment, when used, is applied soon after buds break to protect this vulnerable stage. When treatment is necessary in the early developing varieties, it is usually made in late February when a relatively low percentage of the total GBB population has emerged. Such early treatment protects the opening buds but has little real effect on the overall adult population. On the other hand, treatment in the late developing 'Thompson Seedless,' which constitutes ca. 30% of the vineyard acreage in the Coachella Valley, is made around mid-March and kills a greater proportion of the total reproducing adult population.

The beetles became active ca. 1 h after sundown. In full darkness during February and early March, adults were found crawling up the trunk or on the vine supports and crossarms to feed on the opening buds and small shoots of the early developing varieties. Beetles followed the same activity pattern in the 'Thompson Seedless' vineyards, even though the vines had not started bud break. Activity was not interrupted even on cold, windy nights. During the day, adults were found hiding under the bark, in cracks in wooden stakes and crossarms, and in debris at the base of the trunk. As vine foliage developed, more beetles were found hiding in the vine canopy during the day.

Beetles were occasionally seen flying within or out of a vineyard during the day, but usually they are not active fliers. When vines were vigorously shaken on warm days in March and April, many adults fell to the ground, feigning death. Others flew as they dropped, and nearly all of these flew to vines in the same or adjacent rows. When active beetles were probed with a small stick at night, they clung to the vine or dropped to the ground without flying.

No adult GBB were collected in a black-light trap placed in the 'Thompson Seedless' (1) vineyard overnight. Ebeling (1939) commented that

Table 1. Average number of GBB adults collected per trap per week

Cage no.	Variety				
	'Perlette'	'Beauty Seedless'	'Cardinal'	'Thompson Seedless'(1)	'Thompson Seedless'(2)
1	0.8	4.3	3.0	2.3	0.5
2	2.7	5.0	1.7	2.1	0.0
3	2.8	1.8	4.3	1.4	1.0
4	6.6	2.0	2.2	2.3	0.7
5	3.3	5.7	1.2	1.3	1.7
6	7.6	5.8	1.2	0.6	0.3
7	4.6	2.5	2.3	1.0	0.8
8	12.3	2.8	1.0	0.8	0.8
9	9.9	4.8	0.7	0.4	0.3
10	11.0	4.8	1.5	0.3	1.3
11	29.0	—	0.5	0.9	1.2
12	9.4	—	—	2.2	—
13	31.0	—	—	0.5	—
14	18.4	—	—	1.0	—
15	—	—	—	3.1	—

beetles were more apt to fly at night: this conclusion may have resulted from the fact that the beetles are more active at night rather than from actual observations of flying.

Results of the marking experiment showed that adults were relatively sedentary. Marked beetles were found easily in the 'Perlette' vineyard and tended to remain on the same vines on which they were originally marked, as evidenced by the fluorescent dust on the wooden grape stakes. Coachella Valley grape growers and pest control advisors had thought that adult GBB flew from the early-bud-break varieties to the 'Thompson Seedless' vineyards, thus causing more damage in this late developing variety. However, no marked beetles were found in the 'Thompson Seedless' (1) vineyard during a 30-min search with ultraviolet light. This indicates the beetles did not move from the 'Perlette' to the 'Thompson Seedless.' As mentioned, 'Thompson Seedless' vines are more susceptible to damage because bud breaking occurs after more GBB adults have emerged.

Data from the adult emergence study showed a great variation among the total numbers of GBB captured in various rows in the same vineyard (Table 1). In the 'Perlette' vineyard, in particular, catches increased markedly from east to west, and in other vineyards distribution was uneven. This localized distribution may be attributed to the sedentary behavior of the adults and the fact that eggs are laid in batches.

Night detection of adults with a flashlight is time-consuming because the beetles blend in with the color of the vines, trunk, arms, spurs, canes, and the vine supports. Also, the beetles stop moving when under white light, making detection more difficult. While searching for marked beetles with an ultraviolet light source, we discovered that GBB

Table 2. Ovarian development of GBB females held at 15.5 and 21.1°C

Temp (°C)	Days after emergence ^a	No. females	No. eggs	No. egg batches	Stage of ovaries ^b (two females)
15.5	4-6	11	0	0	II, IV
	7-9	9	0	0	I, III
	10-13	7	60	2	IV, IV
	14-16	4 ^c	60	2	V, V
	17-20	2	0	0	III, IV
21.1	4-6	12	96	3	II, V
	7-9	8 ^d	112	4	II, III
	10-13	6	135	5	II, V
	14-16	4	144	4	III, III
	17-20	2	95	3	II, III

^a Two females dissected on last day of time period.

^b See text for description of the scale used to rate ovarian development.

^c One female died before dissection.

^d Two females died before dissection.

adults naturally fluoresce a bright silver blue. Since adults also stop moving when under ultraviolet light, more accurate counts can be made by holding the ultraviolet lamp 30 to 60 cm away from a vine and quickly counting the immobile brightly glowing beetles. Dead beetles also fluoresce. Other objects that fluoresce include droplets of the fungicide Bayleton and mantid and spider egg masses, but they are easily distinguished from GBB adults. When vine foliage is well developed, accurate beetle counts became nearly impossible, even with ultraviolet lamps, since the foliage provides too much cover in which the beetles can hide.

Adult Feeding and Damage. All of the beetles confined on the vine shoots were alive after 8 days. The greatest amount of leaf damage occurred on the shoot supporting 15 beetles, with ca. 5% of the total leaf surface eaten. Leaf loss to the other shoots was too small to be estimated. None of the florets were damaged on any of the shoots. Only a minute amount of fecal material was found in the bags, further indicating that the adults feed relatively little. This was supported by laboratory observations.

The small amount of leaf tissue consumed is of little importance. Most table grape varieties require some thinning of leaves and shoots as part of normal viticultural practices. Further, the beetle densities used in the feeding tests exceeded those observed in the vineyards. These studies confirmed that the adults present no threat to vines after buds break.

The results of the emergence study showed that peak emergence of GBB adults was not synchronized with the susceptible vine stage. Thus, the severity of damage depends largely on the time and duration of bud-breaking in relation to peak beetle emergence. Any factor delaying or enhancing bud-breaking may also have an effect on the severity of beetle damage.

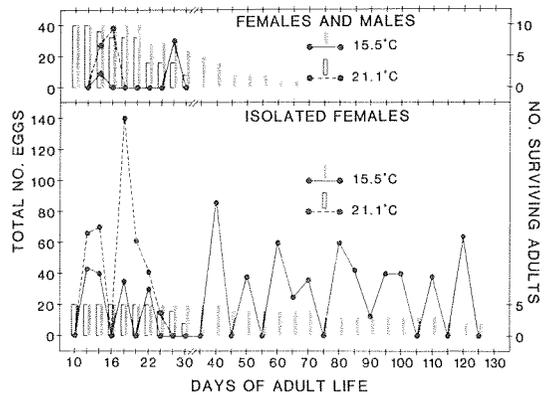


Fig. 2. Grape bud beetle oviposition and longevity comparing paired beetles and isolated females at different temperatures.

In 1983 vines completed bud break 2 to 3 weeks earlier than in 1982, possibly due to above-average January temperatures for the Coachella Valley in 1983. Few treatments for GBB were necessary in 1983, while a large number of vineyards were treated the previous year. Because buds broke early in 1983, most vineyards escaped damage.

Winkler et al. (1974) comment that grapes remain dormant until mean daily temperatures increase to 10°C. Mean daily temperatures in the hot, dry Coachella Valley rarely decline to 10°C. Thus, the developmental threshold for bud-breaking must be higher in the Coachella Valley, or bud-breaking is controlled by more subtle factors.

Ovarian Development, Oviposition, and Egg Development. Female GBB observed under laboratory conditions laid eggs in batches of 12 to 44 eggs. Dissections showed that the number of ovarioles varied from 14 to 22 per ovary. Most commonly, there were 16 to 18. Typically, egg development occurred so that all eggs for a single oviposition developed simultaneously, with one mature egg per ovariole. Once eggs for one batch were near maturity, i.e., in stage III or IV, eggs for the next batch could be seen entering stage I or II.

Results of the dissection experiment are summarized in Table 2. Dissected ovaries in females held at 21.1°C did not show a gradual development as expected. Eggs were laid almost immediately in the 21.1°C container between 4 and 6 days after adult emergence. Even though females held at 21.1°C continued oviposition throughout the experiment, only 2 out of the 10 females dissected contained ovaries in the post-ovipositional stage (stage V). This shows that successive egg batches develop at a rapid rate at 21.1°C, and that intervals between batches may be as short as 3 days.

Ovarian development was more gradual at 15.5°C. Eggs were not laid until the twelfth day

Table 3. Oviposition patterns in the GBB at 15.5 and 21.1°C

Temp (°C)	Test insects	Avg no. eggs per female	Avg no. egg batches per female	Avg duration of female life (days)
15.5	5 ♂♂ + 5 ♀♀	8.8	0.2	26.4
	5 Isolated ♀♀	138.0	4.2	94.0
21.1	5 ♂♂ + 5 ♀♀	13.0	0.4	21.9
	5 Isolated ♀♀	76.0	2.4	34.1

after adult emergence. Total oviposition for females held at 15.5°C was much lower than for females at 21.1°C.

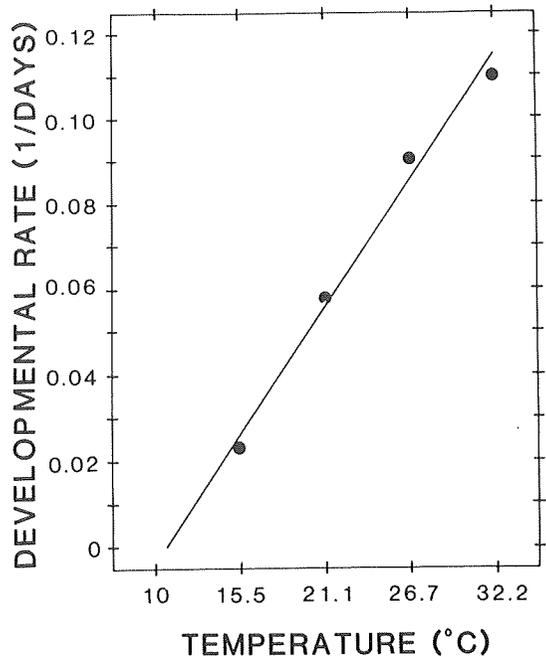
In the above experiment, the age of adults was taken at days after emergence from the soil. However, this could be misleading because of the lack of knowledge concerning the biology of this beetle. It has been assumed that the GBB overwinters as mature larvae in the soil (Stafford and Doutt 1974). However, in 1983 we sampled soil in Coachella grape vineyards and recovered adult beetles as early as October. Since newly emerged adults are found by late January, it seems likely that some portion of the GBB population overwinters as adults. Thus, ovarian development may be partially or fully completed when such females emerge from the soil, allowing almost immediate oviposition.

The results of the oviposition study comparing paired beetles and isolated females at 15.5 and 21.1°C appear in Fig. 2. Nearly all eggs laid were viable, and most completed development and eventually hatched. Isolated females at both temperatures laid at least two egg batches each, showing that mating is not necessary for each oviposition.

At both temperatures, oviposition was much lower when males were continually present. Male GBB are extremely aggressive in their courtship of females and, when not in copulo, will remain mounted on the females for 4 or 5 h and longer. This male behavior apparently interferes with oviposition, and accounts for the reduced oviposition noted in containers holding large numbers of adults

Table 4. Development of grape bud beetle eggs

Temp (°C)	n	% Hatching	Day of first egg hatching	Avg development time (50% of eggs hatch)	Day of last egg hatching
15.1	155	61.7	41	44.0	51
21.1	223	94.2	16	17.2	19
26.7	304	82.9	10	11.1	13
32.2	104	78.8	9	9.1	11

**Fig. 3.** Grape bud beetle egg development rates at different temperatures.

collected from the emergence cages. The sex ratio in these containers was ca. 1:1.

The average number of eggs per female was higher for isolated females held at 15.5°C than those held at 21.1°C (Table 3). Oviposition occurred at a faster rate in the 21.1°C container, but so did mortality. All 15 adults held at 21.1°C had died 34 days after emergence, while 10 of the adults held at 15.5°C were still alive.

The average development times for GBB eggs at different temperatures appear in Table 4. From these data, developmental rates for 50% of the eggs hatching were determined and plotted against temperature (Fig. 3). Regression analysis then yielded a developmental threshold of 10.7°C ($R^2 = 0.99$). Since temperatures in the Coachella Valley during February, March, and April average between 15.5 and 21.1°C, GBB eggs laid in Coachella vineyards should take between 6 and 2.5 weeks to hatch.

Chemical Field Trials. Results obtained from both insecticide trials appear in Table 5. In the first trial, there were two nights for beetle activity and possible exposure to the chemicals before dust storms forced termination of counts. The highest number of beetles killed (59–67% of the total) occurred on the first night. Beetles killed decreased during the second night for all treatments. Phosmet and azinphosmethyl gave statistically similar results and caused significantly higher mortality than diazinon or carbaryl. Thus, we judged phosmet as effective in killing beetles as azinphosmeth-

Table 5. Effect of various insecticides on grape bud beetle adult mortality

Chemical	Dosage (kg [AI]/ ha)	Avg no. dead beetles per replicate			
		Trial no. 1		Trial no. 2	
		18 h ^a	36 h	24 h	72 h
Phosmet	1.41	52.7a	81.7a	14.1a	17.6a
Azinphosmethyl	1.41	45.5a	76.3a	9.6a	13.4a
Diazinon	1.80	18.5b	27.3b	—	—
Carbaryl	1.80	10.3b	16.5b	—	—
Dimethoate	2.25	—	—	5.3b	12.1a

Means followed by the same letter are not significantly different ($P < 0.05$; Duncan's [1951] multiple range test). Data were transformed by log transformation.

^a Time after treatment.

yl, which is most often used by growers for GBB control.

Based on the results of the first trial, phosmet and azinphosmethyl were used to evaluate the effectiveness of dimethoate. In the second trial, beetles had three nights of possible exposure to the chemicals. Phosmet and azinphosmethyl again killed the most beetles (80 and 72% of the total, respectively) on the first night. In contrast, numbers killed in the dimethoate treatment were slightly higher for the second count (59% of the total).

As in the first trial, phosmet and azinphosmethyl killed similar numbers of beetles for both the 24 and 72 h posttreatment counts. At the 24 h count, dimethoate caused significantly lower mortality than the other compounds. However, by the 72 h count, all three compounds gave statistically similar results for total beetle kill.

Azinphosmethyl has long residual activity but is hazardous to applicators and has a 21-day period before workers can enter it again. At times, this can interfere with normal viticultural practices for table grapes. Since phosmet has a 5-day reentry period and is less hazardous to applicators, it may be an effective alternative to azinphosmethyl for GBB control.

Dimethoate did not act as quickly as phosmet or azinphosmethyl but did eventually kill as many beetles. This chemical may not be as immediately effective in controlling the GBB when buds break, when vines are most susceptible, but could be useful for clean-up treatments applied after most beetles have emerged. Dimethoate is often used for thrips control in vineyards in the spring and so treatment for both pests may be combined.

Conclusions

Since GBB is only a threat when buds break, grape growers tend to dismiss the beetle problem once the new shoots are 2 to 3 cm long. Data from our emergence study show that only a small percentage of adults emerge when buds break, and

chemical treatments applied to protect the buds have little effect on the GBB population as a whole.

Therefore, in addition to protective treatment when buds break, later "clean-up" treatment may be advisable when beetles are present in high numbers. The treatment should be applied near peak beetle emergence in late March and may be combined with thrips or leafhopper treatment. Since adults emerge over a long period of time and females are capable of oviposition soon after emergence, a single treatment may not be sufficient to reduce GBB populations. Two or 3 years of clean-up treatment may be necessary. GBB populations should be monitored at night after buds break. Five to six beetles per vine are high enough to warrant treatment (unpublished data).

At present, there are no biological control agents known to suppress GBB populations in the Coachella Valley. Practices that accelerate bud-breaking, such as calcium cyanamide (CaCN_2) treatment to hasten earlier grape harvest and provide more uniform bud-breaking in 'Thompson Seedless,' may alleviate damage from the beetle but would also allow GBB populations to grow unchecked. Eventually, the number of adults emerging in February may reach damaging levels. In addition, high numbers of larvae feeding on the roots may cause weakened vines.

Acknowledgment

This research was supported by funds from the California Table Grape Commission and University of California Statewide Critical Applied Research.

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Received for publication 2 April 1984; accepted 8 June 1984.
