Control of the Grape Leafhopper in California

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The grape leafhopper, *Erythroneura comes* (Say), has become increasingly injurious to grapes in the San Joaquin Valley in recent years. So severe have been its attacks during the period from 1928 to 1931 that extensive investigations and experiments have been conducted during the past two seasons to develop more modern and effective insecticides and other methods of dealing with the pest.

As a result of the combined effects of climatic conditions and leafhopper damage, it is estimated that the crop of raisin grapes was reduced from 295,000 tons in 1930 to 157,000 tons in 1931. If we assume that 40 per cent of this loss was the result of leafhopper injury (55,000 tons at $60.00 per ton) this insect cost the grape growers more than $3,000,000 for that year.

HISTORY AND DISTRIBUTION

The grape leafhopper is a native of North America and occurs in all the important grape-growing areas of the United States. However, its attacks are most serious in the Great Lakes region and in the states of Arizona and California.

While this leafhopper occurs in all the grape-growing regions of California, it is most serious in the Sacramento, San Joaquin, and Imperial valleys, and the greatest losses are occasioned in the southern portion of the San Joaquin Valley.

In California this insect has been known to occur since 1875. In 1908, Quayle2 gave an excellent account of the life history and control with the materials then known to be effective. Since that time, the increase of leafhopper damage and the advent of new materials have necessitated additional experimental work to determine the best present-day methods of control.

The past history of this insect indicates that its attacks occur in a series of fluctuations in which periods of abundance are followed by periods of low populations. These fluctuations are influenced by the

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1 Junior Entomologist in the Experiment Station.
Fig. 1.—Seasonal life history of the grape leafhopper in relation to control measures. **Period 1**: Plow vineyard, leaving trap strips to be treated with calcium cyanide dust or pyrethrum-oil vapor sprays before new vine growth appears. **Period 2**: Last opportunity to destroy the overwintering adults before egg laying. **Period 3**: Time for application of dusts or sprays for first brood nymphs. **Period 4**: Treatments for overlapping broods of adults and nymphs, when numbers necessitate control. **Period 5**: Clean up paper trays, weeds, etc., in and about the vineyard. Plant covercrops which may serve as a fertilizer as well as a trap crop in the spring (Period 1).
number of overwintering leafhoppers and the rapid building up of the spring population. They may be reduced by weather conditions (wet and cold seasons), and by parasitism during the late summer.

**SEASONAL LIFE HISTORY**

The grape leafhoppers pass the winter as adults (figs. 1 and 2), which may feed on various plants growing in or near the vineyard during warmer weather. In cold weather these overwintering adults will be found hibernating under leaves, dead grass, weeds, and old paper trays; in brush and straw piles; in debris along ditches and fences; and in alfalfa fields, dry tule ponds, and old cotton fields. While these adults have been reported as occurring from one-half to one mile from the nearest vineyard, the majority of them are found in or close to a vine-

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**Fig. 2.—Diagram representing the life history of the grape leafhopper in relation to the time of appearance and length of the various stages of the three broods. Note that as the season advances the overlapping of the broods becomes more complex.**
yard. In spring, February to March, they leave their various winter quarters and move to green vegetation to feed, and attack the vines as soon as they begin to leaf out. Thereafter feeding is confined to the grapevines until the leaves drop in the fall.

Egg laying begins about two weeks after the overwintering hoppers attack the vines, which period is usually about April 7–15, in the Fresno area. The young of the first generation begin to appear about May 1, and one to two weeks later in the Lodi-Stockton area. About 18 days are required for maturity. The young of the second generation appear the latter part of June and those of the third from the middle to the last of August.

In autumn, when the leaves drop, the adults seek the winter quarters mentioned above. During favorable seasons, this winter population may be very abundant as was indicated by a number of counts made during the winter of 1931–32, which varied from less than 100 to 1,800 individuals per square foot of debris.

**GENERAL LIFE HISTORY**

*Adults.*—The grape leafhoppers (fig. 3) do not migrate in the true sense of the word but disperse from one locality to another, while moving from winter hibernation to green vegetation in February and March.

Fig. 3.—The adult grape leafhopper, *Erythroneura comes* (Say). (Greatly enlarged.) (After Quayle.)

Fig. 4.—Egg of the grape leafhopper in the tissue of the leaf. (Greatly enlarged.)
They move to the vines as soon as there is suitable green leaves for feeding, but seek protection in trash or other cover beneath the vines in periods of cold weather.

The only adult activity observed during the summer months was the flying from vine to vine during the evening but not for any great distance.

_Eggs._—The eggs of the grape leafhopper are laid singly in the epidermal tissue of the upper and lower surfaces of the leaf. Each egg is minute, about $\frac{3}{100}$ inch in length, and is difficult to see without the aid of a magnifying glass. As it occurs in the leaf tissue it may be recognized as a small bean-shaped blister (fig. 4).

The egg-laying period may be prolonged several weeks, especially in cold weather, resulting in an overlapping of generations. Each female deposits about 100 eggs which have an incubation period of 17 to 20 days in the spring. This period is shorter during the summer months.

_Nymphs._—The young leafhoppers, known as nymphs, resemble the adults in general form, though they are smaller and lack wings. They have the same feeding habit of sucking the sap from the leaves.

When first hatched from the egg, the young nymph is very small and semitransparent with red eyes. There are five successive nymphal stages (fig. 5), each resembling the other except for size and developing wings.

The developing wings, in the form of wing pads become more pronounced in the third, fourth, and fifth stages. Development from the time of hatching requires from two to three weeks.

The nymphs feed almost without exception on the lower surface of the leaves although the eggs may be found in almost equal numbers on both surfaces.

Theoretically the first eggs of each generation may develop, in the Fresno area, as indicated in the tabulation below, with the maximum number of each stage occurring about two weeks later than the respective dates given.

<table>
<thead>
<tr>
<th>Generation</th>
<th>Eggs</th>
<th>Hatching</th>
<th>Adult</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>April 7–15</td>
<td>April 24–May 1</td>
<td>May 20–25</td>
</tr>
<tr>
<td>Second</td>
<td>June 5–10</td>
<td>June 25–30</td>
<td>July 1–8</td>
</tr>
</tbody>
</table>

3 The small droplets of crystalline material found chiefly on the veins of the new growth, especially in the spring, are hardened drops of sap and should not be mistaken for eggs.
Fig. 5.—The five nympha1 stages of the grape leafhopper. Note developing wing pads on the last three. Control measures should be applied when the first few nymphs reach the two most advanced stages. (Greatly enlarged.)

**NATURE OF INJURY**

The most important injury produced by the grape leafhopper is that resulting from the extraction of sap through the innumerable feeding punctures made by the mouthparts of these insects. This injury first appears as scattered, small, white spots, which become more and more numerous until a pale-yellowish blotching, due to the removal of the chlorophyll, results. Eventually the leaves dry up and fall prematurely. The damage produced is in direct proportion to the number of individuals present and the degree of injury increases with the increase in population.

Unless the overwintering adults are exceedingly abundant, the injury produced by them is negligible; but their offspring, which develop on the first six leaves of the new growth, may produce early defoliation in the crown of the vines. This defoliation, which increases as the season
advances, frequently exposes the ripening grapes to sunburn injury, causing heavy losses in table varieties. Defoliation also reduces the sugar content of raisin grapes, reducing the crop in quantity and lowering the quality. In addition, the presence of leafhopper excrement on the table grapes is objectionable.

According to most authoritative estimates, the tonnage of raisin and table grapes has been reduced 25–30 per cent in some seasons as the direct result of the injury produced by this leafhopper. This estimate does not include the loss from lowered quality and the decreased vigor of the vines which may be intensified by long periods of high temperature and inadequate soil moisture.

**FARM PRACTICES IN RELATION TO LEAFHOPPER CONTROL**

While the control of overwintering grape leafhoppers by burning or cleaning up the hibernating places has not proven entirely satisfactory, this method may furnish a degree of relief in some localities. When serious infestations occur over large adjacent areas and when only a few vineyardists resort to this method, results are likely to prove very disappointing.

Many of the adults may be destroyed by plowing while the temperature is below 50°F, when the adults are inactive on weeds or in the litter.

Observations indicate that in wet weather succulent covercrops growing in a vineyard do not harbor large numbers of overwintering adults in comparison with adjacent areas of dead grass, trash, etc. This is evidently because of the cool, moist conditions produced by the growing covercrop. Such a covercrop may be utilized as a trap crop by leaving unplowed strips when the covercrop is turned under as the buds of the grapevines begin to swell in the spring. Fall cultivation in conjunction with a covercrop planted early decreases places for the adults to overwinter.

After the litter has been destroyed (fig. 6) in October or November, a trap strip of barley or rye or a combination of the two, not over 2 feet wide may be planted throughout the vineyard at intervals of 4–8 rows, depending upon vineyard practice (fig. 7). In February or March when the insects become active and move to green plants and just before vine growth begins, all other vegetation in the vineyard and along fences, roads, and ditch banks, should be plowed under or destroyed.

The success of a trap crop depends upon the destruction of the overwintering adults while they are feeding on this crop and before vine
growth starts in the spring and upon the area treated, as the larger the acreage the less will be opportunity for reinfestation from surrounding vineyards. Sufficient irrigation and fertilization produce vigorous vines and often prevent serious injury though populations may be high.

Fig. 6.—Clean-cultivated vineyard. Trash has been plowed under during the dormant season to remove overwintering quarters for adult leafhoppers.

Fig. 7.—Trap crop and vineyard in proper condition for treatment in the spring.
CONTROL MEASURES

Success in the control of the grape leafhopper depends on the selection of the specific means most effective against the life stage of the insect chosen for treatment. There are periods during which no one treatment is sufficient owing to the presence of several different stages of the insect (fig. 2). The selection of the period for treatment will naturally be dependent also upon the degree of infestation and the anticipated damage. Any treatment, to give the most satisfactory results, must be applied before serious damage has been produced. Thus the individual grower always has the responsibility of closely observing the conditions within his vineyard with a view to determining the period and material to select for control measures. Any method adopted will be greatly aided by utilization of the best farm practices to increase the health and vigor of the vines.

Regardless of what materials may be used in the suppression of the grape leafhopper, effective control is dependent upon thorough, prompt, and timely applications of the same. Failure is most often traceable to the improper use of a control measure especially in regard to strength of material and manner of application. Weather conditions also have a bearing on the effectiveness of a particular treatment and are discussed under the various materials.

Spraying represents the oldest method for the control of the grape leafhopper and now includes both liquid and vapor sprays, the latter utilizing air as the diluent and carrier of a concentrated insecticide.

Liquid Sprays.—Nicotine sulfate as a liquid spray, with whale oil soap or other type of spreader or in combination with bordeaux mixture, has long been the recognized control and is still practical in spite of numerous limitations. The most effective combination is made according to the following formula:

- Nicotine sulfate (40 per cent) ........................................ 1 pint
- Casein spreader .......................................................... ½ pound
- Water ................................................................. 100 gallons

Such a spray destroyed 95-97 per cent of the first brood nymphs. It also gave a slight indication of being effective against eggs, but this aspect needs further investigation.

In place of the casein spreader, ½ gallon of liquid whale oil soap may be substituted, though this material at times produces a slight scarring of the fruit.
Experiments conducted with pyrethrum extracts (alcohol, acetone, or pyrethrum-soap emulsion) in water, during 1932, resulted in 93–95 per cent control of the first brood nymphs. As these extracts (commercially sold as Evergreen, Red Arrow, etc.) vary so greatly in pyrethrum content, the recommendations as to dilution, given by the manufacturer, should be followed and checked by field experience.

The above sprays, in the proper concentration and application, are the most effective methods used in nymph control if applied when there is a maximum number of first brood nymphs, normally from May 20 to June 1 in the Fresno area. If the application is too early, many eggs will remain to hatch later; and if too late, many adults will have developed.

A power sprayer, capable of maintaining 200–250 pounds pressure, with angle nozzles attached to rods 3–4 feet long, is necessary for the proper application of these sprays (fig. 8). Set or boom nozzles (fig. 9) may be used but care must be taken that thoroughness is not sacrificed for speed.

Because of many limitations, liquid sprays will have their greatest use when applied in combination with other insecticides for other vine pests, such as red spider, which require liquid sprays for control. The principal limitations are:

1. These sprays are contact insecticides and must be put on the undersides of the leaves where the nymphs are feeding.

Fig. 8.—Spraying for nymphs of the grape leafhopper with angle nozzles. (Photograph by J. L. Quail.)
2. They are effective against the nymphs only and should not be used after the grapes are larger than buckshot because of possible injury to the "bloom" of the grapes.

3. They should be applied at the rate of 100–200 gallons per acre, depending upon the quantity of foliage, and 4 to 8 acres per day is the maximum to be covered with 2 to 4 nozzles.

4. The chief limiting factor is the slowness of application.

Vapor Sprays.—During the 1931–32 season, equipment (figs. 10 and 11) was developed for the vaporization of concentrated insecticides.

Fig. 9.—Spray boom used in the application of liquid sprays. (Photograph by J. L. Quail.)

Of these sprays, one containing oil and an oil extract of pyrethrum was found to be effective against both nymphs and adults, especially the latter when they are forced to fly through the vapor. This material consisted of:

Highly refined kerosene........................................................................87½ gallons
Neutral oil (90 per cent unsulfonatable residue and 60 sec.
Saybolt viscosity) ........................................................................10  gallons
Petroleum oil extract of pyrethrum (containing 2 grams of
pyrethrins per 100 cc4)................................................................. 2½ gallons

4 The concentration of 2 grams of pyrethrins (killing agents in pyrethrum) per 100 cc of oil extract is equivalent to 20 pounds of pyrethrum flowers (containing 0.9 per cent pyrethrins per pound), to the gallon. Because even the best grade of pyrethrum flowers may vary from 0.2 per cent to 2.3 per cent pyrethrins per pound, the ratio of pounds per gallon is not a satisfactory standard for an oil extract of pyrethrum.
This combination, applied with the equipment using the paint-gun type of nozzle (fig. 10), destroyed 87-90 per cent of the overwintering adults when applied, April 15-17, 1932, at the rate of 2 gallons per acre. Later in the season the effectiveness of this type of spray decreased as the vine growth increased, so that an application of 5 gallons of pyrethrum-oil spray per acre early in August gave only 35 per cent control of the adults, where the populations were as high as 18,000 individuals per vine.

Experimental evidence indicates that this material is of greatest value when applied against the overwintering adults before egg laying has started in the spring and when the new growth is not over eight to twelve inches in length. Repetition may be necessary if the adults continue to move in.

Pyrethrum-oil sprays are new materials and, while very effective, are still under investigation with a view to their improvement and reduction in cost.

Use of Dusts.—In recent years, dusts, calcium cyanide or nicotine, have been widely used in the control of the grape leafhopper due to speed of application and the ease of adapting regular vineyard equipment.

It is obvious that these materials cannot be used successfully in wind or even light breezes because a dust cloud cannot be confined to the area under treatment. Convection currents, set up in the vineyard as the
result of hot, dry soil, are equally undesirable. These smaller currents of air are difficult to detect and are seldom recognized by the grower. Irrigation prior to treatment cools the soil and reduces them to a minimum.

*Calcium Cyanide Dust.*—Calcium cyanide dust may be applied for the overwintering adults, either in the trap crop or after they have concentrated on the vines *early* in the spring.

This material is effective against all active stages of the grape leafhopper, and is the most successful material for late summer treatment.

![Photo of vapor spraying with blower type of equipment](image)

Fig. 11.—Vapor spraying with blower type of equipment. (Photograph by J. L. Quail.)

However, it must be used when the atmospheric conditions are such that a lethal concentration of the gas may be maintained in the area treated. This is after midnight when convection currents are at a minimum. (Conditions may be determined by building a smudge fire in the vineyard. When the smoke settles or drifts *very* slowly, dusting should proceed, but if smoke drifts or dissipates rapidly, dusting should not be done.) For the application of calcium cyanide dust, motorized power equipment is recommended, using "H-dust" (or coarse calcium cyanide) at the rate of 20 pounds per acre with the outlets directed toward the ground so that a greater part of the dust will fall with the insects. Thus large acreages can be treated in a short time, with a concentrated blanket of dust over the entire area treated.
In some districts atmospheric conditions prevent or hinder open dusting and this material may be applied under tents made of light drill, or good grade cotton sheeting, 15 feet wide and from 60 to 120 feet long (fig. 12). These tents should only be used when the new growth has matured sufficiently to prevent breakage of the shoots as the tents are pulled over the vines. The dust, known as "A," or fine calcium cyanide, should be applied at the rate of 20 pounds per acre, under the tent as it is being pulled forward. The treatment for each setting of the tent should be about four minutes. By this method, three men with two tents can treat 6 to 9 acres per day.

![Fig. 12.—Tent method of applying calcium cyanide dust in the control of the grape leafhopper. (Photograph by A. F. Kirkpatrick).](image)

In 1931, vineyards treated the first two weeks in April, remained free from injurious numbers of leafhoppers for the entire season. In 1932, calcium cyanide dust applied in July gave 90-95 per cent control of adult populations of 10,000 to 33,000 per vine.

The best results with calcium cyanide dust have been obtained in late summer, at the time when the adults or nymphs were most abundant and the fewest eggs were present. Failure with this material can usually be traced to improper weather conditions.

As calcium cyanide dust produces a poisonous gas it should be handled with care. This material should not be applied with horse-drawn dusting machines or in the immediate vicinity of farmyards containing poultry or livestock, as these are susceptible to the gas released. The operators of commercial dusting equipment should have an adequate gas mask available in case of accident.
Nicotine Dust.—Dusts containing a sufficient concentration of nicotine (not less than 4 per cent actual nicotine), are successful in the control of the first three nymphal stages of the grape leafhopper. Experiments conducted during 1932 show that a good nicotine dust should be free-flowing and should release a large part of the nicotine within a short period of time. Too much emphasis cannot be placed upon the necessity for treatment before the nymphs have entered the fourth and fifth nymphal stages (fig. 5).

Satisfactory results may be obtained with either a good grade of nicotine dust as prepared commercially or with the following homemade material, which contains an activator to release the nicotine:

- Nicotine sulfate (40 per cent) .......................................................... 10 pounds
- Hydrated lime .................................................................................. 80 pounds
- Sodium carbonate (activator)............................................................. 10 pounds

This dust gave 92–95 per cent control of the active nymphs and may be made as follows: Adapt a 50-gallon wooden barrel for the mixing of this dust, according to the directions with each can of nicotine sulfate (Blackleaf 40). Place the lime in the barrel and then add the nicotine gradually instead of all at once. After turning about five minutes add the activator (sodium carbonate) and turn for another five minutes. The success of the homemade mixture depends entirely upon the thoroughness of mixing.

Do not mix more than will be used the same day. After taking the material from the mixer place it in an airtight drum until used, but use it the same day.

Use 15–20 pounds per acre depending upon the size of the vines and apply it just before the first nymphs get their wings. The best results are obtained with the material at temperatures of 90° F, or over, with a minimum of wind and where vineyards have been irrigated before treatment. Nicotine dust has the advantage that it may be applied with the hand or power machines ordinarily used for sulfur. The material must be directed so that the vines are completely enveloped by the dust.

Second applications about two weeks after the first may be necessary for complete control, and thoroughness in application is essential.

Air Sweepers.—Quayle reported experiments with types of suction machines and blowers for the purpose of collecting the leafhoppers which were flying in the immediate vicinity of the vines, but these devices were considered impractical. However, during 1931, there was a revival of this type of machinery and a variety of designs were built and used for the mechanical removal and destruction of the adult leafhoppers (fig. 13).
At best these machines were only effective against the adults, and then only when the vines were shaken to dislodge them. The most effective types may aid in the reduction of the adult population if used throughout the season, but use must begin as soon as the leafhoppers move to the vines in the spring. Counts made of adult populations before and after using several of these machines showed a variation of from 30 to 70 per cent control.

Fig. 13.—One type of mechanical suction machine or air sweeper. This machine has a canvas curtain which drops over the row opposite the fan.

*Natural Enemies.*—Although a number of insects have been recorded as destroying grape leafhoppers, none of them are found in sufficient numbers to reduce the large summer populations.

Early in July, 1931, Mr. A. F. Kirkpatrick reported an egg parasite, *Anagrus epos* Girault, which was found in abundance throughout the balance of that season in most leafhopper-infested vineyards. In spite of the attacks of this parasite, the leafhoppers continued as a serious menace to most vineyards during late summer and fall and adults were very abundant at the time of the first frosts.

During 1932 no parasitized eggs were observed until early in July after the second brood eggs had been laid. Following this there was found an increasing number of parasitized eggs. Thus by August 15, 50–60 per cent of the eggs (third brood) observed were found to be parasitized. This parasitism undoubtedly greatly reduces the number of overwintering leafhoppers but the parasite probably occurs in active numbers too late in the summer to be an efficient check.
SEASONAL CONTROL PROGRAM

The following program represents a full season's control, which in total should seldom, if ever, be necessary, and indicates the most effective measures at various seasons of the year.

1. Clean cultivation followed by covercrops in the fall.
2. Planting of the trap crop and treating it with calcium cyanide dust or pyrethrum-oil sprays to destroy the overwintering adults before vine growth starts.
3. Early spring treatment of adults with calcium cyanide dust or pyrethrum-oil sprays after movement to vines.
4. Two nymphal treatments with nicotine or pyrethrum sprays or nicotine dust.
5. Treatment of first brood adults with calcium cyanide dust or pyrethrum-oil spray.
6. Treatment of second brood nymphs with nicotine dust.
7. Calcium cyanide dust treatment of adults before harvesting crop.
   Treatments 3 and 4 or both are exceedingly effective and are usually sufficient, if thoroughly applied, for practical control.

SUMMARY

The grape leafhopper is the most serious grape pest in California in the San Joaquin and Sacramento valleys. The degree of injury to vineyards may be severe enough to reduce the crop 40 per cent.

This insect overwinters in the adult stage in a wide variety of situations, and moves to the vines as soon as the foliage appears in the spring, and feeds on the vines until fall.

Three broods develop during the summer months, the first nymphs appearing about May 1.

Control may be had by the application of one of a number of materials, as nicotine or pyrethrum sprays, pyrethrum-oil vapor spray, and nicotine or calcium cyanide dusts. These must be applied under definite conditions. These insecticides may be advantageously supplemented by various farm practices.

The egg parasite, Anagrus epos Girault, destroyed over 50 per cent of the third brood eggs in 1932, and thus reduced the number of overwintering adults.
Vineyardists, in order to maintain their vineyards in the best condition and produce the highest quality product, should prevent the grape leafhopper from developing in destructive numbers.

By following such phases of the suggested yearly control program as fits his situation, a grower can keep his losses at a minimum.

ACKNOWLEDGMENTS

The author wishes to acknowledge the assistance of Mr. J. L. Quail, Assistant Farm Advisor of Fresno County, in securing locations for experimental plots and in checking results; of Dr. H. B. Walker, Mr. Roy Bainer, and Mr. O. C. French, for their suggestions in relation to equipment used in experimental work; to Mr. Perez Simmons of the United States Department of Agriculture Entomological Laboratory, for laboratory space. Thanks are also due to Mr. G. L. Smith and Mr. C. E. Norland for assistance in checking experimental work; and to vineyardists of Fresno County, namely, Messrs. H. R. Keller, J. J. Nielsen, H. H. Nielsen, Merle Smith, P. D. Turnbull, and others for the use of their vineyards in the experimental work. The drawings were made by Miss Dorothy Harris.