LIFE HISTORY AND CONTROL OF THE GRAPE LEAF FOLDER IN THE SAN JOAQUIN VALLEY, CALIFORNIA

by

GEORGE HAGOP KALOOSTIAN

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APPROVED:

[redacted]

Professor of Entomology and Head of Department

in charge of Major

[redacted]

Chairman of School Graduate Committee

[redacted]

Chairman of the State College Graduate Council

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INTRODUCTION

In 1936 when these observations were undertaken the grape leaf folder, Desmia funeralis Hbn. (Pyralidae, Lepidoptera), was not considered an insect of economic importance in the San Joaquin Valley, California, except in certain widely separated localities where it was occasionally reported as damaging grapes. During the past three years the habits and the spread of this pest from one of these locations have been studied by the writer. The original locality of study was the John Estes Ranch in the Kings River bottom lands in the Sanger district. In 1938 the insect had spread fifteen or more miles westward from this locality into the great vineyard areas in the Fowler district where control measures were being taken in order to check its ravages. The grape leaf folder is now a major pest of grapes in the San Joaquin Valley.

THE PROBLEM AND ITS HISTORY

Many accounts of the habits of the grape leaf folder have been published since 1854 when Glover first recorded the injury inflicted by this species upon grapevines. Nearly all of these reports appeared under the general discussion of insects and other pests affecting grapes. Strauss (1916) published the first detailed life history of the

insect and reviewed its history from the year 1796 when Hubner described it as Pyralis funeralis to 1916. He studied the insect in Washington D. C., and took into account the early observations of Glover (1854), Riley (1868), Hoy (1879), Woodward (1889), Marlatt (1895), Quaintance (1907), and Essig (1915).

Control measures repeatedly suggested by these authors were arsenate of lead sprays, hand crushing of the larvae in the folded or rolled leaves, and raking and burning of the leaves in which the pupae overwinter. The fact that hand picking and crushing of the larvae have been recommended in all areas of infestation is probably an indication of the relative unimportance of the insect as a pest of the grape until the present outbreak.

Quayle (1907) pointed out the striking difference in the habit of the grape leaf folder in the east and the west. In the eastern part of the United States the leaf is simply folded over on the upper surface and the edges are sewed down by strands of silk. In California the leaf is rolled. Quayle also stated that the leaf is always rolled on the lower side. Whether the leaf is rolled on the lower side or the upper side depends on the variety of the grape attacked. All varieties, except the Thompson Seedless (Sultanina), are rolled on the lower side. Further exceptions are the occasional leaves that are rolled opposite the usual way for the variety. Perhaps a report of the leaf rolling habit of this insect led Riley to make the following statement in 1871: "The worm folds rather than rolls the leaf, by fastening two portions together by its silken threads; and for this reason, in con-

tradistinction to many leaf-rollers, may be popularly known as the 'Grape Leaf-folder'." The common name, grape leaf folder, has been approved by the American Association of Economic Entomologists.

Another habit of the grape leaf folder which shows wide variations even in the same locality from year to year is the number of broods produced each year. The chief factor influencing this variation is the seasonal climatic differences. In cooler regions two broods and a rare third brood may be the rule. In the San Joaquin Valley there are always three broods and during favorable seasons a partial fourth brood is produced.

The terminology of the words "brood" and "generation" have become so confusing in entomological literature that it is necessary to clarify these terms as used in this paper. According to Hyslop (1938) a generation begins with the appearance or birth of the young, the egg being considered but a part of the previous generation. In oviparous insects the generation begins at the time the egg hatches. In ovoviviperous insects the generation begins at the time the young insects are extruded from the body of the parent. A brood is defined by the same author as "a contemporaneous and well-defined group of individuals of any active stage of a species, regardless of geneology, and should be numbered consecutively in each calendar year, or, in the case of insects which require more than one year, may be numbered arbitrarily."

The first brood of the grape leaf folder refers to the adults appearing in the spring from overwintering pupae. These lay eggs and give rise to the first-generation larvae and in turn the first-gener-

ation adults which are the second brood of adults for the calendar year. The succession of broods and generations of the grape leaf folder is given in Table I according to the new definitions advanced by Hyslop.

Table I. Succession of broods and generations of the grape leaf folder according to Hyslop's definition of the terms.

	Spring					Summer								Winter			
Eggs (E)			E			E			E				E				
Larvae (L)				L			L			L				L			
Pupae (P)	P				P			P			P				P		
Adults (A)		A				A			A			A					
Brood No.	4	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4
Generation No.	4	4	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4

SYNONOMY OF THE GRAPE LEAF FOLDER

Strauss (1916) gave the synonomy of the grape leaf folder as follows:

Desmia funeralis (Hubn.)
Pyralis funeralis Hubn., Pyral. f. 103, 1796.
Anania funeralis Hubn., Verz. Schm. 360, 3449.
Botys bicolor ? Swain, Zool. Illustr. II, pl. 77, 1821-2.
Desmia maculalis Westw., Mag. Zool. Class IX, pl. 2. 1832.
Desmia funeralis (Hubn.) Guen., Delt. et Pyral. No. 124, p. 190. 1854.

Although Hubner first described this insect as *Pyralis funeralis* in 1796, he later placed the species in the genus *Anania*. In 1832

Westwood established the genus Desmia and placed the species maculalis in this genus. Guenee in 1854 considered both funeralis and maculalis as separate species of Desmia; but four years later Walker reduced Desmia maculalis to the rank of synonym and thus gave Desmia funeralis Hbn. priority.

DISTRIBUTION OF THE GRAPE LEAF FOLDER

The grape leaf folder is an insect of Boreal America. It has been reported from Nova Scotia, British Columbia, and Ontario in Canada, and from the following states of the United States: Texas, Oklahoma, Ohio, Florida, Louisiana, Alabama, Georgia, Virginia, West Virginia, North Carolina, South Carolina, Tennessee, Kentucky, Mississippi, Maryland, Pennsylvania, New York, Delaware, Massachusetts, Indiana, Illinois, Wisconsin, Minnesota, Michigan, Missouri, Arkansas, Kansas, and California. In California the insect is most abundant in Fresno, Tulare, and Merced Counties.

HOST PLANTS OF THE GRAPE LEAF FOLDER

All varieties of the wild and cultivated grapes are attacked by the grape leaf folder. However, the insect has a distinct preference when it has a choice of two or three varieties in one lot. In a mixed planting of Zinfendals and Feherszagoes the former is not attacked until there is competition for food on the Feherszago vines. In adjacent plantings of Alicante, Malvoise, and Thompson Seedless vineyards the latter is the least infested. In the absence of a preferred variety the available host is accepted and is liable to become heavily

infested regardless of the variety. Emperors, Malagas, Sultanas, Ribiers, Grenache, Carrignans, Muscats, and the Mission are some of the common varieties infested in the San Joaquin Valley. Leaf rolling has also been observed on Zante currants.

Other plants fed upon by the grape leaf folder larvae are the Virginia creeper, Parthenocissus quinquefolia (L.), redbud, Cercis canadensis, and C. chinensis. The larvae will also feed upon and roll the leaves of the mulberry, Morus spp. Natural infestation of the mulberry has not been observed.

SEASONAL HISTORY OF THE GRAPE LEAF FOLDER

Emergence of the grape leaf folder adults began about April 11 in 1936. On this day five adults were noted in the field and three emerging adults were destroyed. Buckets of soil selected at random containing leaves were sifted and a number of pupae collected. Increase of adults in the vineyards and along the banks of the river was recorded during later observations. The abundance of moths along the river was believed to be due to the presence of shade and moisture in such regions. During the warmer periods of the day adults seek cool, shady habitats, and just before sunset they become numerous among the vines. As many as twenty moths were counted above each vine in an Alicante vineyard on the evening of April 23. These were apparently ovipositing upon the leaves, stems and canes. The actual discovery of oviposition was made in the spring of 1938. Eggs are not laid upon dry wood.

The grape leaf folder was not strictly confined to the river bottom

lands alone in 1936. A few adults and larvae were occasionally noted in the Fowler district, Fresno County. Heavy infestations of grapes were also known to be present in the vineyards of Tulare County.

After the first week of May a decline in the numbers of the adults was evident from the results of malt sirup trap records. Where they had been noted by the hundreds previously, their numbers were now reduced to solitary individuals here and there. On the other hand, the number of rolled leaves per vine increased daily. The first brood of moths from the overwintering pupae were all dead about two weeks before the second brood appeared. The first brood of larvae were nearly full grown early in June, and the moths from this larval brood appeared about June 20. The peak of adult emergence for the summer was recorded on August 22. Field trap records (Table II) showed a sharp decline in the number of adults during September. Larvae were present in appreciable numbers throughout this month. Adults were collected up to the week ending November 1. If larvae are unable to attain the prepupal stage by this time of the year they are killed by cold weather and the lack of food.

Four generations of the grape leaf folder were recorded from April to November in 1936. The same number of generations was also produced in 1937 and 1938. The first and fourth brood of larvae are so few in numbers that they apparently do little damage to the vines. The second and third larval broods are the most devastating stages of the grape leaf folder. Normally the larvae are leaf feeders, and do not attack the grapes; but when their food supply is diminished, they

are forced to migrate and feed on the grapes. Infested grapes are unmerchantable, and they are exposed to decomposition by microorganisms.

During April and May three malt sirup traps were exposed in different locations on the John Estes Ranch to determine the distribution and abundance of the moths in the vineyards. The bait for the traps consisted of three-fourths of a pint of diamalt and one-fourth cake of Fleishmann's yeast dissolved in enough water to make six quarts. This formula was developed by the Dried Fruit Insect Laboratory of the Bureau of Entomology and Plant Quarantine, Fresno, California for the study of the raisin moth, Ephestia figulilella Greg. It was found to be very satisfactory for the purpose of the present investigation. The attractiveness of the solution decreases on account of fermentation, therefore it is necessary to renew the bait at least once every seven days during the hot summer days.

The trap in the Thompson Seedless vineyard yielded the least number of moths. All of these were females. The preference of other varieties over this variety is probably due to the fact that the leaves of the Thompson Seedless variety are glabrous and more delicate than the leaves of the Alicante and Malvoise. The males of the grape leaf folder die three to six days after mating while the females live about twelve days. It is probable that the bait attracted the females to the Thompson vineyard from the heavily infested vineyards of preferred varieties. Adults were most numerous in the Alicante vineyards. Trap No. I in the Malvoise vineyard averaged 5.8 moths per day over a period of nine days when the average fell to 1.3 per day. This sudden

decrease in moths was believed to be due to the disturbance created by the plowing of the soil to the vines. The plowing probably covered some of the pupae, and killed some emerging adults. The disturbance, however, did not stop emergence but for one day as the following day twenty-six moths were collected and the average for the succeeding seven days was 7.0 per day.

The average number of moths recorded from trap No. I in the Malvoise vineyard was approximately equal to the average of the three traps kept throughout the months of April and May; therefore, it was decided to continue this trap as an indicator of the fluctuations in the numbers of the adults in the field. The last group of moths from the overwintering pupae was recorded on May 21.

The results of malt sirup trapping from April 15, 1936 to November 22, 1936 are given in Table II.

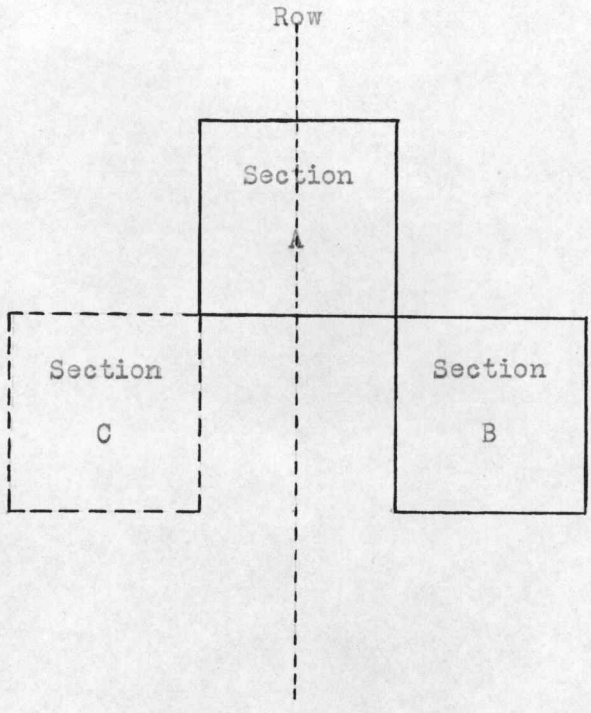
Table II. Malt sirup trap results from April 15, 1936 to November 22, 1936 on the John Estes Ranch, Sanger, California.

Trap No.	Vineyard	Date set	Collected	Male	Female	?	Total
1	Malvoise	April 15	April 18	6	18	0	24
		18	19	3	2	0	5
		19	23	11	10	2	23
		23	25	1	3	0	4
		23	26	23	8	0	31
		26	29	25	13	0	38
		29	May 2	5	7	0	12
		May 16	21	0	0	0	0
		21	23	0	0	0	0
		23	29	0	0	0	0
		June 4	June 7	0	0	0	0
		7	13	0	0	0	0
		13	20	4	4	1	9
		20	27	15	22	1	38
		27	July 3	26	19	0	45
		July 3	11	11	25	4	40
		11	18	0	8	0	8
		18	25	0	0	0	0
		25	Aug. 1	1	0	0	1
		Aug. 1	8	18	14	0	32
		8	16	12	33	4	49
		16	22	25	65	2	92
		22	30	14	28	1	43
		30	Sept. 6	3	6	1	10
		Sept. 6	13	0	1	0	1
		13	20	0	0	0	0
		20	26	0	0	0	0
		26	Oct. 4	0	0	0	0
		Oct. 4	14	3	7	0	10
		14	27	3	2	0	5
		27	Nov. 1	6	2	0	8
		Nov. 1	8	0	0	0	0
		8	22	0	0	0	0
2	Alicante	April 15	April 18	3	8	0	11
		18	19	5	2	1	8
		19	23	12	12	1	26
		23	25	0	2	0	2
		23	26	0	13	0	13
		26	29	4	9	0	13
		29	May 2	20	21	0	41

Table II. Continued. Malt sirup trap results from April 15, 1936 to November 22, 1936 on the John Estes Ranch, Sanger, California.

Trap No.	Vineyard	Date set	Collected	Male	Female	?	Total
2	Alicante	May 16	May 21	3	1	0	4
		21	23	0	0	0	0
		23	29	0	0	0	0
3	Alicante	April 15	April 18	7	14	0	21
		18	19	5	2	0	7
		19	23	20	7	0	27
		23	25	16	23	0	39
		23	26	22	31	0	53
		26	29	8	28	0	36
		29	May 2	13	9	0	22
		May 16	21	1	0	0	1
		21	23	0	0	0	0
		23	29	0	0	0	0

On November 18, 1936 Dr. Heber C. Donohoe and the writer made counts of the number of pupae per square foot by the use of a mechanical device which set off a square foot of ground to be sampled under the vines. This instrument was designed by Mr. Dwight F. Barnes of the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, Dried Fruit Insect Laboratory, Fresno, California. The area three feet wide under each row in which nearly all the pupae overwinter was sampled as demonstrated in the following diagram.



The samples were selected at random two from each vine. In the computations the figures for section B was used for section C. It was assumed that these two areas being corresponding sections beneath the vines would be nearly equal. Accordingly the estimations of the number of pupae are figured on the basis of three samples per vine, two of these (A and B) actually taken and the third derived from section B. The vines are planted 8x12; hence there are twenty-four square feet of space containing overwintering pupae, and 495 vines to the acre. The results are given in Table III.

Table III. Abundance of overwintering grape leaf folder pupae in the Alicante vineyard, John Estes Ranch, Sanger, California. Nov. 1938.

No. pupae per sq. ft. of sample			Total No. pupae	Total sq. ft.
Section A	Section B	Section C	A, B, C	sampled
24	13	13	50	3
37	30	30	97	3
6	0	0	6	3
0	1	1	2	3
7	2	2	11	3
30	2	2	34	3
5	8	8	21	3
44	7	7	58	3
13	1	1	15	3
16	18	18	52	3
18	10	10	38	3
6	6	6	18	3
0	2	2	4	3
20	21	21	62	3
9	2	2	13	3
6	8	8	22	3
21	16	16	53	3
Totals 262	147	147	556	51
Average pupae per sq. ft.			10.9	
Average number of pupae per vine			261.6	
Average number of pupae per acre			129,492.0	

LIFE CYCLE OF THE GRAPE LEAF FOLDER

Adults: The adults of the grape leaf folder are very attractive looking moths (Fig.1) with a wing expanse of about seven eights of an inch. Newly emerged adults are black with two silvery white spots on the fore wings and one (male) and two (female) spots on the hind wings. The males are also distinguished from the females by the knotted or

elbowed appearance of their antennae, in contrast with the smooth, thread-like antennae of the females. As the moths lose their scales by activity and age they become dark brown in color. Although they are evening fliers, adults may be seen in flight during the day in cool, shady situations. Flight and egg laying activities begin a few minutes after sunset.

Egg stage: The eggs are small, flat, opalescent masses deposited generally on the veins of the upper surface of the leaves, and occasionally on the stems and petiols. The incubation period averages about five days.

Larval stage: The newly hatched larvae are minute, green caterpillars. For the first two to three days they feed gregariously on one spot, then they disperse in all directions to select lobes of the leaf to roll individually. It requires about five minutes for a larvae to roll a chosen section of a leaf. Before a larva becomes fully grown three or more rolls are made and consumed. A full grown larva measures about one inch in length and one half an inch in diameter. The larvae are very active and easily disturbed, being extremely sensitive to touch. This habit accounts for their absence in some rolls when one is searching for them in the field. They usually wriggle and fall to the ground while the observer is unrolling the leaf in search for them. The larval period averages about fifteen days. About four days are required for a full grown larva to transform into the pupa. At this prepupal stage the color is changed from green to pink. A larva in this stage is plump and sluggish, but still very sensitive to touch.

The leaf is rolled for food and protective purposes. It is not rolled for a pupa case. When the larva is ready to pupate it will either move to a new leaf or a lobe of the same leaf and fold it. In some cases a portion of the roll in which the larva has been feeding is used for this purpose. The pupal case is partially severed from the rest of the leaf so that it appears like a half moon. The portion of the leaf thus cut enclosing the cocoon gradually dries. The rapid drying of the cocoon prevents excessive moisture from collecting inside the pupal case. In many rolls there are found drops of water which probably is due to the condensation of the water of transpiration from the leaf surface. The presence of moisture in the rolls allows a very favorable growth of mold to develop on the frass deposited inside the rolls.

In order to roll a leaf the larva selects a lobe of the leaf after much exploration of the entire leaf surface. If one leaf is not suitable another is found. It begins the rolling process by fastening its silk to a small vein on the ventral surface of the leaf, then this is fastened to the dorsal edge of the leaf. This starts the leaf to draw together, and as the larva attaches the silk each time a little further from the first point of attachment on the dorsal surface the rolling progresses. While the larva is moving its head back and forth, the fore legs are placed on the first strand of silk that was previously produced. The small weight of the larva exerts enough pressure upon this strand to pull the leaf together; thereby causing it to roll. When the larva is through with one strand, it moves down about an inch and repeats the above procedure. The head of the larva swings back and

forth very much like a pendulum about three hundred times. About three strands are required to roll the leaf once. At this time the larva sticks its head out of one side and connects two more points. The same operation is repeated on the opposite opening of the roll, and the result is another roll of the same lobe. The rolls are about the thickness of a lead pencil, and from two to six inches long.

A full grown larva was placed on a mulberry leaf as an experiment. After the preliminary explorations, it began to roll the leaf. Since the mulberry leaf is much coarser than the grape leaf, the operations of the larva were slowed down, and a better opportunity was offered to observe the leaf rolling tactics of the caterpillar. After spanning four loci the leaf failed to roll. Ordinarily two or three strands would be sufficient for this first operation if a grape leaf were used. The larva went through the same steps in rolling this leaf as it did with the grape leaf, although a far greater amount of energy and time was necessary for the same amount of work.

The significant operations of leaf rolling are: After the silk has been connected between the following two points: (1) the very edge of the dorsal surface of the leaf and (2) the ventral surface at the base of a vein, about two hundred times so that a good strand is produced, the larva manipulates the mass with its legs so that the pressure exerted by the weight of its body upon the strand draws the two points together. Meanwhile, it begins a new strand using the same two points. This second strand is formed while the two points are being drawn together by the manipulations of the larva on the first

strand. This operation leaves the first strand loose and useless, while the second strand is taut and aids in drawing the two points together. If the larva should stop working now, the leaf will not roll because of other factors. To proceed with the leaf rolling new strands are produced each time a little further back from the preceeding one as recorded above.

Pupal stage: Overwintering pupae are found within folds of leaves. When the larva is ready to pupate, the leaf margin at one extremity of the roll is folded and sealed from within and at the same time the whole case is partially severed from the rest of the leaf so that the pupal case gradually dries. The pupa is enclosed head down in the cocoon. Pupation under field conditions of the broods before the overwintering brood has not been satisfactorily determined. Pupae of the summer broods are extremely hard to find. Sifting of soil, collected beneath the vines, has failed to reveal any pupa. Equal numbers of the summer broods of pupae have been found both on green leaves on the vines and on dry fallen leaves beneath the vines. It is probable that pupation occurs on the vines, and the partially severed pupal case breaks off and falls to the ground after it has dried. The pupal period averages seventeen days.

Cultures: On April 18, 1936, a male and a female both of which had emerged a few hours previously were liberated into a rearing cage. The male died on April 23. The following day another male and two females were put into the cage along with the first female. Egg laying activities were observed, but it was not determined whether any

eggs were oviposited. The second male died two days after mating. It was found that adults mated on the date of emergence. The first female lived twelve days before she died. The purpose of this preliminary culture was to observe the reactions of the adults under control conditions. Larvae were found on the leaves seventeen days after the first male and female were caged. The culture rooting was so badly infested by the many larvae, that it was defoliated after ten days of their feeding. Because of the absence of leaves the larvae lowered themselves with the aid of their silk in search of more food. Some larvae pupated on the vines while others transformed into this stage on the cheese cloth covering the cage.

A second cage was built and a female which had emerged on May 3, and a male of May 4, were liberated into it. The female became highly excited. She began simulating the act of oviposition upon the leaves. Within ten minutes the pair mated. The male died on May 8, and the female was found dead the following day. Larvae were observed on May 12. The twenty leaves of the rooting were all rolled by May 23. The whole plant was defoliated by May 26. The larvae began migrating in search of food. In the absence of leaves, those larvae that were ready to pupate spun their cocoons on the cheese cloth netting, and in about four days transformed into the pupal stage.

Life cycle:

Eggs----------6 days
Larvae----------15, 15, 16, 15
Pupae----------17, 17, 14, 21, 16, 12, 12, 19, 19, 19
Total----------38 days (Approximately)

The above data is based upon the results of the two cultures and the rearing of a larva collected on April 29. This larva was about one day old when collected. On May 13 it was full grown, and a change of color from green to pink occurred as it entered the prepupal stage. It emerged on May 31.

PARASITES OF THE GRAPE LEAF FOLDER

On October 4, 1936, observations on the parasitism of the grape leaf folder were made by Dr. Donohoe and the writer. The area selected was a Thompson Seedless vineyard across the road from the Katsura ranch, Parlier. Leaf rolling in portions of the vineyard was severe, with most of the leaves dead. Examination for parasitism failed to reveal a single living larva in the rolls.

A collection of pupae was held in the laboratory, with frequent examinations for parasitism. Only four parasites (all Diptera) emerged after October 21. Since the pupae were exposed to reparasitism after emergence which can be definitely attributed to this source; it appears quite probable that all the parasites attack the larvae and carry over into the pupal stage. The data follow:

Total pupae remaining	221
Parasites recovered:	
Tachinids	147
Sarcophagid	16
Jumping Hymenoptera	16
Immature (accidentally killed)	8
Total	408
Total parasitized	187

Percentage parasitism by (exclusive of 8 accidentally killed):

Tachinids	36.75
Sarcophagids	4.00
Jumping Hymenoptera	4.00
Total	45.83

The most common parasite of the larva of the grape leaf folder is Microbracon cushmani Muesebeck. This small braconid attacks the nearly full grown larva and deposits from ten to fifteen eggs. The eggs hatch in three or four days and the larvae feed and develop upon the host which turns black about the time the parasites are ready to pupate. Small, white cocoons are spun on the dead host. The larval period is four days and the pupal period about six days.

To get some data on the mortality caused by these parasites in the month of May, one hundred leaves were picked at random, and the parasitized larvae recorded. The mortality of the host was found to be thirteen percent at this time of the year. The percentage of mortality caused by this parasite approached one hundred in October, after the greatest damage to the foliage and the grapes was already done.

On October 4, 1936, counts of the number of Microbracon pupae per host larva were made with Dr. Donohoe, and the following results obtained:

7, 10, 5, 2, 4, 3, 11, 8, 10, 13, 5,
14, 10, 16, 6, 9, 12, 11, 17, 8, 7,
4, 3, 6, 12, 10, 5, 6, 3, 5, 8, 4, 8,
13, 5, 9, 15, 1, 17, 5, 6, 12, 13, 7.

A common pupal parasite of the grape leaf folder is Ephialtes sanguineipes (Cress.). The parasite attacks the host in the fall and emerges in the spring. They are also observed during the summer. This

would indicate that more than one generation are produced each year. The determination of this species was made by Mr. R. A. Cushman, United States Department of Agriculture, Division of Fruit Insects.

A list of the parasites of the grape leaf folder is given below:

Parasites and synonyms	Authority
Hymenoptera	
Meteorus dimidiatus Cress.	Strauss (1916)
Pardianlomella ibseni Gir.	Strauss (1916)
Trichistus pygmaeus Cress.	Strauss (1916)
Mesochorus scitulus Cress.	Strauss (1916)
Gemocerus sp.	Strauss (1916)
Aleiodes (Rogas) desmiae (Ashm.)	Howard (1890)
Apanteles choreuti Vier.	Muesebeck (1920)
A. canarsiae (Ashm.)	Muesebeck (1920)
A. housatannuckorum Vier.	
A. maquinnai Vier.	
A. dimidiatus (Cress.)	Muesebeck (1923)
Meteorus noctivagus Vier.	
Microbracon johannseni (Vier.)	Essig (1936)
Habrobracon tetralophae Vier.	
M. gelechiae (Ashm.)	Muesebeck (1925)
Bracon gelechiae Ashm.	
B. notaticeps Ashm.	
Habrobracon johannseni Vier.	
H. gelechiae Johnson	
H. tetralophae Vier.	
H. gelechiae Cush.	
H. johannseni Cush.	
H. gelechiae Stearns	
M. cushmani Mues.	Donohoe (1934)
Habrobracon variabilis Cush.	
Ephialtes sanguineipes (Cress.)	Donohoe (1937)
Brachymeria ovata (Say)	Donohoe (1937)
Diptera	
Phorocera erecta Coq.	Essig (1936)
Tachinophyto variabilis Coq.	Strauss (1916)
Exorista pyste Walk.	Strauss (1916)
Leshiomima tenera Wied.	Strauss (1916)
Anachaetopsis tortricis Coq.	Donohoe (1937)
Zenillia ceratomyiae Coq.	Donohoe (1937)
Nemorilla maculosa Meig.	Donohoe (1937)
Unidentified Sarcophagid and Tachinids.	

Perilampus platygaster Say is listed as a hyperparasite of Meteorus dimidiatus by Strauss.

CONTROL OF THE GRAPE LEAF FOLDER

Control measures must be based on the habits and often on minute details in the life cycle of an insect. A knowledge of the crop attacked is also essential. The following seasonal and daily habits of the grape leaf folder are summarized from the study of its life history. These facts must be considered in any attempts to control the insect.

Seasonal habits: The grape leaf folder overwinters in the pupal stage in the leaves beneath the vines.

The adult emergence begins about the first week in April and continues for about 35 days.

Eggs are oviposited from the first week in April to the middle of May by the spring brood of adults.

The shoots of the vines during the period of spring oviposition are from six to forty inches long, a relatively little amount of growth.

The second brood of adults do not appear for about three weeks after the end of spring emergence.

Leaf rolling becomes apparent three weeks after the beginning of spring emergence and increases rapidly.

The most important parasite of the larva, Microbracon cushmani, becomes apparent in great numbers about the first week in May.

At the time of the appearance of the second brood there is a

dense foliage much to the advantage of the larvae which seek protection in the old first brood rolls.

Daily habits: The adults are evening fliers. They rest in shady situations during the day. They have been observed feeding on flowers near the home and on fallen figs beneath fig trees.

Eggs are oviposited generally on the upper surface of the leaves.

Newly hatched larvae migrate to the lower surface of the leaf, and feed gregariously. After about three days they separate and each individual rolls its own lobe of the leaf.

Pupae are protected in cocoons formed by folding the leaf margins.

The bionomics of the grape leaf folder point to three methods of control. These are mechanical, chemical, and biological.

Mechanical: Control measures should begin in late fall by raking and burning all leaves, or by torch burning of the debris beneath the vines.

Chemical: The second step in the control should begin about fifteen days after adult emergence has been observed in the spring. Dusts and sprays are used to best advantage for the control of the first brood larvae before many of the leaves are rolled. The larvae are killed by feeding on toxic materials deposited by the spray or dust.

It is best to concentrate all efforts to control the pest during the first thirty days after the adults begin to emerge from overwintering pupae. This statement cannot be over emphasized. If control measures are neglected at this time, it is futile to attempt control at a later date against the second brood larvae. It is safe to

estimate that the spring brood of adults, reduced by parasitization and winter mortality, do not represent over forty percent of the fall population. Other advantages of early control are the small amount of foliage in the first month of vine growth, and the lack of old rolls into which newly hatched larvae migrate for protection.

Biological: The possibilities of the biological control of the grape leaf folder have not been studied. Mechanical control is not enough in itself. Chemical control is still in the experimental stage. Granting that the possibilities of these two methods have not been exhausted, the writer believes that, since these have not given an economic control so far, it may be profitable to study the status of one of the more important natural enemies of this pest.

Microbracon cushmani, a little braconid wasp, is well known to all growers whose vineyards have been infested. Some vineyardists do not attempt any chemical control for fear of harming the parasites. This precaution is not necessary, and in heavily infested vineyards it is unadvisable. At the time when the first dust or spray is recommended there are very few parasites present. The parasites are most abundant when it is too late to attempt chemical control; hence, if control measures have not been taken within fifteen to thirty days from the time of spring emergence, a greater percentage of the parasites will be killed and the host will be little affected by late applications.

The short life cycle of Microbracon enables it to reproduce two to three times as fast as its host. The number of eggs laid per female equals those of the host. The parasites disperse readily and find

the host larvae in the rolls of the leaves. Being a larval parasite Microbracon kills after the host has survived the risks of life from the time of hatching to the stage at which it is attacked. Larval parasites are more specific in contrast to the polyphagus egg parasites. Success in biological control is in direct proportion to specificity of the parasite. And yet this parasite has not controlled the grape leaf folder to our satisfaction. On the other hand, it cannot be denied that it is one of the most important checks that we have against the pest. During the peak of infestation the best dust or spray will not surpass the percentage of mortality brought about by the parasitism of the grape leaf folder by M. cushmani.

A comparative study of the host and parasite life histories may give us a clue as to the methods which may be followed in order to alter their relationship to our advantage. The adults of the grape leaf folder emerge about the first week in April. The parasites overwinter in the adult stage, and are present at the time of the host emergence in the spring. The eggs of the host hatch in about five days, and after feeding in the region of hatching for two or three days they migrate to the lobe of the leaves and begin to roll them. The feeding period of the leaf roller larvae is about fifteen days. The parasites lay their eggs upon the nearly full grown host larvae. These hatch within two to three days and after feeding for about six days they spin their cocoons upon the dead host in the leaf roll. The pupal period of the parasite is about six days while that of the host may vary from twelve to twenty days. The entire life

cycle of the host averages about thirty-six days, while that of the parasite is completed in about fourteen days. Thus the parasite has a great advantage over its host in having a decidedly shorter life cycle. This enables M. cushmani to build such a great population by the last generation of the host that the percentage of parasitism and the resulting mortality of the grape leaf folder larvae approaches one hundred percent. This delayed control attained by the parasite does not prevent damage to the grapes as this has already been done, but it does check the potential numbers of the host.

The adults of M. cushmani are confronted with a serious problem in the spring. Because of the destruction of the leaf folder larvae in the fall, their food supply has been reduced. More important than the shortage of food supply is the fact that it is not available to them until the host adults lay their eggs and these hatch and develop to nearly full grown larvae. As a result of this situation many of the parasites probably perish. Fortunately, the high biotic potential of the parasite enables the remainders to overtake the host in the fall.

If we can help the wasp, from the time it overwinters to the time when the first brood of the host is in a vulnerable stage, a sufficient control of the grape leaf folder may be attained. It may be possible to accomplish this in the following manner: Parasite cocoons and adults collected in the fall should be kept under refrigeration in order to retard activity early in the spring. A retardation of fifteen to twenty days will be necessary in order to bring about a synchronization of the

host-parasite cycle to the advantage of the parasite at this time of year. It may also be possible to rear the parasites in the laboratory on the larvae of the Indian-meal moth, Plodia interpunctella (Hbn.), and the raisin moth, Ephestia figulilella Greg.

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Fig. 1

Grape leaf folder adult
(Natural size)

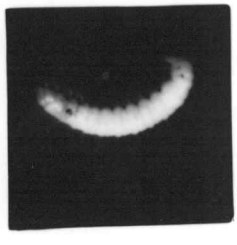

Fig. 2

Grape leaf folder larva
(Natural size)

Fig. 3

Grape leaf folder pupa
(1½X natural size)

PLATE II

Grapes infested by the grape leaf folder larvae.
(Photograph by Dwight F. Barnes. U.S.D.A.)

PLATE III

Fig. 1

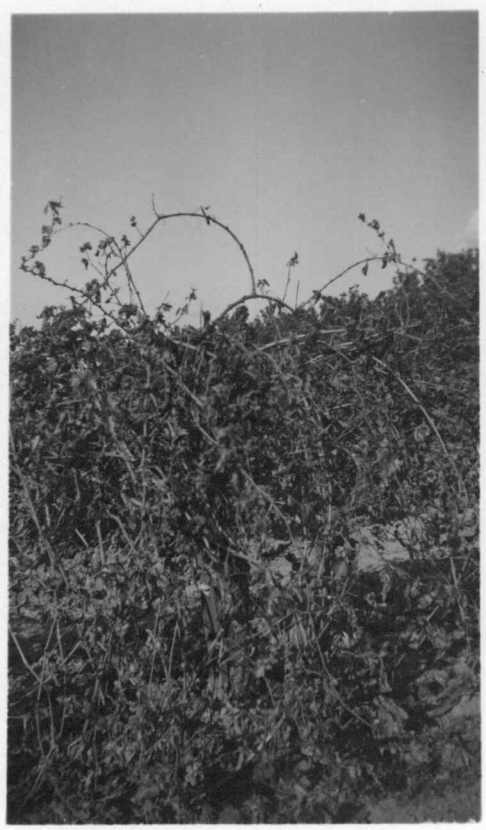

Fig. 2

Fig. 1. Row of Thompson Seedless vines showing varying degree of infestation by the grape leaf folder.
Fig. 2. A heavily infested Thompson Seedless vine nearly defoliated by the grape leaf folder.