# GRAPE LEAFFOLDERS: DETERMINING ECONOMIC IMPACT LEVELS AND ACTION THRESHOLDS


## DAVID G. JAMES



**Final Report 2020-23 Washington State Grape and Wine Research Program**



## 1. Summary

This project aimed to determine the economic impact of the White-headed grape leaffolder (WGL) on wine grape production in eastern Washington. Monitoring of WGL populations in selected, unsprayed Red Mountain vineyard blocks during 2020 indicated that moderate to high density populations of WGL (60-80% occupation of leaves, mean 1-2 larvae/leaf) had low to negligible impact on fruit production and quality, with no economic impacts noted. WGL adults emerged from overwintering pupae in May 2020, and laid eggs that produced a peak in numbers of leaffolding larvae during June. The second adult generation appeared at the end of June and produced a second larval generation during July. A third generation of adults appeared in August with a third and final larval generation in September-October. In 2021 and 2022, a very different scenario occurred with no moths seen until July. Unlike 2020, the first generation of moths during spring (May) was largely absent in 2021 and 2022, as determined by bait trapping. Presumably

numbers of moths that emerged in spring from overwintering pupae were so small that they were undetectable using bait traps.

Only small numbers (< 5.0/trap) were trapped during July (2nd generation) with only a slight increase (up to 15.0/trap) in the 3rd generation during late August-September. Fermenting bait traps were used to monitor adult population trends and were effective in 2020 for the second and third generations of moths, accurately identifying peak flights and when peak egglaying occurred. This in turn, allowed identification of an optimal insecticide application window in 2020 when the majority of the population was in the vulnerable non-leaf folding first instar stage. Effective, long-term control of leaffolder larvae was obtained at this time using a single application of Altacor (Chlorantraniliprole) in two Red Mountain vineyards. A single application of Leprotech (*Bacillus thuringiensis var. kurstaki*) in one vineyard provided inadequate control.

An insecticide trial conducted in a Red Mountain vineyard during August-October 2022, confirmed the efficacy of Altacor as a treatment for WGL providing good knockdown and persistent control over at least two months. The spinosyn insecticides, Delegate (Spinetoram) and Entrust (Spinosad) also provided good knockdown but allowed some minor re-infestation after 5-8 weeks when a new generation of WGL occurred. The *Bacillus thuringiensis* product, Dipel, gave slower knockdown and also allowed minor re-infestation after 5-6 weeks. Similarly, the insect growth regulator, Intrepid, provided slow knockdown (4 weeks) but was less susceptible to reinfestation. Overall, Altacor provided the best, sustained control of WGL.

Progress in this project was limited during 2021 and 2022 by significant downturns in natural populations of WGL in eastern Washington. Bait traps caught no moths during mid-late spring (April-June), the period when adults emerge from overwintered pupae. This suggests that the spring flight was extremely small in both years and perhaps indicates that substantial mortality of pupae occurred during the winters prior to these seasons. No moths were caught in bait traps in both years until July, when a few moths were trapped representing a weak second brood. Greater numbers were trapped in late August (third brood) but still substantially fewer than in 2020 and only at a limited number of sites. Reduced populations of WGL in 2021 and 2022 meant that leaffolders were not a damaging pest of grapes and this interfered with field experiments on economic impact, thresholds and insecticide applications. We monitored the low populations that did occur during the season and the absence of economic damage to fruit quality and production. It appears that if the first generation of adult moths emerging from overwintering pupae in May/June, is small, then populations may not build sufficiently in the following two generations to cause economic damage to vineyards.

The possibility of overwintering being a weak link in the life history of WGL was briefly investigated by looking at the survival of overwintering leaffolder pupae during thtree winters 2020-23. Experiments indicated that survival of overwintering pupae is low, particularly if the leaf shelter/cocoon in which pupae are formed is broken open, exposing pupae to the elements. There may be options for increasing the mortality of overwintering pupae by cultivating the vineyard floor.

2. **Final Report**

3. **Grape Leaffolders: Determining Economic Impact Levels and Action Thresholds**

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5. **Objective(s) of Proposed Research**

1. To determine the economic impact of White-headed Grape Leaffolder (WGL) infestations on wine grape production and quality
2. To determine the population density of WGL at different stages of the season and relationship to fruit production and quality at harvest
3. To determine the population threshold level at which insecticide sprays should be applied to prevent economic damage
4. To identify the best insecticide for WGL control in terms of efficacy, selectivity to natural enemies of WL and sustainability of low pesticide-input IPM

6. **Summary of Major Research Accomplishments and Results by Objective:**

***Obj 1: To determine the economic impact of White-headed Grape Leaffolder (WGL) infestations on wine grape production and quality***

Progress was made on this objective using the monitoring approach. Attempts to conduct the experimental approach were thwarted by covid-19 concerns in 2020/21 and lack of sufficient WGL larvae for artificial infestation. Two Red Mountain vineyard blocks with significant WGL populations were monitored during July-October 2020. Data on adult and larval populations were collected weekly or fortnightly. Two distinct larval generations in July and September were indicated by data on leaf occupancy by WGL larvae and the mean number of WGL per leaf (Fig. 1). Due to a late start in monitoring these blocks, we missed the first larval generation in June. Occupation of leaves by WGL larvae reached 60-80% at the peaks of each generation and between an average of 1-2 larvae per leaf (Fig. 2). These levels are among the highest we have seen since our research began in 2018. One of the blocks (block 43) was left unsprayed by the grower at our request while the other (Candy Mt) developed a large WGL population late in the season (August) and spraying was not considered an option by the grower, so close to harvest. Harvest data from both blocks indicated a normal harvest with no evidence of fruit contamination by larvae. This suggests that in this particular case relatively high densities of WGL larvae did not appear to have an economic impact on grape fruit production and quality. This is a preliminary assessment and will need consideration of harvest data before firm conclusions can be made.

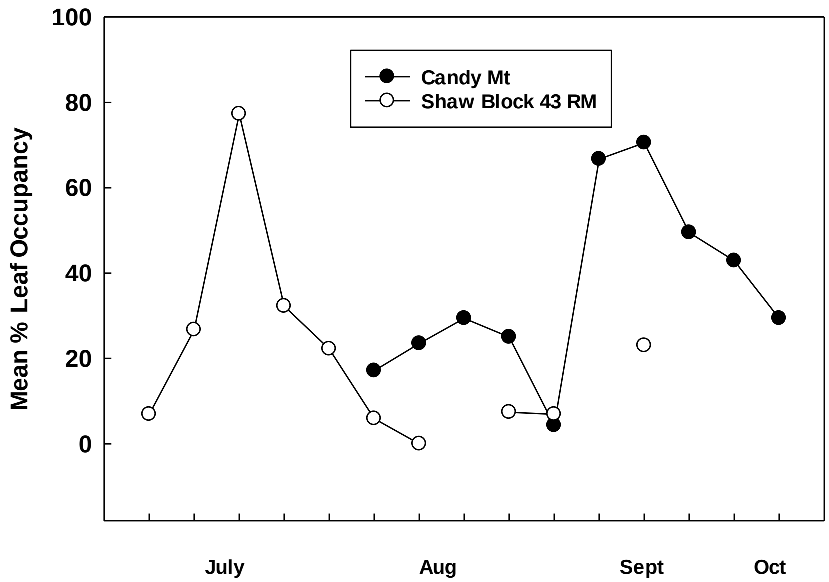


Figure 1. WGL Larval populations assessed as percentage leaf occupation at two unsprayed Red Mountain vineyard blocks during summer-fall 2020

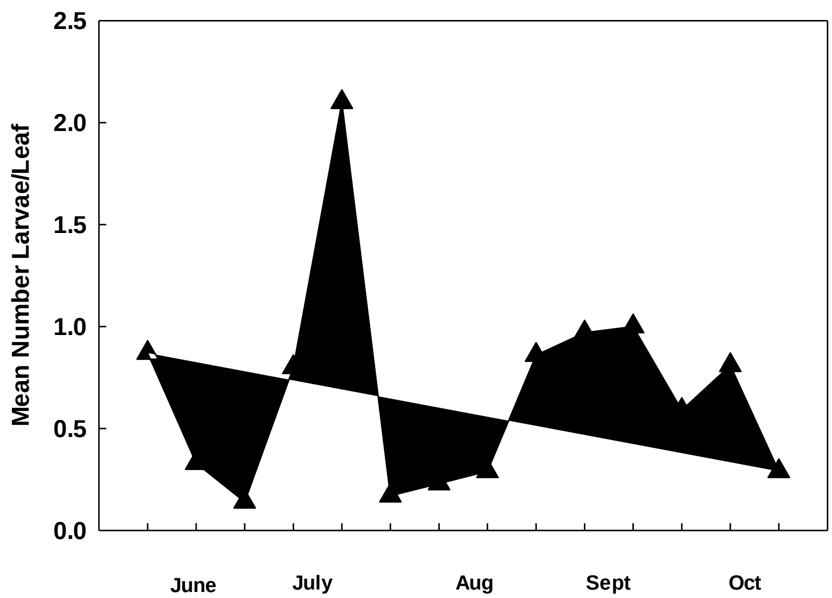


Figure 2. WGL larval populations assessed as number of larvae per leaf using data from two unsprayed Red Mountain vineyard blocks during summer-fall 2020

In 2021, three Red Mountain vineyard blocks with low-moderate WGL populations were monitored during mid-August to September 2020. Prior to mid-August very small numbers (1-5) of moths were trapped in a few vineyards in July and none at all during the spring flight (May-June). No larval infestations occurred during this time. Data on adult and larval populations were collected weekly or fortnightly. Occupation of leaves by WGL larvae reached 30-73% in September at the three Red Mountain sites (Fig. 3). This late infestation of larvae did not cause any problems to harvested fruit and no contamination of harvested fruit with larvae was reported. Relatively high densities of WGL larvae for just four weeks did not have an economic impact on grape fruit production and quality.

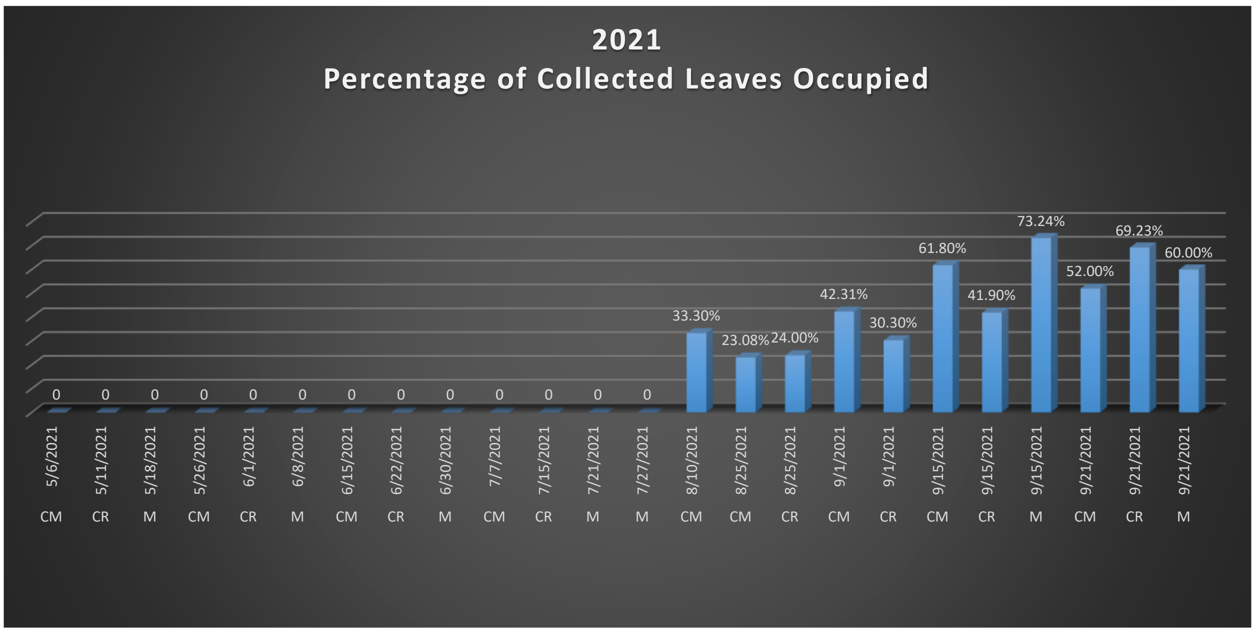


*Figure 3. WGL Larval populations assessed as percentage leaf occupation at three unsprayed Red Mountain vineyard blocks during May-September 2021*

In 2022, for the second consecutive year, the spring flight of WHGL moths was not detected via our bait traps (Fig. 4). After strong spring flights each year during 2018-2020, this was surprising and perhaps indicated that overwintering mortality was greater in winters 2020/21 and 2021/22. Numbers of moths trapped in 2022 were very low compared to earlier years and rarely exceeded 4-5/trap (Fig. 5). In both years lacking a well-defined spring flight, the population recovered in July-August to cause leaffolding damage in wine grape vineyards, but not to the extent and severity seen in earlier years.

*Figure 4. Bait trap with fermenting molasses used to monitor adult moths of White-headed Grape Leaffolder.*

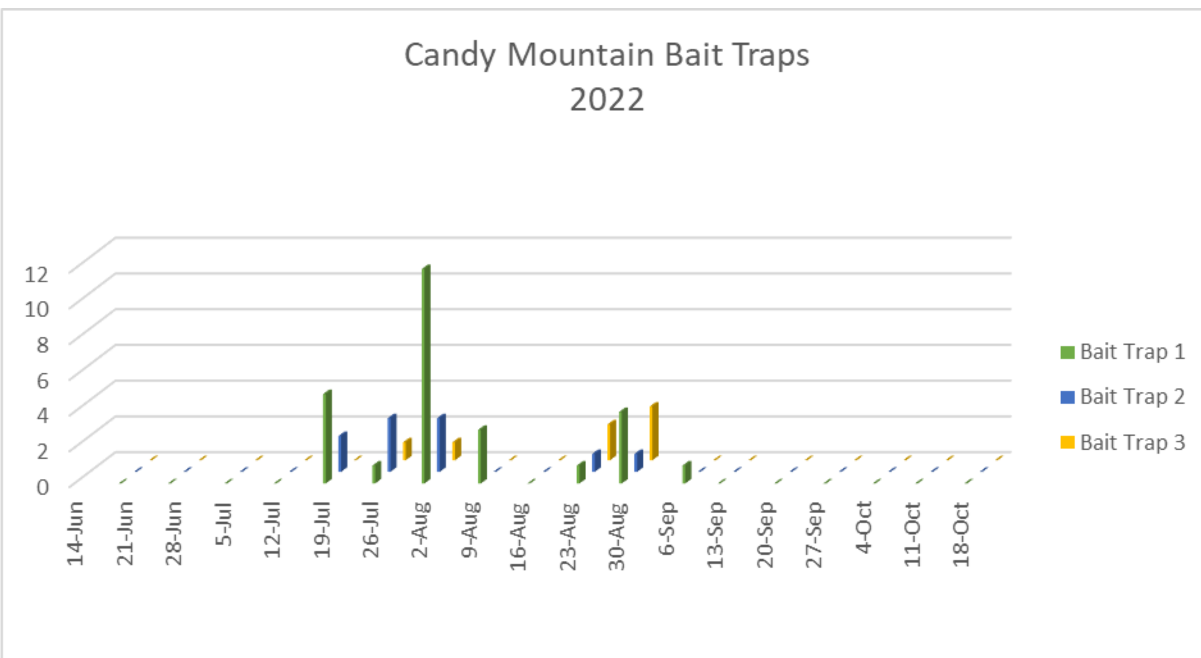


*Figure 5. Bait-trapping of WHGL moths in a Candy Mountain vineyard during June-October 2022.*

The economic impact of moderate to high density (60-80% occupation of leaves with a mean of 1-2 larvae/leaf) had no obvious impacts on grape production and quality in 2020. These levels were also insufficient to cause caterpillar-contaminated harvested fruit, as has occasionally been seen in the past with extreme levels of WGL infestation. In 2021 and 2022, reduced populations of WGL meant that leaffolders were not a significant pest of grapes and this prevented conduct of our planned field experiments on economic impact thresholds.

### *Obj 2: To determine the population density of WGL at different stages of the season and relationship to fruit production and quality at harvest*

Weekly and/or fortnightly monitoring helped provide further data on the relationship between seasonal population levels and the impact on harvest attributes. In 2020, combined data on leaf occupation by WGL larvae from all monitored vineyards (12), indicated that three larval generations occurred (Fig. 6). Adult moths from overwintered pupae began emerging during late May and continued through the first half of June (data obtained from captive overwintered pupae and vineyard observations). By mid-June 2020, WGL occupied 87.5% of leaves sampled and examined. The second peak occurred in late July (56.2%) with the final peak in October (42.9%) (Figs. 6-7). A very different scenario occurred in 2021 and 2022. In 2021 no adult moths were trapped or seen in monitored vineyards until July 7 (Fig. 8). In 2022, the first moths were detected on July 19. Early-mid July is the normal time when the second generation of adult moths emerges. This indicates that the entire emergence of moths in May-June from overwintered pupae was not detected in 2021 and 2022. Presumably, very small (undetectable) numbers of moths did emerge from overwintered pupae, resulting in the small numbers of moths detected in bait traps in early-mid July. A total of 13 moths from 9 monitored vineyards were recorded during July 6-27 2021 and 31 in July 2020. This weak second flight of moths laid eggs resulting in a stronger flight of moths from August 10-September 7 2021. Total numbers of moths trapped during this period ranged from 10-111 per week (Fig. 8). In 2022, the second flight was also weak (Fig. 5).

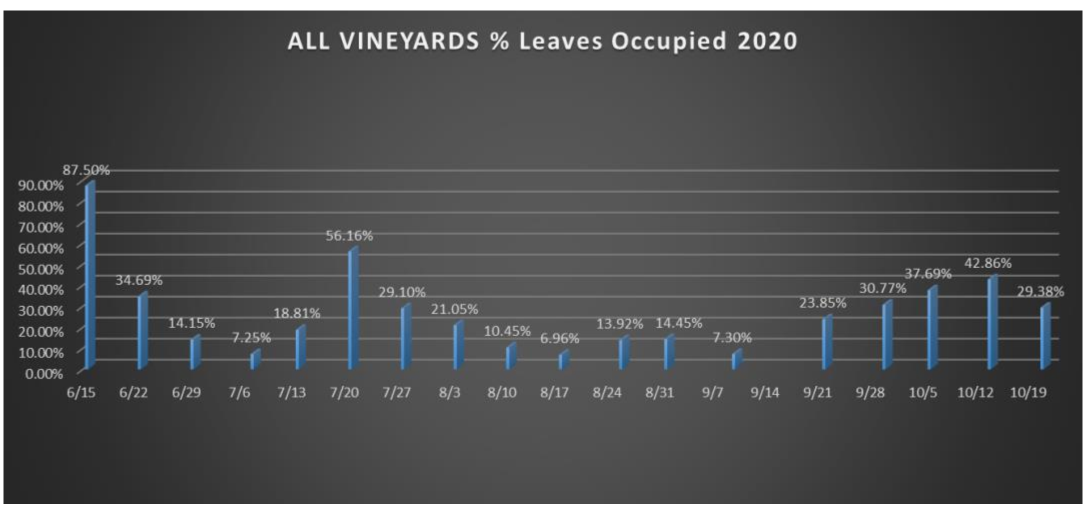


*Figure 6. Percentage of leaves occupied by WGL larvae at 12 vineyard sites (Red Mountain & Mattawa, combined data) during June-October 2020.*

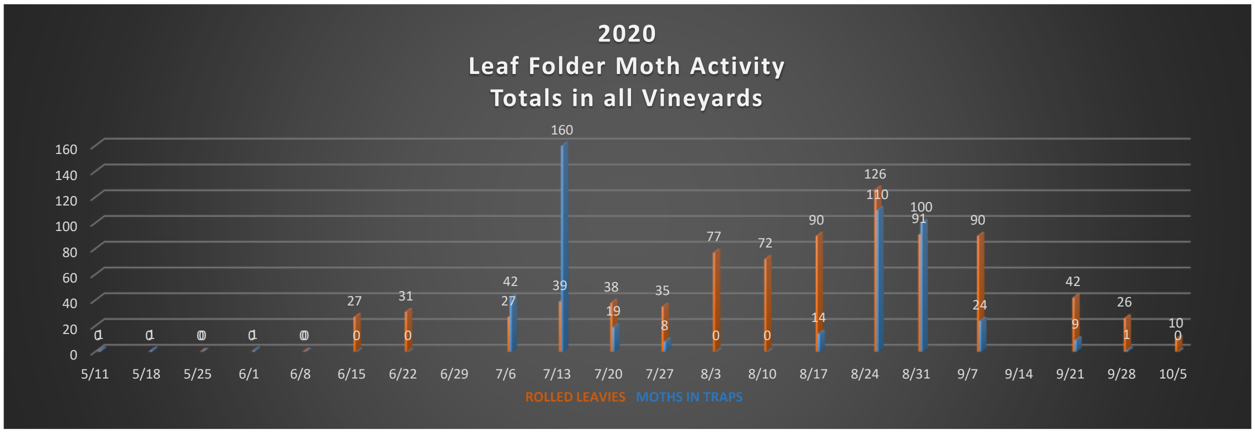


*Figure 7. Adult WGL incidence in bait traps and numbers of rolled leaves in 9 vineyards during May-September 2020*

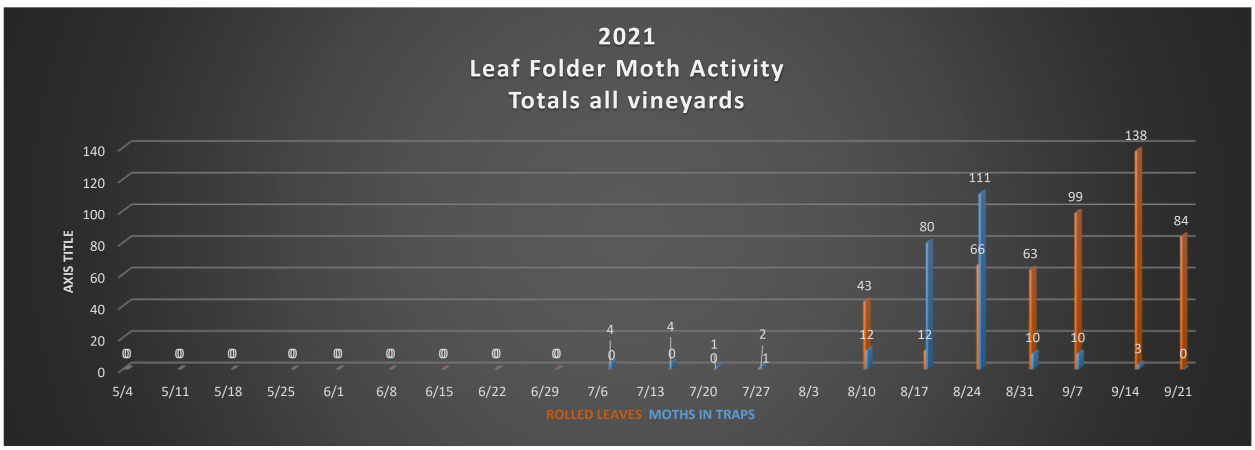


*Figure 8. Adult WGL incidence in bait traps and numbers of rolled leaves in 9 vineyards during May-September 2021*

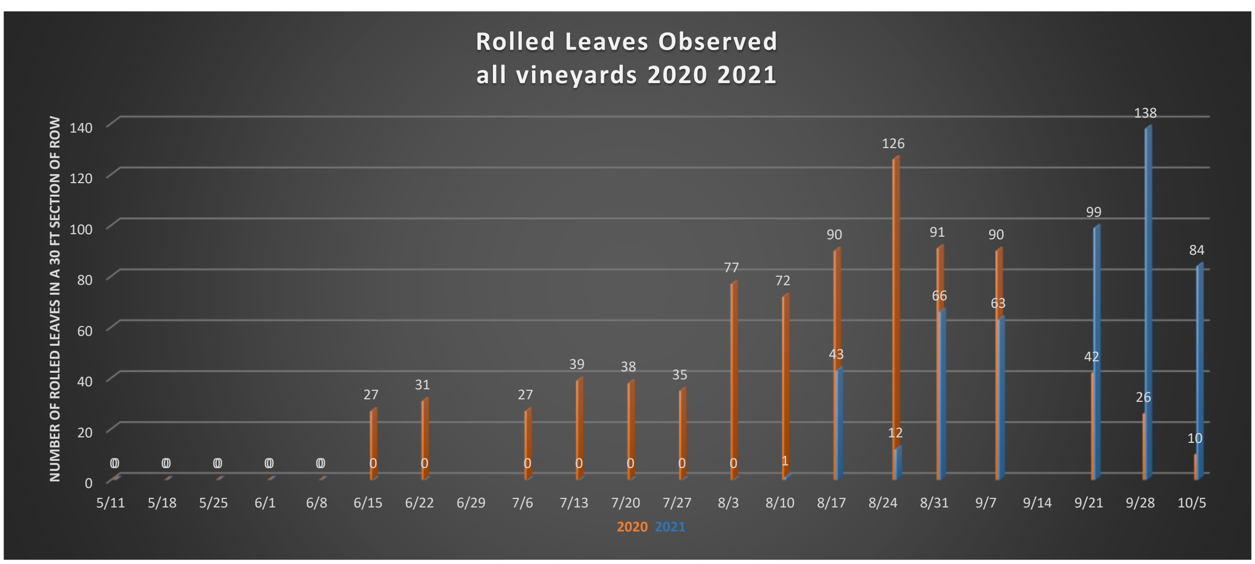


*Figure 9. Comparison of rolled leaf incidence in 2020 (orange) and 2021 (blue)*

Larval populations were not present in vineyards long enough in 2021 and 2022 to cause issues or problems with fruit production. Rolled leaves (Fig. 10) were not observed until the second half of August in 2021 (Fig. 8) and 2022.

*Figure 10. Grape leaves folded/rolled by WGL larvae*

***Obj 3: To determine the population threshold level at which insecticide sprays should be applied to prevent economic damage***

***Obj 4: To identify the best insecticide for WGL control in terms of efficacy, selectivity to natural enemies of WL and sustainability of low pesticide-input IPM***

An insecticide evaluation trial was conducted in collaboration with Shaw Vineyards at Red Mountain in 2020. Two insecticides were evaluated: Altacor (Chlorantraniliprole) and Leprotech (*Bacillus thuringiensis var. kurstaki*) in two trials. Both products are likely to be more effective when targeted at young lepidopterous larvae, more so with WGL, since only young larvae are openly exposed on a leaf surface (Fig. 11). Older larvae ($2^{nd}$ instar onwards) fold or roll leaves, thereby protecting themselves from insecticide sprays. Bait traps were placed in three Shaw blocks (Quint, Quin, Q43) and leaves were sampled weekly from May 18 to monitor adult and larval WGL populations (Fig. 12).

*Figure 11. First instar WGL larvae on a grape leaf relatively unprotected from insecticide sprays unlike older larvae that roll/fold leaves.*

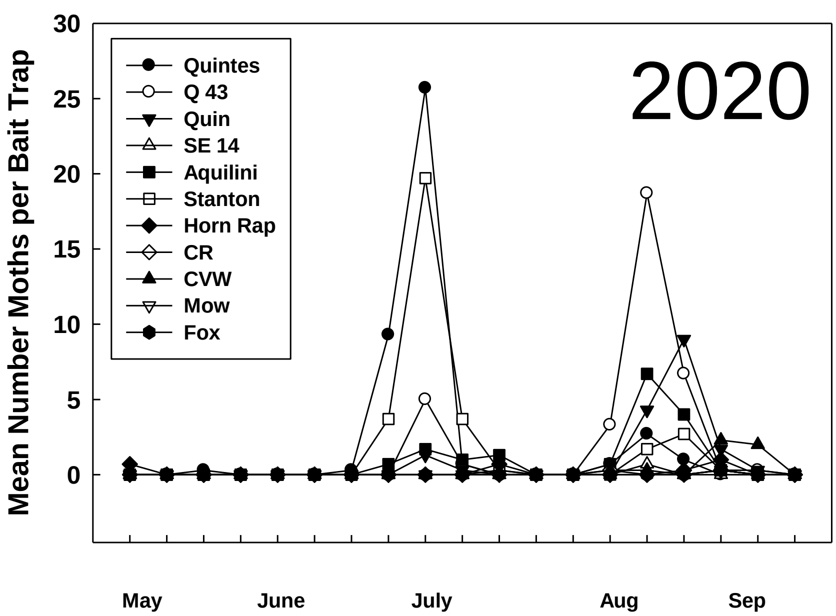


*Figure 12. Adult population phenology of WGL at 11 vineyard sites at Red Mountain and Mattawa during May-September 2020 as indicated by bait trap catches.*

The first adult generation of moths that eclosed from overwintered pupae, was not adequately sampled/monitored by bait traps with only small numbers trapped during May-June, despite observations indicating a much larger population. In contrast, emergence of the second adult generation which began in the last days of June and continued until mid-July, was well indicated by bait trapping with up to 37 moths caught in a single trap (mean ~ 26 moths/trap). The end of the first week of July was considered to represent the mid-point of eclosion and peak egg-laying. Eggs hatch in 4-5 days and we judged that spray application targeted at first instar (non-leaffolding larvae) would be optimal from July 12-16. Altacor was applied during July 14-16.

Larval populations immediately declined following application of Altacor (Fig. 5) and remained low-absent for the rest of the season. In contrast, unsprayed blocks at Red Mountain showed increasing and large populations of larvae during August and September (Figs. 1-2).

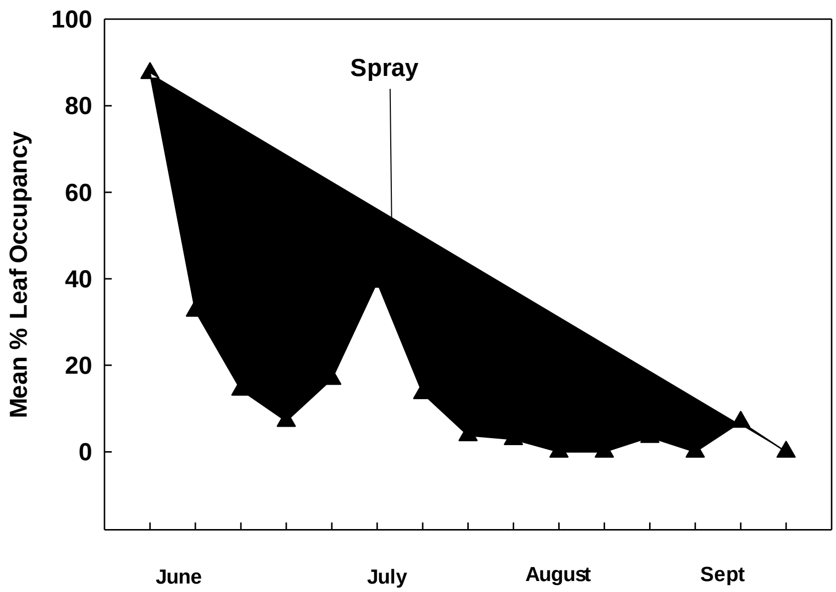


*Figure 13. Impact of Altacor insecticide on WGL larvae (% leaf occupancy)) in a Red Mountain vineyard block in 2020.*

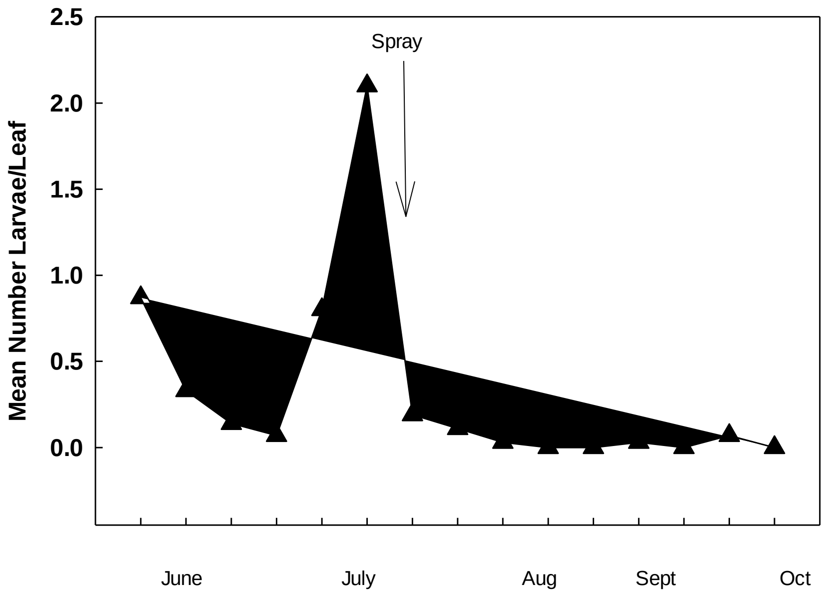


*Figure 14. Impact of Altacor insecticide on WGL larvae (number of larvae per leaf) in a Red Mountain vineyard block in 2020.*

An additional Red Mountain vineyard also applied Altacor in mid-July with comparable results (Fig. 15).

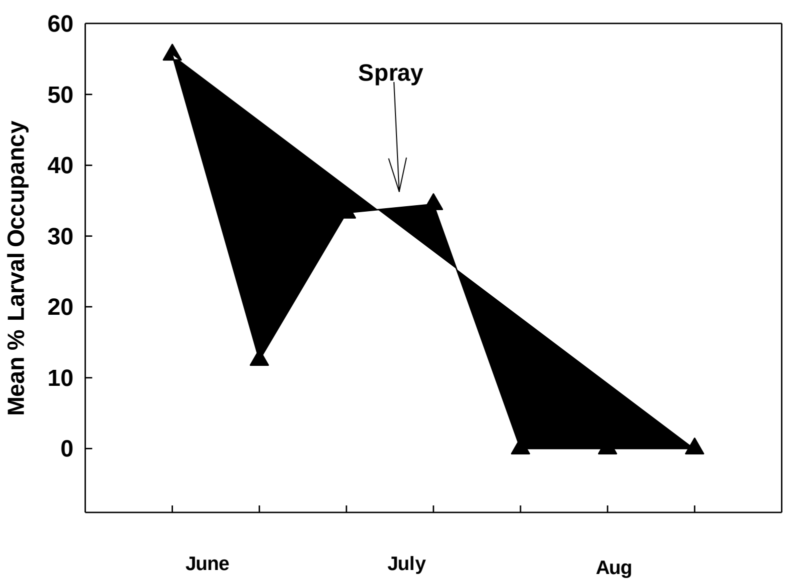


*Figure 6. Impact of a mid-July 2020 application of Altacor on leaf occupancy by WGL at an additional Red Mountain vineyard block.*

In the second Shaw vineyard insecticide trial, the *Bacillus thuringiensis* formulation Leprotech was applied in a different block but at the same time as Altacor (July 14-16). Prior to application, WGL larvae occupied 18% of leaves at a density of 0.5 larvae/leaf. One week post application, these numbers rose to 83.8% and 5.8, respectively. In the following month leaf occupation ranged from 10-44% and larval numbers from 0.10-0.80/leaf. By August 31, these numbers began increasing so a second application of Leprotech was made in early September. This reduced the population to low levels but did not eliminate it.

While Altacor rapidly reduced WGL larval populations to negligible levels, Leprotech was slow-acting and provided poor control. A second application of Leprotech was needed to reduce the population to very low levels.

**Insecticide Spray Trial 2020**

During August-October 2022, a spray trial evaluating the five major insecticides currently available for WGL control in WA, was conducted in a commercial vineyard on Candy Mountain.

Details of the insecticides used:

Spinosad (Trade names: **Entrust** or **Success**)
Methoxyfenozide (Trade name: **Intrepid**)
Chlorantraniliprole (Trade name **Altacor** or **Acelepryn**)
Spinetoram (Trade name: **Delegate** or **Radiant**)
*Bacillus thuringiensis* (Trade name **Dipel** or **Javelin**)

Sprays were applied to one-acre blocks at the following recommended rates:

Intrepid: 16 fluid ounces per acre
Altacor: 4.5 ounces per acre
Delegate: 5 fluid ounces per acre
Dipel: one pound per acre
Entrust: 2.5 ounces per acre

*Spray timing*: Spray application was timed to target the population when eggs, newly hatched or later first instar larvae, dominated the population. Leaf-folding had not yet started so the vast majority of caterpillars were exposed to spray applications. This timing was established by weekly monitoring of bait trap catches of moths and weekly examination of grape leaves for early-stage caterpillars. Using these criteria, the first week of August was considered to be optimal timing for spray application and sprays were applied on August 3.

An adjacent unsprayed vineyard at Candy Mountain and an additional unsprayed block on Red Mountain were used as comparison ‘control’ sites for monitoring WGL caterpillar populations during the spray trial period.

WGL caterpillar populations in all the treatments and unsprayed blocks were monitored weekly from August 10 until October 25. Pre-treatment sampling was conducted on August 1.

**Results:**

Four of the five treatments (Altacor, Dipel, Delegate, Entrust) removed all leaffolder presence by three weeks post-treatment (Fig. 7). The Intrepid treatment did not provide this until five weeks post-treatment. A large, new generation of leaffolder caterpillars appeared in early September which was reflected by populations in unsprayed blocks increasing from a mean 0.5 caterpillars/leaf to 4.7/leaf by mid-September (Fig. 7). The only treatment that remained free of leaffolders in September in spite of the new generation, was Altacor, indicating more effective residuality than the other treatments. However, numbers of leaffolders in the other treatments during the September increase in leaffolder populations were small ranging from 0.03 to 0.5 per leaf (Fig. 7).

Dipel (another *Bacillus thuringiensis* formulation) performed better than Leprotech in 2021, but was slow to achieve good control (only a 33% reduction after one week) and had the highest numbers of caterpillars (up to 0.5/leaf) during the September generation. Although Intrepid was slowest to achieve leaffolder control, it performed the best of all treatments during September.

Altacor (Cholorantraniliprole) is known to persist for 4-6 weeks after application at levels likely to give some control of insect pests. In both 2021 and 2022, this chemical provided prolonged control of leaffolder larvae. This level of persistence may allow its effective use on WGL without strict adherence to targeting of first instar larvae. Altacor is likely to be selective to at least some natural enemies of WGL. It has low toxicity to a number of parasitic wasp species, although we do not know if this is true for the parasitoids that regulate WGL.

Entrust (Spinosad) degrades faster in the field than Altacor and there was some resurgence of WGL 6-8 weeks after treatment. Research reviews indicate that this chemical has little impact on about 70% of predator and parasitoid species.

Delegate (Spinetoram) is closely related to Entrust (Spinosad) with similar residuality and low impact on beneficial insects and mites, although some work suggests it may exacerbate spider mite outbreaks.

Intrepid (Methoxyfenozide) is an insect growth regulator (IGR), effective against caterpillars but with poor residual activity. It is safe to most predators and parasitoids. Although Intrepid was slowest to achieve leaffolder control, it performed the best of all treatments during September.

All of these materials appear capable of providing satisfactory knockdown and control of WGL without substantially disrupting the natural enemy community. However, the most reliable persistent control over one to two months seems best provided by Altacor. Dipel and any product containing *Bacillus thuringiensis*, and the IGR, Intrepid, will be slower to provide full control. All of these materials have a degree of safety to predators and parasitoids, with Dipel and Intrepid being the safest.

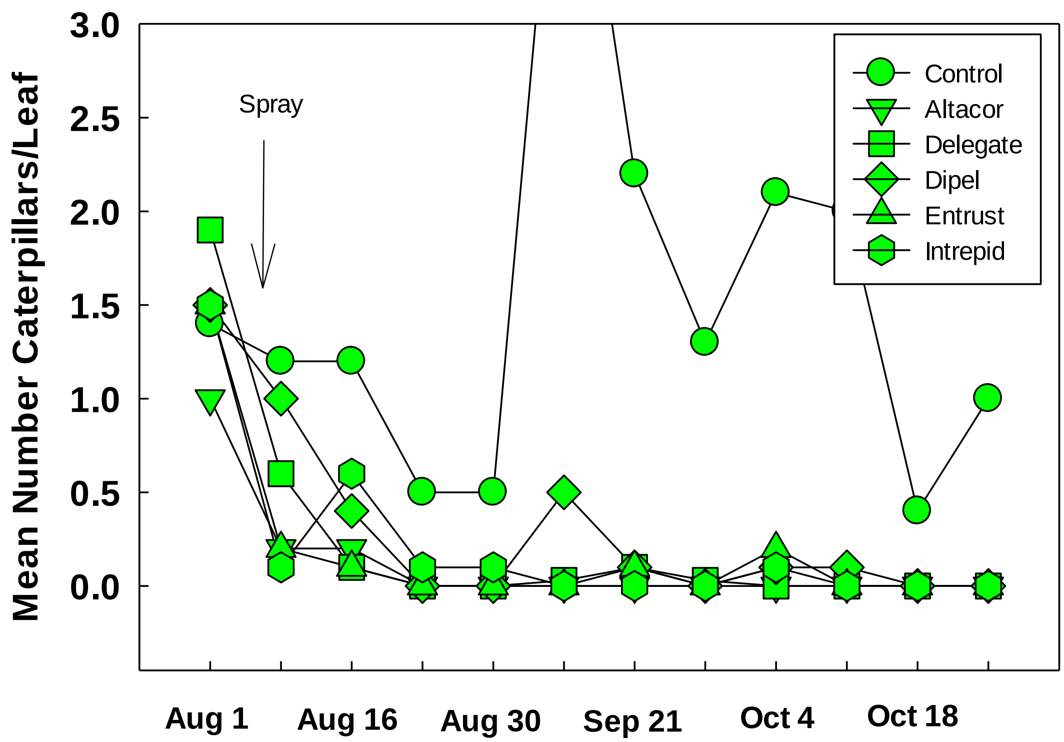


*Figure 7. Efficacy of six insecticides for WGL control. Control data (mean) from two nearby unsprayed vineyards (note control population exceeded 3 caterpillars/leaf in early September).*

**A Note on Overwintering:** Evidence was gained during this project to suggest that overwintering may represent a particularly vulnerable part of the life history of WGL. We also saw that if the first generation of moths from overwintered pupae was very small, then the population struggled to develop large enough numbers to cause economic damage to wine grapes.

Final generation caterpillars in September/October pupate in a section of folded leaf, secured with silk, creating a 'chrysalis burrito' (Fig. 8). This protection appears to be important for pupal survival.

During three winters (2020-23), we conducted experiments looking at the mortality of winter pupae on the ground either within 'burritos' or removed from 'burritos'. We also looked at the effect of burying pupae within 'burritos' or naked, one inch in the soil, or leaving them on the leaf surface.

We found generally low survival in all treatments with the best being from pupae within 'burritos' left on the soil surface (36-74%). Pupae taken from their shelters and left on the soil surface, suffered 100% mortality, likely from desiccation caused by exposure to the sun. If 'naked' pupae were buried, there was some survival (16%). Burying 'burritos' caused major mortality with only 4% successfully emerging as moths.

Removing pupae from their leaf shelters and burying them seems to be effective in drastically reducing overwintering survival of WGL pupae. Although further work needs to be done, it seems likely that cultivation of the vineyard floor during winter might serve to increase mortality of overwintering pupae of WGL, by disturbing the integrity of leaf shelters and burying the cocooned pupae. As noted, overwintering mortality of pupae under natural conditions already seems to be high.

*Figure 8. Overwintering pupae removed from folded leaf shelters ('burritos') or left within the shelters*

**Acknowledgments:** Many thanks to Allyson Leonard who provided excellent technical assistance during the course of this project. Also, to the cooperating wine grape growers on Red Mountain who allowed us to work on their properties.

## 7. Outreach and Education Efforts - Presentations of Research:

A WAVEx seminar on our Leaffolder research was presented during spring 2021 via Zoom. Information on WGL was added to the most recent WA wine grape pest management guide.

James, D. G. (2021). Grape Leaffolders: Biology, Impact and Management. WAVE seminar, March 2021 (Zoom).

James, D.G. (2018). These caterpillars can sure mess up grape leaves! WSU Viticulture and Enology Extension News, Spring p. 8.

## 8. Research Success Statements

This research will enable grapegrowers to monitor and manage grape leaffolders in an efficient, effective and sustainable way. This research provides the tools and strategies needed for management of this relatively new pest which are economically effective, yet preserve the current low input and sustainable vineyard IPM programs, characteristic of eastern Washington.

## 9. Funds Status: All funds expended.