Control of *Epiphyas postvittana* (lightbrown apple moth, Lepidoptera: Tortricidae) on grapevines with tebufenozide

P.L. Lo¹, I.C. Newman¹, L.M. Cole¹, D.J. Rogers¹ and G.M. Burnip²

¹The New Zealand Institute for Plant & Food Research Limited, Private Bag 1401, Havelock North 4157, New Zealand

²The New Zealand Institute for Plant & Food Research Limited, Private Bag 4704, Christchurch 8140, New Zealand

Corresponding author: Peter.Lo@plantandfood.co.nz

Abstract Feeding by leafroller larvae damages grape bunches and makes them susceptible to *Botrytis cinerea* disease. Leafroller infestation of foliage and bunches and the incidence of botrytis was measured on vineyards in Gisborne, Hawke's Bay and Marlborough over 2 years. Forty-four blocks received no leafroller-active insecticides while 22 were sprayed once pre-flowering with the selective insect growth regulator, tebufenozide. Tebufenozide very effectively reduced infestations and gave season-long control. On leaves, untreated blocks averaged 14 leafrollers/search compared with 4 on sprayed blocks. Comparative figures for fruit at harvest were 18/100 bunches and 3/100, respectively. There was a trend for lower botrytis incidence in blocks where tebufenozide was used. Over 99% of the leafrollers reared were *Epiphyas postvittana*. Parasitism of larvae and pupae at 67% on leaves and 50% in bunches, was similar in untreated and treated blocks. *Epiphyas postvittana* in vineyards is easily managed using tebufenozide, which did not compromise biological control.

Keywords *Epiphyas postvittana*, lightbrown apple moth, Tortricidae, leafroller, tebufenozide, grape.

INTRODUCTION

Leafrollers (Lepidoptera: Tortricidae) are one of the few insect pests of vineyards in New Zealand (Bailey et al. 1997; Lo & Murrell 2000). The predominant species is *Epiphyas postvittana* (lightbrown apple moth) (Baker et al. 1994, Lo & Walker 2006). On grapevines, leafroller larvae feed on leaves, flowers and berries. The damage caused to grape bunches results in small yield reductions, but more importantly damaged bunches become susceptible to diseases such as botrytis. The larvae also vector *Botrytis cinerea* spores, thereby

increasing both the incidence and severity of botrytis infections within bunches (Bailey et al. 1997). Indirect losses from disease that have been induced by leafrollers outweigh direct losses from feeding (Buchanan 1977; Lo & Murrell 2000).

The New Zealand winegrape industry is keen to meet "best practice" standards for environmental sustainability in grape production. This includes minimising the use of broad spectrum insecticides and promoting selective products. At the time of this study in 2000-02, insecticide

programmes on vineyards were targeted primarily against leafrollers and mealybugs. Some insecticides used were effective on both pest groups, while others were toxic to only leafrollers or mealybugs. For example, insecticide programmes often began with a combination of the organophosphate prothiofos and mineral oil applied at the end of the dormant period in late August or early September. This spray was used principally to control mealybugs, but it also has activity against overwintering leafrollers. Insecticides applied during the growing season included broad spectrum organophosphates and carbamates, as well as insect growth regulators and *Bacillus thuringiensis*, which are selective.

In the past 30 years, leafroller populations in vineyards and orchards in Hawke's Bay have decreased greatly (Varela et al. 2010). For example, fruit infestation on unsprayed apples declined from over 40% in the mid 1980s to <5% since the late 1990s. This decline was attributed partly to the replacement of broad-spectrum insecticides with selective products that have allowed biological control to increase. Parasitoids of several hymenopteran and dipteran families are important natural enemies of leafrollers in New Zealand and attack all immature stages (Wearing et al. 1991; Varela et al. 2010). It is vital that the diversity of parasitoid species and the degree of control that they exert is maintained on vineyards and orchards.

The insect growth regulator tebufenozide is active only against larval Lepidoptera. It mimics the action of the insect moulting hormone ecdysone, and triggers a lethal premature moult (Wing et al. 1988). In New Zealand, tebufenozide is effective against leafrollers on apples (Walker et al. 1991) and avocados (Brookbanks 1998). The aims of this research were to test how effective tebufenozide is against *E. postvittana* in vineyards, and to determine what impact it had on parasitism.

METHODS

Twenty-eight vineyards in the major grape growing regions of Gisborne (n = 8), Hawke's Bay (14) and Marlborough (6) were visited in 2001 and 2002. Most but not all vineyards were visited in both years. Leafroller infestations were

assessed in 69 blocks of both red and white grape varieties. Insecticide programmes (products and rates) were decided by the vineyard managers. Blocks were divided into two categories; those that did not receive any leafroller-active insecticides during the growing season (untreated) and those that received one application of tebufenozide just before flowering (treated). Tebufenozide was applied between mid November and early December in 2000 and 2001, at 43–172 g/ha in 180–500 litres/ha of water.

A direct comparison of leafroller infestations between the two treatments was possible on 12 of the above treated blocks. In three vineyards in Gisborne, four in Hawke's Bay and two in Marlborough, the managers agreed to leave tebufenozide off part of their treated blocks. The number of vine rows omitted was decided by each manager, and in Gisborne and Hawke's Bay the untreated areas were six rows wide, while in Marlborough they were 50+ rows wide.

The abundance of leafrollers on leaves and shoots was assessed in January or February at the bunch closure stage of grape berry development. In each vineyard block, two observers scanned the foliage for signs of leafroller for 15 min each (30 min in total), while walking slowly along two vine rows. The time was divided into three separate 5-min searches to maintain concentration and to spread the assessments along the rows. The numbers of leafroller larvae, pupae and parasitoid cocoons were recorded. Multiple cocoons from gregarious parasitoid species were counted as one instance of a leafroller.

Leafroller infestation of bunches was assessed twice in each year. At bunch closure, 200 bunches were examined per block. Blocks were re-visited just before harvest in March or April and either 400 (in 2001) or 200 (in 2002) bunches were assessed per block. Bunches were chosen randomly while walking along four centrally located rows in each block.

Each selected bunch was examined for leafroller larvae, pupae, feeding damage and leafroller parasitoids. The combination of these categories gave an overall measure of leafroller infestations. Parasitised larvae were recorded as a larva if they were still alive and as a parasitoid

if the larva was dead. Feeding damage was counted only if none of the other categories were found because it indicated that a leafroller had been present but had since disappeared, either through moving, maturing or dying. Damage was recognisable by the presence of white silk webbing (spun by larvae to create shelters), associated either with clusters of withered berries where the stalks had been chewed or surface feeding on individual berries. In the pre-harvest assessments in Gisborne and Hawke's Bay, the presence or absence of botrytis disease in bunches was also recorded.

Leafroller larvae and pupae from leaves and bunches were collected to identify the species and to measure parasitism. Timing was stopped during visual searches while larvae and pupae were collected. The larvae were reared in test tubes containing artificial diet.

The numbers of leafrollers on leaves and bunches were analysed by one-tailed *t*-tests allowing for unequal variances. A Poisson-generalised linear model found no significant differences in treatment effect by region or year;

therefore these data were combined for an overall analysis. Chi-square tests were conducted to compare treatment effects on parasitism.

RESULTS

Leaves

Tebufenozide-sprayed blocks in Gisborne and Hawke's Bay, but not in Marlborough, had significantly fewer leafrollers than untreated blocks or rows (i.e. those that had no leafroller-active insecticides during the growing season) (Figure 1). For all blocks combined, treated blocks had 69% fewer leafrollers than in untreated blocks. The equivalent figure for the 12 direct comparison blocks was a 67% reduction.

Bunches

There were clear differences in leafroller infestations between untreated and treated blocks, at both bunch closure and at harvest. The trends were similar at both times so data for only the harvest assessment are presented (Figure 2). The number of leafrollers, parasitoids and damaged bunches in untreated blocks averaged

Figure 1 Mean number ($\pm$ SEM) of leafrollers found during 30-min searches of grape leaves in January/February 2001 and 2002. Blocks received either no leafroller-active insecticides during the growing season (untreated) or one application of tebufenozide pre-flowering. Data are presented from three regions and from blocks that had both treated and untreated rows. The numbers of blocks sampled are shown below each column with *t*-test probabilities above each comparison (ns not significant, * $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$).

Figure 2 Mean number ($\pm$ SEM)/100 grape bunches of leafroller larvae and pupae, parasitoids and damaged bunches at harvest in March/April, 2001 and 2002. Blocks received either no leafroller-active insecticides during the growing season (untreated) or one application of tebufenozide pre-flowering. Data are presented from three regions and include a comparison between blocks that had both treatments. The numbers of blocks sampled are shown below each column with *t*-test results above (* $P \leq 0.05$, ** $P \leq 0.01$, *** $P \leq 0.001$).

4.3/100 bunches at bunch closure (range 0-26), which increased to 18.1 (range 0.5-65.5) by harvest. In contrast, tebufenozide-sprayed blocks averaged 0.9 (0-3.5) and 3.0 (0-14) respectively.

On the 12 blocks where a direct comparison between treatments was possible, untreated vines averaged 4.3 leafrollers/100 bunches at bunch closure and 21.8 at harvest. The comparative figures for tebufenozide-sprayed rows were 0.5 and 1.9, respectively. In Marlborough, untreated rows on four of the five blocks had high infestations (10–46/100 bunches at harvest), and in each case the tebufenozide spray reduced leafroller numbers and bunch damage to ≤ 2 /100 bunches (Figure 2).

Leafroller species and parasitism

In total, 541 larvae were reared to adults and 99.1% were *E. postvittana*. For each region, the percentage was between 97.6% and 100%. The remainder were native leafrollers in the genera *Ctenopseustis* and *Planotortrix*.

There was no statistical difference in the percentage of parasitised larvae between

untreated and treated blocks in all three regions and overall (Table 1). The 56.5% parasitism recorded overall was a weighted average across all larval stages; for the six instars it was 17-76%. Parasitism was much higher in Gisborne and Hawke's Bay than in Marlborough. Three species of parasitoids were commonly found; the great majority were *Dolichogenidea* spp. followed by *Glyptapanteles demeter* and *Goniozus* spp. The remaining species that were occasionally reared comprised approximately 5% of the samples and included *Apanteles sicarius*, *Meteorus pulchricornis*, *Glabridorsum stokesii*, *Xanthopimpla rhopaloceros* and *Trigonospila brevifacies*.

Incidence of botrytis

The frequency of botrytis infections was highly variable among blocks. For all blocks combined, there was a non-significant trend ($P = 0.071$) for a lower incidence of this disease where tebufenozide was used compared with untreated blocks (Figure 3).

Figure 3 Mean incidence ($\pm$ SEM) of botrytis infections in grape bunches at harvest in vineyards, 2001 and 2002. Blocks received either no leafroller-active insecticides during the growing season (untreated) or one application of tebufenozide pre-flowering. Data are presented from two regions and include a comparison between blocks that had both treatments. The numbers of blocks sampled are shown below each column with t -test probabilities above (ns not significant, * $P \leq 0.05$).

Table 1 Number of leafroller larvae reared from grape leaves and bunches from vineyards in three regions during 2001 and 2002, and the percentage parasitised. Blocks received either no leafroller-active insecticides during the growing season (untreated) or one application of tebufenozide pre-flowering. The P values of χ^2 tests comparing treatments are shown.

Region	Sample	Untreated		Tebufenozide		Combined		² P-value
		n	%	n	%	n	%	
Gisborne	Leaves	130	74.6	12	83.3	279	84.9	0.934
	Bunches	135	94.8	2	100.0			
	Total	265	84.9	14	85.7			
Hawke's Bay	Leaves	261	69.0	15	60.0	698	62.0	0.490
	Bunches	405	58.0	17	52.9			
	Total	666	62.3	32	56.3			
Marlborough	Leaves	24	33.3	9	0	249	9.2	0.843
	Bunches	212	6.6	4	25.0			
	Total	236	9.3	13	7.7			
Overall	Leaves	415	68.7	36	52.7	1226	56.5	0.527
	Bunches	752	50.1	23	52.2			
	Total	1167	56.7	59	52.5			

DISCUSSION

One application of tebufenozide just before flowering was highly effective at reducing leafroller infestations and gave season-long control. For example, in all blocks where tebufenozide was used less than 7% of bunches had leafroller infestations at harvest, whereas 88% of untreated blocks had over 7% infestation. Tebufenozide prevented outbreaks of leafrollers occurring even where untreated vines had severe infestations. On seven of the direct comparison blocks, harvest infestations reached 19–46% of bunches, which could potentially lead to large losses from botrytis. On the same blocks, the tebufenozide treatment limited infestations to 0–6% and typically less than 3%.

Tebufenozide was applied at a range of concentrations between label rate (172 g/ha) and a quarter rate as determined by the vineyard managers. The reason why the product could be applied to vines at low rates and still achieve good leafroller control was that the label rate for grapes was the same as that used in apple orchards to control codling moth (*Cydia pomonella*) (J.T.S. Walker, Plant & Food Research, personal communication). Codling moth, being a fruit boring pest, is harder to kill than lightbrown apple moth, which is a surface feeder.

The main reason for controlling leafrollers on grapevines is to prevent the spread of botrytis disease and to minimise the severity of the disease. Yield losses caused by larval feeding are relatively minor in comparison (Lo & Murrell 2000). Leafrollers are just one of several causes of botrytis infection and the incidence and severity of disease in vineyards is a result of a complex interaction of these factors. This was demonstrated by the wide variability in infections between the monitored blocks and the weak correlation between the incidence of leafrollers and botrytis. Nevertheless, in general, the observed trend was for a lower incidence of botrytis where tebufenozide was applied.

Tebufenozide must be applied to grapevines before the flowers open in late spring or early summer, to comply with residue limits on

harvested fruit for some countries. At that time of year, various measures of leafroller abundance have not been reliable predictors of subsequent infestations (Lo & Walker 2006). Immature leafrollers are difficult to find early in the season because numbers are low, but with up to four generations per year (Wearing et al. 1991) leafroller populations can increase dramatically during late summer. Grape growers must therefore decide whether or not to apply tebufenozide before they have a prediction of infestations.

The use of broad-spectrum insecticides is now discouraged by the New Zealand wine industry, and is not allowed for control of leafrollers (S. van der Zijpp, Sustainable Winegrowing New Zealand, personal communication). Since this research was conducted, the use of organophosphates and carbamates during the growing season has declined to virtually nil, while tebufenozide continues to be one of the main insecticides used against leafrollers in grapes.

This study confirmed the importance of parasitism for reducing leafroller populations. When the impact of parasitism on successive larval instars is calculated in a life table type analysis, it equated to potentially a 99% population reduction, in the absence of immigration (P.L. Lo, unpublished data). In the present study, applying tebufenozide did not affect the number of larvae that were parasitized. Many other studies have similarly found that tebufenozide did not affect hymenopteran parasitoids (e.g. Tomkins et al. 1995; Brown 1996; McCravy et al. 2001). The high efficacy of the tebufenozide treatment meant that relatively few larvae were reared from treated blocks. Consequently there were too few larvae to determine if the diversity of parasitoid species was maintained compared with what existed on untreated blocks.

Tebufenozide was highly effective against *E. postvittana* on grapes and was not detrimental to parasitism. It is recommended as an excellent preventative measure on vineyards that have had a history of leafroller problems.

ACKNOWLEDGEMENTS

This research was funded by New Zealand Winegrowers and AGMARDT. We thank the following companies for their co-operation: Delegat's Wine Estate, Brancott Estate wines, Te Awa, Te Mata Estate, Villa Maria Estate, as well as the many growers who gave us access to their vineyards. Thanks also to our Plant & Food Research colleagues, Duncan Hedderley who advised on the statistical analysis and Anne Barrington who supplied the artificial diet for rearing leafroller larvae. Comments from Cathy McKenna, Kay Clapperton and an anonymous referee improved the manuscript.

REFERENCES

- Bailey PT, Ferguson KL, McMahon R, Wicks TJ 1997. Transmission of *Botrytis cinerea* by lightbrown apple moth larvae on grapes. Australian Journal of Grape and Wine Research 3: 90-94.
- Baker GJ, Bailey PT, Charles JG 1994. Leaf and fruit pests: Lightbrown apple moth. In: Nicholas PR, Magarey PA, Wachtel MF ed. Diseases and Pests. Grape Production Series, no. 1. Winetitles, Adelaide, Australia. Pp 47-50.
- Brookbanks PA 1998. Control of leafrollers in avocados. Proceedings of the 51st New Zealand Plant Protection Conference: 179-183.
- Brown JJ 1996. The compatibility of tebufenozide with a laboratory lepidopteran host/hymenopteran parasitoid population. Biological Control 6: 96-104.
- Buchanan GA 1977. The seasonal abundance and control of lightbrown apple moth, *Epiphyas postvittana* (Walker) (Lepidoptera: Tortricidae), on grapevines in Victoria. Australian Journal of Agricultural Research 28: 125-132.
- Lo PL, Murrell VC 2000. Time of leafroller infestation and effect on yields in grapes. New Zealand Plant Protection 53: 173-178.
- Lo PL, Walker JTS 2006. Monitoring leafrollers (Lepidoptera: Tortricidae) in vineyards. New Zealand Plant Protection 59: 317-322.
- McCravy KW, Dalusky MJ, Berisford CW 2001. Effects of a broad spectrum and biorational insecticides on parasitoids of the Nantucket pine tip moth (Lepidoptera: Tortricidae). Journal of Economic Entomology 94: 112-5.
- Tomkins AR, Thomson C, Wilson DJ 1995. Effect of tebufenozide on *Encarsia citrina*, an armoured scale parasitoid. Proceedings of the 48th New Zealand Plant Protection Conference: 139-142.
- Varela LG, Walker JTS, Lo PL, Rogers DJ 2010. New Zealand lessons may aid efforts to control light brown apple moth in California. California Agriculture 64: 6-12.
- Walker JTS, Baynon GT, White V 1991. Insect control on apples with RH-5992 a novel insect growth regulator. Proceedings of the 44th New Zealand Weed and Pest Control Conference: 66-69.
- Wearing CH, Thomas WP, Dugdale JS, Danthanarayana W 1991. Tortricid pests of pome and stone fruits, Australian and New Zealand species. In: van der Geest LPS, Evenhuis HH ed. Tortricid pests: Their biology, natural enemies and control. World Crop Pests Volume 5. Amsterdam, Elsevier. Pp. 453-472.
- Wing KW, Slawecki RA, Carlson GR 1988. RH 5849, a nonsteroidal ecdysone agonist: effects on larval Lepidoptera. Science 241: 470-472.