



UNDERSTOREY MANAGEMENT FOR THE ENHANCEMENT OF THE LEAFROLLER PARASITOID *DOLICHOGENIDEA TASMANICA* (CAMERON) IN ORCHARDS AT CANTERBURY, NEW ZEALAND

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Introduction

Leafrollers (Lepidoptera: Tortricidae) are major pests of pipfruit and other crops in New Zealand and elsewhere and have a high pest status in 'conventionally managed' crops, mainly due to the zero tolerance of their presence in export markets and the high requirement for blemish-free fruit (Wratten *et al.* 1998). Natural enemies have not exhibited commercially useful effects on leafroller populations in orchards because the intensive use of conventional insecticides kills them and frequent herbicide use has removed the plants that could provide the habitats, and pollen and nectar resources required by many (van Driesche & Bellows 1996; Barbosa & Wratten 1998). Recently, the adverse effects of intensive pesticide use have become the focus of a major concern for the New Zealand fruit industry. Increasing demands for non-detectable or extremely low levels of residues in exported New Zealand fruit, combined with quarantine requirements for virtually pest-free produce, provide a 'double-bind' for producers and exporters (MacIntyre *et al.* 1989; Wratten *et al.* 1998). Therefore, the New Zealand fruit industry needs to move towards a more integrated pest management approach. In fact, the first priority of ENZAFRUIT New Zealand is to give preference to non-chemical methods of pest and disease control, leading to a decrease in agrichemical usage (Wearing 1996).

Integrated Fruit Production (IFP) is becoming a requirement of ENZAFRUIT New Zealand and the markets that it supplies (Wratten *et al.* 1998). This programme was described by Batchelor *et al.* (1997) and requires growers to use monitoring procedures and action thresholds to determine when pesticide application is essential. The introduction of the insect growth regulator Mimic® (tebufenozide) into IFP programmes has allowed a 'window' for utilising natural enemies for leafroller biological control. This compound is both selective and able to meet export quarantine requirements (Walker *et al.* 1991). However, information on understorey management is still required for the IFP-P manual (Batchelor *et al.* 1997; Walker *et al.* 1997) which, if successful, may result in enhanced control through the additive effects of biological control agents and tebufenozide.

Conservation biological control (the provision of resources to natural enemies to improve their effectiveness at controlling pests; Bugg & Pickett 1998) has potential in orchards and recent reviews emphasise this (Bugg & Pickett 1998; Barbosa 1998; Landis *et al.* 2000). One mechanism is the

enhancement of nectar and pollen resources. For example, buckwheat (*Fagopyrum esculentum* Moench), a herbaceous dicotyledonous annual in the family Polygonaceae with small white flowers with shallow corollae, provides pollen and nectar to a wide range of beneficial insects (Lövei *et al.* 1993), including short-tongued parasitoids. Buckwheat has a short sowing-to-flowering time (Bowie *et al.* 1995) and its seeds are cheap and available in New Zealand and elsewhere. Work with buckwheat as an understorey option in a Canterbury orchard led to significantly higher levels of parasitism by *Dolichogenidea tasmanica* (Cameron) (Braconidae) of released leafroller larvae in buckwheat plots than in controls (Stephens *et al.* 1998). Also, higher numbers of *D. tasmanica* were captured on yellow sticky traps in buckwheat plots. However, the replicate number and plot sizes used in the study were small and further investigation is needed into other understorey options, in conjunction with larger plot sizes and an increase in replicate number, to determine the potential for enhancing leafroller parasitoids and their effects.

The nectar of the flowers of broad (faba) bean (*Vicia faba* L.) is probably inaccessible to short-tongued parasitoids. However, a rich assemblage of ichneumonids attends extra-floral nectaries of broad bean, including parasitoids of agricultural and forest pests (Bugg *et al.* 1989). Broad bean has the added advantages of being able to be planted at any time of the year and the extra-floral nectaries are present soon after germination when the seedlings are only a few centimetres tall. Therefore they may be useful for early-spring enhancement of natural enemy populations.

This research aimed to investigate the influence of buckwheat and broad bean as floral resources on leafroller parasitoid abundance, and consequent leafroller parasitism by *D. tasmanica* in apple orchards not receiving organo-phosphorous pesticide treatments in Canterbury, New Zealand. The work extends that of Stephens *et al.* (1998) by using broad bean as an additional understorey option, by separating the floral effect that the buckwheat provides from the potential shelter effect (by removing buckwheat flowers as one treatment) and by using more replicates and larger plot sizes.

Methods

Site description and experimental design

Four replicates of each of four treatments (buckwheat with flowers, buckwheat without flowers, broad beans and herbicide-treated control) were set up in a randomised block design in an apple orchard at the Lincoln University Horticultural Research Area, Canterbury, New Zealand. Each replicate was 7.4 m × 2 m and consisted of 8-year-old apple trees (cvs. Braeburn, Royal Gala and Cox's Orange). Buckwheat (cv. Shinano Natsu) seeds were sown on December 6, 1996 and on January 6, 1997 to ensure continual flowering. Broad beans (cv. Exhibition Long Pod) were sown on November 11, 1996 and on January 6, 1997. In these plots, a 50 mm wide strip of buckwheat or a row of broad beans was sown each side of the trees at a depth of approximately 30–40 mm. Buckwheat was sown at two seeds/cm and broad beans were spaced approximately 3 cm apart. The orchard had a history of broad-spectrum, persistent herbicide use, with simazine being applied each year. The orchard, therefore was virtually devoid of ground vegetation. Because of the simazine use, the top 20 mm of soil was removed from each of the areas which were due to receive seeds prior to sowing. Approximately six weeks after sowing (mid-January, 1997), the buckwheat began flowering and parasitoid trapping and leafroller release began. Flowers on the 'buckwheat without flowers' treatment were removed by hand every 3–5 d, and on February 14 the top third of the plants in the first buckwheat drilling in the 'buckwheat with flowers' plots was

cut off to encourage lateral flowering and to ensure a longer flowering time, while the second drilling was left uncut.

Parasitoid trapping

One yellow 'Trappit' (Agrisense-BCS-Ltd, Treforest Industrial Estate, Pontypridd, Mid-Gladmorgan, U. K.) trap (catching surface: 200 × 245 mm) was placed 1 m above the ground, in the centre of each plot, facing the middle of the row. After 9-14 d between 31 January and 19 March, 1997, these were collected and replaced. The numbers of *D. tasmanica* were counted under a binocular microscope (20× magnification) in the laboratory.

Egg release

Eggs of the lightbrown apple moth, *Epiphyas postvittana* (Walker), were placed on a branch in the centre of each plot every 15-20 d from 14 January to 19 March, 1997. Stephens *et al.* (1998) released leafroller larvae rather than eggs. However, batches of eggs are easier to count and handle and because the larvae hatch under field conditions they may be better acclimatised to the field environment. Eggs laid on paper in the laboratory were divided into batches, of approximately 150 eggs, by counting the eggs and cutting the paper under a binocular microscope. The paper pieces were stapled to the underside of a leaf of a branch on the middle tree in each plot (150 eggs per branch). A nylon material sleeve (600 × 200 mm) was placed over the branch and closed with string to allow hatched larvae to settle and to protect them and the eggs from predators and egg parasitoids, such as *Trichogramma* spp. Sleeves were removed after 2-5 d, leaving the larvae exposed to parasitoids. The branches were collected 6-8 weeks after egg placement and the number of parasitoid cocoons and leafroller larvae and pupae present were recorded. Parasitism rate was expressed as: number of parasitoid cocoons recovered/(number of parasitoid cocoons recovered + number of leafroller larvae and pupae recovered) × 100.

Trap catches and parasitism rates were compared between treatments and times using repeated measures ANOVA. Where the ANOVA indicated significant main or interaction effects, these were further explored using Fisher's least significant difference test. Trap catch data were log-transformed ($\log_e x + 1$) before analysis to stabilise variances and are therefore reported as geometric means.

Results

Parasitoid trap catches

There was an overall significant ($F = 7.75$, $df = 3,9$, $P < 0.01$) effect of understorey management treatment on the abundance of leafroller parasitoids; their numbers were significantly ($P < 0.001$) higher in the 'buckwheat with flowers' treatment (1.27/trap/d) and in the broad bean treatment (0.52) compared with the control (0.18). The 'buckwheat with flowers' treatment enhanced the abundance of leafroller parasitoids significantly ($P < 0.001$) more than did the broad beans. There was no significant difference ($P > 0.05$) in leafroller parasitoid trap catches between the 'buckwheat without flowers' treatment (0.24/trap/d) and the control (0.18) (see Fig. 3 in Gurr *et al.* 1998).

Leafroller parasitism rate

On one of the leafroller release dates (13 February, 1997) there was an overall significant ($F = 8.32$, $df = 3,6$, $P < 0.05$) effect of treatment on parasitism rate (Fig. 1). There was a significantly ($P < 0.05$) higher parasitism rate in the 'buckwheat with flowers' treatment (86%), the

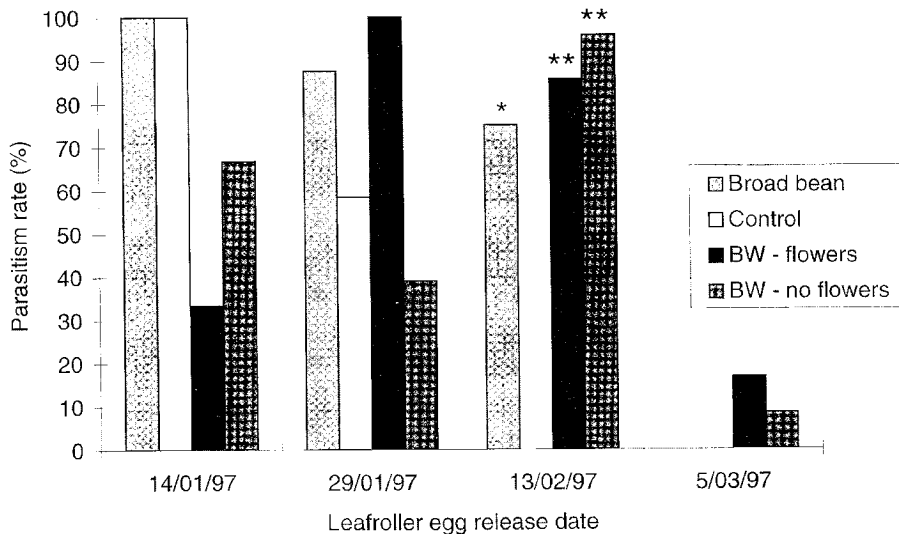


Figure 1 Leafroller parasitism rate by *Dolichogenidea tasmanica* in each understorey management treatment for each egg release date (* = $P < 0.05$, ** = $P < 0.01$, BW = buckwheat).

broad beans treatment (75%) and the 'buckwheat without flowers' treatment (96%) compared with the control (0%). These results were based on 34 cocoons and 15 larvae recovered from the 13 February, 1997 release date. There was a trend of a higher parasitism rate in the 'buckwheat with flowers' treatment compared with the control on the 29 January, 1997 and 5 March, 1997 release dates. However, this was not significant (29 January, 1997, $F = 2.22$, $df = 3, 9$, $P > 0.05$; 5 March, 1997, $F = 0.054$, $df = 3, 10$, $P > 0.05$). Combining all release dates, there were no significant ($F = 1.46$, $df = 3, 30$, $P > 0.05$) differences in parasitism rate between treatments.

Discussion

Parasitoid trap catches

More than seven times as many leafroller parasitoids were trapped in the buckwheat plots compared with controls, suggesting that buckwheat may enhance parasitoid abundance for leafroller biocontrol. These results support the work of Stephens *et al.* (1998). The 'buckwheat with flowers' treatment significantly enhanced parasitoid numbers compared with the controls, whereas there was no significant difference between control plots and 'buckwheat without flowers'. This suggests that it is the buckwheat floral resources that lead to enhanced parasitoid numbers, and not the shelter, which the buckwheat also presumably provides to some natural enemies. Broad beans also enhanced parasitoid abundance, although to a lesser extent than buckwheat. This may be because buckwheat flowers (with their shallow corollae) provide both pollen and nectar to the parasitoid (Lövei *et al.* 1993), whereas broad bean plants provide only nectar, via extra-floral nectaries, because their flowers are too large for short-tongued parasitoids to gain access to floral nectar or pollen (Bugg *et al.* 1989).

Although the plot size used in this study was increased to extend the work of Stephens *et al.* (1998), it may not have been large enough to prevent parasitoids moving between nectar resources and between all plots/treatments. However, it has shown that trap catches do not differ

significantly between small (7.4×2 m) and large (40×5 m) buckwheat plots, and that catches from traps placed at a gradient of distances from a buckwheat plot show that *D. tasmanica* trap catches are significantly higher than in controls for up to 2 m from the nectar source (Irvin unpublished). Buffer zones used in the current study extended beyond 10 m and therefore would have negligible numbers of parasitoids moving between treatments.

Leafroller parasitism rate

Buckwheat significantly enhanced leafroller parasitism by up to 68% compared with the control, indicating that the control potential of these parasitoids is high. In fact, Zandstra and Motooka (1978) showed that only 3.5% of apples were infested with codling moth larvae where buckwheat was present, compared with 1.5% with full chemical control and 54% with no treatment. Orchards in Russia are commonly undersown with buckwheat because its flowers are a food source for adult *Trichogramma* spp., which attack codling moth eggs (Zandstra & Motooka 1978). For *D. tasmanica*, Dumbleton (1935) found that parasitism in Nelson, New Zealand, ranged from 20 to 50%, and Thomas (1965) found rates ranging between 4 and 28% in unsprayed Canterbury orchards. The differences between studies may be accounted for by the differences in the methods of leafroller release and the techniques for calculating parasitism rate. For instance, different release densities, sleeve types and leafroller developmental stages may have affected establishment. In the current work, trap catch data indicates that floral resources are the dominant factor influencing parasitoid numbers. However, parasitism rate data were variable and most leafroller parasitism rates did not differ between treatments. On the release date where treatments did differ, all treatments were significantly different from the control. For example, the buckwheat without flowers treatment appeared to give parasitism rates as high as those for the 'with flowers' plots. This is probably an artefact associated with the methodology. The high dispersal rates of the leafroller larvae (Penman 1984) will tend to make recovery of parasitoid cocoons from the release sites variable, making it difficult to detect differences between treatments. Of those cocoons and larvae that were recovered, a high proportion had been parasitised, giving apparent high parasitism rates. This may have been because those larvae that are not parasitised are more likely to disperse or drop to the ground to pupate, whereas those that have been parasitised may be less mobile. Currently, research is under way to determine which leafroller release technique is the best method to achieve a realistic assessment of parasitism rate. These methods involve the release of leafroller eggs in sleeves, as above, and the recovery of individual released larvae, after two and four weeks. Larvae are then reared individually on artificial diet and the proportion subsequently parasitised is recorded (Irvin unpublished).

Understorey management potential and future work

Buckwheat shows great potential as an understorey management option for leafroller biocontrol in apple orchards in the Canterbury region. It establishes well, has a short sowing-to-flowering time (Bowie *et al.* 1995) and is cheap and available in New Zealand. The introduction of Mimic® (tebufenozide), an insect growth regulator, into IFP programmes will enhance the role of natural enemies, given the minimal non-target effects of this compound (Walker *et al.* 1991). Using buckwheat in orchard understoreys could be a vital part of IFP programmes, by enhancing the effectiveness of natural enemies for leafroller biocontrol. However, future research into the practical use of buckwheat and/or other plant species in this way is required. The number, size and spacing of the plots of conservation biocontrol plantings need to be determined (Landis *et al.* 2000). Also, some mark/release and recapture work may be beneficial to track the scale of movement of *D. tasmanica* and other biological control agents, and may therefore help to determine the optimal buffer zone to use between treatments in future experiments.

The mechanisms by which buckwheat may enhance leafroller parasitoid abundance and increase parasitism rates of leafrollers are unknown. Results from this study indicate that it is the flowers that influence parasitism rate. However, the question remains whether providing buckwheat in the orchard understorey influences other factors, such as increasing the 'fitness' of parasitoids. Field trials are currently being conducted to investigate the effects of understorey management on the sex ratio of emerging parasitoids. Also, choice and no-choice laboratory experiments are being conducted to rank *D. tasmanica* 'preference' for various floral resources, and to investigate the influence of these resources on fecundity and longevity.

Buckwheat is an annual plant and would therefore have to be resown each year. Self-sowing is not a viable option as the plant is frost-tender (Bowie *et al.* 1995) and pre-emergent herbicide use in the understorey inhibits germination. Also, annual-plant understorey options may not suite some orchard growers. Therefore, a large replicated experiment has been set up at Lincoln University, to determine whether alyssum (*Lobularia maritima* (L.) Desv.) is a suitable perennial understorey option for the enhancement of leafroller parasitism by *D. tasmanica*. Twenty-two flowering plant species, including phacelia (*Phacelia tanacetifolia* Benth.), buckwheat, broad bean and coriander (*Coriandrum sativum* L.), were recently ranked in California for their potential use as in-field insectaries; numbers of beneficial insects and pest species being recorded (Chaney 1998). Alyssum showed the greatest potential because no other plant tested flowered as quickly from seed or attracted as many beneficial insect species.

The abundance of *Anacharis* sp., a parasitoid of Tasmanian lacewing, *Micromus tasmaniae* (Walker), can also be enhanced by undersowing buckwheat (Stephens *et al.* 1998). Baggen *et al.* (2000) demonstrated that buckwheat enhanced the fecundity of the potato moth (*Phthorimaea operculella* (Zeller)), whereas no such benefit occurred when borage (*Borago officinalis* L.) was used. Therefore, it is important to determine the influence of understorey plants on pest species and on hyperparasitoids of natural enemies.

Future research into the potential of understorey management to enhance other parasitoids of leafrollers is required. For example, the egg parasitoids *Trichogramma* spp. may be a better agent than the larval parasitoid *D. tasmanica* since the pest is killed before any feeding damage occurs and therefore may suit the zero tolerance requirements by ENZA. However, perhaps the biggest challenge is to determine whether conservation biocontrol can enhance leafroller parasitism to an extent that it reduces leafroller populations below economic thresholds for local and export apple markets.

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