EVALUATION OF LEGUMES FOR DEVELOPMENT OF LEAFROLLER-FREE ORCHARD UNDERSTOREYS

G.M. BURNIP and D.M. SUCKLING

HortResearch, PO Box 51, Lincoln

ABSTRACT

Legume plants in orchard understoreys can provide a useful endogenous source of nitrogen for growing tree fruits. However, many legumes support insect pests, including leafrollers. To identify nitrogen-fixing understorey plants which are not leafroller hosts, eleven legume varieties were screened for this role in trials where larval and adult *Epiphyas postvittana* (lightbrown apple moth) were caged onto plants. There were significant differences in the number of egg batches and total eggs laid between legume types, with the fewest batches laid also on white clover cv. 'Huia'. Larval development was significantly different between cultivars, with one of the slowest development rates on white clover. None of the legumes tested offered better prospects than white clover for reducing leafroller populations in orchard understoreys.

Keywords: Clover, orchard, understorey, legume, leafroller, *Epiphyas postvittana*

INTRODUCTION

More sustainable under-tree management systems are currently under evaluation in the development of a biological production system for New Zealand pipfruit. The potential exists to use legume plant species within such systems, due to their ability to add soil nitrogen (N) without the costs and potential pollution associated with conventional N sources.

The legume, white clover (*Trifolium repens*), is used extensively in New Zealand pasture, where a wide range of N fixation rates have been reported (Ballet *et al.* 1979). In irrigated situations, white clover has been estimated to fix over 200 kg N/ha/year. The recommended rate of N fertiliser application in New Zealand apple orchards is 80-120 kg N/ha/year (Wilton and Clark 1986), to meet the estimated 30-50 kg N/ha/year required by mature trees (Marsh pers. comm.). Although many factors may affect nutrient availability, including shading, plant density, the N requirements of competing plants and the rate of N cycling, a leguminous understorey could potentially provide the total N requirement of pipfruit (Daly *et al.* 1996). A similar approach has been investigated in *Pinus radiata* plantations, using lucerne as the endogenous N source (Mead and Mansur 1993).

Leafrollers are serious insect pests in New Zealand apple orchards and are an important consideration in the development of a biological apple production system. Leafrollers are supported by many leguminous plants and it would be desirable to find leguminous understorey plants that are not hosts of pest insects. The presence of favourable understorey host plants, such as clovers, can lead to an increase in leafroller populations with a corresponding increase in crop damage (Thomas and Burnip 1993). This paper reports experiments designed to evaluate the potential for replacing the standard white clover widely found in orchard understoreys, with alternative species that might be less suitable as host plants for leafrollers. The lightbrown apple moth, *Epiphyas postvittana* (Walker) (Tortricidae), was used to assay the legumes, due to its abundance throughout New Zealand (Wearing 1994) and wide host plant range (Dugdale and Crosby 1995). As host plants have been shown to affect both fecundity (Danthanarayana 1975) and larval development (Tomkins *et al.* 1991) of *E. postvittana*, both these attributes were examined.

MATERIALS AND METHODS

Plant Material

Eleven candidate legume varieties were screened in four tests using white clover cv. 'Huia' as a standard in each. Legumes in each test were compared using the criteria of (a) *E. postvittana* oviposition preference (Tests 1 and 2), and (b) *E. postvittana* larval establishment and development (Tests 3 and 4). Six replicates of each legume were grown in 30 cm diameter pots until well established. All plants were maintained free of leafroller infestation prior to the screening tests. All tests comprised six cages, each enclosing six treatment legumes, arranged in a randomised block design. Fabric cages consisted of white French Voile (ca. 1 m x 1 m x 1 m) supported by an external wire frame. The cages were placed ca. 1.5 m apart, outside for Tests 1, 2 and 3 and in a glasshouse for Test 4.

The varieties tested were: *Trifolium repens* cv. 'Huia' (white clover); *T. repens* (high cyanide selection of white clover); *T. fragiferum* (strawberry clover); *T. pratense* (red clover); *T. subterraneum* (sub clover); *Lotus pedunculatus* ('Maku' lotus); *L. corniculatus* (birdsfoot trefoil); *Lupinus polyphyllus* (Russell lupin); *Onobrychis viciifolia* (sainfoin); *Medicago sativa* (lucerne); *Vicia villosa* (hairy vetch).

Oviposition

Female and male *E. postvittana* pupae were obtained from a laboratory strain (HortResearch Rearing Section, Mt Albert). Newly-emerged adult females were enclosed with males (ambient temperature and photoperiod) for 48 h, removed and placed into cages (six females per cage) located outdoors. The potted legumes were removed from the cages after 72 h, the foliage was examined with a stereo-microscope, and the number of leafroller eggs and egg batches recorded. The mean daily temperature during dusk for the 72 h period was 16°C for Test 1 (Jan 1996), and 10°C for Test 2 (May 1996).

Larval development

Neonate *E. postvittana* larvae from the same laboratory strain as above were transferred into specimen jars. One jar containing 30 larvae was placed, with lid removed, into the foliage of each potted plant (n = 6 reps) and the cages sealed. Test 3 was conducted from January 23 until February 19, 1996, and Test 4 from May 3 until June 5, 1996. At the end of these periods the foliage was examined with a stereomicroscope, and the number and instar of larvae were recorded for each legume. Instars were determined from head capsule widths (Thomas 1965; Green 1984). The mean daily temperature during the tests was 17°C for Test 3, and 19°C for Test 4.

Statistical Analysis

The number of eggs and egg batches laid per plant was compared with those laid on the standard white clover by a Mann-Whitney test (Zar 1984). The total numbers of larvae found on plants at the end of Tests 3 and 4 were tested for main effects due to plant species, using the Kruskal-Wallis test (Zar 1984). The proportion of larvae between instars was tested for differences between host plants by Chi-squared test.

RESULTS AND DISCUSSION

Oviposition

The high cyanide white clover selection was the most preferred plant for oviposition in Test 1 (Table 1), followed by *L. pedunculatus*. The mean number of eggs laid per plant was significantly different from the standard white clover ($P < 0.05$) for both these plants. A high variance meant that there was no significant difference between the standard clover and *O. viciifolia* in the number of eggs laid, although the number of batches was nearly significant ($P < 0.10$). The standard had ca. five-fold fewer eggs laid on it than the clover with a high cyanide content, and appeared to be the least preferred for oviposition, in both tests.

No differences were found in oviposition between legumes in Test 2 (Table 1). The mean number of eggs laid on the standard clover was almost identical in the two tests, with no significant differences found between the number of eggs or batches laid. The range in values across the six plants was less in Test 2, for both the total eggs and number of batches. The high variance in oviposition in these tests was problematical, and a much larger number of replicates would be needed to characterise such small differences in

oviposition preference.

TABLE 1: Comparative oviposition by *E. postvittana* on eleven legumes over a 3 day period (Tests 1 and 2).

Legume	Test	Mean eggs per plant ¹	Std. dev. of eggs	Mean batches per plant	Std. dev. of batches
<i>T. repens</i>	1	48.8	47.8	2.0	1.3
<i>L. corniculatus</i>	1	60.8	47.1	1.8	1.3
<i>M. sativa</i>	1	95.7	48.8	3.7	2.3
<i>L. pedunculatus</i>	1	161.8 *	58.7	4.8 *	1.7
<i>T. repens</i> (high cyanide)	1	255.5 *	177.3	9.2 **	6.8
<i>O. viciifolia</i>	1	266.0	268.7	8.7 ²	8.8
<i>T. repens</i>	2	51.8	104.8	1.2	2.4
<i>T. subterraneum</i>	2	73.5	87.2	2.0	2.0
<i>T. pratense</i>	2	82.0	94.6	2.5	2.3
<i>T. fragiferum</i>	2	86.8	114.3	2.0	2.2
<i>L. polyphyllus</i>	2	112.8	143.9	2.5	2.8
<i>V. villosa</i>	2	126.2	93.9	3.3	2.3

¹ Means significantly different from the standard white clover (*T. repens*) are shown as

* $P < 0.05$; ** $P < 0.01$.

² $P < 0.10$

The plant architecture was quite different between plants, which influenced the position and size of batches laid. For example, hairy vetch (*V. villosa*) has only very few small leaves, and most batches were found on stems. Despite such differences, all plant species were suitable for oviposition.

Larval development

In Test 3, similar numbers of larvae successfully established on the different legumes ($H = 7.62$; $P = 0.18$; $df = 5$, Kruskal-Wallis on counts), but they differed significantly in age distribution between legumes ($\chi^2 = 42.3$; $P < 0.001$; $df = 10$) (Fig. 1). However, when the standard white clover was removed from the analysis, there was no significant difference between the remaining five legumes ($\chi^2 = 8.6$; $P < 0.38$; $df = 8$).

The total number of larvae established was different between legumes in Test 4 ($H = 17.03$; $P < 0.01$; $df = 5$, Kruskal-Wallis on counts), and larval development was again affected (Fig. 1). This result was in part due to *T. subterraneum*, which is a short-lived, cool climate annual that underwent rapid agronomic decline during the experiment. Removal of this treatment from the analysis reduced the difference between treatments ($H = 9.37$; $P < 0.05$; $df = 4$). A difference in larval age distribution was still present between the remaining treatments ($\chi^2 = 13.2$; $P < 0.01$; $df = 4$) (Fig. 2). This experiment had fewer larvae established than Test 3. This highlights the difficulty of synchronising the agronomic status of plants to test the effects of insects, but does not affect the overall conclusion that differences in larval development were present between host plants.

No correlation was found between egg deposition and the incidence of larvae on plants for Tests 1 and 3, Tests 2 and 4, or all the tests combined ($P > 0.1$). This supports field observations, where high leafroller larval populations have been observed on clover orchard understoreys, in the absence of leafroller egg batches (Thomas and Burnip unpubl. data). Larvae migrating from egg batches laid on the apple foliage above the understorey are thought to be responsible, as leafroller are rarely encountered in the pure or mixed swards of clover seed crops and pastures (Schroeder and Clifford 1995). Consequently, larval developmental rates may play a more important role in determining leafroller populations in orchard understoreys than adult oviposition preferences.

Since N fixation is strongly correlated with dry matter yield (Goh *et al.* 1994), a legume species with a higher dry matter yield than white clover may be more desirable (Daly and Thomas 1992). However, white clover is already present in most apple

FIGURE 1: Larval instar distribution and totals of *E. postvittana* found on legumes in Tests 3 and 4, after 27 and 33 days rearing, respectively.

orchards and may be difficult to exclude as an understorey component. Furthermore, mowing of the understorey sward may favour the growth of white clover. While herbicides could potentially be used to favour particular understorey plant species, this is contrary to the goal of reducing orchard inputs and increasing sustainability.

In conclusion, none of the eleven legume plants displayed resistance to either leafroller oviposition, or larval establishment and development. This study suggests that white clover offers the greatest potential for use within orchard understoreys, to provide an endogenous source of N while limiting leafroller host plant availability. However, few major differences in leafroller were observed between the eleven legumes, and other factors, such as N production, should also be considered in the selection of understorey legumes. It is likely that strategies to manage understorey leafroller populations will be required where legumes are used in biological apple production systems.

ACKNOWLEDGEMENTS

We would like to thank Dr K. Widdup, P. Clifford and G. Purves (AgResearch, Grasslands) for seeds, plant material, and advice. We thank Dr C.H. Wearing (HortResearch) for suggesting the approach of using non-host understoreys for reducing pest pressure in orchards, and C. Frampton (Lincoln University) for statistical advice.

REFERENCES

- Ball, R., Brougham, J., Brock, J.L., Crush, J.R., Hogland, J.H. and Carran, R.A., 1979. Nitrogen fixation in pasture I. Introduction and general methods. *N.Z. J. Exp. Agric.* 7: 1-5.
- Daly, M.J. and Thomas, W.P., 1992. Organic apple production: understorey management, some preliminary findings after the conversion from conventional to organic management. *Proc. 9th Int. Sci. Conf., IFOAM, Sao Paulo, Brazil*: 2-8.
- Daly, M.J., McCarthy, T.P. and Marsh, K.B., 1996. Biological apple production: nutrient cycling and understorey management. *Proc. 11th Int. Sci. Conf., IFOAM*,

- Copenhagen, Denmark.
- Danthanarayana, W., 1975. Factors determining variation in fecundity of the lightbrown apple moth, *Epiphyas postvittana* (Walker) (Tortricidae). *Aust. J. Zool.* 23: 439-451.
- Dugdale, J.S., and Crosby, T., 1995. BUGS database of leafrollers and their host plants. Landcare Research, Mt Albert Research Centre.
- Goh, K.M., Ridgen, G.E. and Daly, M.J., 1994. Biological nitrogen fixation and biomass production in the understorey vegetation of an organic apple orchard in Canterbury, New Zealand. Pp 11-18. *In: Biological Fruit Production - contributed papers IFOAM 1994*. Wearing, C.H. (Ed): HortResearch, Lincoln, NZ.
- Green, C.J., 1984. Bionomics of *Epiphyas postvittana*, *Ctenopseustis obliquana*, *Planotortrix excessana* (Lepidoptera: Tortricidae) and *Stathmopoda "skelloni"* (Lepidoptera: Stathmopodidae) on apple cv 'Dougherty' in Auckland. PhD thesis. University of Auckland. Pp 1-128.
- Mead, D.J. and Mansur, I., 1993. Vector analysis of foliage data to study competition for nutrients and moisture: an agroforestry example. *N.Z. J. Forestry Sci.* 23(1): 27-39.
- Schroeder, N. and Clifford, P., 1995. The incidence of insect pests and their arthropod predators in 24 Canterbury white clover seed crops. Pp 29-33. *In: White Clover: New Zealand's Competitive Edge*. Proc. Joint Sym. Agronomy Society of N.Z. and N.Z. Grassland Assoc., Lincoln University, 1995. D.R. Woodfield, (Ed). Grasslands Res. and Prac. Series 6.
- Thomas, W.P. and Burnip, G.M., 1993. Lepidopterous insect pests and beneficials: the influence of the understorey. Pp 13-19. *In: Proceedings of Biological Apple Production Seminar*. T.P. McCarthy, D.J. Daly, G.M. Burnip, (Eds): HortResearch, Lincoln, NZ.
- Thomas, W.P., 1965. Studies on *Epiphyas postvittana* (Walker) (Lepidoptera, Tortricidae) and its parasitoid complex. MSc thesis, University of Canterbury, Christchurch. Pp 1-98.
- Tomkins, A.R., Penman, D.R. and Chapman, R.B., 1991. Leafroller oviposition on larval host plants. *N. Z. Entomol.* 14: 37-41.
- Wearing, C.H., 1994. National Leafroller Survey: Species Distribution Charts for Crops and Regions. HortResearch Internal Report No. IR 94-64.
- Wilton, J.W. and Clark, C.J., 1986. Pipfruit. Pp 35-37. *In: Fertiliser requirements for New Zealand horticultural crops*. C.J. Clark, G.S. Smith, M. Passard and I.F. Cornforth, (Eds): Wellington, NZ, Min. Ag. and Fisheries.
- Zar, J.H., 1984. Biostatistical Analysis. Prentice Hall International, Englewood Cliffs, New Jersey. Pp 718.