

## Pear sawfly (*Caliroa cerasi*) (Hymenoptera: Tenthredinidae) host preference and larval development on six *Pyrus* genotypes

P. W. SHAW  
D. R. WALLIS  
P. A. ALSPACH  
L. R. BREWER

The Horticulture and Food Research  
Institute of New Zealand Limited  
Nelson Research Centre  
P.O. Box 220  
Motueka, New Zealand  
email: pshaw@hortresearch.co.nz

V. G. M. BUS  
The Horticulture and Food Research  
Institute of New Zealand Limited  
Hawke's Bay Research Centre  
Private Bag 1401  
Havelock North, New Zealand

**Abstract** The larvae of the sawfly *Caliroa cerasi* can cause serious damage to pear (*Pyrus* sp.) foliage particularly in organic or reduced-spray orchards. Six pear cultivars and selections, three with low susceptibility to pear slug damage and three with high susceptibility, were subjected to oviposition choice tests in the field and subsequent larval development rates were monitored to clarify the nature of the variable susceptibility. Observed differences in oviposition rates corresponded with the low and high susceptibility categories of the genotypes. Larval development rates differed among genotypes and were inversely related to density of hatched eggs (a surrogate measure of leaf damage). These results confirm that host oviposition preference is a key factor influencing susceptibility to pear slug. It is further argued that feeding-induced plant resistance and larval migration could be important factors influencing pear sawfly populations on pear trees.

**Keywords** pear slug; resistance breeding; oviposition; larval development; organic production

### INTRODUCTION

Pear sawfly (*Caliroa cerasi* (L.)) (Hymenoptera: Tenthredinidae) is a cosmopolitan pest, the larvae of which are commonly referred to as “pear slugs” or “cherry slugs”. Larval feeding causes damage to leaves of *Pyrus* and *Prunus* species in particular. Large leaf veins and lower surfaces of leaves are rarely damaged, resulting in a characteristic skeletonised appearance of leaves. Heavy infestations can reduce plant vigour and completely defoliate plants. Severe damage from larvae in late summer can affect subsequent bud set (Penman 1976). In most parts of New Zealand there are two generations of pear sawfly per year. Adults emerge from pupae in November. Females usually reproduce parthenogenetically and lay 2–5 eggs into leaf tissue, which hatch after 10–14 days. The larvae of the first generation hatch in December, reach maturity on the leaves, and then descend into the soil to pupate. The second generation larvae develop in late summer and cause the most damage to plants (Epenhuijsen & de Silva 1991).

Pear slugs are readily controlled by insecticides and thus have rarely been a problem in conventionally managed orchards. However, they can become a serious pest in New Zealand pear orchards under organic management. Although some biological insecticides and other products acceptable for organic production have been identified to manage this pest, these are not always completely effective. (P. W. Shaw, J. T. S. Walker, and C. H. Wearing unpubl. data).

Brewer et al. (2002) reported considerable variation in natural infestation levels of pear slug in breeding lines of seedling pears and commented on the possibility of breeding for resistance. In a glasshouse study undertaken to verify these findings, Shaw et al. (2003) confirmed that variable susceptibilities to pear slug infestation exist among these pear

genotypes, corresponding to susceptibility classes suggested by Brewer et al. (2002) from field observations. The current paper reports the results of oviposition choice tests and larval development measurements, to examine the mechanisms of pear slug resistance in *Pyrus* genotypes. The relationship between these factors and previously established genotype susceptibility classes is discussed.

## MATERIALS AND METHODS

Six pear genotypes were chosen for this experiment, based on previous observations of susceptibility to pear slug damage (Shaw et al. 2003). Three demonstrated low susceptibility ('Shiyuehuali', 'Yali', and P205R135T006) and three high susceptibility ('Bartlett', P202R131T023, and P209R133T022). Five replicates of each genotype (except for 'Shiyuehuali' for which only three plants were available) were potted into 40-litre plastic planter bags on 27 August 2002. Each plant had previously been pruned back to a single rod c. 1.5 m tall to stimulate branch development and new growth.

Field studies were conducted in the research orchard at HortResearch—Nelson Research Centre, in Motueka, New Zealand. To allow natural and sufficient oviposition to occur in as short a time as possible, the potted plants were introduced into the inter-rows of a breeding block of young pear seedlings (2–2.5 m tall) infested with pear slug, when adult pear slugs were active in the block.

Potted plants were placed in the field on 13 March 2003 in a Latin square design, with one row omitted, and spaced 1.5 m apart, starting 3 m from the northern end of the row with gaps left for the missing 'Shiyuehuali' replicates. They were stabilised with stakes, which ensured there was no contact with neighbouring plants.

On 17 March, plants were transferred to the northern end of a ventilated glasshouse, retaining the same Latin square design, with 1.5 m spacing between plants and rows. Irrigation was provided to maintain growth and health of plants. The number of leaves and the total number of slug eggs on each plant were counted. Six infested leaves from the top of the plants where egg densities were higher were tagged on each plant and the number of eggs recorded. Plants were monitored daily until the first eggs hatched on tagged leaves. The fate of eggs on all tagged leaves was recorded daily from 18 to 27 March, after which time remaining unhatched eggs were checked when monitoring larval development.

The first hatched larva on each individually tagged leaf was allowed to remain; the rest were removed as they hatched. The lengths of the developing larvae were measured every 2–3 days using a digital micrometer ( $\pm 0.1$  mm). All monitoring concluded on 17 April, by which date the last larvae had matured. On 28 April, five typical leaves per plant were removed and the leaf area determined using a leaf area measurement machine (Mk 2, Delta A-T Devices Ltd, Cambridge, United Kingdom).

**Table 1** Mean egg and leaf data for entire plants and the six monitored leaves for each genotype. *F* probabilities for genotype and the low versus high susceptible contrast from the analyses of variance are also shown. Residual degrees of freedom (d.f.) for monitored leaves = 22; for entire plants = 20. (Numbers in parentheses are back-transformed eggs  $m^{-2}$ .)

Genotype	Entire plant				Six monitored leaves			
	Eggs plant <sup>-1</sup>	Leaves plant <sup>-1</sup>	Leaf area		Eggs m <sup>-2</sup> *	Eggs leaf <sup>-1</sup>	(% hatched)	Eggs m <sup>-2</sup>
Mean cm <sup>2</sup>			Total m <sup>2</sup>					
Shiyuehuali	59	57	103.9	0.591	10.0 (99)	3.06	89.0	30
Yali	59	78	82.3	0.640	8.8 (78)	3.33	83.2	40
P205R135T006	52	172	63.9	1.092	6.7 (45)	2.43	82.3	38
Bartlett	264	218	33.3	0.714	18.1 (329)	3.43	86.9	104
P209R133T022	327	233	22.8	0.584	23.0 (529)	3.10	81.5	137
P202R131T023	126	135	68.6	0.901	11.7 (137)	5.17	93.7	73
SED	73	23.1	4.66	0.094	2.62	0.789	7.00	13.7
<i>F</i> probabilities								
genotype	0.009	<0.001	<0.001	<0.001	<0.001	0.047	0.517	<0.001
low versus high	0.001	<0.001	<0.001	0.432	<0.001	0.051	0.453	<0.001

\*Square-root transformed.

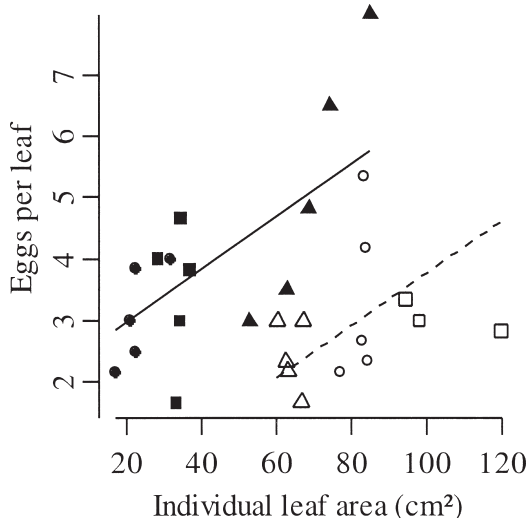
Initial exploratory data analysis involved examining scatterplots of egg hatching and larval growth by date for each plant. Analyses of variance were then undertaken on major variates. A linear model was fitted to the number of eggs to explore the effect of genotype and leaf area on oviposition preference. Larval growth was estimated by fitting an exponential curve for each larva separately, and examining the effect of genotype and leaf damage on the estimated regression coefficients. All analyses were undertaken in R, version 1.8.0 (R Development Core Team, 2003).

## RESULTS

There were clear differences in pear slug oviposition among the genotypes, which reflected the previously established damage susceptibility classes (Table 1; Fig. 1). The low-susceptibility genotypes averaged c. 50–60 eggs per plant, whereas the highly susceptible genotypes averaged well over 100 eggs per plant ( $P = 0.001$ ). Of the highly susceptible genotypes, P202R131T023 plants had fewer eggs on them than the other two genotypes. Although the genotypes had differing total leaf area ( $P < 0.001$ ) (estimated as the product of the number of leaves and the average leaf area of the five measured leaves), there was no relationship between egg numbers and total leaf area among the genotypes (square-root transformed data  $P > 0.05$ ).

The six monitored leaves were not a random selection of leaves on the plant, but were selected to have at least one egg that hatched, and they were those leaves with early hatching larvae. These tended to be the more exposed top leaves with higher egg densities. Thus, it is not surprising that the egg numbers for the monitored leaves within the susceptibility classes showed a more consistent relationship between leaf area and egg number than leaves from the entire plant (Table 1). Genotypes previously classified as having low-susceptibility were less preferred for ovipositioning by sawflies ( $P < 0.001$ ). There were no differences in the proportion of eggs that hatched among the genotypes ( $P = 0.517$ ).

The initial mean length of the larvae was c. 1.75 mm and consistent for the different genotypes ( $P = 0.673$ ) (Table 2). However, growth rate was different among genotypes ( $P = 0.010$ ) with two of the low-susceptibility genotypes supporting the highest growth rates (Table 2). Although total slug damage per plant was not recorded, it was noted that



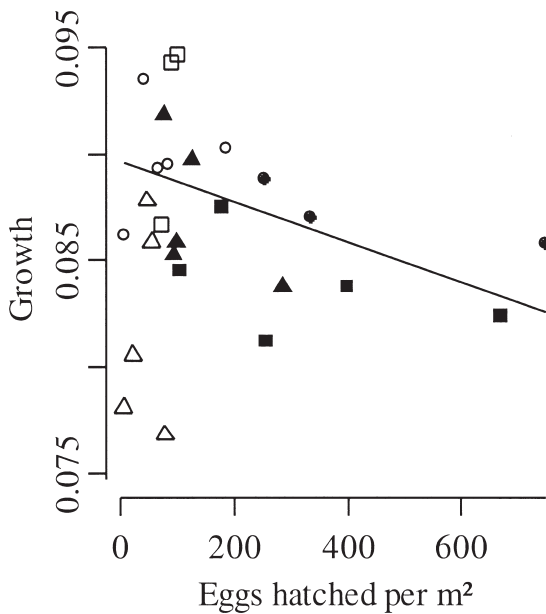
**Fig. 1** Number of eggs and leaf area for the six monitored leaves on each plant. Open symbols are used for low-susceptibility genotypes (□, ‘Shiyuehuali’; ○, ‘Yali’; and △, P205R135T006) and filled symbols for high-susceptibility genotypes (■, ‘Bartlett’; ●, P209R133T022; and ▲, P202R131T023). Ordinary least squares regression lines are shown for low-susceptibility (dashed line) and high-susceptibility (solid line) genotypes.

the highly susceptible genotypes were often almost completely defoliated, except for the monitored leaves where the slug population was limited to one per leaf. Growth rate tended to decline with the number of eggs hatched per square metre of leaf (Fig. 2), which was used as a proxy for leaf damage. Larvae on P205R135T006 (low susceptibility) appeared to grow more slowly than expected given the number of hatched eggs. Omitting this genotype left a significant linear decline ( $P = 0.024$ ) with little evidence of difference among the remaining genotypes ( $P = 0.079$ ).

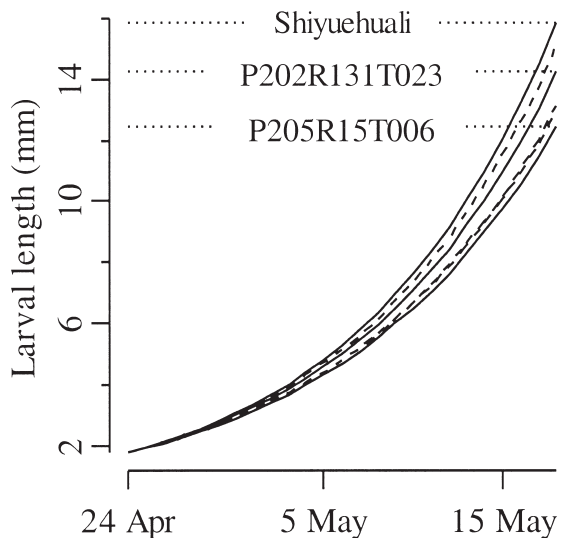
The difference in mean larval growth, as measured by the exponential regression coefficient  $r$ , supported by P205P135T006 (the slowest) and ‘Shiyuehuali’ (the fastest) may not appear very great (Table 2). However, because of the exponential nature of the growth, this small difference in rate would lead to a 25% difference in larval length after a development period of 24 days (12.5 mm versus 15.9 mm) (Fig. 3).

**Table 2** Mean larval growth for each genotype derived from exponential curves of the form  $\text{length} = ke^{r \times \text{day}}$ , where  $k$  = constant and  $r$  = regression coefficient for growth. Thus the daily percentage increase in length is  $100(e^r - 1)$ ; initial length is  $e^k$  (mm).  $F$  probabilities for genotype and the low versus high susceptible contrast from the analyses of variance are also shown. Residual degrees of freedom (d.f.) = 22. (Numbers in parentheses are the genotype numbers referenced in Shaw et al. (2003).)

Genotype	Growth		Initial length	
	$r$	Daily increase (%)	$k$	mm
Shiyuehuali (-)	0.0919	9.62	0.565	1.76
Yali (6)	0.0898	9.39	0.541	1.72
P205R135T006 (3)	0.0818	8.53	0.563	1.76
Bartlett (-)	0.0839	8.76	0.579	1.78
P209R133T022 (20)	0.0834	8.70	0.531	1.70
P202R131T023 (16)	0.0873	9.12	0.585	1.79
SED	0.00255		0.0373	
$F$ probabilities				
genotype	0.010		0.673	
low versus high	0.145		0.659	



**Fig. 2** Larval growth rate,  $r$ , on estimated eggs hatched per square metre of leaf area. Open symbols are used for low susceptibility genotypes (□, ‘Shiyuehuali’; ○, ‘Yali’; and △, P205R135T006) and filled symbols for high-susceptibility genotypes (■, ‘Bartlett’; ●, P209R133T022; and ▲, P202R131T023). Ordinary least squares regression line, excluding P205R135T006, is shown.



**Fig. 3** Predicted growth curves for each genotype. ‘Yali’ is the dashed line between ‘Shiyuehuali’ and P202R131T023, and ‘Bartlett’ and P209R133T022 are the other two dashed lines.

**DISCUSSION**

Oviposition preference as a factor in plant resistance has been reported in a number of insect studies (Westigard et al. 1970; Lamb et al. 2001, 2002; Smith & Lamb 2001). Brewer et al. (2002) suggested that there were two separate factors affecting pear slug infestation in blocks of pear seedlings:

ovipositional preference of the adults and feeding behaviour of the larvae. Although Shaw et al. (2003) confirmed differences among plant genotypes in susceptibility to sawfly damage they failed to observe ovipositional preference. This may relate to the experimental design in which seedlings were grown closely together in a net cage into which an excess number of adult female sawflies was released. The current study has clearly demonstrated the existence of ovipositional preference. It is particularly interesting that P202R131T023 had intermediate egg numbers on its leaves. This genotype was classified as highly susceptible based on feeding damage data in the study by Shaw et al. (2003) which could not detect differences in ovipositional preference. However, Brewer et al. (2002) did record ovipositional preference and perhaps more accurately classified it as having intermediate susceptibility. Shaw et al. (2003) provided limited evidence that eggs failed to hatch on less susceptible genotypes. In the current research, the proportion of eggs that hatched did not differ amongst genotypes, even though we included one genotype (P205R135T006) on which eggs had failed to hatch in the earlier study.

Larval growth was found to be inversely related to the number of eggs hatched per square metre of leaf. It is possible that more hatched eggs might lead to greater leaf damage by larvae, less leaf photosynthate production, and poorer quality feed, which might explain the observed differences in growth rate. Larvae on P205R135T006 had the lowest growth rate, despite low egg numbers per plant and presumably less damage. Shaw et al. (2003) found that this genotype had markedly lower damage area per damaged leaf, which concurs with a low growth rate. Westigard et al. (1970) in his study of psylla resistance in pears found that, in addition to deterring oviposition, some pear species exhibited a degree of antibiosis as expressed by differential development of nymphal populations. Feeding-induced plant resistance is a well-documented phenomenon for leaf-feeding insects and may also be a factor in this study. Resistance to pear slug damage in P205R135T006 is thought to come from 'Huobali', as it derives from a cross between two 'Huobali' × 'Kosui' progeny. Chemical resistance in this genotype may be a mechanism that confers larval growth inhibition not found in low-susceptibility genotypes 'Shiyuehuali' and 'Yali'.

In this study, plant separation prevented larvae from migrating between plants, although there was movement of larvae within a plant. Demonstration of larval feeding preference was therefore limited.

Although larval movement was not recorded, some incidental records made on occasions when a second larva appeared on a tagged leaf permitted indirect measurement of larval movement. Movement of larvae may have been associated with density-dependent factors, although we were unable to link these movement indicators with genotype or damage.

Our results, together with those of Brewer et al. (2002) and Shaw et al. (2003), confirm that there is a likely genetic basis to pear slug resistance in pears, manifesting as oviposition preference and differential larval growth rates. Antibiosis and induced resistance may be involved, but the mechanisms that confer this resistance remain largely a matter of speculation. Although pear slug may not currently be an economically important pest of pear under conventional orchard management, it does provide an interesting study for examining the mechanisms for plant resistance to insect pests. Results from this study indicate that pear slug-resistant pear cultivars could be developed through breeding.

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