Adult eclosion, flight and oviposition of *Choristoneura rosaceana* (Lepidoptera: Tortricidae), in British Columbia apple orchards

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ABSTRACT

Adult eclosion and oviposition of obliquebanded leafroller, *Choristoneura rosaceana* (Harris), was studied under field conditions so that integrated pest management of this species could be appropriately timed. Seasonal flight activity of adult males was monitored with synthetic pheromone-baited traps in unsprayed, organically grown apple, *Malus domesticus* (Borkh.) orchards in the Similkameen (1994-1997) and Okanagan (1996-1997) Valleys of British Columbia. Eclosion of adults from collected larvae and oviposition of female moths was monitored by daily observation in the 1996 and 1997 field seasons to establish relationships between insect phenology and accumulated degree days above 10°C ($°dd_{10°C}$) air temperature after 1 January. Males emerged before females throughout the eclosion period in both years. First catches of males in pheromone-baited traps preceded first-male eclosion of collected males by 7 and 6 $°dd_{10°C}$ in 1996 and 1997, respectively, after which cumulative percentages of trap capture lagged behind cumulative percentages of male eclosion in both years. First and second male flight periods had similar durations in the Similkameen Valley, varying from 481-636 and 476-779 $°dd_{10°C}$, respectively. Mean (±SE) initiation of oviposition was 29 ± 2.2 $°dd_{10°C}$ after the first female eclosed. The nonlinear relationships between plots of cumulative adult emergence, oviposition and trap catch against $°dd_{10°C}$ after 1 January were modelled using Weibull functions. Fifty percent adult eclosion was predicted to occur at 328 and 335 $°dd_{10°C}$ after 1 January for males and females in the overwintered generation, respectively. Fifty percent male and female eclosion in the summer generation was predicted to occur at 843 and 909 $°dd_{10°C}$ after 1 January. Fifty percent oviposition was predicted at 91 $°dd_{10°C}$ after first female emergence. Models of the trap catch in the Similkameen and Okanagan Valleys were similar and predicted 50% of the first flight at 438 (Similkameen) and 485 (Okanagan)$°dd_{10°C}$ after 1 January. Prediction of the occurrence of adult obliquebanded leafroller eclosion, mating and oviposition will aid in the development of a pheromone-based, integrated pest management programme for *C. rosaceana* in British Columbia.

Key words: *Choristoneura rosaceana*, phenology, mating, oviposition, pheromone

INTRODUCTION

Choristoneura rosaceana (Harris) (Lepidoptera: Tortricidae) overwinters as a diapausing larva in protective hibernacula on woody host plants (Chapman *et al.* 1968). Diapause is

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facultative (Chapman *et al.* 1968), allowing for additional generations if conditions are favourable. In British Columbia (BC), overwintering larvae break diapause early in the spring and resume development through the remainder of six instars. Adult flight in BC, usually starts in early June and mating and oviposition are presumed to occur from mid-June to August. The second adult flight begins in August and continues until October (Madsen and Proctor 1985). Eggs are laid during this period and larvae that emerge in September and October overwinter in diapause.

The number of generations each year varies by location: two in New York (Chapman *et al.* 1968), southern Québec (Delisle 1992; Hunter and McNeil 1997) and Oregon (AliNiazee 1986), but only one in northern Québec (Hunter and McNeil 1997), Nova Scotia (Sanders and Dustan 1919) and Utah (Knowlton and Allen 1937). In BC, Venables (1924) reported that *C. rosaceana* is univoltine but Madsen *et al.* (1984) suggested that it is univoltine in the northern Okanagan Valley and at higher elevations, and is bivoltine in the southern Okanagan and Similkameen Valleys. The quality of the host plant influences the proportion of *C. rosaceana* that enter diapause (Hunter and McNeil 1997), which may contribute to variable voltinism in the same area.

The obliquebanded leafroller can cause fruit injury during several time periods. Emergent overwintered larvae can cause premature fruit drop, or deep russetted scarring of the apple (Reissig 1978). Summer-generation larvae cause damage by tying leaves to the surface of fruit under which they feed, resulting in irregular scars on the fruit (Madsen and Proctor 1985). Summer feeding damage can be more serious than that from overwintering larvae, because most damaged apples remain on the tree at harvest (Reissig 1978).

Control of the codling moth, *Cydia pomonella* (L.) (Lepidoptera: Tortricidae) by the Sterile Insect Release programme (Dyck *et al.* 1993) or by pheromone-based mating disruption (Judd *et al.* 1996a, 1997) in the Okanagan, Similkameen and Creston Valleys of BC will reduce insecticide application in orchards and may elevate the pest status of *C. rosaceana* and other leafroller species. The leafroller-eyespotted budmoth (Lepidoptera: Tortricidae) complex in BC can cause 10-20% damage in untreated orchards (Judd *et al.* 1992). In an effort to benefit from non-insecticidal control of *C. pomonella* and produce insecticide-free fruit, growers would like to apply organic methods for managing *C. rosaceana* and other tortricine leafrollers, such as pheromone-based mating disruption. In order to schedule pheromone applications so that they are effective at the time of mating and oviposition, information on the developmental physiology of this insect is required.

AliNiazee (1986) developed a degree-day (°dd) model for predicting seasonal flights of male *C. rosaceana* as measured by moth capture in pheromone-baited traps. In a laboratory study, Gangavalli and AliNiazee (1985a) demonstrated that female *C. rosaceana* laid eggs 35.2 °dd$_{11.9°C}$ after eclosion, egg development from oviposition to hatch took 111.9 °dd$_{10°C}$, larvae needed 435.6 °dd$_{10°C}$ to complete development through six instars, and pupae eclosed after 117.4 °dd$_{10°C}$. Reissig (1978) developed a temperature-driven model to predict egg hatch based on when the first male moth was captured in pheromone-baited traps; this biological indicator is referred to as a "biofix". Onstad *et al.* (1985) developed a model to predict a critical number of larvae hatching to time spray applications. The crucial developmental information required to implement a pheromone-based mating-disruption programme is eclosion of female moths and timing and duration of mating and oviposition in the field.

Our objectives were to determine when adults of both sexes of both generations of *C. rosaceana,* held under field conditions, eclosed and the onset and duration of oviposition on a physiological °dd scale.

MATERIALS AND METHODS

Larval Development. In 1996, active larvae were collected from shoot terminals in an organic

apple orchard in Cawston (49°11' N, 119°46' W), in the Similkameen Valley, from 5 through 8 May, corresponding to 87-89°dd$_{10°C}$ accumulated from 1 January. Larvae were collected throughout the orchard, placed in paper bags, transported to the laboratory in refrigerated containers, and transferred in groups of 5-10 into cylindrical sleeve cages (50 cm long x 20 cm diameter) made from white nylon organza mesh. Each cage was secured at both ends over a leaf-bearing branch about 2 m above ground on cultivar Red Delicious apple trees in an experimental orchard at the Agriculture and Agri-Food Canada, Pacific Agri-Food Research Centre, in the Okanagan Valley at Summerland, (49°34' N, 119°39' W) for the completion of larval development. Caged larvae were moved to a fresh branch when necessary to ensure an adequate supply of apple leaves.

Larvae were collected in 1997 from the same orchard as in 1996. Sixty apple trees were sampled weekly for active larvae from 6 May through 3 June, corresponding to 76-259 °dd$_{10°C}$ accumulated from 1 January. Sampled trees were spaced evenly throughout the orchard and both edge and interior trees were included. A sample consisted of a 5 min full-tree search for larval nests, leaves or petals webbed together, which were removed during the sample. Collected larvae were stored, transported, and reared in groups of 10-20 in mesh cylindrical sleeve cages as in 1996.

Adult Eclosion. Once pupae were detected, caged branches were cut from the tree and sleeve cages and leaves were carefully inspected for pupae and larvae. Searches for pupae were repeated weekly after the onset of pupation from 29 May through 24 July, 1996 and from 21 May through 9 July, 1997, until all larvae had pupated.

In 1996, pupae retrieved from sleeve cages were separated by sex and transferred to a mesh emergence cage with a wooden frame (28 x 28 x 37 cm), located on a platform 1.4 m above ground within the tree canopy in the Summerland orchard. The cage was checked daily for newly-eclosed adults. Adults were sexed and two out of every three males and females were transferred to a mesh oviposition cage with an aluminum frame (44 x 41 x 41 cm) placed on a platform 1.4 m above ground within the tree canopy in the orchard. In the oviposition cage, moths were provided with 3-4 freshly excised apple twigs placed in water as an oviposition substrate and dental cotton wicks in flasks of distilled water as a water source. The remaining adults were transferred to a bottomless field cage (3.6 x 3.6 x 2.4 m) enclosing a small apple tree, that had previously been stripped of all leafroller larvae, to mate and produce larvae as a collection source for the summer generation.

In 1997, pupae retrieved from sleeve cages were separated by sex and transferred to emergence cages as in 1996, but were segregated into five cages by larval collection date. Newly-eclosed adults were collected daily, enumerated by sex, transferred to a communal oviposition cage (44 x 41 x 41 cm) placed on a platform 1.4 m above ground, within the tree canopy in the same orchard, and provided with apple branches and water as in 1996.

In both years, summer generation larvae were searched for within the field cage. In 1997, larvae were collected and arranged in sleeve cages following the same protocol as for the overwintered generation. Adult moth eclosion from the summer generation was monitored only in 1997, as too few individuals were recovered in 1996.

Male Moth Flight. Two monitoring traps were hung in the Summerland orchard on 31 May 1996 and 7 June 1997. Traps were constructed from opposing wing-trap tops (Phero Tech Inc., Delta, BC) held 5 cm apart with pieces of drinking straw. Stickem Special$^®$ (Phero Tech Inc.) was thinly applied to the inside surface of the trap bottom (an inverted top) to capture moths. Lures were suspended from the inside tops of traps using a straight pin. Traps were hung by a wire hanger from trees approximately 1.5 m above ground. Lures used to monitor *C. rosaceana* consisted of a 100:2:1.5:1 ratio of Z11-14:OAc : E11-14:OAc : Z11-14:OH : Z11-14:Ald (Vakenti *et al.* 1988; Thomson *et al.* 1991) loaded onto red rubber septa (The West Company, Linville, PA) at a rate of 3 mg in 200 µl of HPLC-grade hexane per septum. Lures were replaced

every four weeks during the flight period. Traps were checked daily throughout the first flight in 1996 and for both flights in 1997. Each day, trap bottoms with captured males were removed and replaced with fresh bottoms. Monitoring traps were also placed in three orchards in Cawston, from 1994-1997 and checked at 2-3-day intervals throughout the flight period. Trap catches from sites at each location were pooled at each site prior to analysis.

Oviposition. Excised apple branches in the oviposition cages were checked daily, inspected for egg masses and replaced with freshly cut branches. In 1996, egg masses were counted, labelled, transported to the laboratory for enumeration of eggs and discarded. In 1997, egg masses were counted, labelled and transferred to a (3.6 x 3.6 x 2.4 m) field cage covering a small apple tree which had previously been stripped of all leafroller larvae. Larvae emerging from these egg masses were used as a collection source for the summer generation. Monitoring of the oviposition period of summer generation females was conducted in 1997 only, using the same protocol as for the overwintered generation.

Weather Data. Hourly air temperatures were recorded year-round in Cawston at an orchard located approximately 1 km from the orchard in which larvae were collected, and in the Summerland orchard using DP-212 datapods (Omnidata, Logan, Utah) housed in standard-height (1 m) Stevenson screens placed in the centre of each orchard. When temperature data were missing due to malfunction of equipment, replacement data were obtained for the Similkameen Valley site from Integrated Crop Management (Cawston) or Environment Canada (Keremeos), and from the Okanagan Valley site from Agriculture and Agri-Food Canada (Summerland). Daily °dd summations for each location and year were calculated by fitting a sine wave (Allen 1976) to daily temperature minima and maxima using the computer programme described by Higley *et al.* (1986). A lower base temperature of 10°C and upper threshold temperature of 31°C were chosen, based on developmental data for *C. rosaceana* (Gangavalli and AliNiazee 1985a). Degree day accumulations were started on 1 January of each year instead of after the first trap catch (biofix) because larvae originated in a different location from where adults emerged. The difference in °dd accumulations between Cawston and Summerland was added to the °dd accumulations at Summerland, when larvae were moved to this more northerly location.

Statistical Analyses. Daily trap catches, and eclosion of males and females at Summerland in both years were converted to cumulative percentages of total generational trap catch, or eclosion, respectively, and plotted against $°dd_{10°C}$ accumulated from 1 January. Due to low levels of eclosion, cumulative percentages could not be calculated for the summer generation trap catch or eclosion in 1996 or for trap catch in 1997. A non-parametric, two-sample Kolmogorov-Smirnov test was used to test the hypothesis that the cumulative distributions for eclosed adult males and females were equivalent (Conover 1971). The test statistic, T is defined as the greatest vertical distance between the two empirical distribution functions S_1 and S_2, which were obtained by a random sample (Conover 1971).

To determine if the number of egg masses deposited was an adequate measure of total eggs laid, the number of $°dd_{10°C}$ accumulated after first female emergence in 1996 was regressed against the number of eggs per sampled egg mass (SAS 1996). The number of eggs per mass did not change throughout the oviposition period ($r^2=0.0650$) so all calculations in 1996 and 1997 were conducted on the number of egg masses laid. The numbers of egg masses produced daily were converted to cumulative percentages of the total number of egg masses produced per generation and plotted against $°dd_{10°C}$ accumulated from the first female emergence. Cumulative percentages were not calculated for summer-generation oviposition in 1996.

The nonlinear relationship between female eclosion, male eclosion, oviposition or trap catch and temperature was modelled with cumulative Weibull functions (Wagner *et al.* 1984). This technique has been used to describe the relationship between temperature and insect development and eclosion in other species (Wagner *et al.* 1984; Cockfield *et al.* 1994; Judd *et al.* 1996b; Judd and Gardiner 1997; McBrien and Judd 1998).

A cumulative Weibull function of the form:

$$f(x) = 100\left[1 - \exp^{-(x/a)^b}\right] \quad \text{[Equation 1]}$$

in which, $f(x)$ is the cumulative percentage eclosion, oviposition or trap catch, x is the predictor variable (time or degree days), and a and b are parameters to be estimated. Estimated values for parameters were determined using the nonlinear regression procedure in SigmaStat™ (1994).
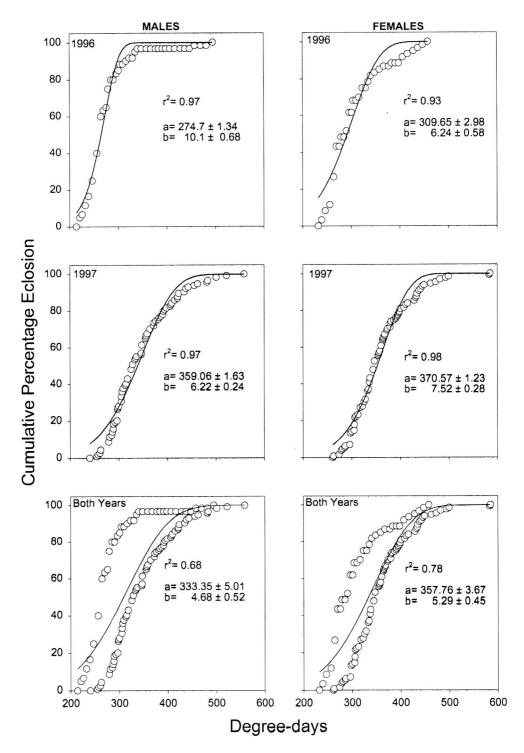
RESULTS

Adult Eclosion. Similar numbers of male and female *C. rosaceana* eclosed in 1996 and 1997 (Table 1), indicating a 1:1 sex ratio in nature. In both years, the first males emerged before the first females. The cumulative distributions of percent male and female eclosion were significantly different for overwintered-generation moths in 1996 ($T_{60,60} = 0.2483$, $P < 0.05$) and in 1997 ($T_{114,130} = 0.15526$, $P < 0.05$). In 1996 and 1997 the first male moths of the overwintered generation eclosed at 221 and 255 °$dd_{10°C}$, respectively, 18 and 7 °$dd_{10°C}$ before first female moths. Fifty percent of overwintered-generation males in 1996 and 1997 eclosed 26 and 19 °$dd_{10°C}$ respectively, before 50% of the females eclosed, indicating protandry throughout the eclosion period. Summer-generation eclosion could only be followed in 1997 (Table 1), as too few individuals were recovered in 1996. As in the overwintered generation, males eclosed before females ($T_{12,19} = 0.4722$, $P < 0.05$). Few larvae that emerged from egg masses deposited by the collected individuals developed through to summer-generation adults in 1997, suggesting that most summer-generation larvae entered diapause in 1997. This is supported by the collection of 288 larvae that emerged on this same caged tree the following spring, 1998 (Evenden, unpubl. data). Adult male and female eclosion in the overwintered generation modelled using Weibull functions described the within year eclosion accurately for both sexes; however, these functions did not fit the multiple-year data well (Fig. 1).
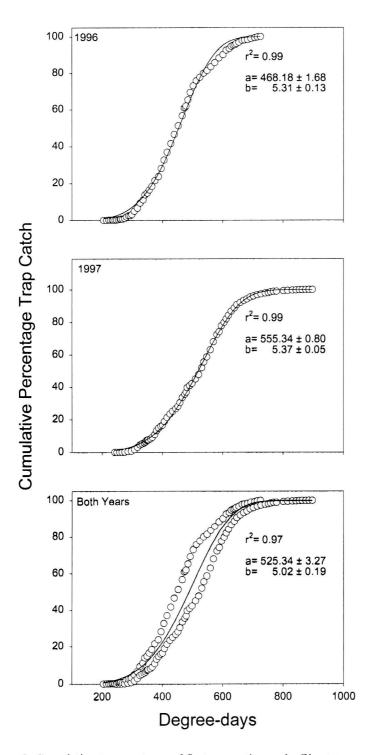
Table 1

Total number of adult *C. rosaceana* eclosing (Ec) and trapped (Tr) in 1996 and 1997, and observed °$dd_{10°C}$ from January 1, 1996 and 1997 for various eclosion and trapping events.

| | | | | | Observed °$dd_{10°C}$ | | | | | | |
| | | | No. of insects | | First occurrence | | 5th percentile | | 50th percentile | | 95th percentile | |
Year	Flight	Sex	Ec	Tr	Ec	Tr	Ec	Tr	Ec	Tr	Ec	Tr
1996	1	♀♀	60		239		246		290		428	
		♂♂	60	3714	221	214	221	306	264	452	335	635
1997	1	♀♀	130		262		285		347		473	
		♂♂	114	4169	255	249	279	332	328	530	482	691
	2	♀♀	16		843		843		909		1000	
		♂♂	12		741		741		843		929	

Male Moth Flight. First trap catches of males in the Summerland orchard occurred at 214 and 249 °$dd_{10°C}$ in 1996 and 1997, respectively (Table 1). The first male trap catch preceded first male eclosion in captivity by 7 and 6 °$dd_{10°C}$ in 1996 and 1997, respectively, which corresponded to only 1 calendar day in both years. Despite the congruence between first trap capture and first
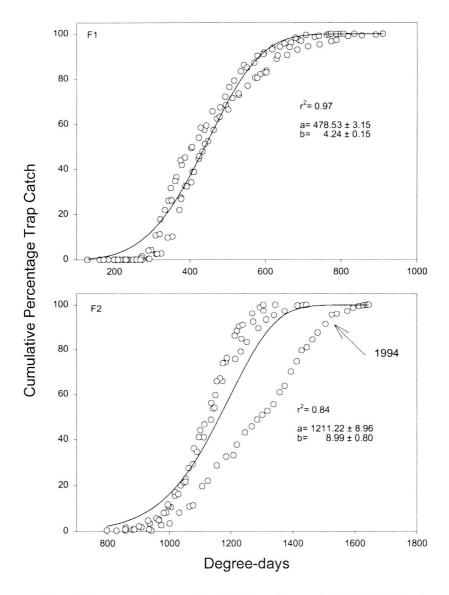
Figure 1. Observed cumulative first-generation *Choristoneura rosaceana* adult eclosion (o) in 1996 and 1997 alone and combined, plotted against $°dd_{10°C}$ air temperature after 1 January compared with curves (solid lines) modelled by Weibull functions with estimated parameters a and b (see text).

Figure 2. Cumulative trap captures of first-generation male *Choristoneura rosaceana* (o) in pheromone traps at Summerland during 1996 and 1997 alone and combined, plotted against °dd$_{10°C}$ air temperature after 1 January, compared with curves (solid lines) modelled by Weibull functions with estimated parameters a and b (see text).

male eclosion, cumulative percentages of males captured in traps lagged behind cumulative percentages of male eclosion in 1996 and 1997 (Table 1). First male trap catch preceded first captive female eclosion by 25 and 14 $°dd_{10°C}$, corresponding to 5 and 2 calendar days in 1996 and 1997, respectively (Table 1). Cumulative percentage curves of male trap captures in 1996 and 1997 also lagged behind female eclosion in captivity.
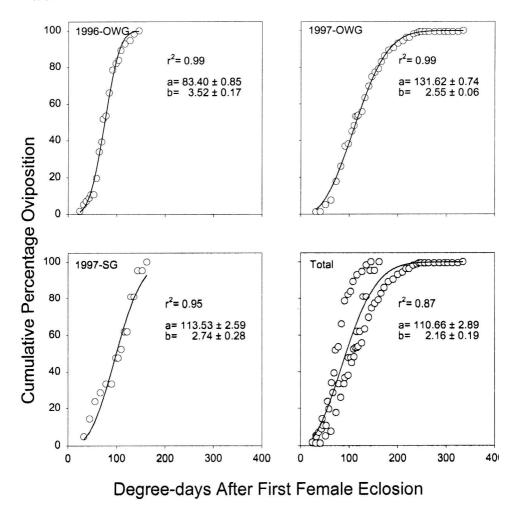
Weibull functions accurately described cumulative percentages of first-flight trap capture at Summerland in 1996 and 1997 and for both years combined (Fig. 2). Similarly, a Weibull function fitted the cumulative percentages of first-flight trap capture in Cawston over a 4-year

Figure 3. Cumulative trap captures of first (F1)- and second (F2)-flight *Choristoneura rosaceana* (o) in pheromone traps in Cawston, 1994-1997 combined, plotted against $°dd_{10°C}$ air temperature after 1 January, compared with curves (solid lines) modelled by Weibull functions with estimated parameters a and b (see text).

period (Fig. 3). The functions of trap catch from the two areas were similar and predicted 50% flight at 438 (Cawston) and 485 (Summerland)$°dd_{10°C}$ after 1 January. Second-flight cumulative trap captures in Cawston were not as accurately described by a Weibull function (Fig. 3), due mainly to a prolonged flight in 1994. First- and second-male flights had similar durations in Cawston, varying from 481-636 and 476-779 $°dd_{10°C}$, respectively.

Oviposition. Oviposition commenced 29 ± 2.2 $°dd_{10°C}$ (mean $\pm$ SE) after first female eclosion (Fig. 4). Weibull functions predicted 50% oviposition to occur 78, 113, 99 and 91 $°dd_{10°C}$ after first female eclosion for the overwintered generation in 1996, and the overwintered and summer generations in 1997, and for all generations combined, respectively. Duration of the oviposition period is probably best estimated by the overwintered-generation oviposition in 1997, because the adults producing the eggs were collected throughout the eclosion period and not at only one time, as in 1996. The oviposition period for the overwintered generation in 1997 lasted 303 $°dd_{10°C}$ after first female eclosion.

Figure 4. Observed cumulative oviposition (o) for overwintered-generation (OWG) *Choristoneura rosaceana* in 1996 and for overwintered (OWG)- and summer (SG)-generations in 1997 plotted against $°dd_{10°C}$ air temperature after first female eclosion, compared with curves (solid lines) modelled by Weibull functions with estimated parameters a and b (see text).

DISCUSSION

Our finding that eclosion of *C. rosaceana* is protandrous in British Columbia, is consistent with reports elsewhere in its range (Onstad *et al.* 1985; Delisle and Bouchard 1995). Weibull functions did not fit the multiple-year eclosion data for either sex well (Fig. 1), suggesting differences in adult eclosion patterns from year to year. These differences probably arise because the larval collection method varied between years of this study. In 1996, larvae were collected between 87-89 $°dd_{10°C}$ after 1 January, instead of throughout the larval activity period as in 1997. Eclosion percentiles in 1996 always preceded those in 1997 (Table 1), suggesting that larvae that broke diapause late may have been missed in the 1996 sample. Therefore, the 1997 data probably most accurately reflect normal eclosion patterns. The capture of males in pheromone-baited traps prior to the first observed eclosion of collected males may indicate that the active range of the pheromone-baited trap is large enough to attract males from slightly warmer microclimates than the captive larvae had experienced.

The relationships between cumulative percent of trap catch and accumulated $°dd_{10°C}$ in the overwintered generation were similar in the four field seasons in Cawston as well as the two seasons at Summerland (Figs. 2, 3). The first male trap catch at 214-292 $°dd_{10°C}$ after 1 January in the six site-years is slightly later, but comparable to male trap catch in filbert orchards in Oregon (197.8-227 $°dd_{10°C}$ after 1 March) (AliNiazee 1986). Any difference between January and March start dates for $°dd_{10°C}$ accumulation would be negligible as few $°dd$ accumulated between 1 January and 1 March in all four years of our study. The first male captured in the summer-generation flight could only be measured accurately from the Cawston flight data (Fig. 3). The first male captured in pheromone-baited traps, 797-942 $°dd_{10°C}$ after 1 January, was similar to the observed summer generation in filbert orchards in Oregon (838.3-923.8 $°dd_{10°C}$ after 1 March) (AliNiazee 1986). Any delay in initiation of flight in filbert orchards may be due to variation in larval development on different hosts (Onstad *et al.* 1985; Carrière 1992) as filbert is a poor quality host (Delisle and Bouchard 1995) that may cause extended larval development times.

The durations of the first and second flights were similar as indicated by $°dd_{10°C}$ accumulations from first to last moth capture in pheromone-baited traps in Cawston which ranged from: 481-636 $°dd_{10°C}$ and 476-779 $°dd_{10°C}$ for first and second flights, respectively. First flight in filbert orchards in Oregon lasted a similar duration (651 $°dd_{10°C}$) but the second generation was shorter than our findings (288.3 $°dd_{10°C}$) (AliNiazee 1986). Duration of the second flight will vary depending on environmental conditions. For example, constant high temperatures of 32°C may cause development of *C. rosaceana* to slow or cease and temperatures between 28-32°C can induce diapause in *C. rosaceana* larvae despite summer photoperiod conditions (Gangavalli and AliNiazee 1985*a*, 1985*b*). High summer temperatures in Oregon prolonged development of the overwintered generation and resulted in a long flight duration (AliNiazee 1986). Low numbers of summer generation adults may be the result of several factors. A late spring eclosion due to cool temperatures could cause first- and second-instar larvae of the summer generation to be exposed to diapause-inducing conditions (short day length, cool temperatures) and cease development. High summer temperatures may also induce summer-generation larvae to enter diapause. Larval hosts can influence diapause induction (Carrière 1992; Hunter and McNeil 1997) and larval development (Onstad *et al.* 1986; Carrière 1992). For example, summer-generation larvae that feed on old apple leaves due to a delay in spring eclosion of overwintering larvae will develop slowly (Onstad *et al.* 1986) and may enter diapause before completing development. A small second flight was observed in 1997 at Summerland, probably because a cool spring delayed adult eclosion, and most summer-generation larvae entered diapause, not emerging until our 1998 collections in spring.

Oviposition started 24, 31 and 33 $°dd_{10°C}$ after first female eclosion in the overwintered

generation in 1996 and the overwintered and summer generations in 1997, respectively (Fig. 4). In comparison, Gangavalli and AliNiazee (1985a) observed a pre-oviposition period of 35.2 $°dd_{11.9°C}$ while Onstad *et al.* (1985) estimated it to be 14 $°dd_{10°C}$. Older studies (Schuh and Mote 1948; Chapman and Lienk 1971) showed that no oviposition occurred within the first 24 h of male-female interaction. Oviposition started approximately 45 $°dd_{10°C}$ after first moth capture and 50% of oviposition was predicted to occur ca. 113 $°dd_{10°C}$ after first female eclosion, approximately 130 $°dd_{10°C}$ after first moth capture. Trap catches can be used as an accurate indicator of adult female eclosion and oviposition because the first trap catch in both years preceded eclosion of females by a small and consistent margin.

Capture of the first male moth in pheromone-baited traps preceded the first observed eclosion of adult males and females of the overwintering generation by a consistent margin in both 1996 and 1997, and therefore could be used as a reliable indicator of adult eclosion (Table 1). Pheromone dispensers, for the purposes of mating disruption, could be positioned in the orchard immediately after biofix and could disrupt mating of even the earliest eclosing females. Pheromone dispensers should release enough pheromone to disrupt adult mate-finding behaviour throughout both flight periods, until early October, as the size of the summer generation is difficult to predict. Alternatively, growers may be able to disrupt the adults that emerge from the overwintered generation and add additional dispensers later in the season if conditions indicate a large second generation. If the second approach is taken, pheromone dispensers to disrupt the first generation should be effective throughout the first oviposition period. Direct correlations between biofix and developmental stages of *C. rosaceana* were not obtained in this study, and should be conducted before recommendations of mating disruption of the overwintering generation alone are made.

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