INTRODUCED AND NATIVE LEAFROLLERS (LEPIDOPTERA: TORTRICIDAE) ON BERRY CROPS IN THE LOWER FRASER VALLEY, B.C.

by

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B.Sc., Simon Fraser University, 1975
M.Sc., Simon Fraser University, 1979

A THESIS SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
in the Department
of
Biological Sciences

SIMON FRASER UNIVERSITY
December 1981

Approval

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Degree: Doctor of Philosophy

Title of Thesis: Introduced and native leafrollers (Lepidoptera: Tortricidae) on berry crops in the Lower Fraser Valley, B. C.

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Date approved: 22 Dec 1981

Title of Thesis/Project/Extended Essay

Introduced and native leafrollers (Lepidoptera: Tortricidae) on berry crops in the Lower Fraser Valley, B.C.

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ABSTRACT

Leafrollers are significant pests of blueberry and cranberry, but not of raspberry and strawberry, in the Lower Fraser Valley, B.C. Leafrollers feeding on fruit clusters reduced blueberry yields by up to 8%. The economic threshold is damage to 1% of clusters. Leafrollers on cranberry devastate fields when not controlled by insecticides. On raspberry and strawberry they are controlled by sprays for other pests. Pest management on blueberry and cranberry is feasible.

On blueberry 14 species of Tortricidae, 1 of Oecophoridae and 1 of Geometridae fed in leafrolls and blossom clusters. The dominant species were _Choristoneura rosaceana_, _Spilonota ocellana_, _Archips rosanus_ and _Cheimophila salicella_. Because _Rhopobota naevana_, the only important leafroller on cranberry, has few alternate hosts, its population can be readily monitored and managed. Common species on raspberry were _C. rosaceana_, _Operophtera bruceata_ and _Acleris comariana_, but these did not cause damage. Larvae of _A. comariana_ were abundant on strawberry at 1 site and did no visible damage.

Parasitism of _C. rosaceana_ (18 to 33%) and _S. ocellana_ (23%) on blueberry and of _A. comariana_ (69%) on strawberry may limit their populations. Parasitism was highest in areas of high _C. rosaceana_ density; no correlation was observed

between density and parasitism of A. comariana.

Alternate plant hosts near blueberry fields harboured potential leafroller pests of blueberry. Larvae of A. comariana in a strawberry field were most numerous near wild vegetation.

Some first-instar leafroller larvae on blueberry aerially disperse on hatching. Control spraying should coincide with this dispersal. Dispersal occurred mostly inside the margins of a blueberry field, limiting its importance in reinfesting fields after control.

High larval densities of R. naevana decreased development time and adult size. This effect would be important only at high field densities.

The female-produced sex pheromone of C. salicella is a mixture of E-11-tetradecenyl-1-O-acetate: E-11-tetradecen-1-ol: tetradecanyl-1-O-acetate in a 20:1:1 ratio.

Introduced leafrollers fed on all crops surveyed. Recently introduced species occurred only on blueberry but were not important. Native leafrollers before hibernation inhabited abandoned rolls of introduced species. Control programs for introduced leafrollers controlled both native and introduced leafroller species. These species also shared common parasites.

ACKNOWLEDGEMENTS

This research would not have been possible without the support, advice and assistance of many people. I thank my senior supervisor, Dr. B.P. Beirne, Professor of Pest Management, Biology Department, Simon Fraser University for providing the direction and guidance, and the constant and generous support which made this research possible. I also thank the members of my supervisory committe, Dr. J.H. Borden, Professor, Biology Department, Simon Fraser University, and Mr. J. Raine, Research Scientist, Agriculture Canada, for their advice and assistance. I am grateful to Prof. T. Finlayson, Professor Emerita, Biology Department, Simon Fraser University, and Dr. T. Cram, Research Scientist, Agriculture Canada, for their advice and criticism of this work in its various stages. I thank Dr. K. Slessor, Associate Professor, Chemistry Department, Simon Fraser University, for introducing me to the marvels of pheromone chemistry.

I thank the staff at the Biosystematics Research Institute, Agriculture Canada, for identifying many of the species encountered in this research, and for the information and instruction which was so freely given to me by them.

I thank D. Quiring, D. Lactin, J. Lighthall, and J. Nelson for the able and industrious technical assistance which each provided during various stages of my work. I also thank the staff of the Agriculture Canada substation in Aldergrove, B.C. for their assistance in tending traps at that location.

A great deal of thanks is due to the many small fruit growers who allowed me to use their field and crops for research purposes. I specifically thank Mr. P. Freeman, Mr. D. March, Mr. A. March, and Mr. B. Goetzke for giving so much of their time to educate me in the mysteries of small fruit farming.

I thank the MacMillan Family Fund for its support in the form of a scholarship.

Finally, I thank my wife, Beth Gillespie, who assisted with and contributed to this work at every stage, from field work to typing.

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CHAPTER I. INTRODUCTION

It was hypothesized that leafrollers could be of economic significance to berry crops and also that the leafroller fauna on those crops had been enhanced by recently introduced species not hitherto reported as causing damage. These hypotheses were explored in relation to berry crops in the Lower Fraser Valley, B.C. The evaluation of the economic significance of the species involved and the identification of ecological and behavioral factors related to it produced sufficient evidence to show that an effective pest management program for blueberry is feasible.

The culture of small, or berry fruits, plays an important role in the agricultural economy of the Lower Fraser Valley, B.C. The most important of these crops are blueberry, cranberry, raspberry and strawberry which together occupy 32% of the agricultural land producing fruits and vegetables and like crops (Table 1). These 4 crops had a value in 1978 of $25,373,613.00, or about 60% of the value of all fruit and vegetable production in the Lower Fraser Valley, B.C. As the culture of these small fruits is important in the Lower Fraser Valley, B.C., pests which could cause them losses are important.

Besides recommendations for characteristic and specific pests of blueberry and raspberry, the "Berry Production Guide" (Ministry of Agriculture, Province of British

Columbia) make recommendations for control of unspecified "leafrollers" if their numbers are "damaging". On the basis of a literature survey it was evident that the species of leafrollers involved, the numbers at which they cause "damage" and the significance of that "damage" were not determined.

The "Berry Production Guide" also recommends control of one tortricid species on cranberry and one on strawberry, but there is no indication if these are the only important species or if there are others requiring controls on these crops.

Furthermore, over 40 species of Lepidoptera of exotic origin, excluding those on stored products, are recorded as present in British Columbia. Many of them were discovered only in recent years (e.g. Doganlar and Beirne 1978a, 1979a, b; Cram 1973; Evans 1966; Lazorko 1977; Gillespie et al. 1978; Raine 1966.). More than one-third of these are Tortricidae, the larvae of which are known as leafrollers and budmoths.

The impact of those species, particularly the recently introduced ones, on agricultural production in the Lower Fraser Valley of south-western British Columbia is virtually unknown. It is not known if these introduced species have displaced native species as pests, or are interacting with them by sharing of parasites or through other common influences.

The status of leafrollers, particularly Tortricidae, as pests of berry crops is largely unknown, and some of the more recently introduced species may be causing problems not hitherto recognized. Therefore the primary goal of this work is to define the impact of the present leafroller fauna of berry crops in the Lower Fraser Valley, B.C. The objectives are:

1. to identify the native and introduced species of leafroller feeding on berry crops in the Lower Fraser Valley, B.C.;
2. to determine facets of the biology of those species on berry crops, particularly related to the timing of hatch and of larval dispersal, which might facilitate their control and management;
3. to define their present numerical and relative abundance so that future changes in species composition and abundance can be detected;
4. to identify the insect species parasitic on Tortricidae on berry crops, determine their rates of parasitism, and deduce if they have potential as natural control agents;
5. to determine if leafrollers are having an economic impact on blueberry and thus require control;
6. to determine the need and potential for pest management programs centred on those species;
7. to determine some of the factors influencing their

abundance and distribution and the efficacy of controls used against them;

8. to recommend where feasible potential techniques and requirements for improved control of the species; and

9. to identify areas relating to the above that require further research so that others may continue to refine this work.

There are numerous records of Tortricidae feeding on these berry crops in Canada (Tables 2 to 5). Some are simply records of occurrence while others indicate damage, presumably economic. Most fail to say how much damage, or even what parts of the plant were damaged.

To assess the importance of leafrollers to production of each of the crops, it is essential to know which species occur on which crops, and at what characteristic densities. The numerically and relatively most abundant species can thus be predicted to be the most important ones. The parts of the plant which are damaged and the timing of feeding are also important in this regard. If a species feeds only on leaves it is less important than a species of the same abundance which feeds only on flower or fruit. Likewise, a species which feeds early in the season and damages many immature fruits is more important than one which feeds late and damages only a few mature fruits.

Other features of the biology of leafrollers may be important in determining characteristic levels of abundance of each species. One such feature investigated is the aerial dispersal of first-instar larvae on silk threads. This is characteristic of those Tortricidae which lay eggs in masses rather than singly (Powell 1964; Chapman and Lienk 1971) and has been implicated as influencing levels of abundance of some species (Paradais and LeRoux 1965; Mayer 1973). This drift could be important in several ways, notably: larvae could drift from host plants to plants on which leafrollers had been controlled; and larvae could suffer mortality at this time by failing to land on a suitable host. Detection of when this drift occurs would indicate timing of hatch, which could be of value in determining the best time to apply controls. Host plants other than the crops could be important by harbouring populations which could re-infest the crop through airborne dispersing larvae.

Intraspecific competition between larvae for feeding sites could be important in determining levels of abundance. The result of this competition could be, for example, mortality of some larvae.

The times of day when larvae feed could be important in determining control strategies for leafrollers. Maximum exposure to poisons could be ensured by timing sprays to coincide with periods of greatest feeding activity, as this would be when larvae would consume the greatest amount of insecticides with leaf tissue.

Insects parasitic on the eggs, larvae and pupae of leafrollers are important as a potential source of population regulation. Thus, it is important to know what species are parasitic on leafrollers, and if there are features of their biologies which could be manipulated to enhance their effects. Of particular importance in this regard are alternate hosts, particularly those of multivoltine parasite species.

As was stated above, there are many subjective records of damage to berry crops by leafrollers, but few of them detail amounts of damage or densities of larvae causing damage. Before an insect or group of insects can be considered a pest of a crop, it should be demonstrated that it causes a loss of yield or other costs sufficient to warrant control. Cranberry, raspberry and strawberry are routinely sprayed for pest insects in the Lower Fraser Valley, B.C., and it is likely that leafrollers other than the target species are also controlled by these sprays. If leafroller populations on berry crops are reduced by sprays not directed at them, it is probable that they are causing few losses, if any. In contrast, blueberry fields in the Lower Fraser Valley are rarely sprayed for insects so that, of the 4 berry crops, blueberry is most likely to have leafroller populations high enough to cause economic damage. Therefore, the effects of leafrollers on yield and productivity of blueberry were determined.

The ultimate objective is to limit the damage caused by leafrollers to berry crops to below economic levels through pest management. The first stage is to measure the amount of damage to determine if the cost of control or management is clearly less than the value of losses caused by leafrollers.

Table 1 Value at farmgate (in 1978) and area of land (in 1971) of berry, vegetable and tree fruit culture in the Lower Fraser Valley, B.C.

CROP	AREA (ha)*	VALUE ($)**
blueberry	NA***	5,262,903
cranberry	NA	3,335,305
raspberry	NA	12,304,640
strawberry	NA	4,470,765
total berry crops	2754	25,373,613
total vegetable crops	5604	17,319,554
total tree fruits	149	115,000
total all crops	8507	42,808,167

* from Anon 1974.

** from Anon 1979 a,b,c.

***not available.

Table 2 Species of Tortricidae previously reported feeding on blueberry in Canada. (CIPR=Canadian Insect Pest Review volume: page: year; CAIPR=Canadian Agricultural Insect Pest Review volume: page: year).

SPECIES	LOCATION	REFERENCES
Amorbia humerosana (Clem.)	N.B.	Wood 1951
Archips argyrospilus (Wlk.)	N.S.	*Wood 1979
Archips cerasivoranus (Fitch)	N.S.	CAIPR 56: 31: 1978
Argyrotaenia citrana (Fern.)	B.C.	Cram & Neilson 1978
Argyrotaenia mariana (Fern.)	N.S.	Wood 1951 Gilliatt 1929
Badebecia urticana (Hbn.)	B.C.	*CAIPR 47: 27: 1969
Cheimophila salicella (Hbn.)	B.C.	*CIPR 40: 172: 1962 *CIPR 41: 164: 1963 *CIPR 42: 151: 1964 *CIPR 43: 173: 1965
Clepsis persicana Fitch	N.S.	Wood 1951
Croesia curvalana (Kft.)	N.S. N.B.	*CAIPR 53: 13: 1975 *CAIPR 54: 15: 1976 *CAIPR 55: 7: 1977 *CAIPR 43: 173: 1965
Grapholitha packardi (Zell.)	N.S.	*CIPR 48: 29: 1970
Sparganothis sulfureana (Clem.)	N.S.	*CIPR 37: 284: 1959

* records economic damage.

Table 3 Species of Tortricidae previously reported feeding cranberry in Canada. (CIPR = Canadian Insect Pest Review volume: page: year; CAIPR = Canadian Agricultural Insect Pest Review volume: page: year).

SPECIES	LOCATION	REFERENCES
Acleris minuta (Rob.)	N.B. N.S.	Razowski 1966 *Maxwell & Pickett 1957 *Franklin 1948 Wood 1975
Rhopobota naevana (Hbn.)	B.C. N.B. N.S.	*CIPR 34: 320: 1956 *CIPR 38: 298: 1960 *CIPR 40: 172: 1962 *Wood 1975 Franklin 1948

* records economic damage.

Table 4 Species of Tortricidae previously reported feeding on raspberry in Canada. (CIPR=Canadian Insect Pest Review volume: page: year; CAIPR= Canadian Agricultural Insect Pest Review volume: page: year).

SPECIES	LOCATION	REFERENCES
Archips rosanus (L.)	B.C.	CIPR 2: 46: 1924
Argyrotaenia citrana (Fern.)	West N.A. esp. Van. Island	*Powell 1964 CIPR 31: 214: 1954 CIPR 33: 139: 1956 CIPR 41: 166: 1963
Argyrotaenia mariana (Fern.)	East N.A. N.S.	Gilliatt 1929
Choristoneura rosaceana (Harr.)	Can. U.S.	*CIPR 17: 52: 1939 CAIPR 53: 17: 1975 Tonks 1953 Schuh & Mote 1948
Exartema permundanum Clem.	Ont.	CIPR 4: 6: 1926
Sparganothis sulfereana (Clem.)	N.S. Ont.	CIPR 17: 52: 1939
Spilonota ocellana (D. & S.)	Ont.	Lockhead 1903

* records economic damage.

Table 5 Species of Tortricidae previously reported feeding on strawberry in Canada. (CIPR = Canadian Insect Pest Review volume: page: year; CAIPR = Canadian Agricultural Insect Pest Review volume: page: year).

SPECIES	LOCATION	REFERENCES
Acleris comariana (Zell.)	B.C.	*CAIPR 50: 3: 1972
		*CAIPR 51: 51: 1973
Ancylis comptana fragariae (W. & R.)	Ont.	Neilson 1969
	B.C.	Anon 1975
	Que.	CIPR 18: 25: 1940
	Sask.	CIPR 26: 43: 1948
	N.B.	*CIPR 43: 175: 1965
	N.S.	
Aphelia pallorana (Rob.)	Ont.	CAIPR 47: 28: 1969
Choristoneura rosaceana (Harr.)	Que.	CIPR 27: 55: 1949
	Ont.	CIPR 26: 15: 1918
	B.C.	CAIPR 47: 28: 1969
		CAIPR 53: 14: 1975
		*CAIPR 55: 23: 1977
Clepsis persicana Fitch	Que.	CIPR 8: 9: 1930
	Man.	Brittain 1933
Cnephasia interjectana (Haw.)	Nfld.	*CIPR 35: 319: 1953
	N.S.	*CIPR 36: 120: 1959
	N.B.	*CIPR 39: 380: 1961
		*CIPR 44: 16: 1966
Cnephasia longana (Haw.)	B.C.	*Cram & Tonks 1959
		*CIPR 36: 141: 1958
		*CIPR 44: 16: 1966

Table 5 continued

SPECIES	LOCATION	REFERENCES
Exartema olivaceanum (Fern.)	B.C.	Neilson 1969
	Ont.	CAIPR 53: 4: 1975
	Que.	*CAIPR 55: 23: 1977
		CAIPR 57: 39: 1979
		CIPR 31: 352: 1953
Exartema permundanum Clem.	B.C.	*CIPR 19: 83: 1941
Olethreutes trinitana (McD.)	Que.	CAIPR 50: 29: 1972
		Rivard et al. 1973
Ptycholoma peritana (Clem.)	Que.	Rivard et al. 1973
	Ont.	Pardais 1975
		CAIPR 47: 29: 1969
		CAIPR 49: 32: 1971
Sparganothis pettitana (Rob.)	Que.	Rivard et al. 1973
	Ont.	
Sparganothis reticulana (Clem.)	Que.	CAIPR 47: 28: 1969
	Ont.	

* records economic damage.

CHAPTER II. LEAFROLLERS ON BERRY CROPS IN THE LOWER FRASER VALLEY, B.C.

Leafrollers (Lepidoptera: Tortricidae) and other lepidopterous larvae with similar habits have been noted on berry crops in the Lower Fraser Valley, B.C. in the past. The British Columbia "Berry Production Guide" for 1981 (Anon 1981) gives control recommendations for "leafrollers" on blueberry and raspberry and specific recommendations for the omnivorous leaf-tier, *Cnephasia longana* (Haw.) on strawberry, and the black-headed fireworm, *Rhopobota naevana* (Hbn.) on cranberry, both Tortricidae. Species mentioned by Neilson (1969) as pests of berry crops in British Columbia are: *Choristoneura rosaceana* (Harr.), the oblique-banded leafroller, and *Argyrotaenia citrana* (Fern.), the orange tortrix, as occasional pests on raspberry; *Exartema olivaceanum* (Fern.) and *Ancylis comptana fragariae* (W. and R.), the strawberry leafroller, as pests on strawberry; *R. naevana* as a serious pest of cranberry; and *Cheimophila salicella* (Hbn.) (Oecophoridae) as a pest on blueberry.

Other than records of damage by leafrollers to berry crops, references in crop production guides, and occasional records of new introductions and studies of particular species, little information is available on the species or status of leafrollers feeding on berry crops in British Columbia. This chapter is an attempt to fill that gap.

It should be stated at the outset that the common name "leafroller" is interpreted here rather loosely to include all Tortricidae (Tortricinae and Olethreutinae) and this includes species known as "budmoths". Some leafrolling species which are not Tortricidae are included because of their status as potential or actual pests of their host crops, or because they were commonly collected in surveys.

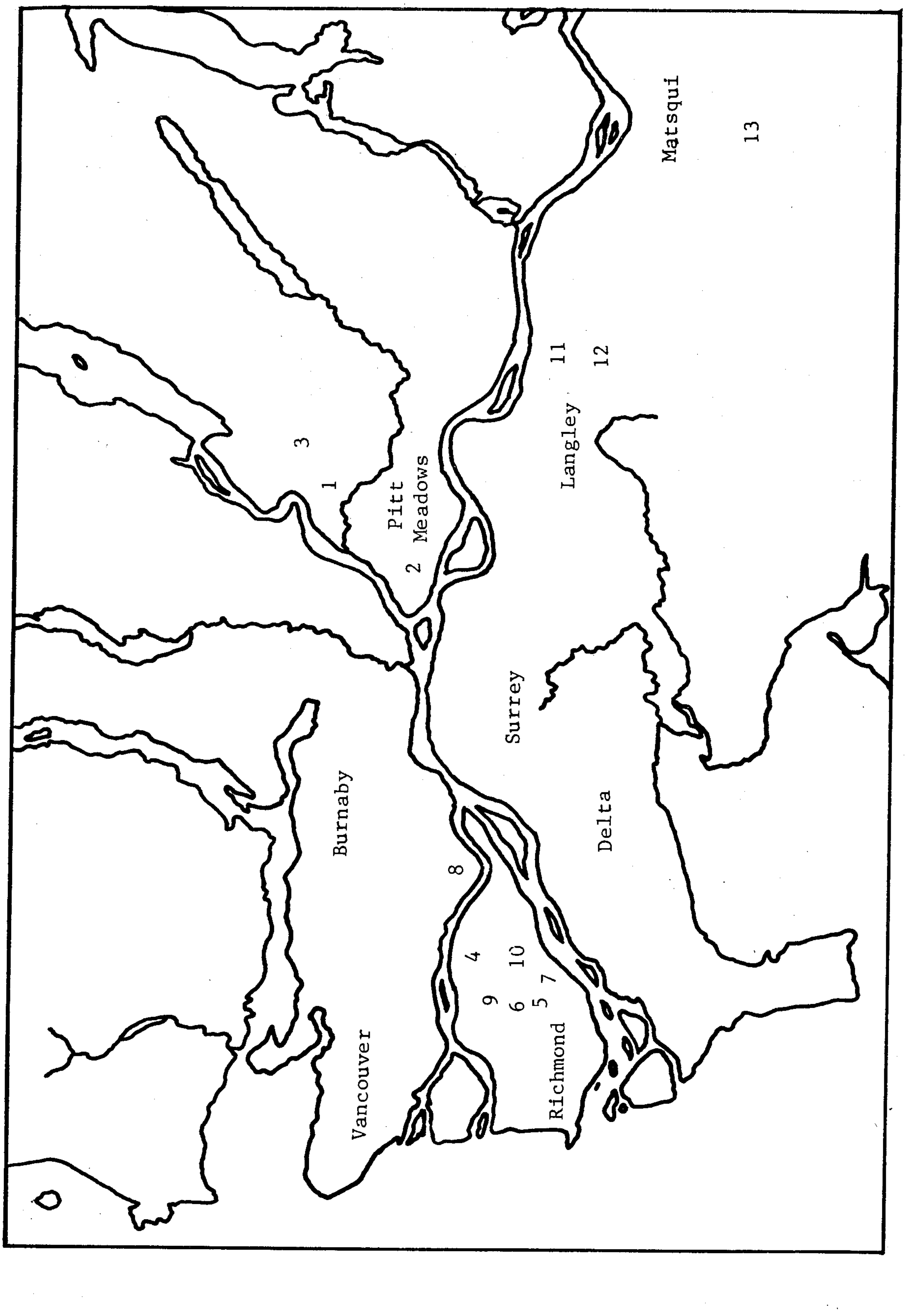
RESEARCH SITES AND REARING TECHNIQUES

Research sites utilized during 1979, 1980 and 1981 are described below. Their general locations are given in Fig. 1 and their exact locations and lot numbers are given in Appendix A. Where more than one crop was examined at a given site, the site number remains the same. All areas given are approximate.

Site 1: 3 ha of mixed blueberry varieties in Pitt Meadows. Field very well tended, with a heavy yearly pruning, very few weeds in field. No insecticides used, dormant oil sometimes applied against Lecanium scale. Fungicides used for mummy berry only.

Site 2: 10 ha of mixed blueberry varieties and 10 ha of cranberry in Pitt Meadows. Blueberry virtually untended, very little pruning or weed control, no insecticides used; fungicide applications erratic. Cranberry untended, badly overgrown with weeds, not irrigated, and not sprayed.

Fig. 1 Approximate locations of berry crop research sites in the Lower Fraser Valley, B.C.


Matsqui
13
11
12
Langley
3
1
Pitt
Meadows
2
Surrey
Burnaby
Delta
8
4
10
7
9
6
5
Vancouver
Richmond

Site 3: more than 40 ha of mixed blueberry varieties in Pitt Meadows. Field well tended, with heavy biannual pruning, very few weeds in field. Insecticides used occasionally, fungicides used for mummy berry and fruit rot.

Site 4: about 10 ha of mixed blueberry varieties and more than 200 ha of cranberry in Richmond. Blueberry field weeded but pruning infrequent by cutting plants to ground level. Insecticides used regularly against leafrollers and other species, fungicides used for mummy berry and fruit rot. Cranberry sprayed regularly with insecticides.

Site 5: about 1 ha of blueberry, mainly Bluecrop, in Richmond. Well pruned and weeded; no insecticides used, fungicides used for mummy berry and fruit rot.

Site 6: about 2 ha of mixed blueberry varieties, mainly Rancoccas and June, in Richmond. Field weeded but only lightly pruned; no insecticies used; fungicides for mummy berry only.

Site 7: about 10 ha of cranberry in Richmond. Field was in poor condition in 1980 but new owner has since improved it considerably. Insecticides used regularly, when target species in susceptible stage.

Site 8: about 100 ha, a former commercial cranberry bog, now owned by B.C. Hydro. Most of cranberry has died back and is distributed patchily through bog. Some blueberry varieties have naturalized in field. No pesticides used on site.

Site 9: about 4 ha of strawberry in Richmond. Somewhat weedy, no insecticides applied in 1980, plowed under in 1981.

Site 10: about 8 ha of strawberry in Richmond. Well weeded, sprayed regularly with insecticides and fungicides.

Site 11: about 15 ha of strawberry and 20 ha of raspberry in Langley. Both crops heavily sprayed with insecticides and fungicides.

Site 12: about 4 ha of strawberry and 0.5 ha of raspberry in Langley. Well tended; insecticides used.

Site 13: about 0.5 ha of raspberry in Aldergrove at Agriculture Canada substation. Well tended; no insecticides used.

All larvae collected in 1980 and 1981 were reared in 30 dram (45 mm x 70 mm) polystyrene snap-cap vials with a clean moist filter paper in the bottom. Leaves of the appropriate plant host were supplied as needed. Complete changes of vials and foliage were made infrequently because of the large numbers being reared. Consequently mortality was relatively high. Records were kept of the date of emergence of each adult.

Initial identifications of all species were made by the research scientists and staff at the Biosystematics Research Institute, Ottawa, Ontario. Subsequently, identifications were routinely made as adults emerged, using previously identified specimens for reference. Supplementary reference works used to aid the identification of larvae and adults were: Balazs and Bodor (1969); Bradley, Tremewan and Smith (1973); Chapman and Lienk (1971); Cram and Neilson (1978); Evans (1970); Freeman (1958); Furniss and Carolin (1977); MacKay (1959); MacKay (1962); Powell (1964); and Raine (1966). The leafroller species dicussed in this work are listed with common name and family, in Appendix B.

SECTION A. LEAFROLLERS ON BLUEBERRY

MATERIALS AND METHODS

Survey techniques.

Populations of leafrollers on blueberry were surveyed by collecting all larvae, pupae and parasites on each of 10 blueberry plants from within 10 row by 10 plant plots inside commercial blueberry fields. At each visit 1 plant was selected randomly from each row and was not re-sampled. Sampling visits were made at approximately 3 week intervals from April 28 to August 19, 1980.

Survey plots (see site descriptions) were:

Site 1 in cv. Bluecrop, planted about 1965, widely spaced for hand picking; no insecticides; heavily pruned, well weeded, and fertilized.

Site 3, plot A in cv. June, planted about 1968, closely spaced

for machine picking; sprayed in early May with insecticide for leafrollers; pruned, weeded and fertilized.
Site 3, plot B in cv. June, planted 1977, spaced as 3A, no insecticides used; pruned, weeded and fertilized.
Site 3, plot C in cv. Stanley, planted 1973, spaced as 3A, no insecticides used; pruned, weeded and fertilized.
Site 3, plot D in cv. Rancoccas, planted about 1973, spaced as 3A; no insecticides used; pruned, weeded and fertilized.
Site 4 in cv. Bluecrop, planted before 1960, spaced for hand picking; no insecticides used; pruned, weeded and fertilized.
Site 5 in cv. Bluecrop, planted before 1960, spaced for hand picking; insecticides used in early May 1980; pruned, weeded and fertilized.

Calculation of rates of parasitism.

Rates of parasitism were calculated by dividing the total number of specimens of parasites reared by the total number of larvae of that host species collected. This calculation presumes that parasitized larvae suffer no mortality in rearing. Consequently, calculated parasitism figures are probably somewhat lower than the actual parasitism in the field. This figure was preferable to that calculated by dividing the number of parasite specimens reared by the total emergence (parasites and hosts) of that species, as this assumes parasitized and unparasitized larvae suffer equal mortality in rearing and would probably overestimate the true rate of parasitism.

Aerial drift of first-instar larvae.

Drifting first-instar larvae were trapped by use of 30 x 30 cm cards mounted on 2 m high poles (Fig. 2). Cards were coated with Stickem Special® (Michel and Pelton Ltd., Emeryville, Calif.) The cards were changed every week, and the larvae on them counted. In 1980, 20 traps were placed at site 1 (Fig. 3) to determine if drift of first-instar tortricid larvae occurred in blueberry fields and if the orientation and location of traps influenced trap catches. Traps were in operation from April 7 to September 1, 1980.

In 1981, 5 traps at each of sites 1, 2 and 3, and 3 traps at site 6 were set out to compare timing of drift in the various locations. Traps were in operation from March 16 to August 31, 1981.

RESULTS AND DISCUSSION

1. Abundance of leafrollers in blueberry fields.

Numbers of leafroller larvae per plant varied considerably between the 7 plots surveyed (Table 6). At most sites, leafroller populations peaked in May, and declined after that time, except for one apparent increase at each of sites 3B and 5 on June 30. Larvae were too rare at sites 3A and 4 for any trends to be apparent.

Fig. 2 Trap used to catch air-borne drifting first-instar leafroller larvae.

Fig. 3 Approximate locations of 20 traps which were used to monitor aerial drifting first-instar leafroller larvae in a blueberry field at site 1 in 1980. The various parts of the field are labelled. Open squares denote north-south facing traps and closed squares denote east-west facing traps.

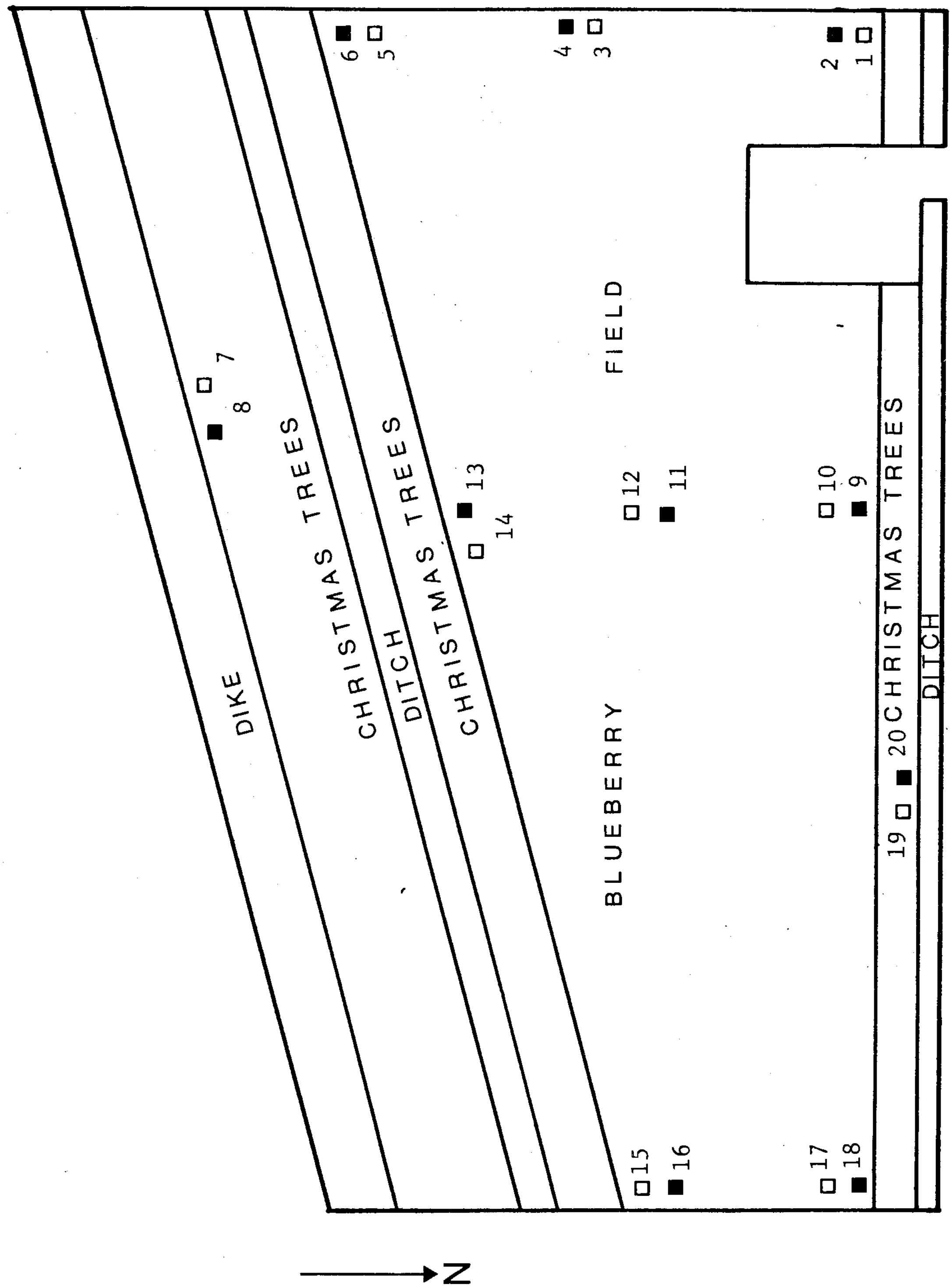

DIKE
CHRISTMAS TREES
DITCH
CHRISTMAS TREES
FIELD
BLUEBERRY
CHRISTMAS TREES
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Table 6 Populations of leafroller larvae on blueberry at 7 sites in 1980. Mean larvae/plant (standard deviation) n=10.

	SITE						
DATE	1	3A	3B	3C	3D	4	5
April 28	13.1 (4.18)	0.3 (0.48)	1.6 (1.58)	1.3 (1.42)	0.9 (0.74)	0	1.7 (2.00)
May 19	14.7 (4.76)	0.2 (0.42)	4.2 (3.49)	2.9 (1.60)	2.5 (1.84)	0	3.3 (1.77)
June 10	11.5 (4.30)	0.4 (1.26)	3.5 (2.55)	2.9 (1.29)	1.8 (2.10)	0.3	1.2 (1.14)
June 30	7.7 (4.14)	0	4.1 (3.21)	2.0 (1.83)	---*	0.1	3.0 (2.11)
July 21	4.1 (2.51)	0.9 (1.20)	0.9 (1.10)	1.1 (1.20)	2.5 (2.17)	0	2.5 (2.51)
August 19	3.8 (3.33)	0	2.8 (2.35)	1.6 (1.78)	--- *	0	0.9 (0.99)

* No sample made.

Insecticides were applied against leafrollers at site 3A in early April, and at site 4 in early May. Both sites had the lowest population levels observed in 1980. At site 4 no leafroller larvae were seen in the field on the sample date just before the spray was applied which suggests that the spray was unnecessary. Insecticides were not used at sites 3B, 3C, 3D and 5 in 1980, but were used there one or two years prevously. These sites had intermediate population levels in 1980. No insecticides had been used at site 1 for at least 5 years. This site had a consistently high leafroller population (Table 6).

From the numbers of larvae at site 3A and 4 it appears that spring insecticide applications keep leafroller populations at low levels. Moreover, from the numbers at sites 3B, C and D and site 5, sprays applied for leafrollers appear to keep populations low for 1 or more years.

On April 29, 1980, site 2 was surveyed in the same fashion as the other sites. The larval population averaged 23.3 per plant (standard deviation=7.1). No further sampling was done at this site because populations were too high to be sampled in the time available for this purpose, though collecting was continued throughout the season. Larval populations were always visibly higher there than at any of the other sites sampled in 1980. Site 2 had not been sprayed for several years and had not been weeded or pruned. Despite the high larval populations at site 1, it was not visibly evident that leafrollers were damaging the crop. In comparison site 2 had much higher early spring populations, and by May 1980 it was apparent that leafrollers had caused a significant amount of damage by feeding on the flowers and the developing green fruit. A similar situation was observed at site 6, which was not sampled in 1980 but was visited on a regular basis. There, leafrolling larvae were highly visible and were evidently doing some damage to the flower clusters.

The farmers at sites 2 and 6 may have encouraged leafrollers by their pruning practices. No pruning was done at site 2, and bushes at site 6 were pruned so that old wood was retained, contrary to the general pruning practice.

In all, 14 species of Tortricidae, 1 of Geometridae, and 1 of Oecophoridae were collected from leafrolls and webbed blossom and fruit clusters on blueberry (Table 7). Six of the Tortricid species and *Cheimophila salicella* (Hbn.) are not native to North America. Seven of the remainder and *Operophtera bruceata* (Hulst) are native to North America, *Clepsis* sp., represented by a single specimen, is of unknown origin.

Discrepancies between Table 6 and 8 for any given date and site are due to rearing mortality. Larvae which could not be identified and from which no adult emerged could not be counted in Table 8. The discrepancy decreases later in the

Table 7 Species of leafrolling Lepidoptera reared from blueberry in 1979, 1980 and 1981. Grouping within family is by approximate order of importance.

SPECIES	FAMILY	ORIGIN	OCCURRENCE *
Choristoneura rosaceana (Harr.)	Tortricidae	Native	General
Spilonota ocellana (D. & S.)	Tortricidae	Introduced	General
Archips rosanus (L.)	Tortricidae	Introduced	General
Croesia curvalana (Kft.)	Tortricidae	Native	Common
Pandemis cerasana (Hbn.)	Tortricidae	Introduced	Common
Badebecia urticana (Hbn.)	Tortricidae	Native	Common
Pandemis heparana (D. & S.)	Tortricidae	Introduced	Occasional
Aphelia alleniana (Fern.)	Tortricidae	Native	Occasional
Pandemis limitata (Rob.)	Tortricidae	Native	Occasional
Archips argyrospilus (Wlk.)	Tortricidae	Native	Occasional
Acleris variegana (D. & S.)	Tortricidae	Introduced	Occasional
Archips podana (Scopoli)	Tortricidae	Introduced	Occasional
Clepsis forbesi Obraztsov	Tortricidae	Native	Rare
Clepsis sp.	Tortricidae	unknown	Rare
Operophtera bruceata (Hulst)	Geometridae	Native	Common
Cheimophila salicella (Hbn.)	Oecophoridae	Introduced	General

* General=20% or more of specimens reared at most sites;
Common= occurred at all sites, but at rates less than 20%;
Occasional= rearings of 1 to 2 specimens at some sites;
Rare= rearings of single specimens.

Table 8. Populations of the 4 dominant species of leafroller on Blueberry at 7 locations in Pitt Meadows and Richmond, B.C. A=Average No. of each species/plant, n=10, B=percent parasitism, based on total specimens collected.*

DATE	SPECIES	Site 1		Site 3A		Site 3B		Site 3C		Site 3D		Site 4		Site 5	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B
April 28, 1980	*C. rosaceana*	2.3	8.7	0.1	-	0.1	-	0.1	-	0.4	-	-	-	0.5	20.0
	S. ocellana	4.4	13.6	0.2	-	0.7	42.9	0.3	33.3	0.2	-	-	-	0.2	-
	A. rosanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	other	0.1	-	-	-	0.3	-	0.2	-	-	-	-	-	0.2	-
	C. salicella	-	-	-	-	-	-	-	-	-	-	-	-	-	-
May 19, 1980	*C. rosaceana*	3.2	12.5	0.2	50	2.4	12.5	0.8	25	1.5	20.0	-	-	1.2	-
	S. ocellana	5.2	19.2	-	-	0.2	-	0.4	25	0.2	100	-	-	0.2	-
	A. rosanus	0.9	-	-	-	0.1	-	0.3	-	-	-	-	-	-	-
	other	0.6	-	-	-	0.5	-	0.1	-	-	-	-	-	1.4	-
	C. salicella	-	-	-	-	-	-	-	-	-	-	-	-	-	-
June, 10 1980	*C. rosaceana*	1.5	33.3	0.2	-	1.7	29.4	1.9	21.1	1.1	18.2	-	-	0.3	33.3
	S. ocellana	2.1	28.6	-	-	0.3	100	-	-	0.1	-	-	-	0.1	-
	A. rosanus	1.6	-	0.1	-	0.5	-	0.4	-	0.2	-	-	-	0.3	33.3
	other	0.4	-	-	-	0.4	-	0.1	-	0.1	-	0.1	-	0.3	-
	C. salicella	3.0	-	-	-	0.3	-	0.1	100	-	-	-	-	-	-
June 30, 1980	*C. rosaceana*	0.8	37.5	-	-	1.5	33.3	0.4	50	-	-	-	-	0.1	-
	S. ocellana	0.6	33.3	-	-	0.3	66.7	-	-	-	-	-	-	0.1	-
	A. rosanus	0.5	20.0	-	-	0.4	-	0.2	-	-	-	-	-	0.2	50.0
	other	0.2	-	-	-	-	-	-	-	-	-	0.1	-	0.6	-
	C. salicella	5.0	-	-	-	2.3	-	1.3	-	-	-	-	-	1.9	-
July 21, 1980	*C. salicella*	3.5	-	0.7	-	0.9	-	0.7	-	2.1	-	-	-	2.0	-
	other	-	-	-	-	-	-	-	-	-	-	0.2	-	0.2	-
August 19, 1980	*C. salicella*	2.4	-	-	-	2.3	-	1.6	6.3	-	-	-	-	0.9	-
	other	0.4	-	-	-	0.8	-	-	-	-	-	-	-	-	-

* Dash indicates that no specimens were reared.

season because the more mature larvae were easier to identify and had a shorter time in laboratory rearing before pupation.

2. Biology of major species.

i. *Choristoneura rosaceana* (Harr.).

Choristoneura rosaceana, the oblique-banded leafroller, was abundant from late April to mid-May in 1980 (Table 8). Larvae were found frequently in leafrolls, and also in blossom clusters and developing fruit clusters, webbing them together and feeding from the interior. Pupation was in June, and adults were seen flying in July and August. Larvae collected on August 19, from egg masses laid by these adults, fed for 2 to 3 weeks, reached the second or third instar, and then apparently entered diapause. First and second-instar larvae were frequently found feeding in abandoned rolls of *C. salicella* in August. No larvae survived the winter in the laboratory. *C. rosaceana* is bivoltine in the southern parts of its range and univoltine in the northern part (Chapman and Lienk 1971). It is univoltine on blueberry in the Lower Fraser Valley, B.C.

C. rosaceana is native to southern Canada and the United States (Prentice *et al*. 1965). The primary hosts, i.e. hosts on which egg masses are laid, are restricted to species of Rosaceae, *Populus*, *Betula*, *Salix*, *Ilex* and *Aesculus* (Chapman and Lienk 1971; Schuh and Mote 1948). To this list can be added blueberry, as numerous egg masses were found on the upper surface of leaves of this plant.

No records were found of C. rosaceana as a pest of blueberry, although it has been recorded as a pest of apple (Chapman and Lienk 1971), raspberry (Schuh and Mote 1948), and dewberry (Knowlton and Allen 1937) as well as young Scots pine (Martin 1958).

Parasitism of C. rosaceana ranged from 18 to 33% (Table 8) in collections of more than 10 larvae on June 10. These figures are probably more accurate than those from earlier dates as rearing mortality decreased dramatically when the larvae were mature.

Nine parasite species were reared from C. rosaceana (Table 9). Predominant was Apophua simplicipes (Cress.), which accounted for 49% of the parasites. This endoparasite probably overwinters as an egg or early larva, because adults emerged from C. rosaceana larvae collected on April 28 when the host was just out of overwintering. Parasite larvae emerged from final-instar host larvae to pupate in July. Adults emerged from mid-July to early-August, well synchronized with the occurence of early-instar C. rosaceana larvae. Emergent adult females readily parasitized second and third-instar C. rosaceana larvae in the laboratory, but would not accept older larvae.

Table 9 Parasites reared in 1980 from *Choristoneura rosaceana* on blueberry with their order, families and relative abundance (percent composition of 43 parasites reared from sample plots).

	% of total
Hymenoptera	
Ichneumonidae	
Apophua simplicipes (Cress.)	49
Diadegma sp.	2
**Itoplectis viduata* (Grav.)	5
**Ischnus inquisitorius atricep* (Cress.)	5
Braconidae	
Microgaster sp.	14
Meteorus sp.	2
Apanteles ater (Ratz)	9
Pteromalidae	
Habrocytus sp.	7
Diptera	
Tachinidae	
**Pseudoperichaeta erecta* (Coq.)	7

*emerged from pupae.

There are two interesting features of the biology of *A. simplicipes* which warrant further investigation; mate attraction and effect on host behavior. Females appear to emit a pheromone while still in the cocoon. On numerous occasions clusters of 10 to 20 males were observed surrounding a cocoon; when such cocoons were collected the emergent was always a female. Parasitized host larvae form a unique leafroll in which *C. rosaceana* pupae were never found. The roll is actually a large egg shaped "nest" of 4 or 5 blueberry leaves webbed together with the ends closed and substantial space inside. The final-instar parasite larva, after emerging from the host, spins a cocoon suspended in the centre of the open space, well away from the wall. Variations of these rolls were seen on birch, blackberry, willow and spirea.

A. simplicipes was reared also from *C. rosaceana* on raspberry and from a larva of *Pandemis* sp. which has a biology very similar to that of *C. rosaceana*. *A. simplicipes* was parasitized by *Mesochorus sylvarum* Curtis.

The second most common parasite of *C. rosaceana* larvae (Table 9) was a *Microgaster* sp. Final-instar parasite larvae emerged from and killed the penultimate instar host larvae, and spun a thick white cocoon about 3-4 mm long. The adult emerged 2 to 3 weeks later. Presumably it also is univoltine as specimens were reared from larvae collected on April 28.

Four other species of Hymenoptera parasitized *C. rosaceana* larvae (Table 9). *Itoplectis viduata* (Grav.), *Ischnus inquisitorius atricollaris* (Walsh.) and *Pseudoperichaeta erecta* (Coq.) were reared from pupae of *C. rosaceana*. They apparently parasitize later instar larvae, or pupae, as only host larvae collected late in their development or pupae produced these parasite species. All these species would therefore require alternate overwintering hosts, a fact that could be important in limiting their numbers.

ii. *Spilonota ocellana* (D. and S.)

Spilonota ocellana, the eye-spotted budmoth, was more abundant than *C. rosaceana* at site 1 but was not so common at other sites (Table 8). This is apparently the first record of its occurrence on blueberry in North America. The biology of *S. ocellana* on apple in New York (Chapman and Lienk 1971) is very similar to that observed on blueberry in British Columbia. Larvae were collected from late April to late June. They were found feeding almost exclusively on developing flower and fruit clusters. Larvae inhabited loose nests inside the clusters constructed of bracts, bud scales, petals and frass held together with silk. Pupation occurred in late June to early July. Eggs were laid singly and hatched in July and August and these larvae overwintered in early instars. Hibernaculae were not observed on blueberry bushes, but probably occur in branch crotches, and under loose bark and bud scales (Chapman and Lienk 1971). On apple *S. ocellana* feed on either leaves or flower and fruit (Chapman and Lienk 1971), whereas on blueberry the larvae almost exclusively associated with the flower and fruit clusters.

Spilonota ocellana was first reported from North America in 1841 from Massachusetts (Harris 1841). It was very common in 1912 in Vancouver (Wilson 1912) and Victoria, B.C. (Brittain 1912) but rare in the Okanagan (Brittain 1912). It is now found throughout southern British Columbia, as well as in Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island (MacNay and Creelman 1958) and wherever deciduous trees are grown in the northern United States (Chapman and Lienk 1971; Baker 1972). It is a pest of fruit trees in British Columbia (Gerber *et al.* 1980) and throughout its range (LeRoux and Reimer 1959; Prentice *et al.* 1965; Baker 1972). Food plants include apple, its most consistent host (Chapman and Lienk 1971), other orchard trees, hawthorn, larch, laurel, oak (Baker 1972), and mountain ash (Prentice *et al.* 1965).

It is a European species (Porter 1924) common in apple growing districts and is also reported from Pakistan, China, Korea and Japan but not yet from the Southern Hemisphere (Chapman and Lienk 1971).

Parasitism of *S. ocellana* at site 1 was relatively high (Table 8). Calculated from the 150 *S. ocellana* larvae collected in 1980 and the 34 parasites reared from those larvae parasitism was about 23 %. The most common parasites of S. ocellana larvae were Meteorus sp., Agathis dimidiator (Nees) and Ascogaster sp. (Table 10), which together contributed 88% of the total parasitism. No parasites were reared from pupae of S. ocellana.

In Nova Scotia apple orchards, Stultz (1955) found Agathis dimidiator [=A. laticinctus (Cress.)] to parasitize more than 10% of larvae of S. ocellana in 75% of orchards observed and more than 50% in 30% of orchards. Also common were Meteorus trachynotus Vier. and Ascogaster quadrindentata Wesm. which could be the same as the Meteorus sp. and Ascogaster sp. (Table 10).

Agathis dimidiator is univoltine and overwinters as a larva in the host (Dondale 1954). It is the most important parasite of S. ocellana in the east (Dondale 1954; Stultz 1955) and reportedly is specific to that host (Mason 1978). Both Meteorus sp. and Ascogaster sp. spun cocoons in the host pupation chamber, evidently after emerging from the mature host larva. Both were reared from larvae collected on April 28, and thus are presumably univoltine. Ascogaster sp. was reared only from S. ocellana, while Meteorus sp. was also reared from C. rosaceana on blueberry. A. quadridentata parasitizes host eggs and overwinters in the host, emerging from the final-instar larva (Rosenburg 1934).

Table 10 Parasites reared in 1980 from *Spilonota ocellana* on blueberry with their order, families and relative abundance (percent composition of 34 parasites reared from sample plots).

	% of total
Hymenoptera	
Braconidae	
Meteorus sp.	47
Agathis dimidiator (Nees)	24
Ascogaster sp.	17
Apanteles sp.	3
Microgaster sp.	3
Ichneumonidae	
Diadegma sp.	3
Scambus transgressus (Holm.)	3

iii. *Archips rosanus* (L.)

Archips rosanus, the European leafroller was prevalent on blueberry but less so than *C. rosaceana* at most sites (Table 8). This is the first record of its occurrence on blueberry in British Columbia.

Larvae were collected from May 19 to late June, mostly from leafrolls but also from fruit clusters. Pupae were found on blueberry in late June and July, and adults were observed in July. Egg masses were observed on old wood of blueberry bushes about 60 cm above ground at site 2. *A. rosanus* overwinters in the egg stage (Chapman and Lienk 1971). Hatch apparently occurred between April 28 and May 19, because larvae were collected on the latter date but not on the former.

A. rosanus was present in eastern United States by 1890 (Comstock and Slingerland 1890) and first found in Canada in 1919 simultaneously at Victoria, B.C. (Blackmore 1921) and in Nova Scotia (Gibson 1924). By 1923 *A. rosanus* was found in Vancouver (Treherne 1923). It is common on apple in the Lower Fraser Valley (Doganlar and Beirne 1978b) and in the Okanagan Valley is a pest on apple (Madsen *et al*. 1977; Mayer and Beirne 1974). It also occurs in Nova Scotia, New Brunswick, Ontario, Connecticut, New York, New Jersey, Washington and Oregon (Freeman 1958; Chapman and Lienk 1971). It has been reported as a pest of filberts in the United States (AliNiazee

1977) and of currant in Nova Scotia (Whitehead 1926), and has also been recorded from privet (Chapman and Lienk 1971; Mayer and Beirne 1974).

It occurs where deciduous trees and bush fruits are grown in Europe, the principal food plants being apple, pear, hawthorn, currant and privet (Chapman and Lienk 1971). It has been recorded as a pest of currant in the USSR (Markelova 1957), and of orchard fruit trees in the USSR (Minder 1959; Markelova 1963), Poland (Krakowlak 1974), and Sweden, Finland, Italy, Spain and England (Chapman and Lienk 1971). The biology of A. rosanus on apple in New York (Chapman and Lienk 1971) is similar to that on blueberry in British Columbia. The duration of the larval stage on blueberry in British Columbia is longer (from early May to early July) than in New York (early May to mid-June), probably because of warmer spring temperatures in New York.

Very few parasites were reared from A. rosanus in 1980. All records are based on single emergences from small collections. Apanteles ater (Ratz.)(Hymenoptera: Braconidae) and an undescribed species of Glypta (Hymenoptera: Ichneumonidae) were reared from larvae. Mayer and Beirne (1974) found Microgaster epagoges Gah., Apanteles cacoeciae Riley (Hymenoptera: Braconidae), Pseudoperichaeta erecta (Coq.) and Nemorilla pyste (Wlk.) (Diptera: Tachinidae) to be common parasites of A. rosanus on apple in the Okanagan.

Baggiolini (1956) found Trichogramma cacoeciae March to be an important parasite of A. rosanus egg masses on apple in Switzerland.

iv. Cheimophila salicella (Hbn.)

Cheimophila salicella was the most abundant species late in the season. At some sites it was as common as, or more common than C. rosaceana had been earlier in the season (Table 8). Larvae were collected first on June 10, although they were noted previously. They fed predominantly in a leaf-roll, characteristically severing a leaf at the petiole, and webbing it to a live leaf on which it fed. Early-instar larvae also fed on the blossom end of developing blueberries causing some minor damage to the berries. Larvae pupated in late August and early-September, and overwintered in this stage. Adults emerged and laid eggs in March. These observations corroborate Raine's (1966) description of the biology of C. salicella on blueberry.

C. salicella was first found in North America on Lulu Island, B.C., in 1955 (Raine 1966). It became a pest of blueberry (Raine 1966) and has not been recorded elsewhere in North America (Hodges 1974).

It is a Palearctic species (Meyrick 1927) and has been recorded as a pest of rose in Holland (Reichert 1932).

Only 1 specimen of *Apanteles* sp. and 1 of *Glypta* sp. were reared from larvae at site 3C (Table 8). No other species of parasites were reared from *C. salicella*. Raine (1966) reared *Macrocentrus iridescens* Fr. (Hymenoptera: Braconidae) from larvae, and *Itoplectis quadricingulata* (Prov.) (Hymenoptera: Ichneumonidae) and *Compsilura concinnata* (Mg.) (Diptera: Tachinidae) from pupae.

3. Biology of Common species.

Of the common species, only *O. bruceata* and *C. curvalana* were observed to be abundant at sites other than those sampled in 1980. *P. cerasana* and *B. urticana* were present at all sites at relatively constant but low numbers and were borderline between common and occasional species.

i. *Operophtera bruceata* (Hulst)

Operophtera bruceata, the Bruce spanworm, was abundant at sites 2 and 6 in April and May, 1980 and 1981. Larvae were found most frequently feeding in flower buds and expanding flower clusters and less frequently in leaf rolls. At sites 2 and 6 in 1981, eggs hatched in early to mid-March; a few larvae were found feeding in flower buds in mid-March. Larvae collected in the spring of 1980 pupated by early May, and adults emerged in November. Overwintering eggs were laid at that time.

Operophtera bruceata occurs from Newfoundland to the coast of British Columbia (Prentice 1963 et al.; Furniss and Carolin 1977). In Alberta the preferred hosts are trembling aspen and willow and larvae also feed on birch, maple, alder, apple and various deciduous shrubs (Prentice et al. 1963; Brown 1962). The life history of O. bruceata on aspen in Alberta (Brown 1962) varies little from that on blueberry in British Columbia. The most important feature of the biology in relation to damage to blueberry, is the early appearance of the larvae.

Parasites reared from O. bruceata were Triclistus crassus (Town. and Tow.) (Hymenoptera: Ichneumonidae) and Cyzenis pullula (Tnsd.) (Diptera; Tachinidae). Gillespie and Finlayson (1981) reared these species plus 7 others from Operophtera spp. from Victoria, B.C. T. crassus emerged from host pupae in April of the year following collection and C. pullula emerged in the spring of the year following collection from puparia formed within the host pupa in the fall (Gillespie and Finlayson 1981).

ii. Croesia curvalana (Kft.)

Croesia curvalana larvae were common at site 6 in May, 1980 and 1981 and at site 2 in May, 1981, and fed in both flower clusters and leaf rolls. Pupae were found in June and adults in late June and July. Captured females laid eggs singly on the lids of small containers in which they were held. None of these hatched, so it is presumed the species overwinters in the egg stage.

The species has been recorded from Nova Scotia, New Brunswick, Quebec, Ontario, Manitoba, and British Columbia in Canada and New Hampshire in the United States (MacKay 1962). The host is blueberry (MacKay 1962). No references were found to the biology of this species.

Croesia albicomana (Clem.), is univoltine and overwinters in the egg stage (Powell 1964) similar to the apparent life history of *C. curvalana*.

No parasites were reared from *C. curvalana* .

iii. *Pandemis cerasana* (Hbn.)

Larvae of *P. cerasana* were collected on blueberry at most sites in May and June, 1980, most often in leafrolls and sometimes in flower and fruit clusters. Adults were seen in June and early July and laid egg masses on the upper surface of blueberry leaves. Egg masses hatched in 5 to 10 days. In August overwintering larvae were found feeding in leafrolls abandoned by *C. salicella*. Evans (1970) found second instar larvae of *P. cerasana* in hibernaculae beneath bud scales and in twig crevices. The biology of *P. cerasana* on oak in Victoria (Evans 1970) parallels that on blueberry.

First found in North America at Saanich, B.C. in 1964

(Evans 1966), *P. cerasana* spread to the Lower Fraser Valley where it was common on apple by 1977 (Doganlar and Beirne 1978b). In British Columbia it feeds on a variety of hosts including *Quercus*, *Malus*, *Alnus* and *Acer* spp. (Evans 1970) and was common on salmonberry *Rubus spectabilis* Pursh. on Burnaby Mountain, B.C. in 1979 and 1980.

It is a Palearctic species (Bradley *et al*. 1973) prominent in the European orchard pest control literature (e.g. Nordlander 1977; Kolev and Balevski 1978).

Only one parasite species, *A. simplicipes* (Cress.), was reared from *P. cerasana* in 1980. As noted previously, *A. simplicipes* is common on *C. rosaceana* and parasitizes its third instar larvae.

iv. *Badebecia urticana* (Hbn.)

Badebecia urticana larvae were collected in late April and May 1980, and were found most frequently feeding in leafrolls and less frequently in flower and fruit clusters. Pupae were found in June and adults were seen from early June to early August.

In the laboratory eggs were readily deposited singly on the upper surface of blueberry leaves, and hatched in 5 to 10 days. The species is apparently univoltine. In the laboratory larvae that were given mature leaves of blueberry fed to the second or third instar, and then rolled a section of the edge of a leaf into a tube about 5 mm long and 1 mm in diameter, lined the tube with silk and sealed it at both ends. Larvae remained alive but inactive in these rolls for 4 months, but eventually succumbed to desiccation. Structures of this type were not seen on blueberry in the fall, but they are probably the hibernacula of this species. If so, this would explain in part the low levels of B. urticana as the leaves of blueberry drop to the ground, where the larvae would be vulnerable to predation and drowning.

Chapman and Lienk (1971) collected larvae of this species on apple in New York. MacKay (1959) listed a number of hosts, including blueberry, but gave honeysuckle as the major host. It is common on Populus spp. in Manitoba and Saskatchewan (Prentice et al. 1965).

The most abundant parasite was Macrocentrus iridescens (Hymenoptera: Braconidae). In the spring of 1981, 28% of larvae collected from blueberry at site 2 were parasitized by this polyembryonic species. Macrocentrus iridescens is probably similar to other species of Macrocentrus, e.g. M. gifuensis Ashm., which are univoltine and overwinter in the overwintering host larvae. Meteorus sp. was also reared from B. urticana in 1980.

4. Biology of other species.

The remaining 8 species of Tortricidae collected from blueberry were either occasional or rare. Little or no information was obtained on their biologies.

Pandemis heparana (D. and S.) was first recorded in North America in the lower Fraser Valley of B.C. in 1978, but may have been introduced much earlier (Doganlar and Beirne 1979b). Larvae occur on apple, crabapple, pear, and species of *Prunus*, *Crataegus*, *Lonicera*, *Rubus*, *Vaccinium* and *Spiraea* (Doganlar and Beirne 1979b). It is found in Europe, the Middle-East, Siberia, Korea and Japan feeding on various trees and shrubs including species of *Malus*, *Prunus*, *Pyrus*, *Tilia*, *Salix*, *Lonicera*, *Betula*, *Ribes*, *Vaccinium* and *Myrica* (Bradley *et al*. 1973). In Europe it occasionally damages apple fruit (Adkin 1924). In Britain egg masses are laid in July, the early instar larva overwinters, larvae feed in May and June and adults are seen from late June to August (Bradley *et al*. 1973). Apparently it is univoltine.

Pandemis limitata (Rob.) is univoltine and has a similar life history to those of *P. heparana* and *P. cerasana* in the northern parts of its range, e.g. Nova Scotia (Gilliatt 1932), but is bivoltine in New York (Chapman and Lienk 1971) and in the Okanagan Valley, B.C. (F. Peters, Ecoyoos Consulting Services, R.R. #1, Osoyoos, B.C. V0H 1V0, pers. comm.).

whether or not it is bivoltine in south-western British Columbia has not yet been determined. A native species, _P. limitata_ occurs from Nova Scotia to coastal British Columbia in Canada (Prentice _et al_. 1965) and to the southern United States (Chapman and Lienk 1971). It feeds commonly on willow, trembling aspen, white birch, sugar maple and elm (Prentice _et al_. 1965), and apple (Chapman and Lienk 1971). In the Okanagan it is a minor pest on apple (F. Peters, Ecoyoos Consulting Services, pers. comm. _vide supra_).

Aphelia alleniana (Fern.) was not common on blueberry but more common on strawberry and its biology is discussed in relation to that crop.

The native _Archips argyrospilus_ (Wlk.), the fruit-tree leafroller, has essentially an identical life history to that of _A. rosanus_ but is more of a problem on apple (Chapman and Lienk 1971). It occurs throughout most of the United States and southern Canada (Prentice _et al_. 1965; Chapman and Lienk 1971).

Archips podana (Scop.) was first recorded in North America in 1937 from Vancouver B.C. and Sycamore, Ont. (Freeman 1958). It was reported feeding on _Amelanchier_ sp. at Vancouver (MacNay 1954). It is not a pest locally; Doganlar and Beirne (1978b) found it to be uncommon on apple. It is native to Europe, Asia Minor, Southern Russia, and eastern Siberia to Japan (Bradley _et al_. 1973). In North America it is found in British Columbia and Ontario (Freeman 1958). Food plants are a wide range of deciduous trees and shrubs and occasionally conifers (Bradley *et al.* 1973). In Europe it is common in fruit orchards and is a pest of apple (Bradley *et al.* 1973; Boness 1976; Krakowlak 1974). Its life history differs from that of *A. rosanus* and *A. argyrospilus*. It is univoltine, overwinters as a third instar larva, feeds and matures in the spring, flies as an adult in June and July, when egg masses are laid, and larvae from these egg masses feed in late summer before forming hibernaculae (Bradley *et al.* 1973).

Acleris variegana (D. and S.) was first recorded in North America from a single specimen collected at Victoria, B.C., in 1920 (Blackmore 1923). Forbes (1923) recorded specimens from New York. In western North America it now occurs in British Columbia, Washington, Oregon and California (Powell 1964). Foodplants in North America are species of *Rosa*, *Prunus*, *Malus*, *Crataegus*, and *Vaccinium* (Powell 1964). The distribution abroad is Europe, North-west Africa, Asia Minor, Central Asia and China (Razowski 1966). It is apparently a relatively common and polyphagous species in Europe (Bradley *et al.* 1973). In Britain *A. variegana* is univoltine, and larvae feed from May to September (Bradley *et al.* 1973). In California it is apparently bivoltine with distinct adult flights in June and July and again from September to November (Powell 1964). Powell (1964) noted that some of the eggs which were laid in September entered diapause, but also found adults in all winter months. This species probably overwinters as diapausing eggs, and adults found in the winter may represent a partial third generation developing under favourable conditions (Powell 1964). It is almost certainly univoltine in south-western British Columbia.

Most species of Clepsis are univoltine and overwinter as early instar larvae (Bradley et al. 1973; Powell 1964) so it may be presumed that C. forbesi and the unidentified Clepsis sp. do likewise. Powell (1964) noted that C. forbesi [=Clepsis persicana forbesi (Obraz.)] reached economic levels in conjunction with outbreaks of S. ocellana, utilizing larval shelters abandoned by that species.

5. Aerial drift of first-instar larvae.

There were 2 distinct periods of aerial first-instar larval drift in 1980 (Fig. 4). The first was in late April and early May, and was composed primarily of first-instar A. rosanus. Some first-instar C. salicella were caught on May 19. The second peak was in late July and early August, and was mainly first-instar C. rosaceana. Some first-instars of P. cerasana were also caught at this time.

The orientation of the trap faces in relation to ordinal compass points did not influence trap catch (Table 11). Traps outside but close to the field caught significantly fewer

Fig. 4 Total numbers of aerial drifting first-instar leafroller larvae caught per week on 20 traps in a blueberry field at site 1 from April 7 to September 1, 1980.

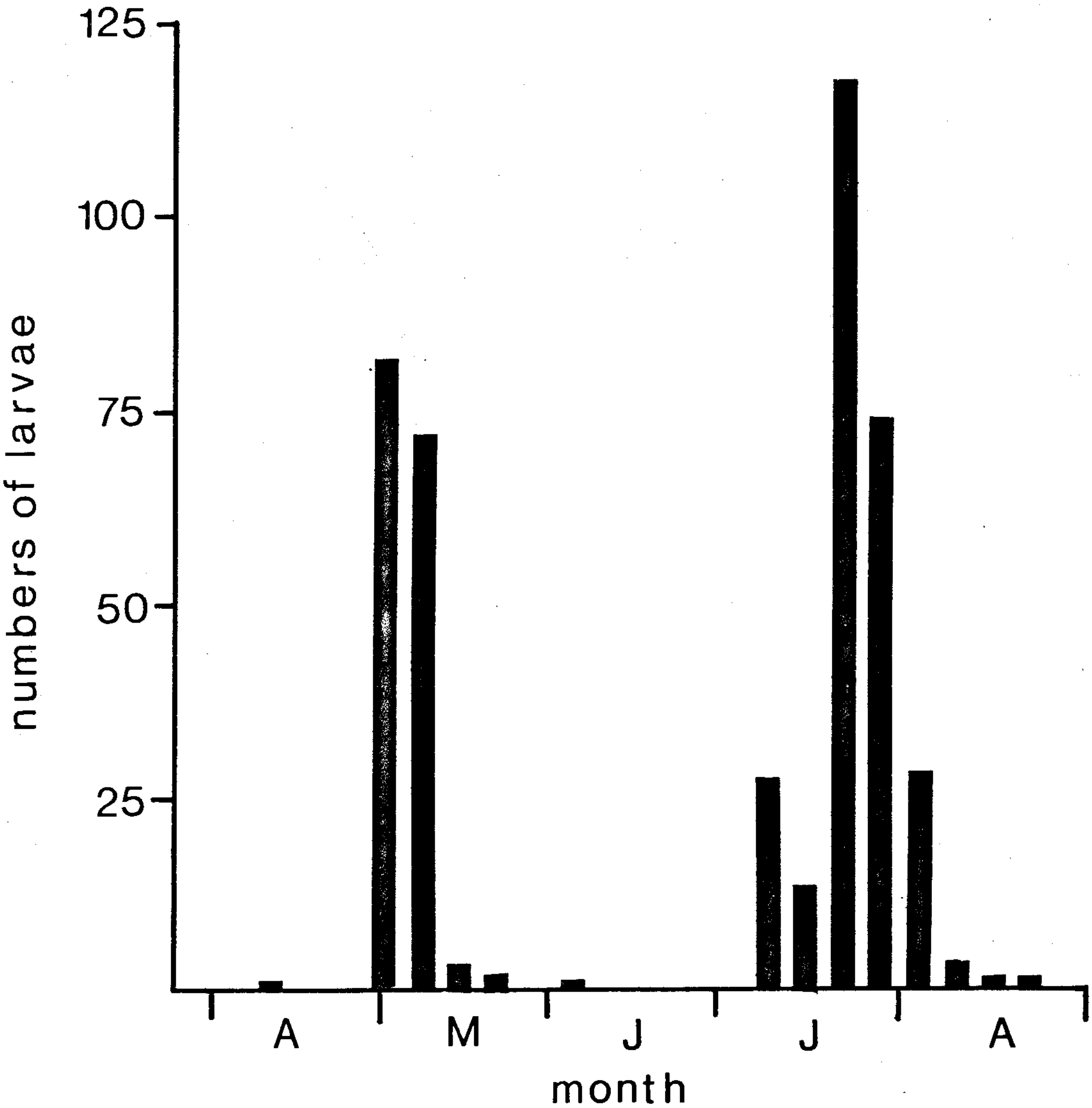

125
100
75
50
25
numbers of larvae
A
M
J
J
A
month

Table 11 Average number of first-instar larvae caught per week ± standard deviation (SD) on traps in blueberry at site 1 in 1980 during the 14 weeks when larvae were found on traps.

TRAP No.	MEAN No. LARVAE/WEEK	SD	TRAP ORIENTATION
1	2.1	3.43	N-S
2	1.9	3.19	E-W
3	1.7	2.84	N-S
4	2.1	3.17	E-W
5	1.5	4.05	N-S
6	0.9	1.41	E-W
*7	0.1	0.36	N-S
*8	0	0	E-W
9	1.5	2.21	N-S
10	2.4	3.78	E-W
11	3.1	4.69	N-S
12	3.6	5.50	E-W
13	2.0	2.96	N-S
14	2.6	3.84	E-W
15	1.5	2.14	E-W
16	1.1	2.02	N-S
17	1.0	1.52	E-W
18	1.1	1.79	N-S
*19	0.4	0.94	E-W
*20	0.4	0.85	N-S

* Traps outside but close to field.

larvae (t-test, $p<0.05$) than those inside the field, indicating that drifting larvae were mainly dispersing within the field rather than entering or leaving it.

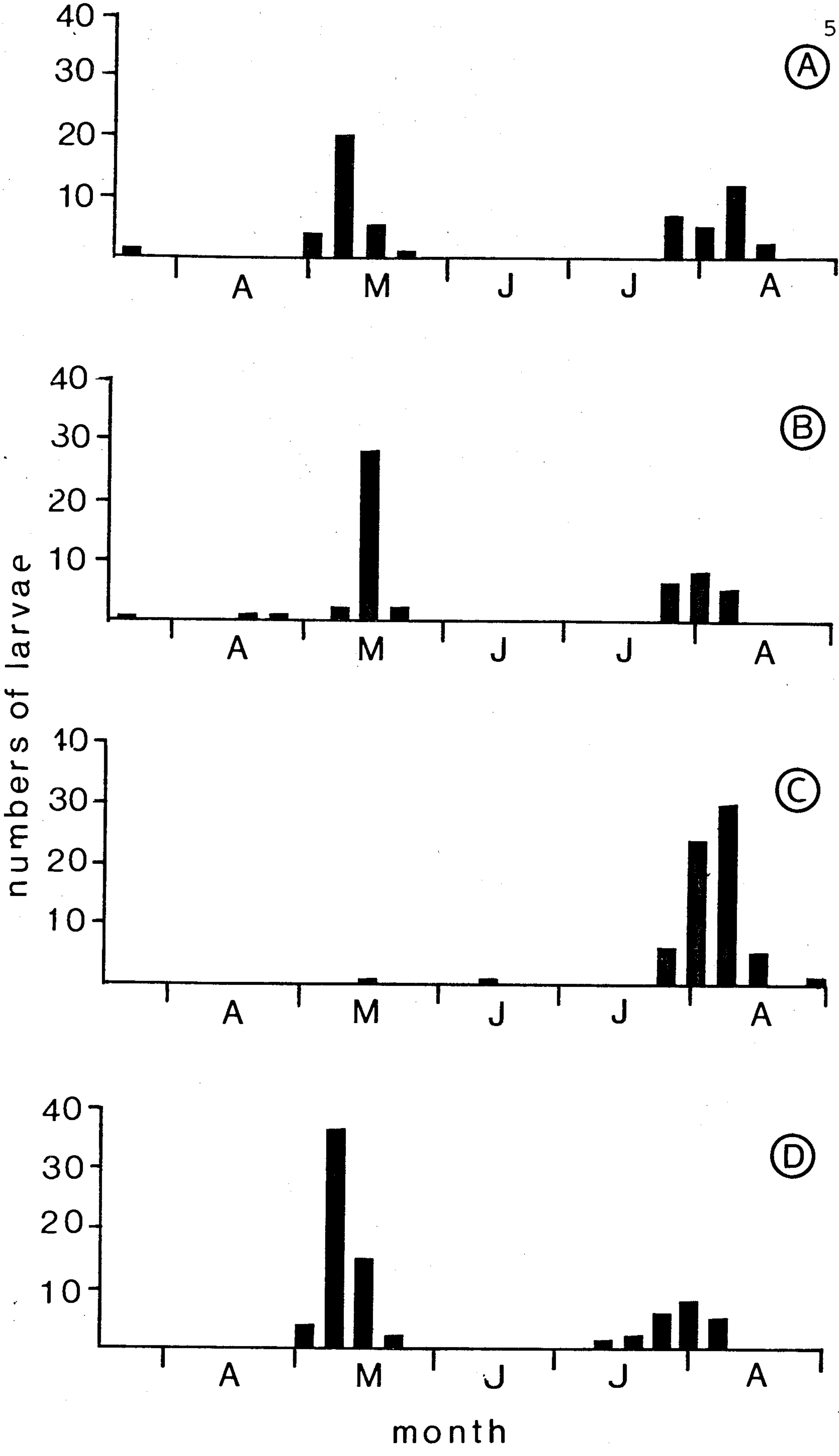
In 1981, trapping at 4 sites disclosed some differences between sites in the catch of air-borne first-instar larvae (Fig. 5).

At site 1 the peak drift in May occurred about 1 week later than in 1980, perhaps reflecting the colder and wetter spring of 1981. At site 2 the peak drift in May occurred 1 week later than at sites 1 and 6 and at site 3, this peak was essentially absent.

The late summer drift of larvae at site 1 both started about 2 weeks later than in 1980 and finished earlier. At site 6, drift both started about 2 weeks earlier than the other sites and finished earlier. Site 6, in Richmond, was drier and warmer in the summer than the other sites in Pitt Meadows.

No explicable differences were seen in numbers of larvae caught. As an example, more C. rosaceana larvae were caught on traps in July and August at site 3 than at any other site, yet very few larvae were observed feeding on blueberry there in the spring. As site 3 was 10 times larger than the other sites, it is likely the size of the field influenced numbers caught. This would limit the usefulness of such traps as population predictors. Good use could be made of these traps

Fig. 5 Total numbers of aerial drifting first-instar leafroller larvae caught per week in 4 blueberry fields from March 16 to August 31, 1981. A=Site 1, B=Site 2, C=site 3, D=Site 6.



A
B
C
D
40
30
20
10
numbers of larvae
A
M
J
J
A
month

in timing spring sprays to coincide with hatch of *A. rosanus*.

6. Significance of leafrollers on blueberry

In south-western British Columbia flower-cluster buds of highbush blueberry begin to swell noticeably in March, although individual flowers do not separate from the cluster at this time. By the end of April the clusters have expanded and the individual flowers are separate. Leaf buds do not begin to swell until early April. They burst in late April. There is very little leaf growth until mid-to-late-May. Blooming begins in early-to-late-May, depending on the variety of blueberry, and is generally over by early June. The fruit requires 60 to 90 days to mature, depending on variety and on prevailing temperatures (Shoemaker 1955). Picking begins in late June and continues into early September.

In March and April the blossom bud offers the largest resource of fresh growing material to larvae on blueberry plants. Early feeding species, particularly *O. bruceata* and *S. ocellana*, feed to a large extent on these buds. In late April and early May, when flowers are somewhat larger but leaves are available as well, species such as *C. rosaceana* and *Pandemis* spp. sometimes feed inside the flower cluster, occasionally severing the stem which causes the death of the cluster. In late May, when the flowers are open, larvae of *A. rosanus*, *C. rosaceana*, and first-instar larvae of *C. salicella* feed inside the flowers. Throughout June, *C. rosaceana* and *A. rosanus* feed commonly on the green fruit, cften hollowing out berries and using them as shelters. C. salicella larvae occasionally feed in the calyx end of green fruit. By July larvae of most species have pupated, but C. salicella does some minor feeding on green fruit. It was not noted feeding on ripe fruit. By the time the overwintering larvae of S. ocellana, C. rosaceana, and Pandemis spp. are present most fruit is ripe or very close to ripe so that minor feeding would not be noticed.

It appears that if "leafrolling" species have an effect on blueberry yields it is probably because of their feeding on flower bud, flower, and developing fruit in the spring.

Spray timing would vary depending on the species being controlled: late March for larvae of O. bruceata; late April for species which overwinter as larvae, i.e., C. rosaceana, S. ocellana, Pandemis spp. etc.; and mid to late May for larvae of A. rosanus and C. salicella. The need for each of these sprays would depend on the numbers of the species it was directed against. The feasibility of the sprays would depend on weather in late March and April, and blossom time in May.

SECTION B. LEAFROLLERS ON CRANBERRY

MATERIALS AND METHODS

Survey techniques

In 1980 larvae were collected from cranberry at 3 week intervals from May 12 to August 18 at sites 2,4 7 and 8. Collections were made by actively searching for larvae. In 1981 eggs and larvae of Rhopobota naevana (Hbn.) were sampled at sites 2, 7 and 8. The sampling unit was all the cranberry stems in a 10 cm by 10 cm area of bog, and was taken with a pair of grass shears. Cuts were taken at the base of the stems, and 10 to 18 samples were cut at each site, bagged, and labelled. The numbers of stems, eggs and larvae in each sample were counted under a dissecting microscope.

Survey plots (see site descriptions) were:

Site 2. about 10 ha of cranberry, badly overgrown with weeds, not sprayed, not flooded.

Site 4. about 200 ha of cranberry, essentially weed-free, sprayed regularly with insecticides, picking by flooding, but no winter or spring flooding.

Site 7. about 10 ha of cranberry in Richmond, B.C., somewhat weed-infested in 1980, cleaned up in 1981, sprayed regularly with insecticides, harvested by flooding, but no winter or spring flooding.

Site 8. about 100 ha of former cranberry bog in Burnaby, B.C., now with scattered patches of healthy cranberry, somewhat weedy, no insecticides used, not harvested, but floods in winter and spring.

Aerial drift of first-instar larvae.

Drift of aerial first-instar larvae was monitored in cranberry at site 2 in 1981 by using traps identical to those used in blueberry fields but set flush with the surface of the cranberry bog. Five traps were in operation from March 16 to August 31, 1981. The catch on the traps was recorded weekly.

RESULTS AND DISCUSSION.

1. Abundance of learollers on cranberry.

The predominant species of leafroller at all 4 sites examined in 1980 was the black-headed fireworm, *Rhopobota naevana* (Hbn.) (Table 12). Generally *R. naevana* was visibly more abundant at sites 2 and 8, which were both unsprayed and untended, than at sites 4 and 7, which were both well tended and sprayed twice in the season. Site 4 was sprayed in late May and again in late July, and site 7 in early June and in early August. At sites 2 and 8 larvae were collected throughout the bogs, but at sites 4 and 7, the growers pointed out trouble spots they were aware of, from which larvae were collected. At site 7 a trouble spot was a bog planted with a particularly early flushing variety which had chronic and recurring fireworm problems. At site 4 a section of a bog was not reached by the sprinkler system, and larvae in this area were not sprayed with insecticide. Consequently, the numbers of larvae reported in Table 12 do not reflect population

Table 12 Number of larvae collected from cranberry at 4 sites in the Lower Fraser Valley in 1980.

APPROXIMATE* DATE	SPECIES	SITE 2	4	7	8
Early May	R. naevana	8	30	-	50
	Tortricid sp.	-	-	-	1
Early June	R. naevana	60	-	6	35
	C. salicella	-	-	-	10
	C. rosaceana	4	-	-	-
Late June	R. naevana	41	4	1	1
	Tortricid sp.	1	-	-	4
Mid July	R. naevana	25	15	22	25
	C. salicella	-	-	-	10
Early August	R. naevana	31	-	1	1
Mid August	R. naevana	11	-	2	-
	C. salicella	2	-	-	-

* Actual dates of collection varied over 5 to 7 days.

numbers at these sites, and should not be used to make comparisons between them.

Rhopobota naevana was the only leafroller collected (Table 12) at sprayed sites 4 and 7. Small numbers of *C. salicella*, *C. rosaceana* and *A. alleniana* were found at unsprayed sites 2 and 8. As each of those species is large and easy to see, the numbers collected (Table 12) do not reflect their relative abundance in relation to the numbers of *R. naevana*. Also collected were 2 specimens of an undetermined species of Tortricidae (Tortricid sp, Table 12)

There were 2 generations of *R. naevana* in 1980, most noticeably at site 8 (Table 12). Larvae of the first generation characteristically fed on the developing new shoots, termed uprights, which bear the current season's crop. Larvae of the second generation fed on flowers, green berries and on upright and lateral shoots which would bear the season's uprights.

In 1981 the number of eggs per cranberry stem was surveyed at 3 sites on March 18 and May 4 (Table 13). Populations were highest at site 2 which had not been sprayed for about 5 years, and intermediate at site 8 which had been unsprayed and untended for at least 15 years. No eggs were found in 15 samples taken at site 7 which was sprayed regularly in 1980.

Table 13 Mean number of <u>Rhopobota naevana</u> eggs per cranberry stem (standard deviation, n) at 3 cranberry sites in the Lower Fraser Valley, prior to hatch of larvae.

DATE	SITE 2	SITE 8	SITE 9
March 18, 1981	0.26 (0.235, 18)	-- *	0.05 (0.055, 10)
May 4, 1981	0.25 (0.160, 18)	0 (0, 15)	0.04 (0.061, 10)

* Dash indicates no samples made.

Sampling had to be discontinued at site 7, as the damage done to the bog by the shears was greater than any possible benefit the grower might have gained from the survey. At site 8 the sampling was also discontinued because spring flooding made the area inaccessible. Sampling was continued at site 2, where the grower was agreeable and the damage due to sampling inconsequential in relation to the damage done by the fireworm.

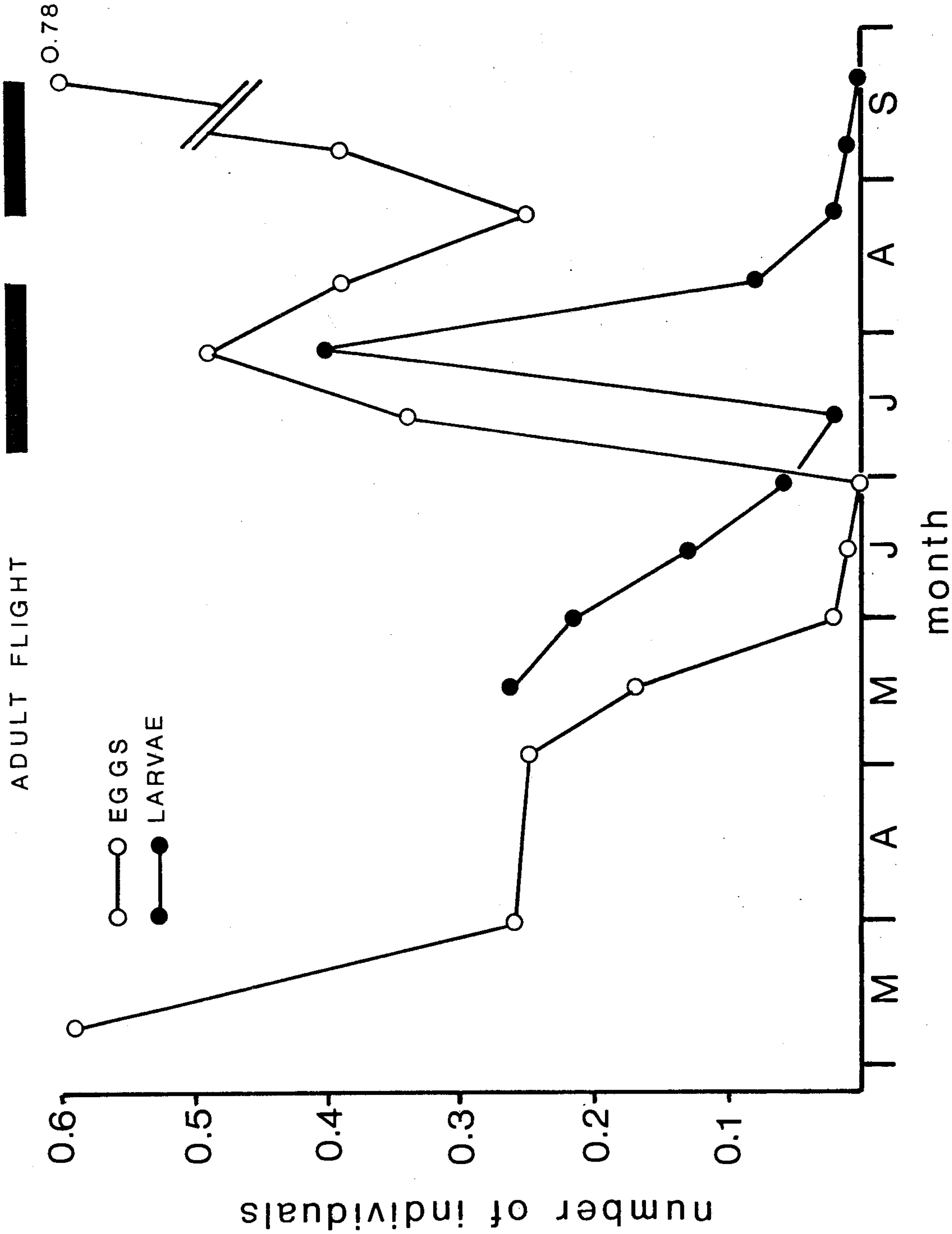
2. Biology of major species.

i. Rhopobota naevana (Hbn.)

There were two full generations of R. naevana at site 2 in 1981 (Fig. 6). Egg hatch started about May 18 and was mainly complete by June 1. Larvae matured and dropped to the leaflitter to pupate about June 13, and the first adults were seen on July 6. Eggs from these adults were laid singly and were found on the undersides of cranberry leaves on July 13, and had started to hatch on July 27. Adults continued to fly and lay eggs until about August 10 when no adults were seen in the field. Larvae from this generation matured, and began to pupate on August 10; the first adults were seen on August 24.

Only some of the eggs laid by first generation moths hatched. On July 27 an estimated 70% of the eggs in the samples were diapausing eggs, i.e., they would not hatch until the following spring. A 20% decrease in egg population 2 weeks

Fig. 6 Mean numbers of eggs and larvae of Rhopobota naevana per cranberry stem at site 2 from March 9 to September 21, 1981. Horizontal black bars denote periods during which adults were observed flying.


ADULT FLIGHT
0.78
EGGS
LARVAE
0.6
0.5
0.4
0.3
0.2
0.1
number of individuals
M
A
M
J
J
A
S
month

later, presumably resulting from hatching of non-diapausing eggs, tended to confirm this estimate. Considerable damage became visible between August 10 and 24. The stems lost a large number of leaves, particularly the older ones. These may have borne numerous eggs to the ground. Eggs from adults of the second generation increased the egg population to roughly the level of the previous year.

Some of the second generation eggs hatched producing a partial third generation. However, the larvae did not complete development.

The life history of R. naevana in British Columbia is essentially the same as that in Massachusetts (Franklin 1948) and in Washington (Plank 1922).

R. naevana is apparently an introduced species. A form known as the black-headed fireworm was probably introduced into Washington and Oregon between 1912 and 1915 on cranberry cuttings from Massachusetts (Plank 1922). It had then been a pest of cranberry in New Jersey, Massachusetts, and Wisconsin for a long time (Plank 1922) and was present then in New York and California. It was first reported in British Columbia in 1954 as a pest of cranberry on Lulu Island (Anon 1954). It since became a very serious pest (Cram and Neilson 1978) throughout the cranberry growing areas of the lower Fraser Valley (Neilson 1969). It is a pest wherever cranberry is grown in North America including New Brunswick, and Nova

Scotia (Maxwell and Pickett 1957), the eastern United States (Franklin 1950), Washington, and Oregon (Breakey 1960; Plank 1922).

A form known as the holly budmoth, (Kearfoot's *ilicifoliana*) was recorded in British Columbia in 1923 and is now known to occur in Washington and Oregon (Swenson 1958). The holly budmoth and the black-headed fireworm are thought to be very closely related (Breakey 1960). The holly budmoth is an important pest in Oregon holly plantings (Swenson 1958).

Rhopobota naevana is recorded feeding on fruit trees, holly, and species of *Crataegus* and *Vaccinium* in Europe (Meyrick 1927; Lucchesse 1941).

Parasites reared in 1980 from cocoons in deserted shelters of *R. naevana* could not be positively associated with that species. On 3 occasions deserted shelters of *R. naevana* were each found to be occupied by 2 cocoons of a species of parasitic Hymenoptera, possibly *Apanteles* sp. (Hymenoptera: Braconidae) on the basis of final-instar remains (Finlayson and Hagen 1977). Of the 3 sets, one did not emerge and the other 2 were hyperparasitized by *Hybracytus* sp. (Hymenoptera: Pteromalidae). The evidence associating the parasites with *R. naevana* is good but somewhat circumstantial. On one occasion 5 specimens of *Colpoclypeus floras* (Wlk.) emerged from a deserted larval shelter on cranberry. The host is unknown. One individual of a *Spilochalcis albifrons* (Walsh) (Hymenoptera:

Chalcidae) emerged from a pupa of R. naevana collected in 1981. Five specimens of Habrobracon xanthonotus Ashm. (Hymenoptera: Braconidae) were reared from larvae on five separate occasions in 1981.

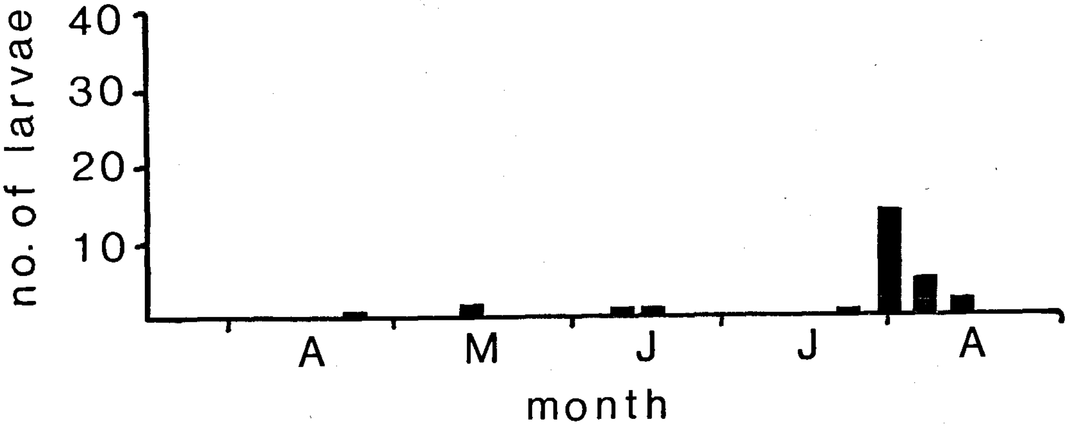
Although no parasites were reared from R. naevana eggs, a few eggs were seen in April, 1981, at site 2 which appeared to have been parasitized because of their blackened color.

In early spring there was a reduction in numbers of eggs per stem and in numbers of first generation larvae also. The causes of this decline are unknown. Although no instances of predation on larvae were observed, predatory insects such as lady-bird beetles and ground beetles (Coleoptera; Coccinellidae et Carabidae), and spiders such as Harvestmen (Araneae: Opiliones: Phalangiidae) were common in bogs, particularly at sites 2 and 8. These could well have had some impact on larval and pupal populations. Franklin (1948) ascribed some control potential to Nemorilla maculosa (Fall.) (Diptera: Tachinidae).

3. Aerial drift of first-instar larvae.

There was no evidence that first-instar R. naevana drift as do larvae of the other tortricid species. The early-season drift (Fig. 7) was of larvae of A. rosanus. The peak drift in late July and early August corresponded to drift of first-instar C. rosaceana in blueberry (Figs. 4, 5). However,

Fig. 7 Total numbers of aerial drifting first-instar leafroller larvae caught per week on 5 traps in a cranberry field at site 2 from March 16 to August 31, 1981.


no. of larvae
40
30
20
10
A
M
J
J
A
month

the captured larvae more closely resembled those of *A. alleniana* in size and coloration. *Aphelia alleniana* oviposits on several species of bog plant (Martin 1958) and its egg masses were found on *Ledum* sp. at site 2.

Traps for drifting larvae have no value in determining hatch times for *R. naevana* as its larvae do not drift, and thus could not be used to time sprays for that species.

4. Significance of leafrollers on cranberry.

Populations of black-headed fireworm are held in check by regular spray applications by cranberry growers. Where these sprays are neglected, it can devastate a bog in 2 to 3 years, and could have a significant impact on cranberry yield in a single season. Although some other leafroller species are present in cranberry bogs, they are of a secondary nature, and would probably not cause problems even if alternate controls for fireworm were available.

It is most significant that *Acleris minuta* (Rob.), the yellow-headed fireworm, and a pest of cranberry elsewhere (Franklin 1948; Maxwell and Pickett 1957), was collected from other hosts in south-western British Columbia in 1979 and 1980, but was not found at all on cranberry. This species may not utilize cranberry in the western part of its range perhaps because of biological differences between eastern and western populations.

Black-headed fireworm adults are weak fliers (Plank 1922) and thus would not spread far from the field in which they emerged. Moreover, the species has few, if any, alternate hosts (Breakey 1960), so few adults would emerge from plants surrounding the bogs to re-infest a bog once it had been controlled. Thus, there is a potential for pest management of cranberry, based on this species. Once an economic threshold has been established, decisions could be made on whether to spray or not. Numbers of eggs on leaves or numbers of adults caught in traps of some sort might serve as control indicators.

Because of the damp and humid nature of cranberry bogs *Bacillus thuringiensis* or other microbial control agents might be effective against the fireworm.

SECTION C. LEAFROLLERS ON RASPBERRY

MATERIALS AND METHODS

Survey techniques

Leafroller larvae, pupae and parasites were collected from raspberry at 3 week intervals from April 23 to August 25, 1980, at sites 11 and 12. Sample plot layout and sampling techniques were as described for blueberry. Larvae were collected at site 13 at 3 week intervals from June 3 to September 1 and reared for identification. Three other commercial raspberry fields were visited in April 1980.

At site 13 in 1981, larvae were collected at 3 week intervals from April 21 to September 1 as in 1980. On the same dates larval populations were sampled on 2 varieties, Willamette and 68-20/54. These varieties each were planted in 8 plots of 5 plants. Samples were taken by randomly selecting 2 canes from each plot and collecting all the leafrollers on each cane. Since each plant was pruned to about 5 canes, larger samples would have increased the probability of re-sampling a cane in subsequent visits. Larvae were isolated according to plot and identified.

Survey plots (see research sites) were:

Site 11. about 20 ha of raspberry cv. Willamette, sprayed regularly 2 plots, one plot near centre (A) one plot near edge (B) in Langley

Site 12. about 0.5 ha of raspberry, c.v. Willamette, sprayed regularly, Langley

Site 13. about 0.5 ha of raspberry, mixed varieties, not sprayed, Aldergrove.

Calculation of rates of parasitism.

Rates of parasitism were calculated as described in section A.

Aerial drift of first-instar larvae.

Drift of first-instar larvae was monitored at site 13 from March 17 to September 8, 1981. Traps as described for blueberry were set 2 m above ground, 20 m apart. Five traps were set out and the catch of larvae counted weekly.

RESULTS AND DISCUSSION

1. Abundance of leafrollers on raspberry.

Surveys on raspberry at 3 sites in 1980 (Table 14) showed leafrollers to be relatively uncommon. At all sites peak populations occurred on April 23. In late April, 1980, malathion was sprayed on all fields for the western raspberry fruitworm, *Byturus bakeri* (Barber) (Coleoptera: Byturidae). This spray apparently also reduced leafroller populations. After another malathion spray for *B. bakeri* in mid-June, 1980, no leafrollers were seen on raspberry.

The predominant species (42%) on April 23, 1980, at all sites was *O. bruceata*. Also collected were *B. urticana*, *Acleris comariana* (Zell.) (Lepidoptera: Tortricidae), *C. rosaceana*, and *Herpetogramma pertextalis* (Led.) (Lepidoptera: Pyralidae). After April 23, 87.5% of larvae collected at all sites were *H. pertextalis*.

No larvae were found in 2 other commercial fields visited on April 23 and May 14, 1980.

At site 13 bulk collections were made from June 3 to August 25. This experimental field had never been sprayed. Leafrollers were relatively easy to find, although not common

Table 14 Populations of leafrolling larvae on raspberry at 3 sites in the Lower Fraser Valley in 1980. Mean number of larvae/plant (standard deviation) n=10.

DATE	SITE		
	11A	11B	12
April 23	0.9 (0.74)	1.7 (0.88)	0.5 (0.85)
May 4	0.2 (0.42)	0.3 (0.48)	0
June 3	0.2 (0.42)	0	0.1 (0.32)
June 24	0	0	0
July 15	0	0	0
August 25	0	0	0

by comparison with other crops e.g. site 1.

In 1981 samples were taken from 2 varieties of raspberry at site 13. Again, populations were highest in April and then decreased (Table 15). Operophtera bruceata comprised 56% of the larvae collected in April. The major difference from 1980 was that H. pertextalis did not form such a large proportion of larvae in 1981. Although sample units were different (larvae/plant in 1980, larvae/2 canes in 1981) the samples can be compared by multiplying the 1981 means by 3 to yield means/6 canes, roughly the number of canes to which commercial raspberry plants are pruned. It is then quite obvious that populations at site 13 in 1981 (Table 15) were much higher than those at sites 11A, 11B and 12 in 1980 (Table 14).

Operophtera bruceata fed extensively on flower buds of raspberry, and was found most often in the tips of sprouting laterals in April and early May. By May 26 all flower buds had grown beyond the shelter of leaves on the laterals, and no larvae of any species were observed feeding on flowers past this date.

Nine species of larvae fed in leafrolls on raspberry in 1981 (Table 16). Of these, 6 were Tortricidae, 2 of which, A. comariana and A. rosanus, are introduced. In comparison, 7 of the 16 species on blueberry are introduced. While the number of species found on raspberry was lower than that on blueberry, the range and size of collections was much smaller

Table 15 Populations of leafrolling larvae on 2 varieties of raspberry at site 13. Mean larvae per 2 fruit-bearing canes (Standard deviation) n=8.

	VARIETY *	
DATE	68-20/54	Willamette
April 21, 1981	1.6 (2.13)	1.1 (1.13)
May 12, 1981	0.5 (0.76)	0.9 (1.10)
May 16, 1981	0.4 (0.52)	0.3 (0.46)
June 16, 1981	0.1 (0.35)	0.4 (0.74)
July 7, 1981	0	0
July 28, 1981	-	-

*Dash indicates variety not sampled.

Table 16 Species of leafrolling Lepidoptera collected on raspberry in 1980 and 1981 listed in approximate order of abundance

SPECIES	FAMILY	ORIGIN
Choristoneura rosaceana (Harr.)	Tortricidae	Native
Operophtera bruceata (Hulst)	Geometridae	Native
Acleris comariana (Zell.)	Tortricidae	Introduced
Herpetogramma pertextalis (Led.)	Pyralidae	Native
Badebecia urticana (Hbn.)	Tortricidae	Native
Archips rosanus (L.)	Tortricidae	Introduced
Archips argyrospilus (Wlk.)	Tortricidae	Native
Aphelia alleniana (Fern.)	Tortricidae	Native

because of the emphasis on the use of insecticides in the culture of raspberry.

2. Biology of major species.

The life histories of A. rosanus, A. argyrospilus, A. alleniana, B. urticana and O. bruceata do not differ on raspberry from those described in sections A and D. The life history and biology of A. comariana are discussed in section D, as strawberry is its major host. Its life cycle is identical on raspberry and strawberry; there are 2 generations, the first from overwintering eggs which hatch in mid-April, and the second from eggs laid in July.

On August 7, 1980, 37.5% of A. comariana larvae were parasitized by Copidosoma sp. (Hymenoptera: Encyrtidae). On May 26, 1981, 50% of the larvae were parasitized by this species.

i. Choristoneura rosaceana

Choristoneura rosaceana on raspberry is bivoltine, whereas on blueberry, larvae from egg masses laid in July enter diapause and overwinter. On raspberry at least some of these larvae develop to adults in August. Larvae from egg masses laid by these females overwinter.

Photoperiod is the most important factor determining diapause in C. rosaceana (Chapman and Lienk 1971), and a photophase of >16 h induces continuous breeding (Chapman, Lienk and Dean 1968). Some larvae may hatch and mature on raspberry before the diapause inducing photophase of <16 h is reached. Alternatively or additionally the quality of raspberry as food may be such that larvae mature faster than on blueberry, or the quality of the food might override the diapause-inducing photophase. There is some evidence that the quality or amount of food can influence diapause (Chapman 1971) but none available that high quality or quantity of food can override diapause; feeding on senescent potato foliage induces diapause in adult Colorado potato beetle, but feeding on new foliage did not overcome the diapause-inducing photophase (Danilevskii 1965). Finally, warm and sunny weather in August could favour a fractional second generation.

As on blueberry, *Apophua simplicipes* was the most important parasite. Parasitism was in the range of 5 to 10% in the first generation at site 13 in 1981, mainly by *A. simplicipes*, which was also reared from larvae of the second generation.

ii. *Herpetogramma pertextalis* (Led.)

Larvae of *H. pertextalis* were found in May and early June, and pupated in early to late June. Adults emerged in the laboratory in late June and early July, but none was observed flying in raspberry fields. The mode of overwintering is unknown. The species is bivoltine in New York (Forbes 1923).

One larva was parasitized by a Triclistis sp. (Hymenopera: Ichneumonidae) which emerged from a host pupa in 1980. A pupa of H. pertextalis collected on June 16, 1980 was parasitized by Phaeogenes cacoeciae Vier. (Hymenoptera: Ichneumonidae).

3. Aerial drift of first-instar larvae.

No larvae were caught on traps in the spring. Six larvae were caught in July and August, corresponding in time with drift of first-instar C. rosaceana in blueberry (Figs, 4, 5). It appears that populations are so low in raspberry that 5 traps were not adequate to assess dispersal of larvae.

4. Significance of leafrollers on raspberry.

On the basis of a questionnaire sent to raspberry growers in the Lower Fraser Valley, B.C., Roddick (1979) concluded that "leafrollers" were not perceived as a major problem. The most serious concern was that mechanical picking may dislodge larvae along with the picked fruit, which can reduce fruit standards.

The current observations on leafrollers on raspberry confirm these conclusions to some extent. However, there are some observed and historical considerations which should temper that opinion.

The Bruce spanworm, O. bruceata, while not a leafroller in the true sense, is perceived by growers as such. The early feeding of this species means that it could mature and be in pupal chambers in the soil before the first sprays are applied for other species. Also, the larvae feed on flower clusters contained within the lateral tips, and in outbreak years could cause a significant reduction in yield before the grower could apply any controls. While no records were found of *O. bruceata* larvae causing losses in raspberry, serious defoliation of other host plants has been noted (Brown 1962; McMullen 1973).

The oblique-banded leafroller, *C. rosaceana*, has been a serious problem on raspberry in Oregon (Schuh and Mote 1948), and could become so in British Columbia. Sprays for western raspberry fruit worm probably prevent serious problems with *C. rosaceana*, although site 13, which was unsprayed, did not have any obvious problems with this species. On the other hand, Schuh and Mote (1948) found the most serious damage to be by first to fifth-instar larvae of the summer generation feeding in the cups of the ripe fruit. Possibly the presence of feeding larvae and ripe fruit does not coincide in south-western British Columbia.

One possibly important species, *A. comariana*, has not been previously reported on raspberry. In Europe, where it is a pest of strawberry (Alford 1975), it is not known to occur on black or red raspberry (D.V. Alford, ADAS, Brocklands Avenue, Cambridge, England, pers. comm.). In most years larvae on raspberry in British Columbia would be killed by the fruitworm sprays. If some sprays were eliminated, second generation larvae of this bivoltine species might be pests at harvest time.

SECTION D. LEAFROLLERS ON STRAWBERRY

MATERIALS AND METHODS

Survey techniques

In 1980 leafrolling larvae were collected from strawberry at 3 week intervals from April 22 to August 20 at sites 9, 10, 11 and 12. An additional sample was made at site 9 on April 15. Sites 11 and 12 were not sampled after June 26 because the fields and sample plots were plowed under.

Ten samples were collected at each visit. All larvae and all pupae of leafrolling larvae were collected from 10 1 m sections of row chosen randomly from within a 10 row by 30 m sample area. A sampled 1 m was not re-sampled. Larvae and pupae were reared for identification and parasitism.

Plots (see research sites) were:

Site 9. about 4 ha, Richmond, B.C.; bordered by overgrown pasture and deciduous forest; no insecticides in 1980.

Site 10. about 8 ha, Richmond, B.C.; bordered by pasture, sprayed in 1980.

Site 11. about 15 ha, Langley, B.C.; bordered by deciduous forest, sprayed in 1980.

Site 12. about 4 ha, Langley, B.C.; bordered by mixed agriculture; Sprayed in 1980.

Calculation of rates of parasitism.

Rates of parasitism were calculated as described in Section A.

Distribution of larvae in field.

On April 20, 1980, at site 9, 10 samples as described above were taken from each edge (North, East, South, West) and from 4 plots in the centre of the field (Fig. 8) to see if the distribution of larvae in the field was uniform. Records were made of the number of each species in each sample and the parasitism associated with that species.

Data were analyzed by analysis of variance and means were compared by Tukey's W-test. Percentage parasitism figures were subjected to an arcsin-square-root transformation before being subjected to analysis (Sokal and Rohlf 1969).

RESULTS AND DISCUSSION

1. Abundance of leafrollers on strawberry.

Very few leafrollers were found in most commercial strawberry fields (Table 17). At site 10 in Richmond and site 11 in Langley, no leafroller larvae were collected, either in

Fig. 8 Approximate locations in a strawberry field at site 9 from which samples were taken on April 20, 1980, to investigate within-field distribution of leafroller larvae feeding on strawberry.

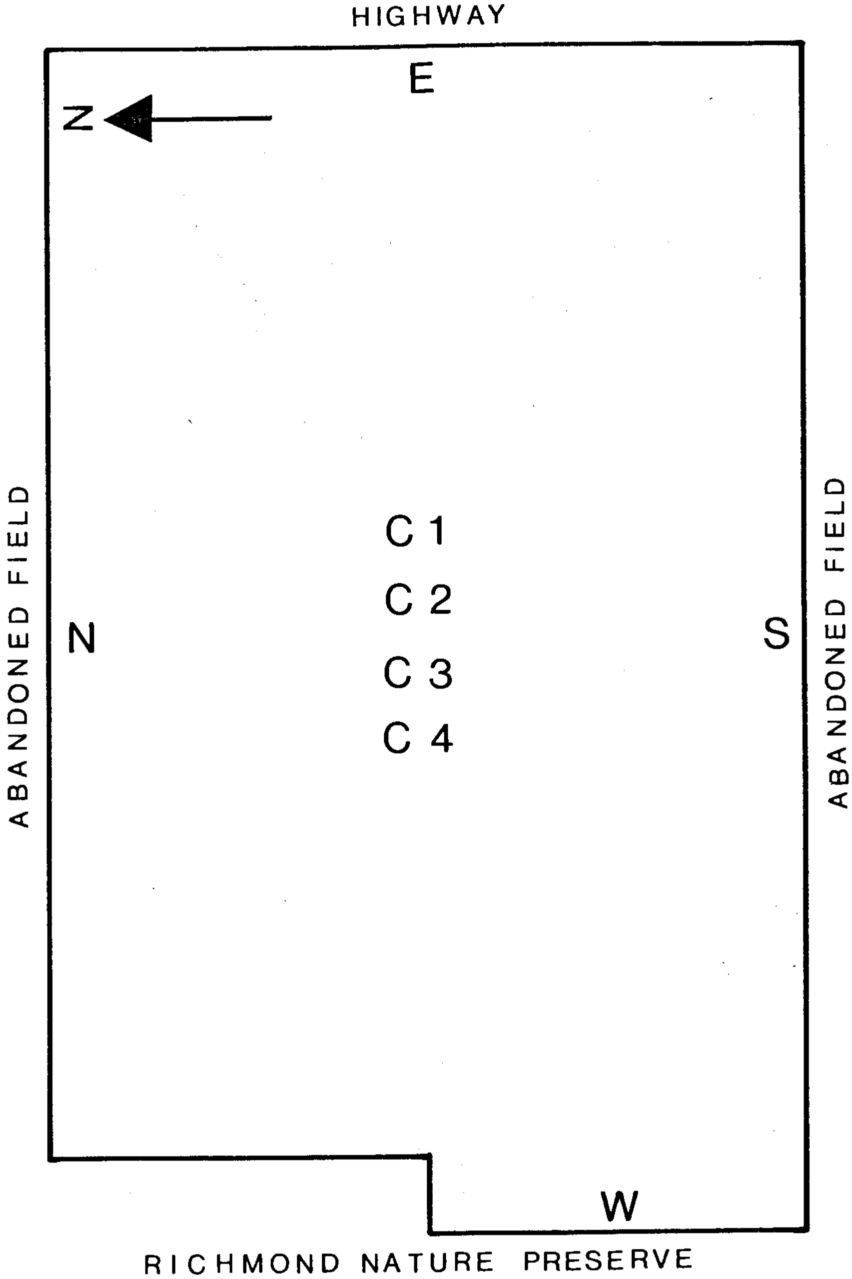

HIGHWAY
E
N
ABANDONED FIELD
N
C 1
C 2
C 3
C 4
S
ABANDONED FIELD
W
RICHMOND NATURE PRESERVE

Table 17 Populations of leafroller larvae on strawberry at 4 sites in the Lower Fraser Valley in 1980. Mean larvae per 1 m of row (standard deviation) n=10.*

DATE	SITE 9	SITE 10	SITE 11	SITE 12
April 5	2.7 (1.34)	--	--	--
April 22	4.7 (6.70)	0	0	0.5 (0.53)
May 13	28.0 (10.77)	0	0	0.3 (0.68)
June 4	3.8 (2.78)	0	0	0.6 (0.70)
June 26	0.2 (0.42)	0	0	0
July 16	5.8 (2.66)	0	--	--
August 8	18.8 (4.57)	0	--	--
August 20	13.4 (5.25)	0	--	--

* dash indicates site not sampled.

sample plots or by searching large areas. Both sites were sprayed early in the season, site 10 for aphids and site 11 for root weevil. At site 12 a few larvae of A. comariana and C. rosaceana were found. By June 26 adults of both species were seen, and the field was plowed under shortly thereafter.

Site 9 was not sprayed in 1980 or post harvest in 1979. Consequently larval populations became quite high (Table 17, 18) . At the peak on May 13, there were 28.0 larvae per 1 m of row.

Only four tortricid species were collected on strawberry. In order of abundance they were: A. comariana, A. alleniani, B. urticana and C. rosaceana. Only A. comariana is introduced.

2. Biology of Major species.

i. Acleris comariana (Zell.)

Acleris comariana was the most abundant species in all collections but the earliest (Table 18). Hatch apparently started before April 15, and continued until after April 22. Peak populations were seen on May 13, most larvae had pupated by June 4, and adults were seen on June 26. Larvae of the second generation appeared on July 4, and had begun to pupate on August 20.

Acleris comariana was first reported in North America in 1972 as a pest of strawberry and raspberry in Richmond, B.C.

Table 18 Species of Tortricidae collected from strawberry at site 9 in 1980. Mean larvae per 1 m of row. n=10.

DATE	SPECIES *			
	Acleris comariana	*Aphelia alleniana*	*Choristoneura rosaceana*	*Badebecia urticana*
April 15	0.4	0.8	0.3	-
April 22	1.9	0.6	-	0.4
May 13	16.5	0.4	-	0.1
June 4	2.8	0.4	-	-
June 26	-	-	-	-
July 4	4.9	0.9	-	-
August 8	17.0	1.4	-	-
August 20	9.3	3.0	-	-

* dash indicates this species not reared from collections on that date.

(Cram 1973). It now occurs on strawberry and raspberry throughout the Lower Fraser Valley of B.C. but has not yet been recorded elsewhere in North America.

It is found in Europe, China,and Japan, and is apparently native to Europe (Bradley *et al.* 1973). It is a pest of strawberry in England (Alford 1975, 1976b; Vernon 1971; Petherbridge 1920) and Hungary (Balazs and Bodor 1969). Marsh cinquefoil, *Potentilla palustrus* (L.), is the main wild host plant in England (Vernon 1971).

Acleris comariana was a serious problem in Richmond, B.C. strawberry plantings when it was first discovered (Cram 1973). In Britain it is an occasional but sometimes serious pest (Alford 1975). *Acleris comariana* larvae prefer leaves to flowers or developing fruitlets (Alford 1975). This preference was also observed at site 9, where very few larvae were associated with flowers or fruits. Those that were observed had webbed the flower petals to the immature green berries, but no obvious feeding damage was observed on these berries. Alford (1976b) observed no effect on yield at densities of up to 6.5 larvae/m of row.

Densities of up to 28 larvae/m of row produced no *obvious* damage to berries or yield in the survey plot at site 9, i.e. the visible impression of the field was that there were many berries and that very few were damaged or deformed. Because so few larvae feed on flowers and fruits, the observed densities were probably also within economic limits. At no time during either generation did the field appear defoliated.

Acleris comariana was more frequently a problem in wet lowland areas than uplands districts of Britain (Vernon 1971). *Potentilla palustris* (L.), marsh cinquefoil, was a frequent wild host there. Although no species of *Potentilla* were observed in or around site 9, it was close to areas where they might grow, particularly to the Richmond Nature Preserve which is predominantly boggy lowland. Larvae of *A. comariana* were collected from *Spiraea* sp., *Rubus* sp. and *Malus* sp. bordering site 9. It is possible that *A. comariana* may follow the same pattern as in Britain, and not become a problem in the dryer strawberry growing areas of Langley and Abbotsford where it now occurs.

Acleris comariana was heavily parasitized (Table 19), mostly by *Copidosoma* sp. (Hymenoptera: Encyritidae). All *Copidosoma* spp. are polyembryonic and parasitize the egg stage of their hosts, emerging from the final-instar larva (Clausen 1940). The apparent difference in parasitism rates over the season is probably due to higher mortality in parasitized larvae than unparasitized larvae. The most realistic rate is therefore the last one for each generation, 67.9 and 67.7%, which was when larvae were mature and suffered the least mortality.

Table 19 Percentage parasitism of larvae of *Acleris comariana* on strawberry at site 9 in 1980.

DATE	SPECIES * *Copidosoma* sp.	*Microgaster* sp.	*Nemorilla pyste* (Wlk.)	OTHER	TOTAL
April 15	- *	-	-	-	-
April 22	15.8	5.3	-	-	21.1
May 13	28.5	3.0	-	-	31.5
June 4	67.9	3.6	-	-	71.4
June 26	-	-	-	-	-
July 16	34.7	-	-	4.1	38.8
August 8	57.1	-	5.3	-	62.4
August 20	67.7	-	3.2	-	71.0

* dash indicates species not reared from samples on that date.

Microgaster sp. (Hymenoptera: Braconidae) parasitized first generation larvae, and *Nemorilla pyste* (Wlk.) (Diptera: Tachinidae) parasitized second generation larvae.

Eggs of *N. pyste* were observed on the dorsum of the thorax on 10 to 20% of the later-instar larvae collected. These were kept separate from other larvae. Many of these individuals were also parasitized by *Copidosoma* sp., as they produced the latter and not the former. Apparently the already resident *Copidosoma* sp. larvae outcompete the larva of *N. pyste* for posession of the host.

Parasites appear to be a important in regulating populations of *A. comariana*. In Britain *A. comariana* is heavily parasitized by *Litomastix aretas* (Wlk.) which has a similar biology to that of *Copidosoma* sp. (Alford 1976a).

ii. *Aphelia alleniana* (Fern.)

Larvae of *A. alleniana* had emerged from their overwintering sites and were quite large by April 15. Larvae were still present on June 4, although pupae were also found on that date. Adults were common in June, and egg masses were frequently seen on the upper surfaces of the strawberry leaves. First-instar larvae were found feeding between the basal veins of the strawberry leaves, and in deserted rolls on July 4, August 8 and 20. On subsequent visits in September, larvae were found in much the same positions, but were concealed by silk, which probably forms the overwintering sites.

Aphelia alleniana is a native species, distributed from British Columbia to New Brunswick (Chapman and Lienk 1971). Its primary hosts are cinquefoil, *Potentilla recta* L., and bladder campion, *Silene cucubalus* Wibel, (Martin 1958).

Larvae were found feeding on a wide variety of plants: *Rubus* spp. (including raspberry), *Betula* spp., *Spiraea* spp., and *Vaccinium* spp. (including both blueberry and cranberry). Eggs were found on cultivated strawberry only at site 9. The egg mass was exclusively laid on the upper surface of older and exposed leaves. None of 25 egg masses collected on June 26 was parasitized. One specimen of *Pseudopericheta erecta* (Coq.) (Diptera: Tachinidae) emerged from a pupa, and some larvae were apparently parasitized by *Microgaster* sp. (Hymenoptera: Braconidae). No distinction could be made between *Microgaster* parasites of *A. comariana*, which overwinters as an egg, and those parasites of other tortricids which overwinter as larvae. At least some *Microgaster* spp. are egg-larval parasites (Clausen 1940), so there actually may be two species involved, one overwintering in *A. comariana* eggs and the other in larvae of *A. alleniana* and other species.

3. Distribution of larvae in field

The mean number of larvae/m of row was significantly different in the different plots (Fig. 8 Table 20). Plots on the edge of the field generally contained more larvae than those in the centre. The west edge, which was closest to the Richmond Nature Preserve, had the highest numbers of larvae. The north and south edges had the next highest populations. The north edge was next to a former strawberry field, plowed under that spring, and the south edge bordered on an abandoned area of scrub, mainly of *Rubus* spp., *Betula* spp, *Populus trichocarpa* and *Spiraea* spp. The east edge had the lowest populations of the edge plots, and these were not different from those in any of the centre plots. This edge was next to a major highway, and there were very few low shrubs between it and the highway.

In all plots *A. comariana* comprised more than 90% of the larval population, and as much as 98% on the west edge. It was the species that varied in numbers while the other species ranged from 3 to 5 larvae per plot.

The distribution of *A. comariana* can vary considerably within fields, and is apparently influenced by the proximity of alternate hosts. As *A. comariana* lays its eggs singly and is not known to drift in the first-instar, the variation in larval densities must come from the dispersion of adults. In June, 1980, adults of *A. comariana* were very numerous in the vicinity of the west edge of the field possibly because of immigration from the bordering Richmond Nature Preserve.

Table 20 Mean number of larvae/m of row and percent parasitism of *Acleris comariana* in 8 plots in strawberry at site 9. *

PLOT	LARVAE/m mean	LARVAE/m SD	% PARASITISM** mean	95% confidence limits lower	95% confidence limits upper
North Edge	13.5a	6.12	33.5a	13.23	57.74
East Edge	5.4b	1.58	63.0a	29.52	90.58
South Edge	11.5a	4.06	59.3a	49.01	69.26
West Edge	21.4c	5.08	46.7a	37.65	55.94
Centre 1	3.6b	2.50	27.9a	4.12	62.21
Centre 2	5.5b	2.95	24.8a	7.77	47.35
Centre 3	4.4b	1.35	51.8a	23.71	79.28
Centre 4	3.9b	1.52	42.4a	10.10	79.00

*Numbers in the same column followed by the same letter are not significantly different (Means only; Analysis of Variance; Tukey's W text; p=0.05).

**Retransformed means and 95% confidence limits of arcsin square root of x transformation.

The varying density of larvae has profound implications for management of this pest. Decisions regarding control cannot be made on the basis of an inspection of the edge of the field, but must be based on an examination of several areas within the field. Growers might be able to obtain satisfactory control simply by spraying the edges of the field or areas near alternate hosts. The technique of spraying resevoir populations has been suggested for pests of onion in the Lower Fraser Valley (Vernon 1979).

The incidence of parasitism in the various plots was not significantly different (Table 20)(Anova, p=0.05), suggesting that the major parasite, Copidosoma sp., distributes itself evenly over the field, and does not respond to higher concentrations of its host.

4. Significance of leafrollers on strawberry.

At most sites, tortricids seem to be controlled by application of insecticides and acaricides. Provided that the status and control of these other pests remains the same, leafrollers should not be a serious problem.

Timing of sprays for these other pests may be important. Müller (1962) found that once larvae of Tortricidae had formed rolls on strawberry ,insecticide applications were considerably less effective, and recommended that control measures be taken early in the season, well before blossom.

Acleris comariana, which was most abundant in the unsprayed site, would presumably become abundant at other sites if sprays for other pests were stopped. Strawberry seems to tolerate high numbers of this pest because it does little direct damage to the berries. In fact, none of the tortricid species directly damaged the berries.

Four species known to feed on strawberry and to occur locally were conspicuous by their absence from field collections. One is *Cnephais longana* (Haw.), the omnivorous leaf-tier, which has been found tunnelling in ripening strawberries in the Lower Fraser Valley (Cram and Tonks 1959). It is an important species as it does do direct damage to strawberry fruit.

Another species not found was *Ptycholoma peritana* (Clem.), which feeds on decaying leaves and fruit in contact with the ground in Quebec (Paradais 1975). At high populations it has damaged sound strawberry fruit in California (Allen 1959). It occurs throughout southern Canada (Powell 1964).

Ancylis comptana fragariae (W. & R.) and *Exartema olivaceanum* (Fern.) have both been recorded as pests of strawberry in south-western British Columbia (Neilson 1969), but neither was collected in the present study.

It is not known if the absence of these species reflects consequences of interactions between tortricid species, natural fluctuations in abundance, or a decrease in abundance due to increased use of insecticides for other species.

Alford (1975) notes several tortricid species that do direct damage to strawberry in Britain. One of them, Cnephasia interjectana (Haw.), occurs in Eastern North America, where it has been recorded as damaging strawberries (Table 4). The introduction of this or other species capable of doing direct damage to strawberry could have a serious impact on the British Columbia industry.

CHAPTER III. EFFECTS OF LEAFROLLERS ON BLUEBERRY YIELDS

There are basically two ways that leafroller larvae cause loss of yield in blueberry plantings. One is defoliation causing stress in the plants and thus loss of yield. Serious defoliation did not occur in any of the sites examined, although there are records of such damage to many hosts by leafrollers and other lepidopterous larvae (Table 2).

The second, and more serious cause of damage is feeding on the flowers, fruit clusters, or the berries. The objective was to evaluate the amount of damage done by larvae feeding on flower and fruit clusters.

MATERIALS AND METHODS

1. Relative numbers of larvae in leafrolls and in flower and fruit clusters.

The numbers of larvae feeding in leafrolls and in flower and fruit clusters were counted on each of 10 plants at site 1 on April 28, May 19, June 10, June 30 and July 31, 1980. The average number of larvae feeding on each part of the plant was computed.

2. Relative proportions of major leafroller species on flower and fruit clusters.

The relative proportions of larvae of the major species of leafrollers on flower and fruit clusters were compared by collecting 5 randomly selected samples of approximately 20 larvae each from clusters or leafrolls at each of sites 1, 2, and 6 on April 24, May 4, June 1 and June 29, 1981.

Larvae were handled and, in some cases, reared for identification as in Chapter 2. The percentage of each species in each sample was calculated and averaged for each group of 5 samples.

3. Effect of leafroller feeding on yields of fruit clusters.

The effect of leafroller feeding on yields of fruit clusters was estimated by collecting 2 samples of approximately 100 random clusters each, one of clusters damaged by leafrollers and the other of undamaged clusters. Collections were made at site 2 on April 20, May 4, June 1 and June 29, 1981; and at site 6 on May 4, June 1 and June 29, 1981.

Damaged clusters were identified by the presence of silk and frass, feeding damage, and leafroller larvae, in that order of importance. On April 20 at site 2, small and unequal sized samples were collected. On May 4 some of the apparently damaged clusters were webbed with spider silk which was confused with leafroller damage when the samples were collected, but was distinguished before they were counted.

The number of flowers and berries in each cluster was counted. For each damaged cluster the number of flowers or berries which had been damaged by feeding was subtracted to give a projected yield for that cluster.

To ensure that the undamaged clusters and those damaged by leafrollers came from the same population, the original number of flowers in the damaged clusters was estimated on April 20, 1981, at site 2 by counting the number of petiole scars from previously dropped flowers on the cluster stem and adding that number to the number of existing flowers in each cluster. The means of the number of flowers in undamaged clusters and the original number of flowers in damaged clusters were compared.

It appeared possible that clusters with smaller numbers of berries might produce individually larger berries, thereby compensating, at least in part, for damage done by larvae. Therefore, on July 20, 1981, at site 2 the largest ripe berry from each of 10 clusters containing 1, 2, 3, 4, or 5 berries was collected and weighed.

4. Rates of damage by leafroller larvae to fruit clusters.

The proportion of damaged clusters was estimated by counting the number of damaged clusters in each of 10 groups of 20 clusters at sites 2 and 6 on March 24, 1981, and at sites 1, 2, and 6 on April 1, May 4, June 1 and June 30, 1981. On May 4, June 1 and June 29, 4 sets of 10 groups of 20 clusters each were counted, each set in a different area of the field.

Groups of clusters were selected and counted by first randomly selecting a cluster at the tip of a branch at about chest height. Clusters were then counted along that branch and its side branches until 20 had been encountered. The number of damaged clusters in each group of 20 was recorded. Ten groups were counted within about 30 m of each other, and each set of 10 groups was in a different quadrat of the field. The data for the 4 sets were pooled to provide an overall estimate of damage per 20 clusters for each field on each date.

5. Comparison of leafroller-infested and leafroller-free plants.

To assess the effect of leafrollers on yield of blueberry, 10 of a group of 20 young cv. Bluecrop plants at site 2 were sprayed with malathion 50 EC to eliminate their leafroller populations.

The plants were in two rows of 10 each, with about 1.2 m between plants and 2 m between rows, and the two rows were in the approximate centre of a block of plants 10 rows wide by 30 plants long. The first plant in row 1 was designated to be sprayed by a flip of a coin, and treatments alternated spray, no spray ...etc in row 1. Row 2 had the opposite alternation. The malathion was mixed at 1 ml/L and sprayed to run-off with a back-pack sprayer. Sprays were applied on April 6, April 30, and May 27, 1981.

It was originally intended that the plants be harvested when the berries were ripe and the yields compared. This did not prove to be feasible because of inadequate grower cooperation and of variability between plants. Instead, the following observations were made:

1. The number of clusters on each bush was counted on June 15 and July 20, 1981.

2. The numbers of leafroller larvae occurring in clusters and in leafrolls on each bush were counted on May 11 and June 15, 1981.

3. The number of berries in each of 15 randomly chosen clusters from each plant was counted on June 22 and July 20, 1981. On June 22 the clusters were counted on the plants, while on July 20 they were removed and counted in the laboratory. The number of berries in each cluster was

determined by the same rules as for damaged clusters in section C. The total weight of berries in each cluster collected on July 20 was also recorded.

Data Analysis

Paired means were compared using a t-test (p=0.05). Multiple means were analyzed by analysis of variance (p=0.05), followed by Fisher's Least Significant Difference test (p=0.05).

The significance of regression was determined using analysis of variance. Slopes and y-intercepts of regression lines were compared using t-tests.

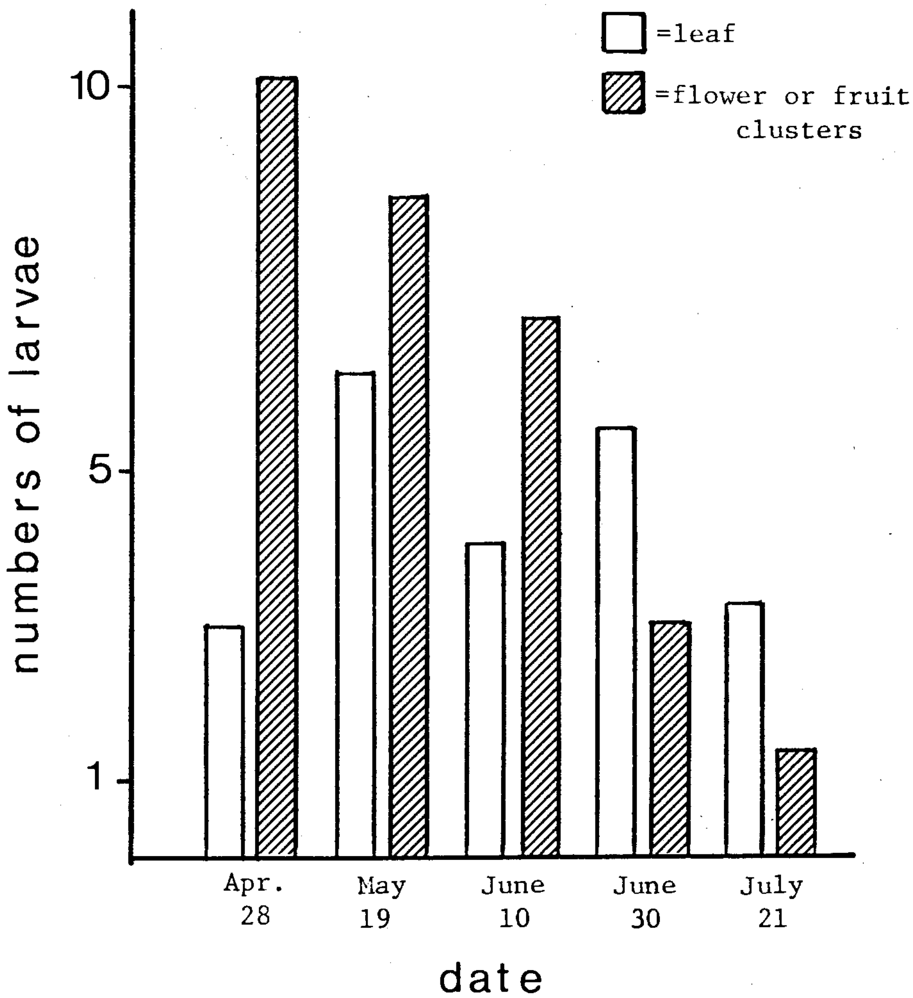
RESULTS AND DISCUSSION

1. Relative numbers of larvae in leafrolls and in flower and fruit clusters.

On the first 3 sampling dates in 1980, more larvae were found feeding in flower and fruit clusters than on leaves (Fig. 9). Subsequent to this, more larvae were found in leafrolls than in berry clusters.

On the first 3 dates *S. ocellana* was the predominant species. As *S. ocellana* was predominantly in flower and fruit clusters rather than in leafrolls, it probably accounts for the higher number of larvae in flower and fruit clusters on those dates.

Fig. 9 Average numbers of larvae feeding on leaves, and on flower and fruit clusters of blueberry at site 1 on 5 dates in 1980.


=leaf
=flower or fruit clusters
numbers of larvae
10
5
1
Apr. 28
May 19
June 10
June 30
July 21
date

It was estimated that there were approximately 1000 flower clusters per sample plant on the plants sampled on April 28. On this basis about 1% of the clusters were occupied by leafrollers. It is apparent that leafroller larvae could cause significant losses to blueberry production.

2. Relative proportions of major leafroller species on flower and fruit clusters.

Spilonota ocellana was the predominant species feeding on flower clusters at site 1 in late April and early May (Table 21). It was rarely found feeding in leafrolls. It was not common at sites 2 or 6.

Choristoneura rosaceana was the predominant species on on flower clusters at both sites 2 and 6 in late April and early May. Other species frequently found in flower clusters were *O. bruceata* and *C. curvalana*.

In early and late June none of the major species except *S. ocellana* appeared to feed predominantly in fruit clusters. At site 2 *C. rosaceana* continued to be the major species, while at site 6 it was less common than *A. rosanus* and *C. salicella*.

Spilonota ocellana feeds predominantly in flower and fruit clusters while the other major species seem to have no such preference. However, *O. bruceata* usually feeds in

Table 21 Comparison of the relative percentages of the 4 major species of leafroller feeding on leaves (L) and on flowers and fruit (F) of blueberry at 3 sites on 4 dates. *

DATE	SPECIES	SITE 1 L	SITE 1 F	SITE 2 L	SITE 2 F	SITE 6 L	SITE 6 F
April 28, 1981	C. rosaceana	-	-	52	48	14	67
	S. ocellana	-	100	4	-	-	-
	A. rosanus	-	-	-	-	-	-
	C. salicella	-	-	-	-	-	-
	other	-	-	44	52	86	33
May 4, 1981	C. rosaceana	84	3	81	85	24	37
	S. ocellana	3	97	-	3	-	30
	A. rosanus	-	-	-	-	14	4
	C. salicella	-	-	-	-	-	-
	other	13	-	19	12	62	29
June 1, 1981	C. rosaceana	41	46	64	78	16	21
	S. ocellana	3	27	-	3	-	3
	A. rosanus	37	8	9	9	53	36
	C. salicella	11	15	-	-	24	33
	other	8	4	27	10	7	7
June 29,	C. rosaceana	47	45	71	56	2	3
	S. ocellana	5	10	1	1	-	-
	A. rosanus	3	18	14	26	14	1
	C. salicella	40	25	10	17	81	93
	other	5	2	4	-	3	3

* Dash indicates this species not collected.

flower clusters in late March and early April (Chap. II).

Thus, it is apparent that the relative proportion of leafroller species in the leafroller complex varies between fields, and that control decisions and timing of sprays should consider which species predominate in an individual field.

3. <u>Effect of leafroller feeding on yields of fruit clusters.</u>

Clusters damaged by leafroller larvae had significantly lower projected yields on all dates at both sites than undamaged clusters (Table 22).

The means of numbers of flowers in damaged clusters that were corrected for flower loss and in undamaged clusters were not significantly different (t-test, $p=0.05$), so it can be said both damaged and undamaged clusters were from the same population.

The mean number of berries in both damaged and undamaged clusters at both sites decreased significantly between the first and last sampling dates (Table 22). The relative percent damage did not change dramatically after May 4, 1981 (Table 23). This result suggests that the damage by leafrollers to fruit clusters was done before that date, i.e. in April. After this date, the same or similar factors were acting on both damaged and undamaged clusters.

Table 22 Mean numbers of berries in undamaged and damaged blueberry clusters (Standard deviation, n) at 2 sites on 4 dates.*

DATE	SITE 2 **		SITE 6 **	
	UNDAMAGED	DAMAGED	UNDAMAGED	DAMAGED
April 20, 1981	9.3 a (2.15, 40)	7.4 a (2.04, 36)	-- ***	-- ***
May 4, 1981	7.9 b (1.83, 100)	4.6 b (2.64, 74)	8.0 a (1.92, 100)	4.2 a (2.64, 73)
June 1, 1981	8.5 c (2.16, 100)	3.6 c (2.30, 100)	5.6 b (1.80, 100)	2.0 b (1.77, 100)
June 29, 1981	5.0 d (2.17, 100)	2.5 d (1.87, 100)	3.5 c (1.67, 100)	1.7 b (1.41, 100)

* Numbers within columns followed by the same letter are not significantly different (Anova, $p < 0.01$; Fishers LSD, $p=0.05$).

** Numbers of berries in damaged and undamaged cluster significantly different at both sites on all dates (Anova, $p < 0.05$, Fishers LSD, $p=0.05$).

*** Dash indicates no measurements made.

Table 23 Percentage reductions of damaged over undamaged clusters at 2 sites on 4 dates, calculated from means in Table 22. ((undamaged-damaged)/undamaged)x100

DATE	SITE 2	SITE 6
April 20, 1981	20	-
May 4, 1981	42	48
June 1, 1981	58	64
June 29, 1981	50	51

At site 2 the difference between damaged and undamaged clusters changed very little, but the number of berries in both decreased steadily (Fig. 10), to reach 61% damage by June 29. At site 6 numbers of berries per cluster decreased in both damaged and undamaged clusters, but the undamaged clusters lost berries more quickly (Fig. 11). Consequently the percentage damage increased only marginally over time, and the end result by June 29 was that the yield of damaged clusters had been reduced to 58% of that of undamaged clusters.

A main difference between the two sites was that mummy berry, a fungus disease, caused losses at site 6 and not at site 2. In addition, the plants were of different varieties, Rancoccas at site 6 and Bluecrop at site 2.

There was no significant difference in the mean weights of ripe berries from fruit clusters of different sizes (Anova, $p=0.05$). Therefore, the reduction of cluster size by leafroller larvae was not compensated for by larger berries in clusters of smaller sizes.

It is concluded that leafrollers feeding in flower and fruit clusters reduced the yield of these clusters by about 60%.

Fig. 10 Regression of numbers of berries per cluster versus date for undamaged blueberry fruit clusters (line A, open circles) and leafroller-damaged blueberry fruit clusters (line B, closed circles) from site 2 in 1981 (Table 22). Fit of both lines significant (Anova $p<0.0001$). Slopes not significantly different and intercepts significantly different (t-test, $p=0.05$). Line A: $y=11.0-1.3x$, $r^2=0.25$, Line B: $y=8.0-1.4x$, $r^2=0.29$.

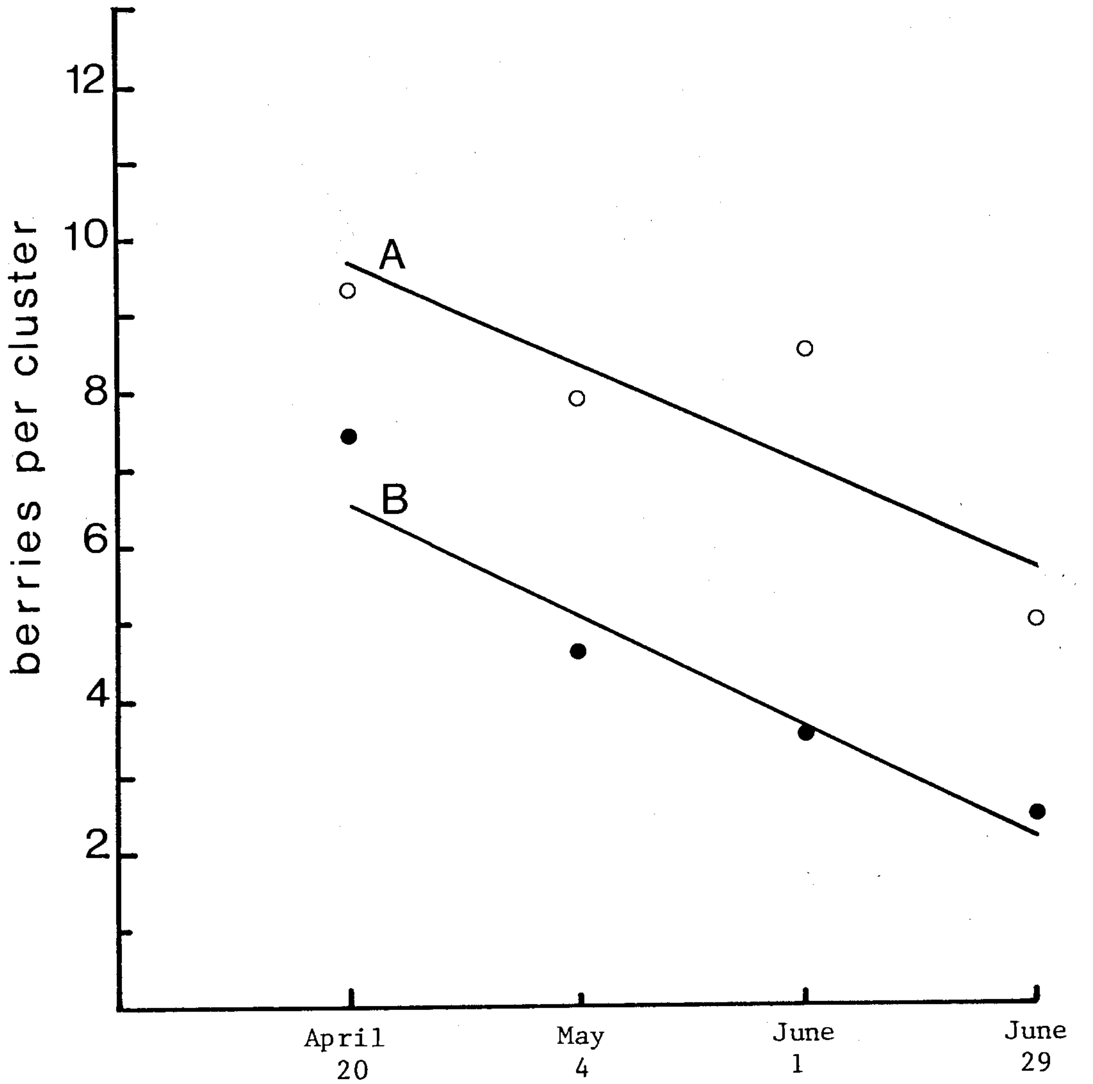
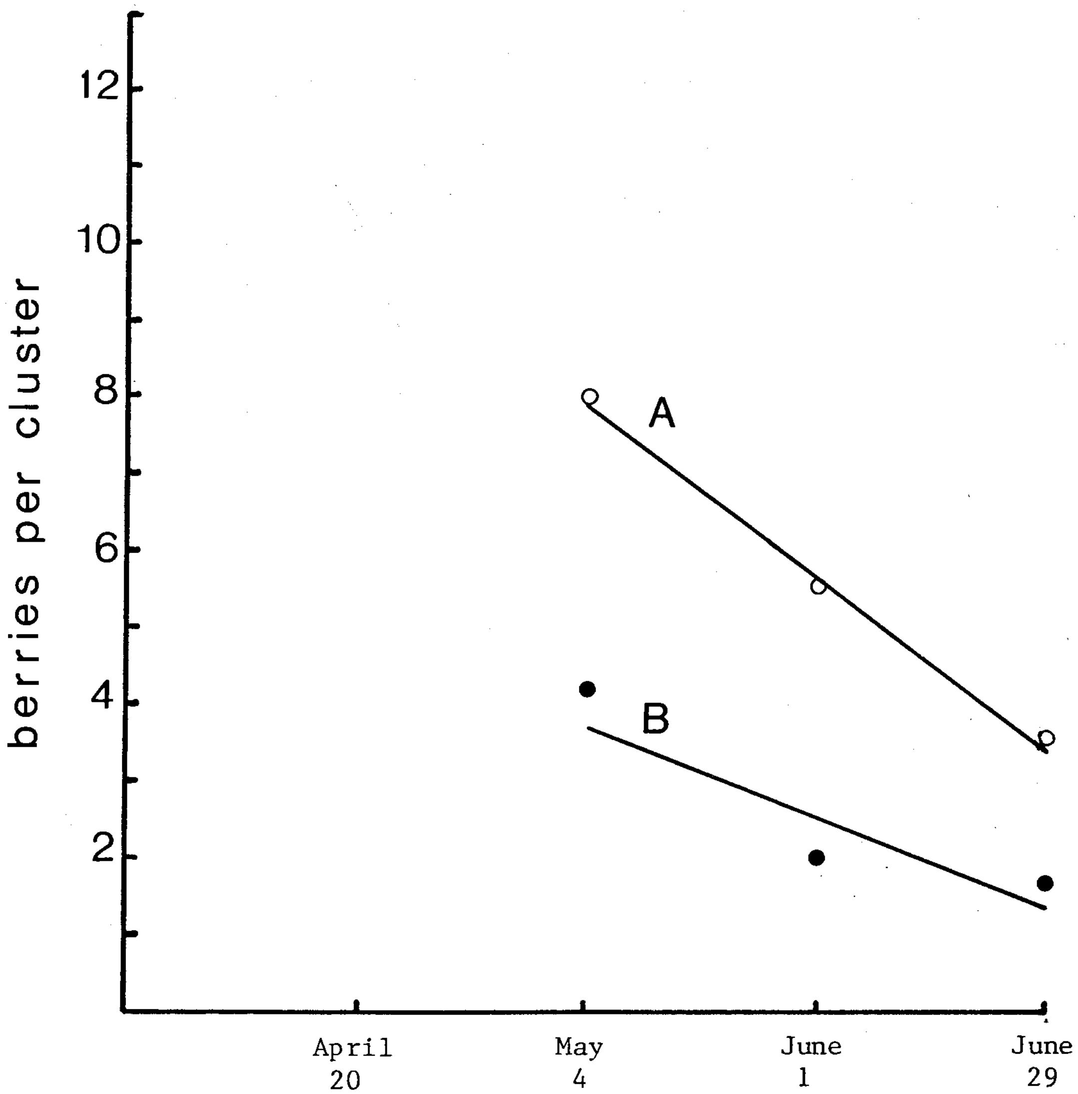

berries per cluster
12
10
8
6
4
2
A
B
April 20
May 4
June 1
June 29

Fig. 11 Regression of numbers of berries per cluster versus date for undamaged blueberry fruit clusters (line A, open circles) and leafroller-damaged blueberry fruit clusters (line B, closed circles) from site 6 in 1981 (Table 22). Fit of both lines significant (Anova $p<0.0001$). Slopes and intercepts significantly different (t-test, $p=0.01$). Line A: $y=12.4-2.2x$, $r^2=0.51$; Line B: $y=6.1-1.16x$, $r^2=0.18$.



berries per cluster
12
10
8
6
4
2
A
B
April 20
May 4
June 1
June 29

4. Rates of damage by leafroller larvae to fruit clusters.

The time when leafrollers damaged clusters was quite different at the three sites surveyed (Table 24). At sites 2 and 6 no damage had occurred by March 24, 1981. On April 1, 1981, damaged clusters were detected at all three sites, but at site 6 the rate of damage per 20 clusters was significantly higher than the others (LSD $p=0.05$). This was probably because an early feeder, *O. bruceata*, was present in fairly high numbers at site 6 but was less frequent at the other sites. Damage rates were consistently and significantly higher at sites 2 and 6 than at site 1 (LSD, $p=0.05$).

Because the damage remained visible on the plants for two or more months the rates of damage per 20 clusters are considered to be cumulative, i.e., the damage seen on date t+1 is the damage seen on date t plus an increment which occurred in the interim. Therefore, the highest mean damage for each site represents most realistically the proportion of fruit clusters damaged by leafrollers.

The estimates of the percentages of damaged fruit clusters at each site are: 5% at site 1, 14% at site 2 and 13% at site 6.

Table 24 Mean number of damaged fruit clusters per 20 fruit clusters (Standard deviation, n) in blueberry at sites 1, 2 and 6 on 5 dates. There was a site and a date effect (Anova, $p < 0.05$). *

DATE	SITE 1	SITE 2	SITE 6
March,24, 1981	--	0 (10)	0 (10)
April 1, 1981	0.05 (0.224, 20)	0.53 (1.717, 30)	2.05 (2.164, 20)
May 4, 1981	0.50 (0.679, 40)	1.38 (1.390, 40)	2.48 (1.987, 40)
June 1, 1981	0.93 (0.859, 40)	2.83 (2.417, 40)	2.53 (1.601, 40)
June 29, 19 1981	1.05 (1.131, 40)	2.73 (2.264, 40)	1.98 (1.527, 40)

*Dash indicates site not sampled.

Although only 1% of the clusters were occupied by leafrollers on April 28 at site 1 in 1980, sequential attack over time and movement of larvae to new clusters would account for the damage being greater than the infestation rate.

The reduction in number of berries per cluster caused by leafroller feeding was estimated to be about 60%. Theoretically then, leafrollers reduced the yield at site 1 by 3% and at sites 2 and 6 by 8%.

5. Comparison of yields of leafroller-infested and leafroller-free plants.

The mean numbers of clusters per plant on June 15 and July 20 were 52.4 (SD=49.76) and 55.5 (SD=48.19), respectively, for sprayed (leafroller free) plants, and 53.5 (SD=35.73) and 65.3 (SD=41.5), respectively, for unsprayed (leafroller-infested) plants. There were no significant differences between the means of sprayed and unsprayed plants (t-test, $p>0.05$). The standard deviations show there was considerable variability between the plants which would make it difficult to compare yields between the treatments.

Even three sprays with malathion, two before May 1 and one between May 11 and June 15, did not give total control. However, on both sample dates, the mean number of larvae per plant was significantly lower on sprayed than on unsprayed plants (Table 25) (Anova $p<0.05$, LSD=0.05). The mean number of larvae decreased between dates on sprayed plants but increased significantly on unsprayed plants (Anova, $p<0.05$, LSD, $p=0.01$).

On sprayed plants there was a mean of 4.4 berries per cluster on both June 22 and July 20, 1981, and on unsprayed plants a mean of 3.5 berries per cluster on June 22 and 3.3 on July 20. There was a significant difference between treatment means on both dates but not between dates for either treatment (Anova, $p=0.05$; LSD, $p=0.05$). The difference between treatments was about 20% on June 22 and about 26% on July 20.

Clusters on sprayed plots weighed an average of 3.3 g/cluster while clusters on unsprayed plants were significantly lighter (Anova, $p<0.05$) at 2.4 g/cluster. The 27% reduction in weight was due to a lower number of berries on unsprayed plants.

In the final analysis, plants infested by leafrollers had about a 25% lower expected yield than plants not infested by leafrollers.

This figure is considerably higher than the damage estimate for site 2, which was about 8 %. There are two possible explanations.

Table 25 Comparison of mean numbers of larvae per bush on sprayed and unsprayed blueberry plants at two sites on two dates (Standard deviation), n=10. *

	SPRAYED			UNSPRAYED		
DATE	BUD	LEAF	TOTAL	BUD	LEAF	TOTAL
May 11, 1981	0.5 (0.53)	1.4 (1.27)	1.8 (1.48)	3.5 (2.37)	8.7 (3.74)	12.2 (5.10)
June 15, 1981	0 (0)	0.9 (1.29)	0.9 (1.29)	6.1 (4.93)	14.7 (9.01)	20.8 (10.87)

* Anova, $p < 0.05$, means of sprayed and unsprayed plants significantly different on both dates; Anova, $p < 0.1$, means of each of sprayed and unsprayed are different on the two dates.

First, it is possible that the sprays controlled additional factors that may have been responsible for loss in yield, such as lecanium scale or root weevils. Neither of these, nor any other pest insect was observed on the plants.

Second, the small bushes with few clusters on them had proportionately higher numbers of larvae per cluster than larger bushes. The ratio of average number of larvae in clusters per bush to average number of clusters per bush was 0.1 larvae per cluster. This equates with 2.0 larvae per 20 clusters which is approximately equivalent to the number of damaged clusters per 20 clusters seen elsewhere in the field. Therefore the larvae that feed on more than one cluster would cause considerably more damage on smaller bushes than on larger bushes.

6. Impact of leafrollers on blueberry.

Recently, blueberry growers have been receiving about $1.10/kg for their crop from the Blueberry Growers Co-operative Association. Actual prices have varied from $1.00 to $1.20 per kg.

Yields of blueberries per hectare are quite variable between fields and from year to year. At site 1 in 1980 the field average was about 9 tonnes/ha, but a 0.4 ha plot of cv. Bluecrop produced at a rate of 20 t/ha. According to some growers, yields of 25 t/ha are possible. The grower at site 6 estimated a 7 t/ha yield in 1980 and claimed to average 11 t/ha in most years. No estimates were available for site 2 as the field was not picked thoroughly. A yield of about 10 t/ha seems to be typical for most fields.

At site 1 a 3% loss due to leafrollers amounts to about 270 kg/ha at a yield of 9 t/ha. At $1.10/kg the value lost is about $297.00/ha. Similarly at site 6, an 8% loss resulted in a value lost of about $616.00/ha at an expected yield of 7 t/ha.

On an average field yielding 10 t/ha, a 1 percent loss would cost $110.00/ha, a 3 percent loss about $330.00/ha and an 8 percent loss about $880.00/ha.

The point at which it becomes economic to control leafrollers in a field depends on four factors:

--1. The number of leafrollers in the field and the amount of damage they are doing. These parameters can be assessed by counting samples of 20 clusters each and multiplying the resulting percentage of damage by 0.6.

--2. The anticipated yield of the field. This can vary enormously from year to year depending on such factors as the previous years yield, fertilization, and, most importantly, weather and disease.

--3. The anticipated unit price received for the crop. Again, this varies from year to year.

--4. The cost of controlling leafrollers. An estimate was obtained from Crop Care Aviation Ltd., Abbotsford, B.C. which does much aerial-spraying of blueberry, as follows. Airplane at $29.00/ha and materials (malathion at $14.00/L and 2L/ha) at 28.00/ha would give a total cost to spray of $57.00/ha.

If two sprays are required to obtain economic control that cost is, of course, doubled.

It is apparent that leafroller larvae caused considerable economic damage at the three sites examined. At any of the sites the grower could have had insecticides applied by air and theoretically gained on the transaction. However, the treatment would be prophylactic, as there is no proven method of predicting damage at present.

Given an average field and one spray for total control 1, the tolerable damage is aboue 1% of the clusters damaged.

The logical extension of this is to provide a mechanism for *a priori* determination of the presence of economic levels of leafroller larvae. Possibilities include pheromone trapping systems (see Chap. VII) and counting of overwintering larvae or egg masses. Because the damage is caused by several species with different life histories and times of occurrence, a great deal of work will be required to correlate numbers of individuals with potential damage.

In conclusion two important points should be noted. First in 1980, site 1 had the highest population surveyed in that year. It is quite probable that there are many blueberry plantings in the lower Fraser Valley that do not have damaging leafroller populations. Second, when the information regarding percentage loss, costs, and thresholds was presented to the grower at site 1, and he was asked if he felt the possible gains in income would be worthwhile, his answer was "No".

CHAPTER IV. ALTERNATE HOSTS OF BLUEBERRY-FEEDING LEAFROLLERS IN THE LOWER FRASER VALLEY, B.C.

Many deciduous shrubs and trees are common in and around blueberry fields in the lower Fraser Valley. The most abundant of these are hardhack, *Spiraea douglasii* Hook.; western white birch, *Betula papyrifera communata* (Regel) Fern.; Himalayan blackberry, *Rubus discolor* Weihe and Nees; European blackberry *R. vestitus* Weihe and Nees; and various species of willow, *Salix* spp. The principal means by which these plants could affect populations of leafrollers on blueberry are: serving as resevoir hosts for species that attack the crop; and harbouring alternate hosts for parasites of leafrollers on the crop.

The objective was to determine if these alternate hosts could affect populations of leafrollers on blueberry in these ways.

MATERIALS AND METHODS

Collections were made at site 2 in Pitt Meadows (see site descriptions). Larvae were collected from blueberry, birch, and hardhack inside the field and from blackberry, willow and hardhack outside the field. Collections on blueberry were made 1 week before collections on the other hosts, which were on May 11, June 8 and July 6, 1981.

The relative abundance (as a percentage of the total) of individuals of leafroller species in the total leafroller population on each host plant was surveyed by collecting 5 samples of about 20 larvae each from each host plant. It was necessary to compare relative rather than absolute abundance because the host plants varied enormously in amount of foliage, form and distribution.

At site 2 hardhack often formed a continuous layer between rows of blueberry plants, and was very common outside the field. Birch amongst the blueberry grew as isolated trees 1 to 3 m tall. Blackberry grew in thickets outside the field. The closest willow trees, of 2 to 4 m in height, were about 100 m from the field.

Larvae were reared to disclose the identity of their parasites, rates of parasitism, and in some cases, for identification, as described in Chapter II.

Data collected were percentages of each species represented in each sample from each host, and percent parasitism. They were subjected to an arcsin-square-root transformation before being analyzed (Sokal and Rohlf 1969) by analysis of variance ($p=0.05$). Comparisons between means were made using Fisher's LSD ($p=0.05$).

RESULTS AND DISCUSSION

1. Alternate host plants.

Larvae of most leafroller species found feeding on blueberry (Chap. II, Table 8) were also found on all the other plants surveyed. Notable exceptions were *Croesia curvalana*, which was found only on cultivated blueberry, and *Spilonota ocellana*, which was found only on cultivated blueberry and, rarely, on blackberry. Except for those two species, the plants surveyed could serve as reservoir hosts of species that attack blueberry.

Only 4 of the species from blueberry occurred regularly at rates of 1 larva or more per 20 larvae in all samples. Of these, *Choristoneura rosaceana* was found most frequently (Table 26). It comprised more than 50% of the leafroller populations on most hosts on most dates.

Archips rosanus, Cheimophila salicella and *Badebecia urticana* were collected regularly. *A. rosanus* and *C. salicella* tended to be less frequently collected on birch than on other hosts. *A. rosanus* was less frequent on hardhack, particularly from outside the field than on other hosts. *C. salicella* tended to be more common on willow and hardhack than on other hosts.

Table 26 Mean percentages of 6 species feeding on 6 hosts on 3 dates at site 2 in 1981. n=5. '0' means "< 0.05%." *

SPECIES	DATE	HOST BLUE- ** BERRY	BIRCH	BLACK-BERRY	WILLOW	HARDHACK inside field	HARDHACK outside field
Choristoneura rosaceana	May 11	81 a	42 a	54 a	33 a	64 a	64 a
	June 8	66 a	48 a	66 a	41 a	50 a	56 a
	July 6	72 a	76 a	77 a	88 a	66 a	53 a
Archips rosanus	May 11	0 a	0 a	0 a	0 a	0 a	0 a
	June 8	7 a	'0' a	5 a	5 a	0 a	0 a
	July 6	11 c	0 ab	11 c	0 ab	4 bc	'0' ab
Cheimophila salicella	May 11	0 a	0 a	0 a	0 a	0 a	0 a
	June 8	0 a	1 ab	5 abc	11 bc	21 c	14 c
	July 6	7 a	2 a	1 a	11 a	16 a	3 a
Badebecia urticana	May 11	7 ab	8 bc	26 c	0 a	'0' ab	9 bc
	June 8	1 a	9 a	2 a	3 a	6 a	4 a
	July 6	0 a	1 ab	'0' ab	0 a	4 b	7 b
Acrobasis betulella	May 11	0 a	47 b	0 a	0 a	0 a	0 a
	June 8	0 a	24 b	0 a	0 a	0 a	0 a
	July 6	0 a	14 b	0 a	0 a	0 a	0 a
Olethreutes albiciliana	May 11	0 a	0 a	0 a	0 a	6 b	0 a
	June 8	0 a	0 a	1 a	0 a	17 c	4 b
	July 6	0 a	0 a	2 b	0 a	0 a	1 b

*For each species and date, numbers in the same row followed by the same letter are not significantly different (Anova, $p < 0.05$, Fishers LSD, $p=0.05$).

**For blueberry actual sample dates were May 4, June 1 and June 29, 1981.

Only two leafroller species not found on blueberry were collected on the alternate host plants (Table 26). *Acrobasis betulella* Hulst. (Lepidoptera: Pyralidae) was common on birch and was not collected from any other surveyed host. *Olethreutes albiciliana* Fern. (Lepidoptera: Tortricidae) was common on hardhack, particularly inside the field. Neither was parasitized by species that were reared from leafrollers on blueberry, so it is unlikely they would serve as alternate hosts for parasites of pest species.

2. Parasites.

Leafrollers on the resevoir host plants were parasitized by the same species that parastized them on blueberry (Chap. II). Only *C. rosaceana* was sufficiently frequent on all host plants for its rate of parasitism to be statistically compared between hosts. *Apophua simplicipes* was its predominant parasite. On July 6, parasitism of *C. rosaceana* by that species was significantly higher on blueberry, birch and hardhack inside the field than on blackberry, willow and hardhack outside the field (Table 27).

Because the blueberry, birch and hardhack were inside the field and the others were outside the field, it appears that the environment inside the field encourages parasitism. Larval populations appeared to be higher on the first three hosts than on the last three hosts. Female parasites would

Table 27 Mean percent parasitism of Choristoneura rosaceana by Apophua simplicipes on 6 plant hosts on July 6, 1981 at site 2, with 95% confidence intervals (CI). n=5.*

PLANT HOST	MEAN PERCENT PARASITISM	95% CI LOW	95% CI HIGH
Blueberry	20.1 a	15.04	27.16
Birch	31.8 a	22.68	41.61
Blackberry	5.2 b	0.22	23.74
Willow	5.8 b	3.63	8.38
Hardhack inside field	25.5 a	13.66	39.59
Hardhack outside field	5.1 b	0.46	14.17

* Means followed by the same letter are not significantly different (Anova, $p < 0.05$, Fishers LSD, $p=0.05$).

therefore find hosts more readily inside the field than outside, which would encourage them to remain inside the field.

It is concluded that other host plants could harbour parasites which would attack the same host species on blueberry, and that parasitism might be high in areas where larval density was high.

In summary, plants associated with blueberry harbour species of leafrollers that affect blueberry, and also harbour populations of their parasites. Whether the net effect would be beneficial or detrimental to the blueberry crop is unknown.

Leafrollers from these reservoir hosts could re-infest blueberry after controls had been applied, either by aerially dispersing larvae or by adults. It was shown previously that the majority of drift of first-instar larvae occurred within rather than into or out of a blueberry field, which might limit the importance of drifting larvae. Conversely, parasites of larvae on these reservoir hosts could supplement the within-field parasite population.

CHAPTER V. DIEL PATTERNS OF FEEDING ACTIVITY IN LARVAE OF *Choristoneura rosaceana*.

Diel patterns of activity, particularly those relating to feeding behavior of larvae, may be important in modifying control strategies against tortricid pests.

For example, pesticides might be applied just prior to the larvae's most active time. This practice would ensure maximum exposure of larvae to an insecticide.

The objective was to investigate the diel feeding activity of *Choristoneura rosaceana*, the most abundant species on blueberry and raspberry in south-western British Columbia.

MATERIALS AND METHODS

General

Larvae were placed individually in clear plastic petri dishes 100 mm in diameter and 25 mm deep with a single blueberry leaf in the bottom and a dampened filter paper in the lid. Each larva was given time to fix the leaf with silk to the bottom of the dish and situate itself between the plastic bottom and the leaf, thus simulating a leaf-roll. The dish was then inverted, and a clear plastic grid marked with 2.5 mm squares was fastened over the leaf and larva. The outline of the leaf and the area of leaf eaten by the larva were marked with a felt pen. The rate at which the leaf was eaten by the larva was measured by counting the squares over the consumed area.

1. Comparison of feeding rates in dark and light.

To see if larvae fed more in light or dark the feeding rate of mature larvae of *C. rosaceana* exposed to light was compared with that of those in the dark.

Eighteen larvae were placed in dishes as described above. After 12 h they were divided into 2 groups of 9 larvae each. One group was allowed to feed in the light for 3 h and then in the dark for 3 h, and the other was subjected to the opposite regieme. The amount of leaf eaten by each larva was measured after each 3 h period. Larvae that did all of their feeding in one of the two periods and those which did not feed at all were not considered in the analysis because these invariably moulted and would have biased the results.

To reduce the effect of variability in feeding rates between larvae, the area of leaf eaten by each larva in each 3 h period was converted to a proportion of the total area it ate during the 6 h experiment. The data were then subjected to an arcsin-square-root transformation (Sokal and Rohlf 1969), and analyzed by a paired t-test (p=0.05).

Two experiments were performed. The first was in uncontrolled conditions in the laboratory at temperatures of 22 to 23 C. Because it was possible that the movement of people in the laboratory may have influenced the behavior of these larvae in the light, the second experiment was in undisturbed conditions at a constant 20 C.

2. Diel patterns of feeding rates.

Rates of feeding by larvae of *C. rosaceana* were observed over 24 h. Thirty larvae were placed individually in dishes as described previously. After 2 to 4 h, those that had fixed leaves to the dishes were placed in an observation area that was open at the sides and covered with transluscent fibreglass. The consumption of leaf by these larvae and the air temperature was measured every 2 h over 24 h. Two sets of 20 larvae each were observed, the first on July 17 to 18, and the second on July 25 to 26, 1981.

Larvae that did not eat during the 24 h period and larvae that did all of their feeding in 3 or fewer 2 h periods were not considered in the analysis. The area of leaf eaten by each larva during each 2 h period was expressed as a proportion of total consumption. Proportions were averaged over each 2 h period and were graphed on a 24 h scale.

RESULTS AND DISCUSSION

1. Comparison of feeding rates in dark and light.

In the first experiment in uncontrolled conditions, larvae averaged 45% of their feeding in the light and 55% in the dark. In the second experiment in controlled conditions, 44% of the feeding occurred in the light, and 56% in the dark. In both experiments larvae fed significantly more in the dark than in the light (paired t-test, $p=0.05$). This result suggested that larvae of *C. rosaceana* are primarily nocturnal feeders.

2. Diel patterns of feeding rates.

Outdoors, *C. rosaceana* fed more during most 2 h periods in the daylight hours than in most 2 h periods at night (Fig. 12). Because it was possible that the time at which the experiment was started and ambient temperature may have affected larval feeding, the experiment was repeated with much the same results (Fig. 13).

These results are contrary to those of the laboratory experiments. One possible cause for this is temperature fluctuations over the 24 h periods (Figs. 12, 13). It is apparent that the feeding rate, and thus activity of the larvae decreased as temperature decreased during the night. Thus temperature fluctuations could have a greater effect on feeding than have light conditions. The other possible cause

Fig. 12 Average percent of total feeding done by individual larvae of Choristoneura rosaceana in 2 h intervals over a 24 h period while exposed to outdoor lighting (photoperiod) and ambient temperatures (C) on July 17-18, 1981. Arrow marks time experiment was started.

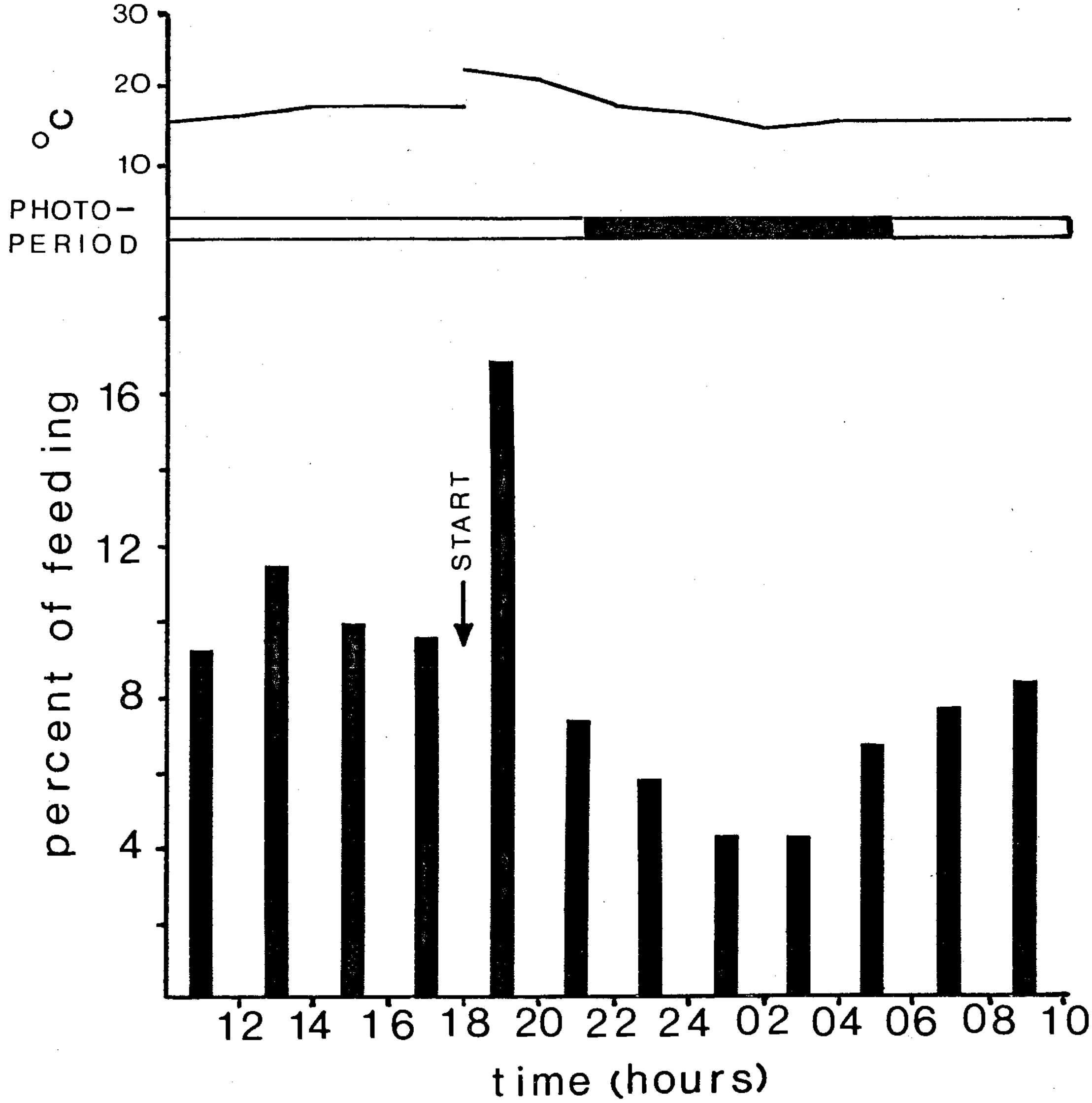
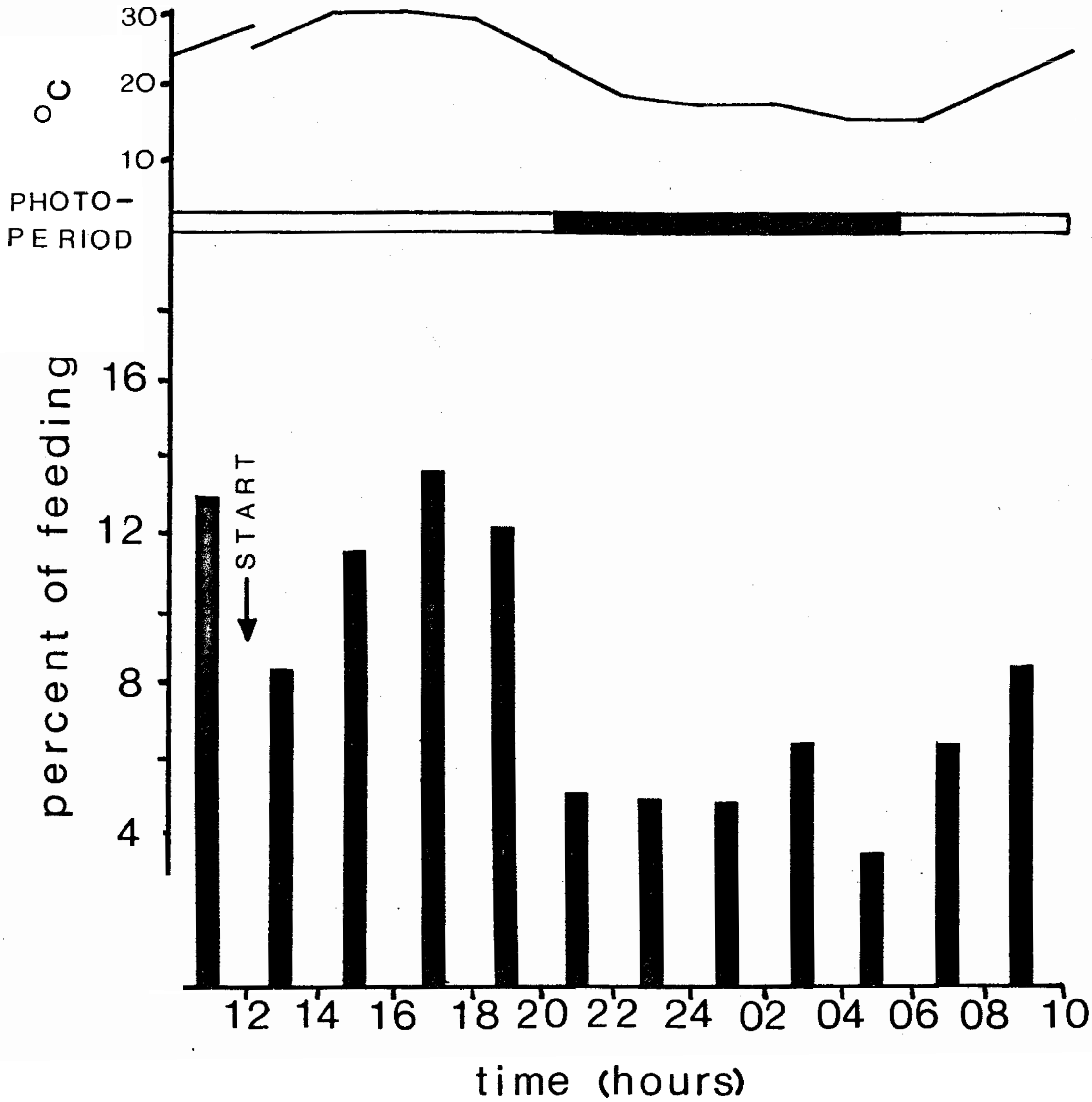

30
20
10
°C
PHOTO-
PERIOD
16
12
8
4
percent of feeding
START
12 14 16 18 20 22 24 02 04 06 08 10
time (hours)

Fig. 13 Average percent of total feeding done by individual larvae of *Choristoneura rosaceana* in 2 h intervals over a 24 h period while exposed to outdoor lighting (photoperiod) and ambient temperatures (C) on July 25-26, 1981. Arrow marks time experiment was started.



30
20
10
°C
PHOTO-
PERIOD
16
12
8
4
percent of feeding
START
12 14 16 18 20 22 24 02 04 06 08 10
time (hours)

is that the 3 h light/dark experiments, which were conducted during the day, interfered with a normal circadian rhythm, and that placing these larvae in darkened conditions induced abnormal behavior in them.

The more significant finding is that C. rosaceana larvae feed continuously during a 24 h period in contrast with other species of Lepidoptera, e.g. cutworms (Noctuidae), many of which are nocturnal feeders (Imms 1964) and spend much of the daylight period concealed and quiescent.

Continuous feeding could be an advantage to survival and development. For example, feeding during the normally warmer daylight hours could allow more rapid development by increasing the amount of food ingested in 24 h. By being active during the daylight hours, larvae could defend themselves actively against predators and parasites. One of the more obvious characteristics of tortricid larvae is their vigorous movement when disturbed.

The leafrolling habit might be connected with continuous feeding. A natural leafroll would produce muted lighting, and would provide some insulation against colder nighttime temperatures. The tendency to feed more in total darkness could compensate in part for the lower feeding rate apparently resulting from lower night temperatures.

On the basis of diel feeding patterns in *C. rosaceana* larvae, the time of application of insecticies against leafrollers is probably not an important factor, because larvae feed continuously.

CHAPTER VI. EFFECTS OF LARVAL POPULATION DENSITY ON MORTALITY, SIZE, AND DEVELOPMENT TIME OF Rhopobota naevana.

Larvae of the black-headed fireworm of cranberry, Rhopobota naevana, occurred at the highest populations density at site 2 in Pitt Meadows, B.C. Larval densities of 1 per 2 to 4 stems were common (Fig. 6), and the ratio of larvae to stems exceeded 1:1 in some samples. It seemed possible that these densities might be sufficiently high to have some intrinsic effects on the population.

Freshly hatched larvae of R. naevana were reared to adults at four different densities to investigate possible effects of crowding in the larval stage on population mortality, time to reach the adult stage, and adult size.

MATERIALS AND METHODS

Freshly-hatched, laboratory-reared larvae were used for all experiments.

Groups of 40 larvae were divided so that 10 larvae were reared as 1 larva per vial, 10 as 2 per vial, 10 as 5 per vial and 10 as 10 per vial. Each vial (45 mm in diameter and 70 mm deep) contained 10 shoots of fresh cranberry and a wet filter paper. Thus the highest experimental density of 1 larva per stem approximated the highest larval densities observed in the field. These were replicated 10 times. Five fresh cranberry stems were added to vials when most of the available foliage had been consumed.

The experiment was conducted in the laboratory in uncontrolled conditions of light and temperature. After day 13 of the experiment, vials were checked daily for emerged adults. Emerged adults were sexed, and their wing length from base to tip was measured as an indicator of size (Miller 1977). Day of emergence, sex and wing-length were recorded for each adult. Mortality was the proportion that failed to emerge at each density in each of 10 replicates. Data were analyzed by analysis of variance ($p=0.05$) and multiple comparisons made by Fisher's LSD ($p=0.05$). Proportional mortality data were subjected to an arcsin-square-root transformation prior to analysis (Sokal and Rohlf 1969).

RESULTS AND DISCUSSSION

Mortality was not significantly higher in crowded conditions than in uncrowded conditions (Table 28). Therefore, cannibalism did not occur to any significant extent over the range of densities examined. In addition, there was enough available food at the higher densities for all larvae to complete development.

There was no significant difference in sex ratios between the densities (Anova $p>0.05$), and the sex ratio was close to 1:1. Therefore, it appears that mortality factors

Table 28 Effects of density on <u>Rhopobota naevana</u>: mean mortality (n=10) with 95% confidence intervals (CI); mean winglength in males and females (standard deviation, n); and mean development time in males, females and both sexes combined (standard deviation). *

DENSITY	MORTALITY (%)**	LOW (CI)	HIGH (CI)	WING LENGTH (mm) MALES	WING LENGTH (mm) FEMALES	DEVELOPMENT TIME (DAYS) MALES	DEVELOPMENT TIME (DAYS) FEMALES	DEVELOPMENT TIME (DAYS) BOTH SEXES
1	10.7a	1.79	25.84	5.20a (0.354, 39)	5.58a (0.337, 46)	29.2a (2.02)	30.8a (2.73)	30.1a (2.54)
2	7.4a	0.40	22.04	5.21a (0.304, 48)	5.42b (0.274, 37)	27.8b (2.64)	30.0ab (2.41)	28.8b (2.75)
5	10.3a	3.57	19.82	5.17a (0.275, 47)	5.36bc (0.292, 41)	28.6ab (1.81)	29.6b (2.28)	29.0b (2.09)
10	15.3a	5.56	28.76	4.98b (0.338, 41)	5.26c (0.308, 40)	28.2b (2.23)	29.7ab (4.07)	29.0b (3.33)

*Mortality: Anova $p < 0.05$; wing length: Anova $p < 0.05$; development time: Anova $p < 0.05$; means in the same column followed by the same letter are not significantly different (Fishers LSD, p=0.05).

**Retransformed from arcsin square root of x.

operated on the sexes equally.

Males and females were significantly different from each other in adult wing length and in development time at all densities (Anova $p<0.05$; LSD $p=0.05$). However, there was no interaction between density and sex with respect to these two parameters (Anova $p>0.05$), demonstrating that density had more or less the same effects on males as on females.

For each sex, solitary larvae generally took longer to complete development than those in groups (Table 28). When the data from both sexes were combined and analyzed as a single set, it was apparent that solitary larvae took significantly longer to complete development than those in groups.

The forewings of females from larvae reared under solitary conditions were on average significantly longer than those of females from more crowded conditions (Table 28). In both sexes, the shortest average wing length occurred at the highest density.

Miller (1977) showed wing length to be a good predictor of body size in Tortricidae. In Lepidoptera generally a larger female body size is correlated with greater fecundity in many species (e.g. Podoler 1974, Norris 1933). Therefore, it is expected that females from the solitary larvae would produce on an average more eggs than those from crowded larvae.

These results agree with those from similar studies on effects of crowding on lepidopterous larvae. Development rate was speeded and pupal weight decreased by crowding in _Porthetria dispar_ (Leonard 1968), _Pieris brassicae_ and _Plusia gamma_ (Zaher and Long 1959), and in several species of Lepidoptera (Long 1953). Zaher and Long (1959) showed that crowding of larvae reduced fecundity in adults of _P. brassicae_.

As the highest experimental densities used here approximated those in the field, it is quite likely that crowding was having some effects on the populations in the cranberry field at site 2.

CHAPTER VII. DETERMINATION OF THE SEX PHEROMONE OF *Cheimophila salicella*.[1]

Female produced sex pheromones are available for 3 of the 4 major leafrolling species on blueberry, namely *C. rosaceana* (Roelofs and Tette 1970), *A. rosanus* (Roelofs *et al.* 1976), and *S. ocellana* (Arn *et al.* 1974). The identification of the sex pheromone of the fourth, *C. salicella*, would therefore mean that the abundance or timing of emergence of all 4 species could be surveyed using pheromone traps.

The objective was to identify and field-test the female-produced sex pheromone of *C. salicella*.

MATERIALS AND METHODS

In March 1980, 10 traps were baited with virgin *C. salicella* females and suspended from blueberry bushes at site 3 in Pitt Meadows.

Larvae were collected in July and August, 1980, from blueberry in Pitt meadows and Richmond, B.C. and reared to pupation on fresh blueberry foliage. Pupae were overwintered outside at ambient temperatures. Larvae and adults were identified using characteristics given by Raine (1966) and

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[1] In collaboration with K.N. Slessor, V.A. Salas-Reyes and G.G.S. King, Chemistry Department, Simon Fraser University, Burnaby, B.C. who did all gas chromatographic analysis and chemical synthesis.

Hodges (1974).

Laboratory analysis

A small number of females emerged from overwintered pupae in mid-March, 1981. In the early morning, females were taken to the laboratory and placed in individual petri dishes containing a clean white filter paper dampened with distilled water. Within 1 h of exposure to light and warmth in the laboratory, the females began calling by extending their ovipositors and rhythmically moving their abdomens.

After 1-2 h of this behavior, a single female was selected and her last abdominal segment and ovipositor excised. Washing the abdominal tip with redistilled spectral analyzed heptane (3 uL in a pointed vial) (Klun *et al*. 1979) yielded an etract which was chromatographed on a Hewlett-Packard 5880A splitless capillary vapour phase chromatograph. A 25 m, 0.2 mm O.D. flexible fused silica capillary column coated with polar Carbowax 20 M as the stationary phase, and a flame ionization detector were employed. A similar column coated with nonpolar methyl silicone was used in an identical manner to facilitate pheromone identification.

General field methods

Bait mixtures were placed inside rubber septa (Arthur H. Thomas, No. 8753-D22) mounted on insect pins. These were placed inside traps which were either 2 L milk cartons open at the ends and coated inside with Stickem Special, or 15 x 30 cm cards coated with Stickem Special, folded in thirds, and fastened to provide a triangular tube 10 cm on a side and 15 cm long. Traps were suspended from blueberry bushes 0.6 to 0.9 m above the ground. Trapping was done at site 2 from March 21 to March 28, 1981.

Test for attractancy of Z-10 and E-11 isomers of Tetradecenyl-1-O-acetate

Z-10-Tetradecenyl-1-*O*-acetate and *E*-11-tetradecenyl-1-*O*-acetate were field tested to determine which was biologically attractive to males of *C. salicella*. Triangular traps containing 100 ug of compound or an empty septum were dispersed in a 10 replicate, randomized block experiment. There were about 9 m between blocks and 15 m between traps within blocks. Traps were set out on March 26, 1981 and the catch counted on March 28, 1981.

Activity of secondary pheromone components

The attractance of the potential secondary components of the pheromone, which were identified by laboratory analysis, were also field tested. Trap baits were 100 ug of *E*-11-tetradecenyl-1-*O*-acetate or alcohol; 100 ug of *E*-11-tetradecenyl-1-*O*-acetate and 5 ug of *E*-11-tetradecen-1-ol; 100 ug of

E-11-tetradecenyl-1-O-acetate and 5 ug of alcohol and 5 ug of tetradecanyl-1-O-acetate; or blank. These were placed in milk carton traps dispersed in a 5 X 5 Latin square design with about 18 m between rows and 30 m between columns. Traps were set out on March 21, 1981 and the catch counted on March 23, 1981.

Effect of stimulus concentration

The ternary mixture in the previous experiment was tested at a ratio of 20:1:1, with concentrations of E-11-tetradecenyl-1-O-acetate at 0 (blank), 10, 100 and 1000 ug. The effect of tetradecanyl-1-O-acetate was also checked at 100 ug by eliminating it from a set of traps. Triangular traps were dispersed in a 10 replicate randomized block experiment on March 26, 1981. There were about 15 m between traps and blocks. The catch was counted on March 28, 1981.

Data analysis

Variances in all experiments were significantly heterogenic (Bartlett's and Hartley's tests, p=0.05), and the data were in the form of counts with some 0's. Therefore a square root plus 0.5 transformation was applied to all counts (Sokal and Rohlf 1969), correcting heterogeneity of variance. Transformed data were subjected to analysis of variance. Multiple comparisons between treatment means were made using Fisher's LSD (p=0.05).

RESULTS AND DISCUSSION

Traps baited with virgin *C. salicella* females caught an average of 18 males per trap from March 18-31, 1980, which suggested the presence of a female produced sex pheromone.

Laboratory analysis

Three separate experiments with single calling females disclosed 3 components in the splitless gc of the heptane extract. Retention characteristics on the polar column indicated a tetradecanyl-1-*O*-acetate, and a tetradecenyl-1-*O*-acetate and alcohol. Retention times (Table 29) suggested the unsaturation to be the same in acetate and alcohol, and indicated either *Z*-10 or *E*-11. These components were seen in extracts from 3 calling females with amounts varying slightly, and were not seen in extracts from non-calling females.

On the non-polar methyl silicone column, extracts from 2 further females were chromatographed in a splitless mode. Three peaks were seen corresponding to tetradecen-1-ol, the corresponding acetate, and tetradecanyl-1-*O*-acetate. Retention characteristics (Table 29) favoured *E*-11 over *Z*-11 but no choice could be made.

Table 29 Retention characteristics of *Cheimophila salicella* female pheromone components and selected standards.

	TIME* (min)	AMOUNT PRESENT (ng)	TIME** (min)	AMOUNT PRESENT (ng)
C_{14}OAc Component A	10.36	1-2	12.24	1-2
E-11 C_{14}OAc Component B	11.48	6-18	12.12	7-9
E-11 C_{14}ol Component C	13.89	1/2-1	10.34	0-1/2
Z-9 C_{14}OAc	11.16	-	-	-
Z-10 C_{14}OAc	11.46	-	12.10	-
Z-11 C_{14}OAc	11.76	-	-	-
E-10 C_{14}OAc	11.14	-	-	-
E-11 C_{14}OAc	11.46	-	12.12	-
E-12 C_{14}OAc	12.18	--	-	-
E-11 C_{14}ol	13.89	-	10.32	-
C_{14}OAc	10.36	-	12.25	-
E-10 C_{14}ol	13.91	-	10.28	-

* Carbowax 20 M, He carrier, 25 m, 0.2 mm OD splitless mode at 100°, after 2 min, 30°/min to 140°, 1.5°/min to 170°.

** Methyl silicone, He carrier, 25 m, 0.2 m OD splitless mode at 80°, after 2 min, 15°/min to 180°.

Test for attractancy of Z-10 and E-11 isomers of tetradecenyl-1-O-acetate.

The E-11 isomer of tetradecenyl-1-O-acetate was biologically active and the Z-10 isomer was not (Table 30).

Activity of secondary pheromone components

Traps containing all 3 components in a 20:1:1 ratio caught significantly more males per trap than the E-11-tetradecenyl-1-O-acetate alone (Table 31). Traps containing the E-11 acetate and alcohol mixture were intermediate in performance. The E-11 alcohol was not attractive by itself. The catch in traps baited with binary and ternary mixtures did not differ significantly.

Effect of stimulus concentration

Increasing concentration of pheromone inversely affected catch of males in traps over the ranges examined (Table 32). Traps at the 1000 ug level for the E-11 acetate caught significantly fewer males than traps at the 10 and 100 ug levels. The highest concentration appears to lower the response of C. salicella males.

Table 30 Comparison in field traps of *E*-11-tetradecenyl-1-*O*-acetate and *Z*-10-tetradecenyl-1-*O*-acetate as attractants for male *Cheimophila salicella*. Experiment run 26-28, March, 1981; n=10.*

TRAP BAIT (ug)	Males/Trap
E-11-C_{14}-1-*O*-Ac (100)	2.1a
Z-10-C_{14}-1-*O*-Ac (100)	0 b
Control (Blank)	0.1b

*Numbers followed by the same letter are not significantly different (Anova, $p < 0.05$, Fishers LSD, $p=0.05$).

Table 31 Comparison in field traps of pheromone components alone and in combination as attractants for male *Cheimophila salicella*. Experiments run 21-23 March, 1981; n=5.*

TRAP BAIT (ug)	Males/Trap
E-11-C_{14}-1-*O*-Ac (100), *E*-11-C_{14}-1-ol (5), C_{14}-1-*O*-Ac (5)	11.8a
E-11-C_{14}-1-*O*-Ac (100), *E*-11-C_{14}-1-ol (5)	9.3ab
E-11-C_{14}-1-*O*-Ac (100)	4.1b
E-11-C_{14}-1-ol	0 c
Control (Blank)	0 c

*Numbers followed by the same letter are not significantly different (Anova, $p < 0.05$, Fishers LSD, $p=0.05$).

Table 32 Effect in field experiments of stimulus concentration on catch of male *Cheimophila salicella*, and retest of effect of tetradecanyl-1-*O*-acetate on catch. Experiment 26-28 March, 1981; n=10.*

TRAP BAIT (ug)	Males/Trap
E-11-C_{14}-*O*-Ac (10), *E*-11-C_{14}-1-ol (0.5), C_{14}-1-*O*-Ac (0.5)	9.3a
E-11-C_{14}-1-*O*-Ac (100), *E*-11-C_{14}-1-ol (5), C_{14}-1-*O*-Ac (5)	8.4a
E-11-C_{14}-1-*O*-Ac (100), *E*-11-C_{14}-1-ol (5)	6.2ab
E-11-C_{14}-1-*O*-Ac (1000), *E*-11-C_{14}-1-ol (50), C_{14}-1-*O*-Ac (5)	3.5b
Control (Blank)	

*Numbers followed by the same letter are not significantly different (Anova, $p < 0.05$, Fishers LSD, $p = 0.05$).

Concluding discussion

The sex pheromone of *C. salicella* approximates therefore, a 20:1:1 mixture of *E*-11-tetradecenyl-1-*O*-acetate: *E*-11-tetradecen-1-ol: tetradecanyl-1-*O*-acetate. Attraction of males of a species of *Cheimophila* to traps baited with E-11-tetradecenyl-1-*O*-acetate has been previously reported (Ando *et al*. 1977). This is the first report of the pheromone complex of a member of the family Oecophoridae.

This pheromone can be used to detect the spread of *C. salicella* populations, and to disclose introductions of this pest into other blueberry growing areas of North America.

As a component of a pest management program in blueberry, it could be used to monitor population trends of *C. salicella* as suggested for the gypsy moth (Elkinton and Carde 1981). However, there are major problems with the use of pheromone traps for monitoring population levels, especially in interpreting trap catches and correlating them with field populations and damage levels (Vick *et al*. 1981). In apple orchards pheromone trap catches of leafroller adults correlate not at all, or only at high larval densities, with populations of larvae (e.g. Madsen and Madsen 1980; MacLellan 1978). Thus the sex pheromone of *C. salicella* will probably not be of immediate significance to pest management of blueberry pests.

Sex pheromone traps for the 4 major species on blueberry could be used to identify leafroller species in the fields, and to help indicate when the moths are active, which might be useful in timing control measures as suggested by Madsen and Madsen (1980) for leafrollers in Okanagan apple orchards. Because the leafroller population complex varies between blueberry fields, sex pheromones might be useful for detecting differences in species composition.

CHAPTER VIII. SUMMARY AND CONCLUSIONS

Surveys showed leafrollers to be abundant in commercial blueberry fields. Average numbers of larvae in 1980 ranged from 0 to 23.3 per plant and decreased in most fields as the season progressed. Populations were lowest in fields that were sprayed in the current season, intermediate in those that had been sprayed one or two seasons previously, and highest in fields that had not been sprayed for at least 5 years. Insecticide applications control leafrollers, and appear to keep population numbers low for at least 1 or 2 years afterwards.

Pruning practices appeared to have an effect on leafroller numbers because the highest populations were in fields that were not pruned, or were pruned incorrectly to retain old wood. Many leafroller species either form hibernaculae or lay eggs on older wood, so removal of this wood could decrease the population.

Larvae of 14 species of Tortricidae, 1 of Geometridae and 1 of Oecophoridae were found inhabiting leafrolls and blossom clusters on blueberry. Seven of these species are introduced, two of them apparently recently.

The majority of leafroller larvae on blueberry were of *Choristoneura rosaceana*, *Spilonota ocellana*, *Archips rosanus* and *Cheimophila salicella*. Larvae of *Pandemis cerasana*, Badebecia urticana, Operophtera bruceata and Croesia curvalana were common.

Parasitism of larvae of the four major species ranged from almost nil for A. rosanus and C. salicella, to 18 to 33% for C. rosaceana, and to about 23% for S. ocellana. Numbers of larvae of other species were too low for percent parasitism to be estimated. Depending on what other sources of mortality occur in the populations, parasites might be important in regulating numbers of C. rosaceana and S. ocellana.

S. ocellana and O. bruceata feed preferentially in flower clusters so they are potentially the most economically damaging species. Other species feed somewhat more frequently on leaves than on flower clusters, but can still be important where numbers are high.

Surveys with traps showed two periods of larval dispersal in blueberry fields. The first occurred in late April and early May when A. rosanus and C. salicella hatched. The second occurred in late July and early August when C. rosaceana and P. cerasana hatched. There was a very early period of larval dispersal in early March when O. bruceata hatched, but the traps were not set out sufficiently early to detect this.

The greater part of the larval drift occurred within the field, which could limit the threat of immediate re-infestation of a field by larvae drifting from adjoining fields or from nearby alternate host plants.

Leafrollers have their greatest impact on blueberry yields by feeding on berry clusters. On the basis of the life history and dispersal of the larvae, 2 to 3 sprays would be necessary to control all species of leafrollers: one in late March for early feeding species such as O. bruceata; one in mid-April for intermediate species such as C. rosaceana; and one in mid-May for late species such as A. rosanus and C. salicella.

More larvae fed in blossom clusters than in leafrolls on blueberry in April and May. Spilonota ocellana was the predominant blossom-feeding larva at one site, while O. bruceata then C. rosaceana were the most abundant at others. At one site it was estimated that larvae were present in about 1% of the clusters in April, 1980. These numbers appeared to be sufficient to cause economic damaage.

Leafrollers caused significant damage to clusters in which they fed. The yield of these damaged clusters was reduced by about 60%, and it appeared that the majority of the damage was done early in the spring.

The percentages of clusters damaged by leafrollers were 5, 13 and 14% at the three fields studied. These fields supported the highest leafroller populations seen in this study, so the figures probably represent the upper extemes of damage.

Combining the data on loss of berries in a cluster with percentages of clusters damaged, losses of yield for these fields range from 3 to 8%.

Spraying with malathion to control leafrollers on 10 plants raised their estimated production by about 25% over 10 unsprayed plants. It appeared that either some unexpected beneficial effects would be derived from controlling leafrollers on blueberry, or more likely, that these plants, which were much smaller than normal, had a proportionately higher leafroller population than the larger plants elsewhere in the field.

Costs of controlling leafrollers by aerial application of malathion are such that any of the three fields could have been treated economically. Based on a cost of $57.00/ha to spray, a yield of 10 t/ha, and a crop value of $1.10/kg, the economic injury level is about 1% of clusters. Changes in the cost of application, the numbers of required applications, the yield and the crop value will affect the economic injury level accordingly. Because the survey techniques that were used to assess the damage were on an *a posteriori* basis, they are insufficient for predicting the need for controls. Further research will be required to establish *a priori* estimates of damage. Before it can be stated with certainty that pest management is feasible or even necessary for leafrollers on blueberry it is also necessary to find the characteristic levels of damage. Leafrollers were apparently the only pests of blueberry present that reduced yields by feeding on the fruit, so they will be the key pests in any prospective pest management program.

Larvae of most of the major leafroller species that feed on blueberry were present at about the same relative frequencies on birch, blackberry, willow, and hardhack in the vicinity of blueberry fields. Leafrollers on these alternate hosts could re-infest blueberry fields through aerial drift of first-instar larvae and through adult flight. However, as noted previously, the drift of first-instars may be of limited significance. Surveys showed that these alternate host plants do not harbour leafroller species that are alternate hosts of parasites of leafrollers that feed on blueberry.

The parasite complex of the blueberry-feeding leafrollers is essentially the same on their alternate hosts. An exception was *Apophua simplicipes* which parasitized a higher percentage of *C. rosaceana* larvae inside the field than outside. This could have been because the numbers of larvae on plants inside the field were higher than on plants outside.

Larvae of *C. rosaceana* feed continuously over 24 h but under normal conditions of light and temperature feed more actively during the day than at night. Because *C. rosaceana* larvae are continuously active, the time of day at which controls are applied is probably not important.

The female produced sex-pheromone of *C. salicella*, identified as a mixture of *E*-11-tetradecenyl-1-*O*-acetate: *E*-11-tetradecen-1-ol: tetradecanyl-1-*O*-acetate in a 20:1:1 ratio, offers some potential for monitoring emergence times and spread of that species.

The only major leafroller species on cranberry was the introduced black-headed fireworm, *Rhopobota naevana*, a well-known pest of cranberry. It was the only species of leafroller found in commercial bogs where it was at low numbers because of insecticides applied against it. It was extremely common in abandoned and unsprayed bogs where small numbers of other species were also found. In the absence of controls *R. naevana* populations can reach very high levels and could destroy a cranberry planting in a very short time. Parasitism of *R. naevana* was extremely low.

Larvae of *R. naevana* did not disperse by aerial drifting. Larvae of *Aphelia alleniana* originating from eggs masses on *Ledum* sp. were noted drifting in cranberry fields, but their occurrence on cranberry is incidental. The yellow-headed fireworm, *Acleris minuta*, was not found on cranberry although it is native to south-western British Columbia and is a pest of cranberry in eastern North America (Wood 1975; Franklin 1948).

High larval densities in laboratory rearing conditions shortened development time and decreased adult size of *R. naevana*. The reduced adult size would also decrease fecundity of females. Increased larval density did not increase mortality of larvae. Densities at which these effects were observed were so high that they would only occur in extremely high natural populations such as those in unsprayed bogs.

On cranberry *R. naevana* is the major pest. It is controlled by regular applications of insecticides. It should be possible to set economic thresholds for this species and to provide the growers with a way of predicting when controls need be applied.

Leafrollers in commercial raspberry fields are controlled by applications of insecticides against other pest species. The most abundant species in an unsprayed field were *C. rosaceana* and *Acleris comariana*. *O. bruceata* was common in March and April in both sprayed and unsprayed fields. Seven leafroller species were found feeding on raspberry of which *A. rosanus* and *A. comariana*, were introduced. *Choristoneura rosaceana* on raspberry is at least partially bivoltine, while on all other host plants surveyed it was univoltine.

Too few larvae were caught drifting to reach any conclusions about periods of hatch and dispersal of larvae of leafrollers on raspberry. The low numbers of larvae caught reflect the generally low leafroller populations on that crop.

On raspberry *O. bruceata* completes feeding before insecticides are applied for other species, so it could be an important pest species if its numbers are high. Historically, the most important leafroller on raspberry is *C. rosaceana*. Its second generation larvae enter the fruit cup, and remain in the berry at harvest, lowering fruit quality (Schuh and Mote 1948). *Acleris comariana*, a recently introduced species whose normal host is strawberry, is reported here for the first time on raspberry. Its potential as a pest of raspberry in unknown. Provided growers continue to use insecticides to control other pests, leafrollers are not likely to be important on raspberry with the possible exception of *O. bruceata*.

As on raspberry, leafrollers in commercial strawberry fields are controlled by insecticides applied against other species. Larval populations in an unsprayed field reached a peak of 28 per m of row. The predominant species there was

A. comariana. Even at that high density, few larvae were observed feeding on fruit and there was no apparent effect on yield. About 68% of the larvae were parasitized, mainly by *Copidosoma* sp. Parasites of *A. comariana* could well regulate its populations, although strawberry fields are normally plowed under after 2 to 4 years which might not be sufficiently long for the host-parasite system to stabilize.

Larval population densities differed between different areas of a strawberry field. These differences could be correlated with relative proximity to wild vegetation. The edges of the field generally had higher populations than the centre, and the edge with the highest population was next to an area of mixed deciduous forest. Rates of parasitism did not vary significantly between the areas of the field. Thus parasites appeared to respond to increased densities of the host.

If growers continue to use insecticides to control pests, the present leafroller species will likely not be pests of strawberry culture.

Thus, the hypothesis set at the beginning that leafrollers could be of economic importance to berry crops has some validity in relation to those crops in the Lower Fraser Valley, B.C. An economic effect of leafrollers on blueberry yields has been demonstrated. Similarly, *R. naevana* can devastate cranberry fields if left uncontrolled, although this does not normally occur because of regular insecticide applications against it.

Leafrollers would become management targets on raspberry and strawberry only if insecticide applications against pest species are reduced by pest management.

Three of the 4 most abundant species on blueberry are introduced, and a total of 7 introduced species of leafroller were found feeding on blueberry. Two of these, *Pandemis cerasana* and *P. heparana*, have been introduced recently, i.e. probably sometime in the last 20 years.

Rhopobota naevana was the only important species found feeding on cranberry. It is introduced, but not recently. Other species of leafroller were found in low numbers and only in unsprayed sites. Of the 8 lepidopterous leafrollers on raspberry *A. comariana* and *A. rosanus* are introduced, the former recently so.

Of the 4 tortricid species collected from strawberry only the common *A. comariana* is introduced; the others are native. One introduced species, *Cnephasia longana*, previously reported (Cram and Tonks 1959) damaging strawberry in the Lower Fraser Valley was not collected.

The hypothesis that the leafroller fauna on berry crops has been enhanced by recently-introduced species not hitherto reported causing them harm is only partly proven.

Ten of the 16 species found on blueberry had not been previously reported damaging that crop, but of the 10, only 2, P. cerasana and P. heparana, are recently introduced and these were not numerous enough.

No previously unreported leafroller species were found causing economic harm in cranberry fields.

The recently-introduced A. comariana (Cram 1973), was reported on raspberry for the first time. It was previously reported damaging strawberry (Cram 1973), but was not numerous enough on raspberry to cause harm.

No previously unreported introduced species were found feeding on strawberry.

It is difficult to tell if there have been any interactions between native and introduced species because there have been no previous surveys of Tortricidae on berry crops in the Lower Fraser Valley, B.C. Whether the absence of previously reported species on strawberry reflects consequences of interactions between species, natural fluctuations in abundance, or a decrease in abundance due to increased spraying of insecticides for other pests is not known.

Powell (1964) noted that larvae of Clepsis forbesi became abundant on apple in the presence of high larval densities of S. ocellana by utilizing the rolls of that species as shelters. In this study first-instar larvae of the native *C. rosaceana* on blueberry were frequently found feeding in deserted leafrolls of the introduced *C. salicella*. Similarly, first-instar larvae of the native *A. alleniana* were commonly found feeding in deserted rolls of the introduced *A. comariana*.

There were few indications of sharing of parasites between native and introduced species. A *Meteorus* sp. and a *Microgaster* sp. (Hymenoptera: Braconidae) parasitized several native and introduced species on blueberry and strawberry. Because the specific identities, native origins, and preferred hosts of those parasites are not known, it is not clear if these are native species attacking new and introduced hosts or introduced species attacking new and native hosts.

On the basis of the conclusions of this study it is reccmmended that:

1. leafroller populations on and the damage they cause to blueberry be assessed throughout the lower Fraser Valley so that a decision can be made as to the practicability of a pest management system for leafrcllers on blueberry;
2. regular surveys of leafroller species feeding on berry crops should be conducted to detect changes in the abundance of species and the introduction of additional species;
3. insecticide sprays against leafrollers on blueberry be

applied early in the season, as this is when the damage occurs and be timed to coincide with the presence of the important species in any individual field; and

4. research leading to the pest management of *R. naevana* on cranberry be initiated.

APPENDIX A. PRECISE LOCATIONS OF RESEARCH SITES

In order that farms and locations used in this research may be relocated by others the following lists the sites by numbers used in the text, and gives, where possible, legal descriptions and/or street locations of the sites used.

Site 1. 20066 McNeil Rd. Pitt Meadows, B.C. Lot 1 of Section 23, Tnshp. 10, range 11, Plan #2112 Tnshp 10 range 11 Tp 4 Pl.

Site 2. 17989 Ford Rd. Pitt Meadows, B.C.

Site 3. Menten Ave., Pitt Meadows, B.C. North Half of the southeast quarter of Section 13, Tnshp 40 ECM, and south half of the northeast quarter of Section 13, Tnshp 40 ECM.

Site 4. 2611 No. 7 Rd, Richond, B.C.

Site 5. 7451 Sideaway Rd., Richmond, B.C. Lot 19-18-4-5-31600.

Site 6. Between Jacombs and Knight St. and Gilley Ave and Westminster Hwy., Richmond, B.C. Acess from south end of Jacombs Rd. For more precise location contact site 9.

Site 7. Francis Rd. Allowance, 6.5 Rd. 0.25 mi east #6 Rd., Richmond, B.C., Lot #1-21-4-5-3400.

Site 8. Lots 22 to 26 of district lot 155b, group 1 plan 1248 NWD.

Site 9. 2611 No. 7 Rd., Richmond, B.C.

Site 10. 5451 No. 7 Rd., Richmond, B.C.

Site 11. 24382- 70 Ave. RR. 6 Langley, B.C. Plan 58912 Section 15, northwest quarter Tnshp 11, ECM.

Site 12. 4921 240 St. RR. 7, Langley, B.C.

Site 13. 31790 Walmsley Rd., Abbotsford, B.C.

3894-53-Airport lease 93454.

APPENDIX B. CLASSIFICATION AND COMMON NAMES OF LEPIDOPTEROUS LEAFROLLERS ON BERRY CROPS.

To aid readers unfamilar with the names and classification of Lepidoptera, the species of importance to berry crops which are discussed in the thesis are listed below according to family, genus and species. Approved common names are included where available. The classification of Tortricidae follows that of Chapman and Lienk (1971), Freeman (1958), Powell (1964), and others, who treat the olethreutids (Olethreutinae) and tortricids (s.s.) (Tortricinae) as subfamilies of the Tortricidae. Species asterisked are those reared from berry crops in this study.

GEOMETRIDAE

*<u>Operophtera bruceata</u> (Hulst), the Bruce spanworm.

OECOPHORIDAE

*<u>Cheimophila salicella</u> (Hbn.)

PYRALIDAE

*<u>Herpetogramma pertextalis</u> (Led.)

TORTRICIDAE

*<u>Acleris comariana</u> (Zell.)

<u>Acleris minuta</u> (Rob.), the yellow-headed fireworm.

*<u>Acleris variegana</u> (D. & S.)

<u>Amorbia humerosana</u> (Clem.), the dusky leafroller.

<u>Ancylis comptana fragariae</u> (W. & R.), the strawberry leafroller.

*<u>Aphelia alleniana</u> (Fern.)

<u>Aphelia pallorana</u> (Rob.)

*<u>Archips argyrospilus</u> (Wlk.), the fruit-tree leafroller.

<u>Archips cerasivoranus</u> (Fitch), the ugly-nest caaterpillar.

*<u>Archips podana</u> (Scop.)

*<u>Archips rosanus</u> (L.), the European leafroller.

<u>Argyrotaenia citrana</u> (Fern.), the orange tortrix.

<u>Argyrotaenia mariana</u> (Fern.), the gray-banded leafroller

*<u>Bacebecia urticana</u> (Hbn.)

*<u>Choristoneura rosaceana</u> (Harr.), the oblique-banded leafroller.

*<u>Clepsis forbesi</u> Obraz.

<u>Clepsis persicana</u> Fitch, the white-triangle leafroller.

<u>Cnephasia interjectana</u> (Haw.)

*<u>Cnephasia longana</u> (Haw.), the omnivorous leaf-tier.

*<u>Croesia curvalana</u> (Kft.)

<u>Exartema olivaceanum</u> (Fern.)

<u>Exartema permundanum</u> Clem., the raspberry leafroller.

<u>Grapholitha packardi</u> (Zell.), the cherry fruitworm.

<u>Olethreutes trinitana</u> (McD.)

*<u>Pandemis cerasana</u> (Hbn.)

*<u>Pandemis heparana</u> (D. & S.)

*<u>Pandemis limitata</u> (Rob.), the three-lined leafroller.

<u>Ptycholoma peritana</u> (Clem.), the garden tortrix.

*<u>Rhopobota naevana</u> (Hbn.), the black-headed fireworm.

<u>Sparganothis pettitana</u> (Rob.)

<u>Sparganothis reticulana</u> (Clem.)

Sparganothis sulfureana (Clem.)

**Spilonota ocellana* (D. & S.), the eye-spotted budmoth.

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