LEAF ROLLER (LEPIDOPTERA: TORTRICIDAE) HOST PLANT AND PARASITE RELATIONSHIPS IN THE OKANAGAN VALLEY OF BRITISH COLUMBIA

by

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Leaf roller (Lepidoptera: Tortricidae) host plant and parasite relationships in the Okanagan Valley of British Columbia.

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ABSTRACT

Seven species of leaf rollers (Tortricidae) feed on apple in the Okanagan Valley of British Columbia: Archips rosanus (L.), Archips argyrospila (Wlk.), Pandemis limitata (Rob.), Platynota idaeusalis (Wlk.), Syndemis afflictana (Wlk.), Argyrotaenia dorsalana (Dyar), and Choristoneura rosaceana (Harr.).

The abundance of each species varied primarily with the destiny of alternative host plants and with the environment in which the host apple was growing and secondarily with the application of sprays.

Each species had different alternate host plants except for rose which is the major alternate host plant of all the species. Other important alternate host plants were privet for A. rosanus, dogwood for P. limitata, and antelope bush for A. argyrospila.

Thirty-eight species of parasites were reared from leaf rollers. Eight of these were abundant while the other thirty species were only incidentally associated with the leaf rollers. The incidence of parasitism varied between 1.0% and 32.4%, apparently depending on the amount of spraying. On unsprayed host plants the incidence of parasitism averaged 25%. It is doubtful if the present parasite complex of leaf rollers in the Okanagan Valley is exerting significant biological pressure on the leaf rollers.

There has been a change in the relative abundance of leaf roller species from that found fifty years ago. Some species have become rare or are absent while other species that were absent or rare have become abundant.

This change appears to be due to increased urbanization and increasing land cultivation that decreased the arid type environment of the Valley.

Urbanization and cultivation are continuing to increase while spraying is decreasing as integrated control programs are developed. Because of these changes the relative abundance of the leaf roller species may change in the future. Populations of A. rosanus, P. limitata and some of the minor species may increase.

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INTRODUCTION

The ecology of leaf rollers, which are the larvae of apple-feeding tortricid moths, was investigated in the Okanagan Valley of British Columbia during 1972. The species concerned are of the sub-family Tortricinae of the family Tortricidae (Obraztsov 1954; Chapman and Lienk 1971).

Archips argyrospila (Wlk.) was apparently one of the major apple pests in the Okanagan Valley before the codling moth, Laspeyresia pomonella (L.), appeared there (Venables 1937). The subsequent use of arsenates, chlorinated hydrocarbons and then of organophosphates for codling moth control apparently kept A. argyrospila populations at levels that required no specific control recommendations (Marshall 1963). Due to a re-evaluation of the orchard preventative spray program and the use of integrated controls the present modified spray program includes an early spring spray for A. argyrospila control. This spray plus the codling moth sprays generally keep leaf roller populations low in commercial orchards.

Work aimed at eradicating the codling moth by the sterile-male technique is in progress (Proverbs, Newton, and Logan 1969). If this is successful, spray treatments in commercial orchards will be reduced and this may permit A. argyrospila to increase to its former injurious levels.

It is known that A. argyrospila, at the present time, has the potential to become a serious pest of apple in situations where codling

moth and/or leaf roller sprays are reduced or eliminated: A. argyrospila has increased in orchards where sprays are modified or omitted (Madsen and Downing 1968); it has required treatment in orchards where a sterile-male codling moth control program is being applied (Proverbs et al 1969); and it increased to injurious levels in an orchard that has not been sprayed for codling moth for six years (Madsen 1969). It is therefore probable that it and perhaps other species of leaf rollers might increase in the Okanagan Valley after the codling moth has been reduced or eliminated by the sterile-male technique and the spray program consequently reduced or stopped.

The recent use of sex pheromone traps for A. argyrospila has indicated that more than one species of leaf roller attacks apple in the Okanagan Valley (Madsen, personal communication, 1972). Two of these species were not found in an earlier investigation of apple-feeding tortricids in the Okanagan Valley (Venables 1924). Studies since 1924 have largely been concerned with the biology and control of A. argyrospila (Venables 1937; Madsen 1970). Other studies, though not specifically concerned with the apple-feeding Tortricinae of the Okanagan Valley, have been conducted on Lepidoptera in British Columbia (Blackmore 1921; Prentice 1965). Museum records of leaf rollers collected in British Columbia were given by Freeman (1958) and MacKay (1962).

Therefore, to provide a basis for a pest management program for leaf rollers in the Okanagan Valley the following information was needed: their identities, relative abundance, periods of activity, host plant relationships, and parasite relationships. To obtain such

information and to reach conclusions from it were the main objectives of the present investigation.

METHODS AND PROCEDURES

1. Plants Surveyed

Plant species chosen for surveying were those that were suitable hosts of apple-feeding leaf rollers as determined from a literature review and/or that were growing near apple or privet. Pyrus communis L., pear, was not surveyed because it and apple have the same general leaf roller fauna. The seventeen species of food plants that were surveyed for leaf rollers are as follows:

Acer sp., maple, a fairly common ornamental tree in urban areas;

Alnus sp., alder, a common native tree usually found along creek edges or where there is wet ground;

Betula sp., birch, a fairly common ornamental tree in urban areas;

Caragana arborescens Lam., an uncommon ornamental shrub;

Cornus stolonifera Michx., dogwood, a common native shrub in wet situations;

Crataegus douglasii Lindl., hawthorn, a common native tree in wet situations;

Elangus angustifolia Pall., Russian olive, a fairly common ornamental tree in urban areas and an introduced wild tree in wet situations;

Juglans regia L., walnut, a common ornamental tree;

Ligustrum vulgare L., privet, a common ornamental shrub or hedge;

Mahonia nervosa (Pursh), Oregon grape, a common native shrub in wet situations and an ornamental in urban areas;

Prunus virginiana L., chokecherry, a common shrub growing where the ground is damp;

Purshia tridentata (Pursh), antelope bush, a common shrub in arid areas;

Pyrus malus L., apple, a common commercial tree and a fairly common wild tree in wet situations;

Ribes cereum Dougl., currant, a fairly common shrub in arid areas;

Rosa spp., rose, a common shrub in all situations and an ornamental in urban areas;

Salix spp., willow, a common tree in wet situations;

Sorbus aucuparia L., mountain ash, an uncommon ornamental tree.

2. Description of Study Areas

Study areas were selected on the basis of two criteria: a) condition of host plants; and b) habitat types as indicated by vegetation. This was done to determine and compare species and population numbers of leaf rollers and their parasites in different situations.

a) Condition of host plants.

The amount of man's care of the plants ranged from complete neglect to commercial cultivation with and without pesticide applications. Abandoned apple orchards were those that had not been cared for by man for at least fifteen years; wild apple and other wild plants were considered to be the equivalent of abandoned orchards. Unsprayed-commercial apple orchards and other semi-commercial plants were those that received cultivation, pruning, and fertilizer but were not treated with chemical pesticides. Commercial apple orchards and other commercial

plants were those subjected to normal cultural procedures the same as the semi-commercial plants but including treatment with chemical pesticides in 1971 and/or 1972.

b) Habitat types as indicated by vegetation.

Habitat types are fundamental ecological units (Daubenmire and Daubenmire 1968). There are climatic parameters that permit quantitative definitions of the zones of steppe vegetation and these nearly always concern the environmental water balance (Daubenmire 1970). Small differences in the amount and timing of moisture available to the vegetation, or the environmental water balance, are critical in determining the composition of plant communities, or habitat types. Based on Daubenmeir's (1970) classification three different habitat types were surveyed. The habitat types ranged from a very dry situation to a relatively wet situation. These types were:

A very dry situation, indicated by the presence of Purshia tridentata-Festuca idahoensis habitat type. P. tridentata was the dominant shrub and there was a mixture of grasses such as F. idahoensis and Agropyron spicatum in the herb layer. This habitat type was found alternating with the moderately dry habitat type.

A moderately dry situation, indicated by the presence of Pinus ponderosa-Purshia tridentata habitat type. P. ponderosa was the dominant tree, P. tridentata the dominant shrub along with Rosa spp., and the herb layer consisted of a mixture of grasses such as F. idahoeniss and A. spicatum, and forbs, such as Balsamorhiza sp.

A relatively wet situation, indicated by the presence of Crateaegus douglasii-Symphoricarpos albus habitat type. The shrub layer was a mixture of plants including C. douglasii, S. albus, C. stonifera, and Rosa spp. This habitat type was found only along streams or lakes or at places where man was increasing the environmental water balance by irrigation such as in urban areas.

3. Collecting Sites

Nine collecting sites were selected for plant surveys in the southern Okanagan Valley (Figure 1). These were divided into two groups: sites that had apple trees; and sites that did not have apple trees.

The collecting sites containing apple, from south to north, were located near Okanagan Falls, Summerland, and Kelowna.

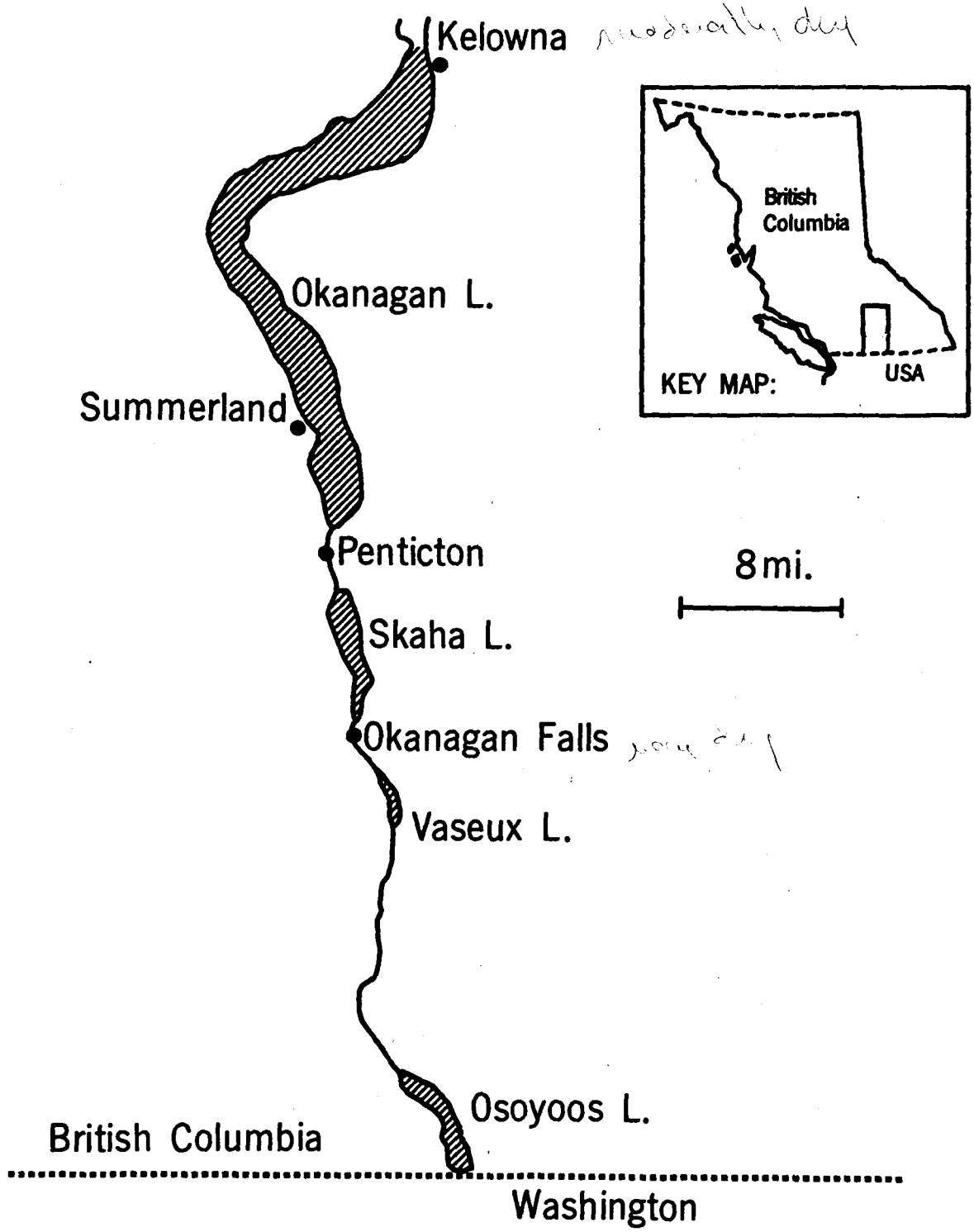
Okanagan Falls collecting site.

The apple trees surveyed near Okanagan Falls were located in the P. tridentata-F. idahoensis, or very dry, habitat type. This site had the lowest environmental water balance of any of those surveyed during this study. It contained a twenty-tree apple orchard that had been completely abandoned for fifteen to twenty years. Antelope bush, currant, and wild rose were also surveyed at this site.

Summerland collecting site.

This site, near Summerland, was located about thirty miles north of the Okanagan Falls site. The habitat type was C. douglasii-S. albus,

Figure 1 Map of the southern Okanagan Valley of British Columbia showing the major lakes and cities.


Kelowna
Okanagan L.
Summerland
Penticton
Skaha L.
Okanagan Falls
Vaseux L.
Osoyoos L.
British Columbia
Washington
British Columbia
KEY MAP:
USA
8 mi.

or relatively wet, and the environmental water balance was higher than that of the other sites containing apple surveyed during this study. Wild apple trees, commercial apple, unsprayed-commercial apple, and nursery apple were surveyed. The apple orchards were surrounded by a number of wild and cultivated plants, notably privet, rose (wild and commercial), dogwood, willow, chokecherry, hawthorn, mountain ash, alder, birch, C. arborescens, and Russian olive, all of which were surveyed.

Kelowna collecting site.

This site, near Kelowna, was located about forty-five miles north of the Summerland site. The habitat type was P. ponderosa-P. tridentata, or moderately dry, and the environmental water balance was intermediate between that of the other collecting sites containing apple. The twenty-acre apple orchard was representive of a commercial orchard operation in the Okanagan Valley except no sprays were applied to the orchard during the course of this study. The apple orchard was surrounded by other commercial apple orchards, a commercial vineyard, wild rose, antelope bush, and pine. Apple, rose, and antelope bush were surveyed for leaf rollers. Commercial apple and commercial grape were not surveyed since pesticides were applied and pine was not considered as a host plant for apple-feeding leaf rollers.

The collecting sites that did not contain apple were in urban and non-urban locations.

Urban sites

Privet hedges in four urban sites in relatively wet situations in the cities of Okanagan Falls, Penticton, Summerland, and Kelowna were

selected for surveying on the basis of proximity to streets and extent to which they were trimmed. Other plants surveyed were rose, maple, walnut, and Oregon grape where they were near privet hedges.

Non-urban collecting sites.

Two different sites in non-urban areas in moderately dry situations located near Summerland were selected. Wild rose, currant, antelope bush and chokecherry were surveyed.

4. Sampling Methods

Egg masses were collected by hand from apple, rose, dogwood, and privet and examined for egg parasites. Samples of egg masses from Okanagan Falls, Summerland, and Kelowna and from apple, rose, dogwood, and privet were allowed to hatch and were reared to adults to determine the species of leaf roller present.

Larvae and pupae are generally found on the leaves of host plants. Allowing for the differences in gross morophology of the various host plants surveyed, the leaf cluster of apple and the leaf group of the other plants was the most suitable sample unit. Both sample units consist of five to seven leaves and are equivalent to one another. With respect to leaf roller larval feeding, later instars usually tie together only one leaf of a leaf cluster and two or more of a leaf group. The term leaf cluster is synomynous with leaf group. The seasonal average of each leaf roller species was calculated from sampling during the season while the leaf roller was in the larval and pupal stage. The percentage of each leaf roller species from each host plant and site was calculated from the numbers reared to adult stage.

Plants were selected at random and leaf clusters were chosen at random from all parts of each selected plant. The method of ensuring random samples varied depending on the plants and was modified from that of Paradis and LeRoux (1962). On apple, trees were divided into four vertical quadrants and two horizontal levels and leaf clusters were taken from each of the eight sections. On privet, the procedure was to take five steps along the hedge and then sample twenty-five clusters. Much the same type of procedure was used to survey rose and dogwood. In some cases the same plant was surveyed more than once.

Samples of larvae and pupae were taken at five to seven day intervals from each site and from each host plant between the beginning of May and end of July. A few samples were taken in the middle of August and at the end of September.

Data on the parasites is presented in terms of the species of parasites recovered from different species of leaf rollers, from each habitat type, and from each host plant. The percentage of parasitism from each host plant and site was calculated from larval and pupal rearings of the leaf rollers. Parasites that died before reaching maturity or that were unidentified because of loss or damage to key characters were included in the calculation of percent parasitism.

5. Rearing Methods

Larvae and pupae were hand picked from the leaf cluster and brought into the laboratory to be reared to adult stage for positive identification. In most cases parasitism could not be determined without

rearing to the parasite adult. Leaf rollers and their parasites were reared at 80-90°F. and a relative humidity of 70-80%.

The rearing procedures were modified from Chapman and Lienk (1971). Most larvae were reared individually in corkstoppered 25x95 mm. shell vials containing one or two apple leaves. Every four to five days the larva was transferred to a clean vial containing apple leaves. This procedure was repeated until the larva or parasite had pupated. During the latter part of the study some leaf roller larvae, after being separated by species, site, and host plant, were reared five to a one-half pint jar containing apple leaves.

Paper towelling was placed on the bottom of a clean vial with the pupa laid on top of the paper towelling during individual rearings. An apple leaf was also placed in the vial and then the vial was cork-stoppered. Field collected pupae, after separation by host plant and site, and the pupae from the mass rearing, were placed in a petri dish containing filter paper and wet cotton and held until emergence.

All vials, jars, and petri dishes were washed and heat sterilized before use. This procedure, plus changing the leaves every four to five days, virtually eliminated mold problems. Mortality of leaf rollers and their parasites in the laboratory was low.

RESULTS

1. Artificial Key to Last Instar Larvae

To determine the pest status of a species it is necessary to identify it readily. Chapman and Lienk (1971) provide a readily usable system for identification of adult leaf rollers by the use of water-color illustrations.

In many cases it is advantageous to determine the species while it is in the larval stage. I developed the following field key which may be used to identify the later-instar larval stages of leaf roller species found on apple in the Okanagan Valley.

1) - Head green, body light green 2
   - Head reddish brown, dark brown or black, body dark green or brownish green 3

2) - Full grown at about the end of apple bloom; larvae relatively sluggish ..... Argyrotaenia dorsalana
   - Full grown two or three weeks later; larvae relatively active ..... Pandemis limitata

3) - Head reddish brown to brown, body brownish or brown green ... 4
   - Head brown to black, body dark green 5

4) - Body brownish, sometimes two sub-dorsal dark brown stripes; full grown late in summer or early fall .....Syndemis afflictana
   - Body brown green, no sub-dorsal stripes; full grown in late spring or early summer ..... Platynota idaeusalis

5) - Prothoracic legs brown, other thoracic legs green; not found on privet ..... Archips argyrospila
   - All thoracic legs greenish; privet a common host plant ..... Archips rosanus

2. Leaf Rollers

A list of the ten species observed on apple and other plants in

the Okanagan Valley is given in Table 1.

The history, status, and ecology of the species of leaf rollers as observed in the Okanagan Valley during this study are discussed below in the order of apparent pest importance. With the exception of A. argyrospila and Choristoneura rosaceana (Harr.), the life-cycles of the apple-feeding leaf rollers found in this study were primarily unknown in the Okanagan Valley.

a) Archips rosanus (L.), The European leaf roller.

Blackmore (1921) and Freeman (1958) reported A. rosanus from the lower mainland of British Columbia and Vancouver Island. It was first found on apple in the Okanagan Valley in 1971 (Madsen, personal communication, 1972).

Larvae were found feeding on privet in the cities of Okanagan Falls, Penticton, Summerland, and Kelowna. They were collected from apple and rose at all collecting sites containing apple. Dogwood occurred only in the relatively wet habitat type, and there A. rosanus was found feeding on it. Larvae were also found on alder, chokecherry, hawthorn, maple, Oregon grape, Russian olive, walnut, and willow. Egg masses were found on apple, dogwood, privet, and rose.

This species is univoltine and overwinters in the egg stage. The egg masses are laid on woody stems and branches that are larger than one-half inch in diameter. The eggs began to hatch during the very end of April and first part of May. Hatching date depends on the host plant. This was also noted by Gibson (1924) on Vancouver Island. On

Table 1 Species of leaf rollers in the order of apparent pest importance and their overwintering stage as observed in the Okanagan Valley.

Scientific Name	Common Name	Overwintering stage
*Archips rosanus (L.)	European leaf roller	egg
Archips argyrospila (Wlk.)	Fruit tree leaf roller	egg
Pandemis limitata (Rob.)	Three-lined leaf roller	larva
Platynota idaeusalis (Wlk.)	Tufted apple bud moth	larva
Syndemis afflictana (Wlk.)	Fall dead-leaf roller	larva
Argyrotaenia dorsalana (Dyar)	None	larva
Choristoneura rosaceana (Harr.)	Oblique-banded leaf roller	larva
Croesia albicomnana (Clem.)	None	larva
Acleris forbesana (McD.)	None	larva
Acleris species near bowmana (McD.)	None	larva

* Introduced to North America from Europe

apple the eggs began to hatch when the plant was in the one-half inch green-bud stage of bud development. On privet the majority of the egg masses began to hatch one to two weeks later than they did on apple. Hatching was completed by the middle of May on apple when the trees were in the pink stage of bud development.

Newly hatched larvae immediately move away from the egg mass and crawl towards the branch apex, often dropping on silken threads and being blown by the wind. On apple they often feed on developing buds by boring into them. Later larvae tie growing leaves together with strands of silk and feed on them. Blossom feeding is common: the larvae tie the blossoms together over the developing sex organs and feed on the pollen. They also feed on the developing fruit. On apple, mature larvae roll a single leaf lengthwise using strands of silk to tie the leaf into a roll. This shelter-leaf is often attached to the fruit. Larvae are inside the rolled up leaf with only the head and first thoracic segment exposed during feeding. On privet, larvae appear to prefer the young, growing tips. Two to five leaves are rolled together along the stem to fashion a feeding shelter. Mature larvae can be found from the early part of June until the early part of July.

Larvae pupate in their last feeding site, or drop to the ground to do so, or move to another leaf which is rolled but not fed upon. The pupal stage lasts ten to fifteen days. Pupae were found in the field from the middle of June until the middle of July.

Adults began to emerge about the middle of June and emergence was completed by the end of July. They fly during the evening, when mating

probably occurs though two copulating pairs were observed at different dates on privet during mid-morning. During the day adults sit motionless on the upper surfaces of leaves of host and non-host plants. When disturbed they fly short distances and alight.

Largest visible numbers occurred when the majority of the larvae were in the last two instars. These peaks occurred at different times on different host plants at the same collecting site (Figure 2). They were about two weeks later on privet and rose than on apple at Summerland.

Populations were highest at Summerland and the urban sites; next highest at Kelowna; lowest at Okanagan Falls; and no larvae were found at non-urban sites (Table 2).

At Summerland, where A. rosanus was the dominant species, populations were higher on privet than on other host plants and next highest on commercial apple. Population numbers were about equal on unsprayed apple, wild apple, and dogwood. The numbers found on commercial and wild rose were about equal and somewhat higher than on unsprayed apple or dogwood. At Kelowna and Okanagan Falls populations were very low on apple and rose (Table 3).

Larval feeding causes two kinds of damage to the fruit: the feeding on developing buds, blossoms and flowers is a direct loss of potential fruit; and the feeding on the fruit causes wounds which make the fruit unmarketable.

The life-history as described above for the Okanagan Valley shows no significant difference from the descriptions given by Chapman and Lienk (1971) for New York State or by Gibson (1924) for Vancouver Island, British Columbia.

Figure 2 Number of A. rosanus per 100 leaf clusters at different times on apple, rose, and privet at Summerland.

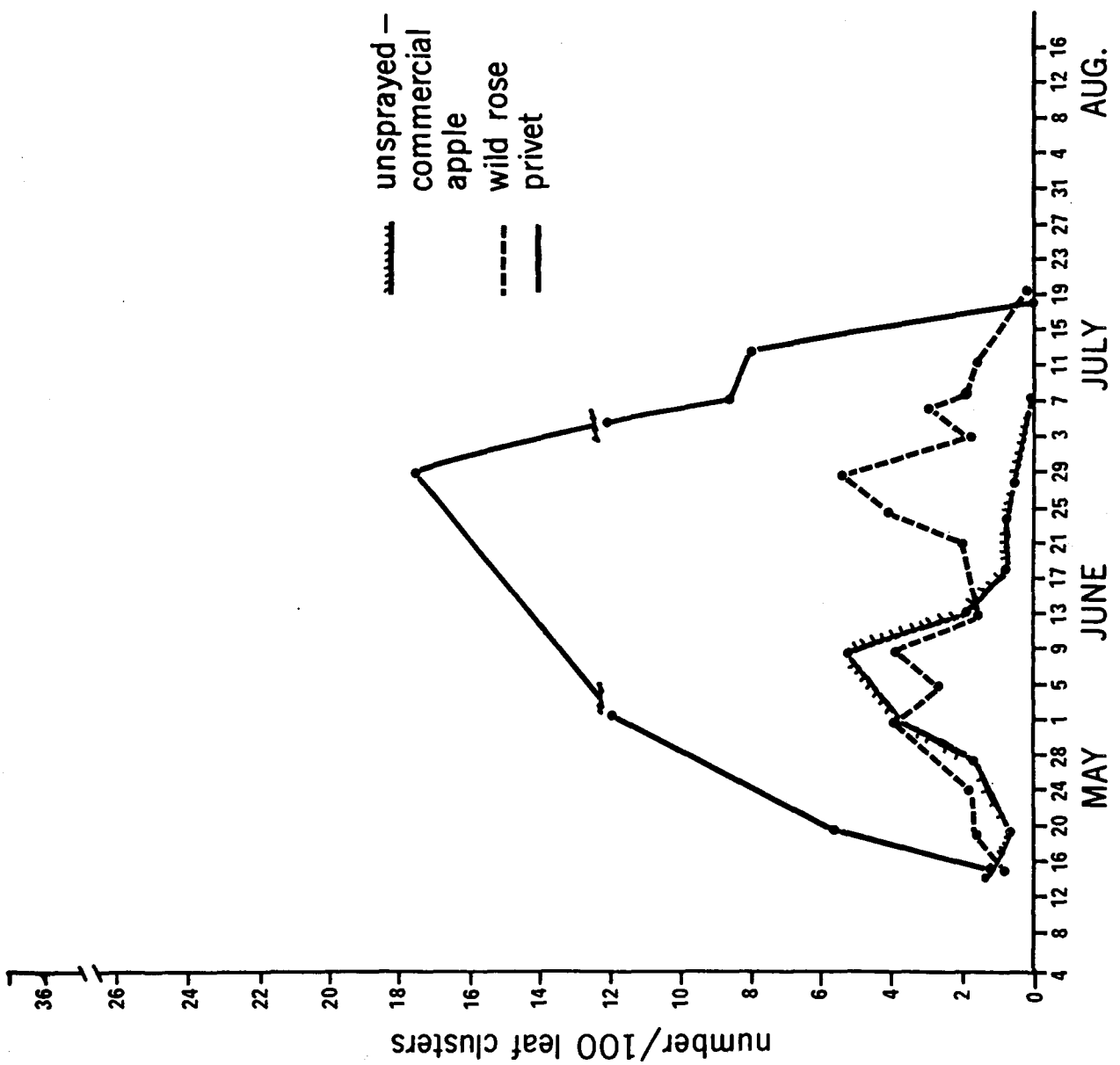

unsprayed – commercial apple
wild rose
privet
number/100 leaf clusters
0
2
4
6
8
10
12
14
16
18
20
22
24
26
36
4 8 12 16 20 24 28 1 5 9 13 17 21 25 29 3 7 11 15 19 23 27 31 4 8 12 16
MAY
JUNE
JULY
AUG.

Table 2 Average number of leaf rollers, by species, per 100 leaf clusters of all plants surveyed at the different sites.

Species	Site				
	Summerland[2]	Okanagan Falls[1]	Kelowna[3]	Urban[2]	Non-Urban[3]
A. rosanus	3.54	0.01	0.45	11.1	0
A. argyrospila	1.34	3.33	10.3	*	0
P. limitata	0.47	0	0.17	*	0

* Privet was the main host plant surveyed and it is not a host plant of A. argyrospila or P. limitata

1 dry situation
2 relatively wet situation
3 moderately dry situation

Table 3 Seasonal average of number of A. rosanus per 100 leaf clusters on different host plants at Summerland, Kelowna, and Okanagan Falls.

PLANT	SITE		
	Summerland	Kelowna	Okanagan Falls
privet-wild	8.6	----	----
apple-commercial	6.2	0.68	----
apple-unsprayed-commercial	1.1	----	----
apple-wild	1.8	----	0.04
rose-commercial	2.8	----	----
rose-wild	2.38	0.22	0.01
dogwood-wild	1.4	----	----
antelope bush-wild	---	0	0
currant-wild	---	----	0

---- plant absent

0 plant present - no larvae found

b) Archips argyrospila (Wlk.), The fruit tree leaf roller.

A. argyrospila was first reared from apple in the Okanagan Valley in 1922 (Venables 1924). Since the early 1920's it has been the major leaf roller pest of apple in the Okanagan Valley (Madsen, personal communication, 1972).

Larvae were found feeding on apple and rose at all collecting sites containing apple. Larvae were collected from antelope bush at Okanagan Falls. They were also found feeding on birch, Caragana arborescens, Russian olive, walnut, willow, and Oregon grape. Egg masses were found on apple, rose, and antelope bush.

This species is univoltine and overwinters in the egg stage. Egg masses are laid on the stems and branches of host plants. No egg masses were found on twigs smaller than one-half inch in diameter. The eggs began to hatch about the end of April. On apple this was when the trees were in the one-half inch green-bud stage of bud development. Egg masses on all host plants began hatching at approximately the same date. Hatching was complete by the first week of May.

No significant differences were detected between the feeding habits of larval A. argyrospila and of larval A. rosanus. Mature larvae were found from the end of May until the end of June.

A. argyrospila larvae pupate in the same situations as A. rosanus. Pupae were found in the field from the first part of June until the first part of July.

Adults began to emerge during the first part of June and emergence

was completed by the second week of July. Adults normally fly during the evening but when distrubed during the day they fly short distances and alight. During the day they were observed sitting on the upper surface of leaves of host and non-host plants.

Highest visible populations occurred at about the same date on all host plants surveyed at a collecting site (Figures 3 and 4). Peaks were at approximately the same date at the collecting sites where it was the dominant leaf roller (Figures 3 and 4). No egg masses were found on rose at Okanagan Falls and the larvae found on it from 18 May to 5 June were the result of dispersal from apple and antelope bush. Antelope bush was not surveyed until 24 May because it was not thought to be a host plant. At that time hatched eggs were also found on it as were new egg masses later in the season.

Populations were highest at Okanagan Falls, next highest at Kelowna, lowest at Summerland, and no larvae were found at non-urban sites (Table 2).

At Okanagan Falls and Kelowna, where A. argyrospila was the dominant species, populations were highest on apple which had been sprayed every year except 1972, next highest on abandoned apple, followed by antelope bush, rose, and currant. At Summerland, where it was not the dominant species, populations were higher on commercial apple and rose than on wild apple or rose (Table 4).

Feeding larvae cause the same type of fruit loss to apple as described above for A. rosanus.

Except for the use of antelope bush as a host plant, the life-history and habits described above show no significant differences from the descriptions given by Venables (1937), Madsen (1970), and Madsen and

Figure 3 Number of A. argyrospila per 100 leaf clusters at different times on apple, antelope bush, and rose at Okanagan Falls.

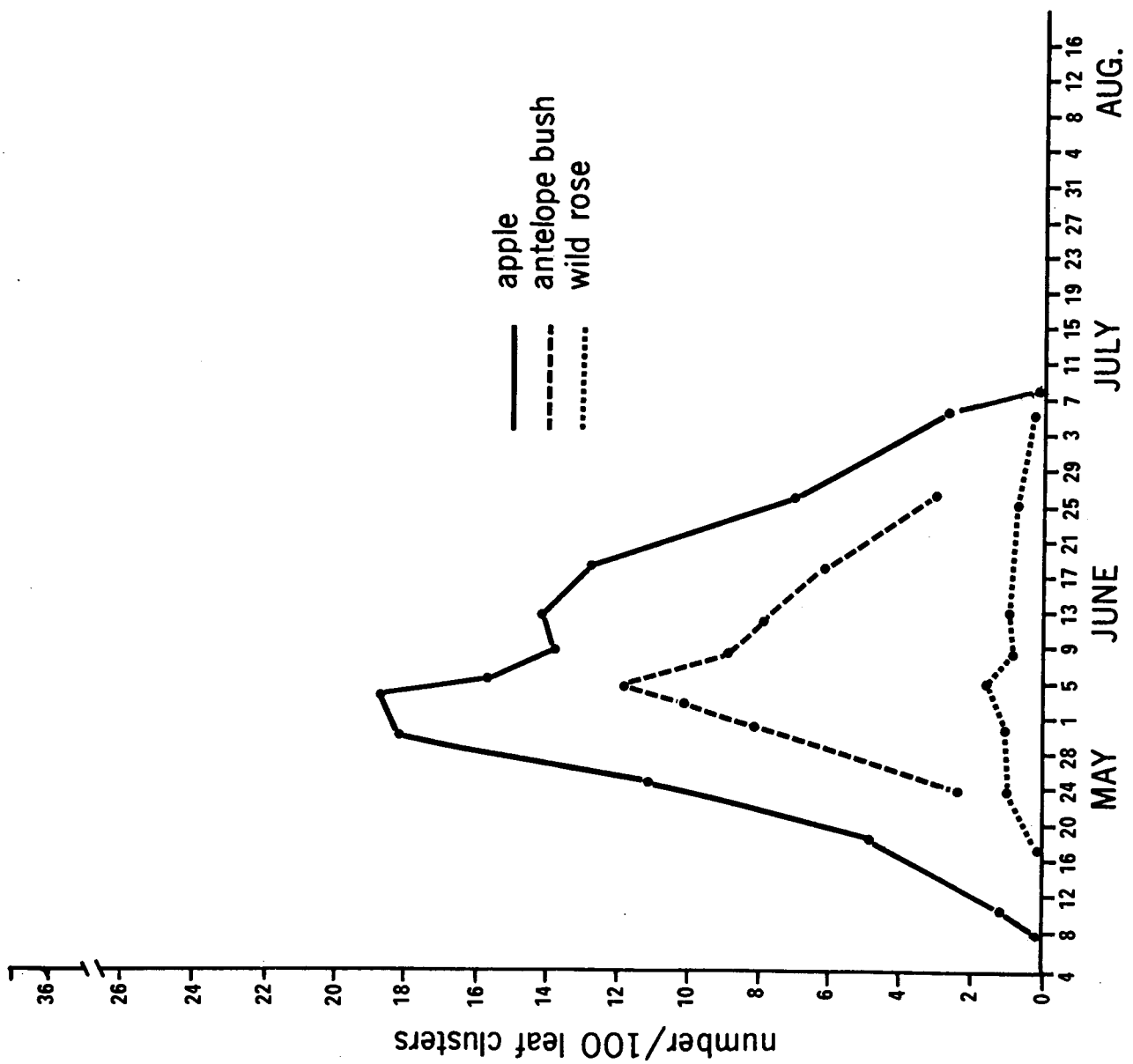

number/100 leaf clusters
apple
antelope bush
wild rose
MAY
JUNE
JULY
AUG.

Figure 4 Number of A. argyrospila per 100 leaf clusters at different times on apple and rose at Kelowna.

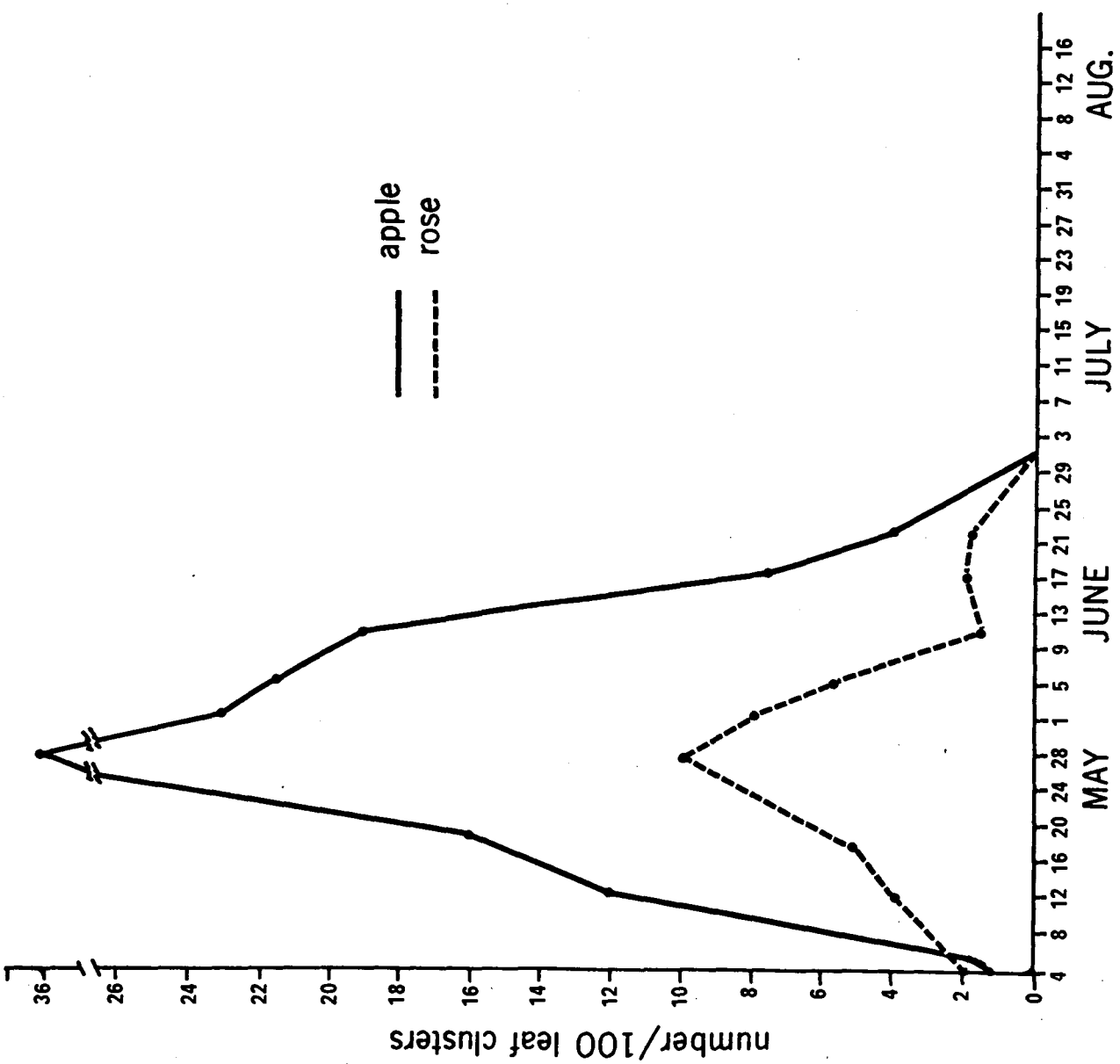

apple
rose
number/100 leaf clusters
0
2
4
6
8
10
12
14
16
18
20
22
24
26
36
4 8 12 16 20 24 28 1 5 9 13 17 21 25 29 3 7 11 15 19 23 27 31 4 8 12 16
MAY
JUNE
JULY
AUG.

Table 4 Seasonal average of number of A. argyrospila per 100 leaf clusters on different host plants at Summerland, Kelowna, and Okanagan Falls.

PLANT	SITE		
	Summerland	Kelowna	Okanagan Falls
privet-wild	0	----	----
apple-commercial	5.2	16.2	----
apple-unsprayed-commercial	0.98	----	----
apple-wild	0.6	----	6.9
rose-commercial	2.4	----	----
rose-wild	0.46	4.9	0.4
dogwood-wild	0	----	----
antelope bush-wild	----	0	6.3
currant-wild	----	----	0.1

---- Plant absent

0 Plant present - no larvae found

and Davis (1971) for the Okanagan Valley.

c) Pandemis limitata (Rob.), The three-lined leaf roller.

Freeman (1958), Mackay (1962), and Prentice (1965) recorded P. limitata from the southern part of British Columbia. It was first found on apple in the Okanagan Valley in 1971 (Madsen, personal communication, 1972).

Larvae were found feeding on apple and rose at Summerland and Kelowna. Dogwood occurred only at Summerland and there P. limitata was found feeding on it. Larvae were also collected from birch and willow. Egg masses were found on apple, rose, and dogwood.

This species is univoltine in the Okanagan Valley and overwinters as a third or fourth instar larva.

Larvae left the overwintering sites and began feeding during the first few weeks of May, when apple trees were in the pink stage of bud development. They feed on the developing buds and leaves. As the leaves grow, larvae tie them together to form a feeding shelter. Later instars roll the leaf in a typical leaf roller fashion or tie a leaf to an apple and then eat a cavity in the fruit. In general, larval feeding habits were the same as for the other leaf rollers observed during this study and as described for A. rosanus. Last instar larvae were found from the middle of June until the middle of July.

Larvae pupate in their final feeding site. The pupal stage lasts ten to fifteen days. Pupae were found in the field from the middle of June until the middle of July.

Adults began to emerge during the last part of June and were found until the middle of August. During the day they sit motionless on various plants and fly short distances when disturbed. They were less active than the adults of other species of leaf rollers observed.

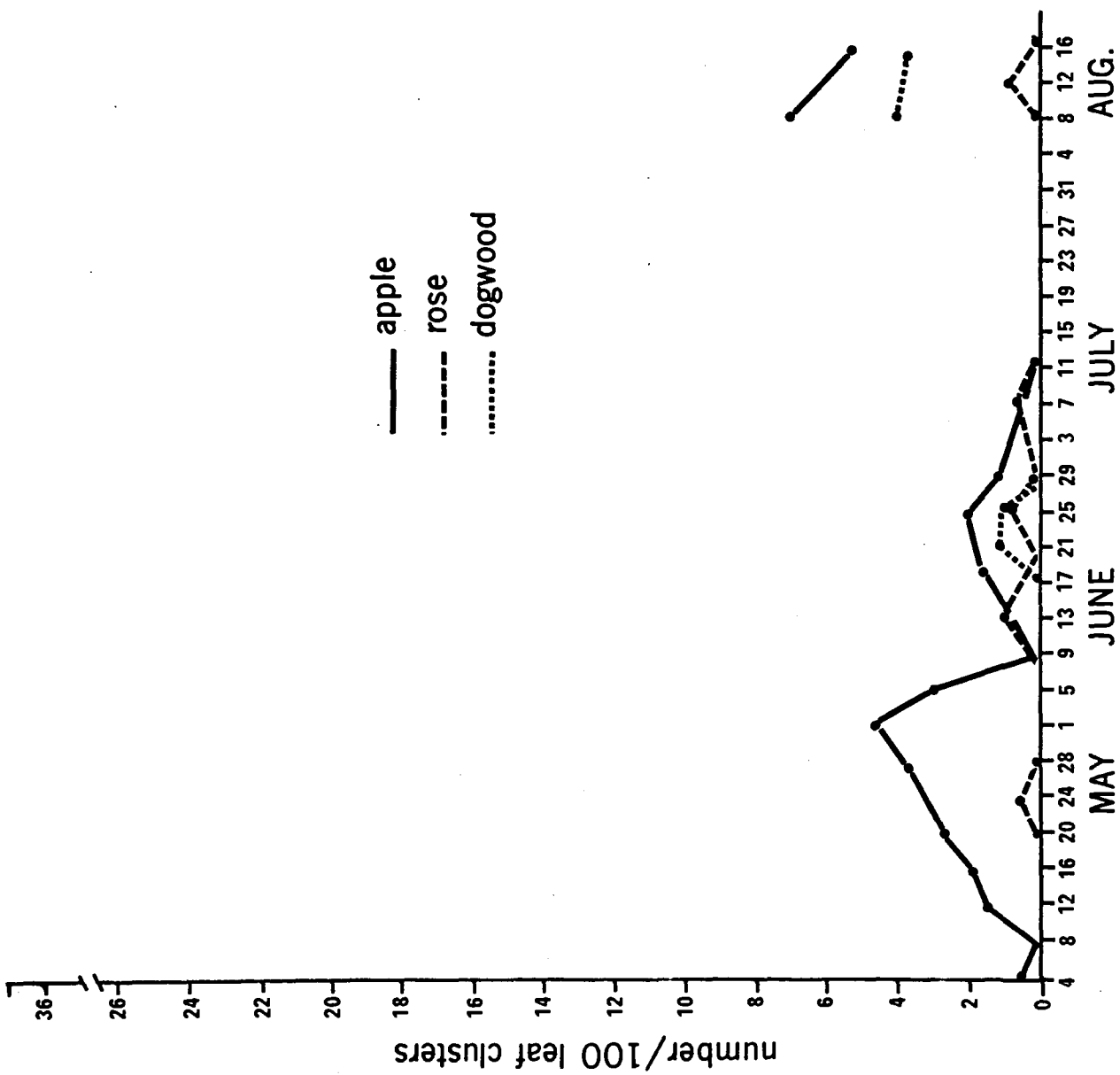
Eggs were laid on the upper surface of the leaves of host plants during July and August. Egg masses were observed hatching during the first and second week of August.

Early instar larvae feed on the under surface of leaves under a protective webbing. They did not roll the leaves and were usually found on leaves that had not been fed upon by other leaf rollers during the spring. By the end of September these larvae had moved off the leaves to their over wintering sites. No larvae could be found over-wintering, though Newcomer and Carlson (1952) found larvae overwintering in silken cocoons on the branches and twigs of apple trees.

A slight population increase was noted at Summerland on apple during the fall and spring, but on other host plants populations were fairly level or sporadic during the season (Figure 5). The apparent population increase i the spring occurs when larvae leave the overwintering site and the one in the fall when eggs hatch (Figure 5). No larvae or pupae were found from the middle of July to the first part of August.

Population numbers were highest at Summerland, next highest at Kelowna and no larvae were observed at Okanagan Falls or the non-urban sites (Table 2).

Figure 5 Number of P. limitata per 100 leaf clusters at different times on apple, rose, and dogwood at Summerland.


apple
rose
dogwood
number/100 leaf clusters
0
2
4
6
8
10
12
14
16
18
20
22
24
26
36
4 8 12 16 20 24 28 1 5 9 13 17 21 25 29 3 7 11 15 19 23 27 31 4 8 12 16
MAY
JUNE
JULY
AUG.

Population numbers were higher on unsprayed-commercial apple than any other host plant surveyed (Table 5). It was the dominant species of leaf roller on unsprayed-commercial apple at Summerland. At Summerland, populations were about equal on wild apple and rose and slightly lower on dogwood (Table 5). At Kelowna, populations were about equal on commercial apple and wild rose (Table 5).

Overwintered larvae cause the same type of feeding damage as described above for A. rosanus. The early instar stages that hatch in the late summer and overwinter were not observed to feed on apple fruit.

The life-history and habits as described above show some significant differences from observations made on this species elsewhere in North America. These differences will be discussed in a later section.

d) Platynota idaeusalis (Wlk.), The tufted apple bud moth.

MacKay (1962) reported that specimens of P. idaeusalis collected in British Columbia are in the Canadian National Collection.

Larvae were found feeding on apple, rose, and willow. This species was found only at Summerland and at low densities. Populations were about the same on unsprayed-commercial apple and wild rose (Table 6).

P. idaeusalis is univoltine and overwinters in the larval stage. Late-instar larvae were found during the end of May and first part of June. Larval feeding habits were the same as previously described for A. rosanus. Larvae pupate in the rolled up leaf of their final feeding site. Pupae were found in the field during the first part of June.

Table 5 Seasonal average of number of P. limitata per 100 leaf clusters on different host plants at Summerland Kelowna and Okanagan Falls

PLANT	SITE		
	Summerland	Kelowna	Okanagan Falls
privet-wild	0	----	----
apple-commercial	0.23	0.17	----
apple-unsprayed-commercial	1.43	----	----
apple-wild	.33	----	0
rose-commercial	0.53	----	----
rose-wild	0.20	0.17	0
dogwood-wild	0.16	----	----
antelope bush-wild	----	0	0
currant-wild	----	----	0

---- Plant absent

0 Plant present - no larvae found on it.

Table 6 Seasonal average of number of P. idaeusalis, S. afflictana A. dorsalana and C. rosaceana per 100 leaf clusters on different host plants at Summerland and Okanagan Falls.

PLANT	SITE			
	Summerland		Okanagan Falls	
apple-unsprayed-commercial	P. idaeusalis	0.1	----	
	S. afflictana	0.07		
	A. dorsalana	0.03		
apple-wild	0		C. rosaceana	0.04
rose-wild	P. idaeusalis	0.2	0	
	A. dorsalana	0.03		

---- Plant absent

0 Plant present - no larvae found

Middle-instar larvae were found feeding in rolled up leaves in August and September. These larvae are the overwintering stage.

The life-history and habits described above show some differences from those in eastern North America. These differences will be discussed in a later section.

e) Syndemis afflictana(Wlk.) The fall dead leaf roller.

S. afflictana is a northern species that has been recorded from British Columbia (Freeman 1958).

Larvae were found feeding only on apple and only at Summerland in the unsprayed-commercial orchard. Populations were low (Table 6).

S. affictana is univoltine and overwinters as a last-instar larva. Adults were observed in the field from the middle of May until the end of June. They were observed sitting on the limbs of apple trees during daylight hours and were less active than adult A. rosanus and A. argyrospila though more active than adult P. limitata.

Middle-instar larvae were found during June and larvae in the middle and last instars were found until the middle of August. All larvae observed were feeding in rolled up leaves. By the end of September larvae had moved away from the leaf cluster to their overwintering site. None could be found overwintering as larvae, though Chapman and Lienk (1971) found them in fallen leaves on the ground.

The life-history as described for the Okanagan Valley shows no significant difference from the descriptions given by Chapman and Lienk (1971) for New York state.

f) Argyrotaenia dorsalana (Dyar).

Freeman (1958) reported specimens of A. dorsalana in the Canadian National Collection from British Columbia.

Late-instar larvae were found feeding in typical leaf roller nests during the early and middle part of May on apple, in the unsprayed-commercial orchard, and wild rose at Summerland. Populations were low and about equal on both hosts (Table 6). It is univoltine and overwinters in the larval stage.

The habits as described for the Okanagan Valley show some differences from thos reported by Freeman (1958) for North America and Powell (1964) for California. These differences will be discussed later.

g) Choristoneura rosaceana (Harr.), The oblique-banded leaf roller.

C. rosaceana was formerly the major pest species of apple in the Okanagan Valley (Venables 1924).

In this study only low numbers of this species were found. It was found only at the Okanagan Falls site feeding on apple (Table 6). From this, no conclusion can be drawn on the life-history though the absence or rarity of it provides the basis of some conclusions discussed in a later section.

h) Other species.

Three species of leaf rollers were found feeding on rose or dogwood but not on apple. Populations of all of them were low. As this study was not directed towards non-apple feeding species they are mentioned only briefly. Acleris forbesana (McD.) and Acleris sp. near bowmana (McD.) were found only on dogwood at Summerland. Powell (1964) stated that

A. forbesana is apparently specific to dogwood in California. Croesia albicomana (Clem.) was found only on rose at Kelowna. Powell (1964) found it only on rose in California.

Other species of Lepidoptera which were found feeding on apple were: Lithophane georgii Grt. (Noctuidae); Epinotia rectiplicana Wlshm. (Olethreutidae); Hedia ochroleucana Hbn. (Olethreutidae); Epiblema spp. (Olethreutidae); Exartema punctanum Wlshm. (Olethreutidae); Filalima demissae Keif. (Glechiidae); and Trachoma walsinghamiella Busck (Gelechiidae). All these species were found as larvae feeding on the foliage.

3. Natural Enemies

a) Parasites.

Thirty-eight species of parasites were reared from leaf rollers during this study. Eight families and thirty-two genera were represented. Parasite species were divided into two classes, i) significant, ii) and incidental, based on the number of each species reared.

(i) Significant species. Those species which were well represented and considered significant because of the numbers found, are as follows in order of apparent numberical significance;

Itoplectis quadricingulata (Prov.) (Hymenoptera: Ichneumonidae) was reared from A. argyrospila, A. rosanus, and P. limitata feeding on apple, rose privet, dogwood and antelope bush and was found at all collecting

sites where leaf rollers were found.

Pseudoperichaeta erecta (Coq.) (Diptera; Tachinidae) was reared from A. argyrospila and A. rosanus feeding on apple, rose, privet, antelope bush and dogwood. It was found at all collecting sites where leaf rollers were found but was more common at Okanagan Falls than at other sites.

Nemorilla pyste (Wlk.) (Diptera: Tachinidae) was reared from A. argyrospila and A. rosanus feeding on apple, rose and privet. It was found at Okanagan Falls, Summerland, and urban areas in about equal numbers.

Hemisturmia tortricis (Coq.) (Diptera: Tachinidae) was reared from A. argyrospila, A. rosanus and P. limitata feeding on apple, rose and privet and was found only at Summerland and urban sites.

Diadegma sp. 1 (Hymenoptera: Ichneumonidae) was reared from A. rosanus, P. limitata, and P. idaeusalis feeding on apple, privet, dogwood and willow and was found only at Summerland.

Microgaster epagoges Gahan (Hymenoptera: Braconidae) was reared from A. argyrospila, A. rosanus, and P. limitata feeding on apple, rose, and dogwood. It was found mainly at Summerland and urban sites though a few were found from Kelowna.

Apanteles cacoeciae (Riley) (Hymenoptera: Branconidae) was reared from A. argyrospila, A. rosanus, and A. dorsalana feeding on apple, rose, privet, dogwood, and Russian olive. It was found at Summerland only.

Habrobracon xanthonotus (Ashm.) (Hymenoptera: Braconidae) was reared from A. argyrospila feeding on apple and found only at Okanagan Falls.

(ii) Incidental species. Those parasite species of which only a trace (less than five individual rearings of a species) was found were

considered incidental parasites. They are listed by order and family as follows:

Diptera: Tachinidae

Compsilura concinnata (Mg.) - from A. rosanus feeding on rose;

Eumea caesar (Ald.) - from A. rosanus and A. argyrospila feeding on privet and apple;

Hymenoptera: Braconidae

Oncophanes americanus (Weed) - from A. rosanus feeding on privet;

Agathis annulipes (Cress.) - from A. argyrospila and A. rosanus feeding on rose and privet;

Agathis sp. - from A. rosanus feeding on privet;

Apanteles sp.#49 - from A. rosanus and P. limitata feeding on apple and privet;

Hymenoptera: Ichneumonidae

Hercus pleuralis (Prov.) - from A. rosanus feeding on rose and dogwood;

Scambus tecumseh (Harris) - from A. rosanus feeding or rose;

Exochus nigripalpis tectulum Townes - from A. argyrospila feeding on apple;

Phytodietus sp. - from A. rosanus feeding on privet;

Glypta sp.- from P. limitata feeding on apple;

Acropimpla albiorcta (Cress.) - from A. rosanus feeding on rose;

Diadegma sp. #2 - from A. argyrospila feeding on apple and rose;

Gelis sp. - from A. rosanus feeding on rose and privet;

Pimplinae - from A. rosanus feeding on rose and privet;

Hymenoptera: Trichogrammatidae

Trichogramma minutum Riley - from A. rosanus and A. argyrospila on apple, rose, and privet;

Hymenoptera: Chalcididae

Spilochalcis albifrons (Walsh) - from A. rosanus feeding on apple;

Brachymeria ovata ovata (Say) - from A. rosanus and P. limitata feeding on apple and privet;

Hymenoptera: Elasmidae

Elasmus atratus Howard - from A. rosanus and A. argyrospila feeding on apple;

Hymenoptera: Pteromalidae

Habrocytus phycidis Ashm. - from A. rosanus and A. argyrospila feeding on apple and privet;

Catolaccus aeneoviridis (Girault) - from A. rosanus and A. argyrospila feeding on apple and privet.

Dibrachys cavus (Wlk.) - from A. argyrospila feeding on apple;

Dibrachys poss. new sp. A - from A. rosanus feeding on privet;

Hymenoptera: Eulophidae

Eulophus anomocerus (Crawford) - from A. argyrospila feeding on apple;

Sympiesis marylandensis Girault - from A. rosanus feeding on dogwood;

Dicladocerus westwoodii Westwood - from A. argyrospila feeding on apple;

Pediobius sp. - from A. argyrospila feeding on apple;

Elachertus aeneoniger (Girault) - from A. rosanus feeding on rose;

Elachertus cacoeciae (Howard) - from A. rosanus feeding on rose;

Elachertus sp. - from A. argyrospila feeding on antelope bush.

Table 7 gives the percentage of parasitism of leaf rollers on each

host plant from the different collecting sites with the exclusion of urban sites which is given in Table 11; the highest (32.4%) was on abandoned apple at Okanagan Falls while the lowest was on commercial apple and rose at Summerland and Kelowna. On unsprayed host plants the incidence of parasitism averaged about 25%.

b) Predators.

No egg predators were observed and no predators were found feeding on early instar larvae.

Known predatory insects that were found in leaf roller nests with dead leaf roller larvae may be presumed to be predators. They were: Chrysopa carnea Step. (Neuroptera; Chrysopidae); Chrysopa spp. (Neuroptera: Chrysopidae); Adalia bipunctata L. (Coleoptera: Coccinellidae); and Tapinoma sessile (Say) (Hymenoptera: Formicidae). Their numbers were low at all sites.

On one occasion an unidentifed species of bird was observed tearing apart leaf roller nests at Kelowna.

c) Nematodes and microbial pathogens.

Some P. limitata larvae in the unsprayed-commercial orchard at Summerland contained a granulosis virus. Apparently, no virus disease has been reported previously for this species.

Field collected larvae that were infected developed normally until the last instar. They then began to turn a milky, whitish color. The tissues became flaccid and disintegrated.

Attempts to infect A. rosanus larvae with this virus were not •

Table 7 Total percent parasitism of leaf roller larvae and pupae on different host plants at different sites.

PLANTS	SITES		
	Summerland	Kelowna	Okanagan Falls
apple-commercial	5.3	3.1	----
apple-unsprayed commercial	20.0	----	----
apple-wild	19.0	----	32.4
rose-commercial	1.1	----	----
rose-wild	26.0	16.0	+
privet-wild	28.2	----	----
antelope bush-wild	----	0	6.6
dogwood-wild	21.0	----	----
currant-wild	----	----	+

---- Plant absent

0 Plant present - no leaf rollers

\+ Plant present with leaf rollers - no parasites

successful. Infected last-instar P. limitata larvae were put in a rearing jar with middle to last-instar A. rosanus larvae and apple leaves. All A. rosanus larvae developed normally.

Thomas (personal communication, 1972) stated that most granulosis viruses are fairly host specific though there is a slight chance that the granulosis infecting P. limitata may infect A. rosanus and/or A. argyrospila.

Approximately one-hundred field-collected leaf roller larvae and fifty field-collected adults were dissected to see if they contained nematodes. No evidence of nematode infection was found.

3. Changes in Abundance of Leaf Rollers and their Parasites

a) Changes between habitat types.

As each of the collecting sites containing apple (Okanagan Falls, Summerland, and Kelowna) were located in different habitat types, comparisons between the abundance of different species of leaf rollers and their parasites could be made on the basis of habitat type.

It will be noted from Table 8 that the leaf roller species present and relative abundance of each varied by collecting site: A. rosanus, P. limitata, P. idaeusalis, S. afflictana and A. dorsalana were rare or absent except at Summerland which was located in the relatively wet habitat type; the opposite situation existed with C. rosaceana and A. argyrospila though the latter was present in all three habitat types. A. rosanus was the dominant species at Summerland and A. argyrospila was the dominant species at Okanagan Falls and Kelowna.

Table 8 The relative abundance of leaf rollers found on apple at the three collecting sites containing apple which were located in different habitat types.

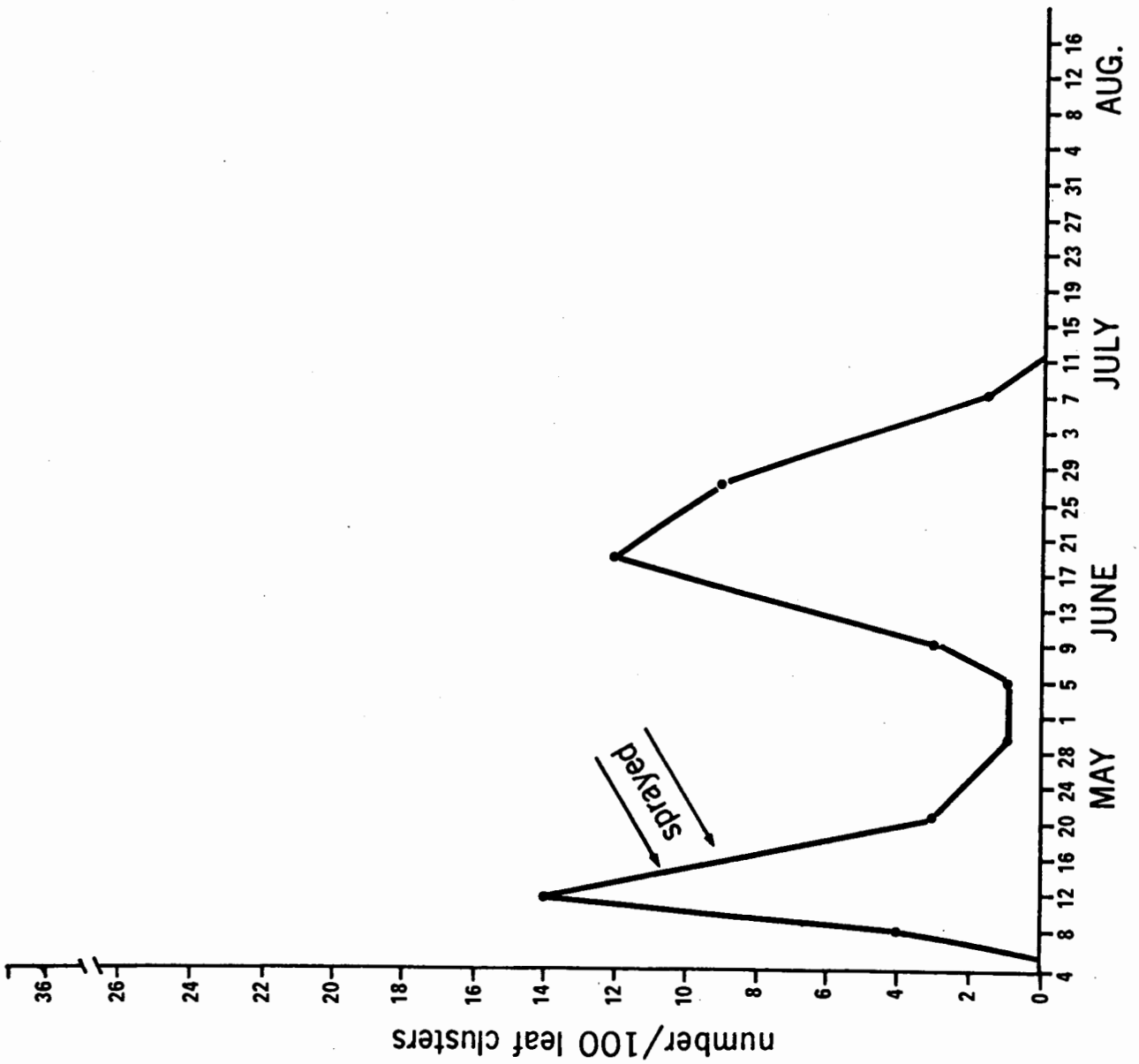
RELATIVE ABUNDANCE	SITE					
	Summerland		Kelowna		Okanagan Falls	
Dominant	A. rosanus	52%	A. argyrospila	95%	A. argyrospila	99%
Sub-dominant	A. argyrospila	35%	A. rosanus	4%	A. rosanus	0.5%
					C. rosaceana	0.5%
Other	P. limitata	11%	P. limitata	1%		
	P. idaeusalis	0.5%				
	S. afflictana	0.4%				
	A. dorsalana	0.2%				

As pointed out in a previous section some of the significant parasites were more common in one or the other collecting sites. P. erecta and H. xanthonotus were more common at Okanagan Falls in the dry habitat type than at the other sites in relatively wetter habitat types. H. tortricis, M. epagoges, and A. cacoeciae were more common at Summerland in the relatively wet habitat type than at the other collecting sites in relatively drier habitats.

b) Changes due to dispersal.

There is reason to believe that larval dispersal occurs by crawling, by dropping on a silken thread, and by being blown by the wind using the silken thread as buoyant. This dispersion was also evidenced by: the presence of feeding sites without larvae and without evidence of predation such as cast predator skins or larval remains; the occurrence of late instar larvae on plants that had been thoroughly searched earlier for eggs and/or early instar larvae; the presence of feeding sites on wild rose and pupae on nearby Saskatoon bush (which is not a food plant) in rolled up, undamaged leaves; the presence of pupae in rolled up leaves of apple that had not been fed on; and the results shown in Figure 6. This figure shows what happened when rose was sprayed to control leaf rollers. Before the spraying the larval populations were fourteen per one-hundred leaf clusters. After spraying populations dropped to near zero but approximately a month after spraying populations were up to twelve larvae per one-hundred leaf clusters. The increase in larvae on rose after spraying was evidently a consequence of larval dispersal from nearby,

Figure 6 Number of leaf rollers per 100 leaf clusters on cultivated rose at different times at Summerland. Sprayed on about 17-19 May.


number/100 leaf clusters
0
2
4
6
8
10
12
14
16
18
20
22
24
26
36
sprayed
4 8 12 16 20 24 28 1 5 9 13 17 21 25 29 3 7 11 15 19 23 27 31 4 8 12 16
MAY
JUNE
JULY
AUG.

beyond twenty feet, leaf roller infested apple trees which had not been sprayed.

My observations tend to agree with those of Paradis and LeRoux (1965), working with A. argyrospila, that larval migration away from a situation can be a major factor in reducing the population there.

c) Changes due to spraying.

Virtually no leaf rollers are found in orchards that are under a preventive spray program for codling moth or leaf roller control (Madsen, personal communication, 1972).

The number of leaf rollers per one-hundred leaf clusters was higher on apple sprayed in 1971 than on wild (abandoned) apple or unsprayed-commercial apple (Table 9). The situation was not as clear with respect to rose. The average number per one-hundred leaf clusters was about the same on commercial rose at Summerland and wild rose at Kelowna, but the commercial rose at Summerland had about twice the population as wild rose at Summerland (Table 9). The numbers per one-hundred leaf clusters on unsprayed-commercial apple, wild apple, and wild rose were about equal at Summerland, indicating that this is the situation when sprays are not applied; at the same site numbers were three times as high on commercial apple. When rose was sprayed early in the season the larval population was reduced, but by the end of the season the numbers were nearly as high as before the spraying (Figure 6).

Spraying lowered the population of P. limitata, P. idaeusalis, S. afflictana, and A. dorsalana relatively more than it did A. rosanus or

Table 9 Seasonal average of leaf rollers per 100 leaf clusters on different plants.

PLANT	SITE		
	Summerland	Kelowna	Okanagan Falls
apple-commercial	11.6	17.0	----
apple-unsprayed-commercial	3.5	----	----
apple-wild	2.9	----	7.0
rose-commercial	5.9	----	----
rose-wild	3.3	5.5	0.8

---- Plant not present

A. argyrospila at Summerland (Table 10).

d) Changes due to pruning and vehicle traffic.

Leaf roller populations on privet were highest on trimmed hedges on side streets; next highest on untrimmed hedges on busy streets, lower on an untrimmed hedge on a side street, and lowest on trimmed hedges near busy streets (Table 11). No clear trends are shown though it does appear that the combination of trimming and hedge location near a busy street lowers leaf roller populations.

Percentage parasitism was highest on a hedge on a side street which was untrimmed and lowest on trimmed hedges on busy streets (Table 11). This table shows that there may be a definite relationship between incidence of parasitism, hedge trimming and vehicle traffic.

6. Cross-Breeding of A. rosanus and A. argyrospila

A large number of adult A. rosanus and A. argyrospila were available as a result of the primary objectives of this study. They appear to be closely related in their habits, life-cycles, food plants, larval external characteristics, and as shown by Madsen and Vakenti (In press, 1973) they have closely related sex pheromones indicating they may be capable of interbreeding.

A number of experiments using various types of cages were conducted in the laboratory to determine if adults of the two different species would mate with each other. The adults were supplied with a water source but seldom lived for more than four days. Conditions were not optimal

Table 10 Relative abundance of different species of leaf rollers on various host plants at Summerland.

PLANT	RELATIVE ABUNDANCE		
	Dominant	Sub-dominant	Other
apple-unsprayed-commercial	P. limitata 42%	A. argyrospila 27% A. rosanus 26%	P. idaeusalis 3% S. affictana 2% A. dorsalana 1%
apple-commerical	A. rosanus 53%	A. argyrospila 45%	P. limitata 2%
apple-wild	A. rosanus 80%	A. argyrospila 10% P. limitata 10%	
rose-commercial	A. rosanus 49%	A. argyrospila 42%	P. limitata 9%
rose-wild	A. rosanus 72%	A. argyrospila 14%	P. limitata 6% P. idaeusalis 6% A. dorsalana 1%

Table 11 The density and degree of parasitism of A. rosanus on urban privet hedges. 1. Average of 5 sample sites, 2. Average of 3 sample sites, 3. 1 sample site.

Site		Number per 100 leaf clusters	Degree of parasitism (%)
Location	Condition		
Busy street	Trimmed	7.5[1]	4.4[1]
Side street	Trimmed	16.0[1]	11.2[1]
Busy street	Untrimmed	13.6[2]	17.6[2]
Side street	Untrimmed	10.0[3]	32.0[3]

for mating because of high temperatures in the laboratory and lack of a suitable lighting system. Adult males and females of both species were put into cages together in varying ratios from 1:1 to 1:10. The total number of adults put into a cage also varied from two to eleven depending on the number available each day.

Only one successful mating was observed between a female A. rosanus and a male A. argyrospila out of a total of forty-three experiments. The cage contained four male A. argyrospila and one female A. rosanus. The copulating pair were observed to remain together for approximately three hours. Unfortunately, no eggs resulted from this mating. The experiments were not under continuous observation and other matings may have occurred.

The conclusion is that the two different species can mate with each other but the frequency and successfulness of these matings is open to question.

DISCUSSION AND CONCLUSIONS

1. Feeding Habits

In general all leaf rollers observed in this study have the same feeding habits utilizing leaves though there is some fruit feeding. They are pests of apple because of the nature of their feeding and of their ability at high populations to defoliate trees. Early instar larvae feed on the developing fruit and buds in the spring, reducing the potential fruit set. Later, larval feeding on the developing fruit produces small, distorted, or scabbed (healed-over feeding injuries) mature fruit at harvest. This fruit is generally unmarketable.

At the population levels found on apple in the Okanagan Valley during this study, there appeared to be little or no competition between the various leaf roller species for larval food. Although all the leaf rollers and a number of other species of Lepidoptera feed on leaves, at no time during the season did there appear to be a lack of suitable feeding sites. This also indicates that competition for food is neither an interspecific nor an intraspecific limiting factor of leaf roller populations on apple.

My observations agree with those of Chapman and Lienk (1971) that fruit feeding by the early instar larvae of P. limitata is rare, while Gilliatt (1932) found that early instar larvae generally attached a leaf to the fruit and fed on the fruit. In eastern Canada early instar larvae of P. limitata were dependent on other, old, partly-fed-on leaf roller nests to establish feeding sites (Hall 1929; Gilliatt 1932). In effect

there would be intraspecific competition among early instar larvae for these favorable feeding sites that would limit populations. In the Okanagan Valley this type of competition did not occur and early instar larvae were found feeding on the under-surface of leaves that had not been fed on by other leaf rollers.

In central Washington State, approximately 300 miles south of the Okanagan Valley, P. limitata has two generations a year (Newcomer and Carlson 1952), while in southern British Columbia it is univoltine. These populations are not necessarily separated by geographical facters as there is actually one long valley from southern British Columbia into northern Oregon. This valley runs north - south and has mountain ranges on the east and west. This indicates that the difference in life-cycles between the Okanagan Valley and Washington populations is probably due to environmental factors instead of genetic ones since there would apparently be genetic flow between the populations. The univoltine life-cycle of P. limitata in the Okanagan Valley would tend to reduce the probability of its becoming a pest there compared with multivoltine strains of more southern areas where the shorter generation time enables populations to build up faster.

P. idaeusalis is univoltine with two different sizes of larvae over-wintering in New York (Chapman and Lienk 1971). In Pennsylvania, south of New York, it appears to be bivoltine (Frost 1923). In eastern Canada it is univoltine (Prentice 1965). In the Okanagan Valley it is univoltine with only one size larvae overwintering. Apparently this species is

univoltine in the more northern reaches of its range.

In New York, the majority of S.afflictana larvae construct their nest out of dead leaves or cause a living leaf to die by partially severing the leaf's petiole (Chapman and Lienk 1971). In the Okanagan Valley the majority of the larvae found had shelters of living leaves.

These observations point out the variability of different populations of leaf rollers in different geographical areas. It is surprising that, for the most part, Archips spp. do not exhibit this variability. The two species found in this study are univoltine throughout their range, which is very wide, and all local populations appear to have the same general feeding habits.

2. Factors Influencing Abundance of Leaf Rollers

The results of this study suggest there are a number of inter-related factors which influence the abundance of leaf roller species in the Okanagan Valley. These factors are intrinsic, or within the population of the species, and also extrinsic, and due mainly to man's activities.

a) Host plant relationships.

All of the Tortricinae found using apple as a host plant in this study have the habit of depositing their eggs in egg masses. Chapman and Lienk (1971) suggest that this habit accounts for dispersal pressure on the newly hatched larvae and consequently the general wide host range found among the Tortricinae. Chapman and Lienk (1971) also suggest that later instar larvae of A. argyrospila will feed on most any plant rather

than starve. My observations using privet leaves to rear A. argyrospila and Saskatoon leaves to rear larvae of A. rosanus and A. argyrospila, plants on which these species were not found in the field, also suggest this. Tortricinae, generally, are described as polyphagous feeders (Freeman 1958) though there is evidence that the number of primary hosts may be restricted (Chapman and Lienk 1971). Those plant species on which larvae and eggs are consistently found and normal development is completed are considered primary hosts.

The primary host plants of A. rosanus appear to vary within large geographical regions such as western and eastern North America. They also vary on a much more local scale as shown by the results of this study.

The high populations of A. rosanus found on apple at Summerland in the Okanagan Valley is not the general situation in North America. In Europe it has much the same pest status as A. argyrospila does in North America but apparently has not appeared in sizeable numbers on apple in North America. Why is unknown. In the Okanagan Valley currant was not a host;(though)it appears to be in eastern Canada (Whitehead 1926).

A. rosanus has been present on privet hedges in the Okanagan Valley for at least five years. Yet, populations on apple were low at both the Kelowna and Okanagan Falls site and relatively high at Summerland. Apple was a primary host only at Summerland. Prior to 1971 A. rosanus had not been found on apple in the Okanagan Valley. Possible explainations of why it was not found on apple are: it was not looked for; it was not

using apple as a host; and/or apple was growing under environmental conditions adverse for A. rosanus. Though it is difficult to separate the last two explanations, observations in support of the second follow: A. rosanus was found utilizing privet and rose as primary hosts in the urban areas of Okanagan Falls and Kelowna but not at the sites containing apple which in some cases were within a mile of the infested hedges; A. rosanus was in fairly high populations on apple and rose at Summerland where a privet hedge was located and it is possible that populations had built up on this hedge and moved off to other host plants. It is possible that the strain of A. rosanus which was introduced into North America was closely associated with privet and only now has begun to utilize other host plants. This is not characteristic of a polyphagous species though. The same general situation occurred with rose at Summerland. Rose was a primary host plant of A. rosanus at the site where apple and privet were present but not at a nearby site where only rose was present. The indication is that if a plant species is a primary host at one location and not at another, given appropriate dispersal time, local environmental conditions as well as a suitable primary host plant influences distribution.

A. rosanus has recently been found in the inland apple growing regions of Washington State, about 200 miles south of the Okanagan Valley (Madsen, personal communication, 1973). This suggests that A. rosanus populations on apple are on the increase in the Pacific Northwest. The indication is that A. rosanus populations are increasing on apple for the first time in

North America. The Okanagan Vally may be the start of population explosions of A. rosanus in the apple growing regions of North America parallel to that of A. argyrospila as it moved into apple growing areas in the early 1900's causing a great deal of fruit loss.

Not only did primary hosts vary in the Okanagan Valley but so did the population levels of A. rosanus on different hosts. The results of this study showing the number of a leaf roller species per one-hundred leaf clusters is an indication of host preference and alternate host importance. These population levels appear to be independent of number of host plants as there was no lack of suitable feeding sites or host plants. Possible reasons for these differences, assuming that A. rosanus is polyphagous, follow.

A. rosanus was more abundant on privet than on any of the other host plants surveyed. This could be due to : later egg-hatching dates, enabling larvae to avoid early season weather extremes; less dispersion loss because privet grows in thick hedges; and a continuous new food source as privet shoots grow throughout the summer. The same reasons that account for the higher populations on privet may possibly account for the lower populations on other host plants. Larval populations were about equal on apple and rose though eggs hatch later on rose and apparently less larvae would be killed by weather. This could be explained by assuming that apple is preferred over rose for egg laying and more egg masses are laid on apple. The low abundance on dogwood was probably due to the fact that its leaves are much larger and the establishment of feeding sites by young larvae would tend to be difficult.

The list of host plants for A. argyrospila numbers well over a hundred. The primary host plants of A. argyrospila varied by collecting site in the Okanagan Valley though not to the extent as for A. rosanus. Apple was a primary host at all sites. This suggests that A. argyrospila may be closely associated with apple though local environmental factors may influence its distribution in the same manner they do that of A. rosanus. Antelope bush was a primary host of A. argyrospila at the Okanagan Falls site. Larvae were found on it at one mile from the apple but rose was not a primary host plant at this site even though it was growing within fifty yards of the apple. Antelope bush was not a host plant at Kelowna but rose was a primary host. A. argyrospila was not found at the non-urban sites which did not have apple but had two other apparent primary hosts, antelope bush and rose. The indication is the same as for A. rosanus: that local environmental conditions determine primary host plants though A. argyrospila appears to be associated with apple while A. rosanus is associated with privet and apple.

Population levels of A. argyrospila varied in the Okanagan Valley on different host plants in much the same manner as A. rosanus populations did. Possible reasons for this follow.

A. argyrospila was more abundant on apple than on any other host plant surveyed. This could be due to either climatic effects on early instar larvae and/or a general preference of apple for egg laying. Egg masses on different host plants hatch at approximately the same time regardless of suitability of the host for feeding by early instar larvae. Rose leaves appear at least one week after egg masses have begun to hatch.

The larvae which emerge from the earliest egg hatching on rose have no leaves to feed on and starve or disperse. Rose is not a suitable host during that period though it does become suitable later. Antelope bush is a new host record for A. argyrospila and its use as a host plant is also an indication of the general wide host range of this species. Antelope bush leaves are small and sticky, compared to apple leaves, which probably makes it difficult for the young larvae to tie them into a shelter.

Apple and rose are new host records for A. dorsalana. Powell (1964) considers species of Pinacae as the normal hosts of this species while Freeman (1958) gives oak, Quercus spp., as the host plant. The larvae of this species found feeding on apple and rose may represent a change in the feeding habits. Oak was not present at Summerland where A. dorsalana was found and it was quite some distance to the nearest pine which was not surveyed on the assumption that it was not a host of apple-feeding leaf rollers, indicating that apple and rose were probably primary host plants.

The host plant relationships of P. limitata were difficult to determine because of low populations. It does appear that apple, rose, and dogwood are primary hosts.

The general conclusion is that each species of leaf roller does have alternative host plants which serve as local foci of the leaf roller species. These vary by both the species and by the geographical location. The density of alternative hosts in the immediate area of apple appears to have an effect on species of leaf roller found on apple.

b) Environmental conditions.

The relative abundance of the different species of leaf rollers on apple appeared to vary by the habitat type in which apple was growing. By observation and classification of habitat types it may be possible to determine what species of leaf roller(s) will be present on apple in that situation.

One method of comparing the similarity of two different community associations or habitat types is based on species presence. I used leaf rollers, trees, and shrubs to determine the index of similarity which is defined as: Index of Similarity = $\frac{2 \times \text{Species occurring in both communities}}{\text{Number of species in A} + \text{Number of species in B}}$ The index ranges from 0 to 1.0 to quantify the range from no similarity to complete similarity. The index of similarity between Summerland and Okanagan Falls was 0.35; between Summerland and Kelowna 0.48; and between Okanagan Falls and Kelowna 0.77. This points out the same gradient as the indicator plants of habitat types as discussed earlier. The relatively wet Summerland site was more closely related to the moderately dry Kelowna site than to the very dry Okanagan Falls site.

Not only were there differences in the presence of species of leaf rollers in the different habitat types but the habitat types themselves were different. This difference could be explained by the environmental water balance or the establishment of a moisture gradient. The Summerland site was located near a stream and a lake and also irrigated, the Kelowna site was irrigated, and the Okanagan Falls site was neither close to a stream or lake nor irrigated. The gradient is from the very dry

Okanagan Falls site to the relatively wet Summerland site.

Apple, a suitable host plant, was present at all three sites, indicating that food source was not the limiting factor in the distribution of the different species of leaf rollers. This indicates that some species of leaf rollers, notably A. rosanus and P. limitata, are stenoecious while others, such as A. argyrospila, are euryecious.

The leaf roller fauna of apple in the Okanagan Valley has changed during the last fifty years. Some species have become rare or absent while other species that were absent or rare have become abundant. The relative abundance of the different species by habitat type suggests that overall changes in the environmental water balance of the Okanagan Valley may have affected their relative abundance. A possible explanation for the change in species follows.

C. rosaceana was the dominant pest species on apple until the early 1920's (Venables 1924). Venables then found A. argyrospila to be the major pest with small numbers of C. rosaceana, Acleris maximana (B.& B.) and Aphelia alleniana (Fern.). In 1972, A. rosanus, A. argyrospila, and P. limitata were the major pest species followed by low numbers of P. idaeusalis, S. afflictana A. dorsalana, and C. rosaceana.

Two of the new pest species are interesting since they were thought to have a coastal distribution. A. rosanus has been present on both coasts of North America for at least fifty years. A. dorsalana was also considered to have a coastal distribution in British Columbia (Freeman 1958).

There has been a sequence of environmental changes that began with the

introduction of apple into the Okanagan Valley. C. rosaceana was native to the area and adapted for the original dry, arid environment. An abundant food source was supplied by the introduced apple and populations built up to large numbers.

The environment became less dry and arid and more humid as increasing numbers of people moved into the area and more land became cultivated. Population decrease of C. rosaceana was coincident with increased human population and increasing environmental water balance. A. argyrospila populations increased and it became the dominant leaf roller apple pest. Recently, the environmental water balance has increased to a high enough point that other species of leaf rollers, notably A. rosanus and P. limitata, have been able to build up large populations and become pests in certain situations.

The relative abundance of the species found at Summerland may be a good indication of the future leaf roller fauna of apple in the Okanagan Valley. As the environmental water balance of the Valley as a whole increases and spraying decreases, A. rosanus and P. limitata along with a number of minor species could become major pests.

c) Species removal.

Though the presence of A. rosanus and P. limitata and the other minor species of leaf rollers at Summerland is a fact the dominance of A. rosanus and P. limitata may only be apparent. Sex pheromone trapping of adult A. argyrospila, larval sampling of A. argyrospila, and egg mass sampling of A. rosanus and A. argyrospila has been quite extensive at this site. It

is possible that A. argyrospila has, in effect, been removed from the site resulting in the low populations found there. It is doubtful if there is a competition factor which, with the reduction of A. argyrospila, has allowed the other species to build up populations. The most likely effect, if there has been an effect, is the reduction of the overall leaf roller populations and the apparent dominance of leaf roller species other than A. argyrospila.

d) Traffic and pruning.

Two factors, vehicle traffic and hedge-pruning, appear to lower A. rosanus populations on privet and to lower the incidence of parasitism. Vehicle traffic was probably the major factor.

The major effect of vehiclar traffic on leaf rollers may have been from exhaust emissions though noise may be a possible contributing factor in lowering populations. With increased urbanization there will be increased vehicle traffic that may tend to decrease leaf roller populations but it is doubtful if populations will be lowered significantly by vehicle traffic. It does appear that increased vehicle traffic will tend to lower the incidence of parasitism.

Privet hedges are normally pruned at least twice during the summer, when A. rosanus is in the larval stage. Privet hedge-prunings were not destroyed but were left wherever they fell on the hedge or ground and the larval loss from pruning was probably low. Pruning and the destroying of the prunings before the larvae have a chance to move back onto the hedge can be utilized as a local control method in the future. It is

not likely that the pruning done during this study had a great effect on lowering the incidence of parasitism since larvae were capable of moving back onto the growing privet hedge.

At the begining of this study it was felt that the cultural practice of pruning apple trees in the winter had possibilities as a control method. The prunings with the Archips spp. egg masses attached to them could be destroyed before hatching in the spring reducing the leaf roller populations. In New York A. argyrospila egg masses were generally found on the small diameter branches (Chapman and Lienk 1971) and these are generally the ones that are cut from the tree during pruning operations. During this study no egg masses were found on branches less than one-half inch in diameter and the majority of the masses observed were on the main scaffold limbs, which confirmed the results given by Madsen (1970) for A. argyrospila egg masses in the Okanagan Valley. At the present it does not appear as though winter pruning and destroying of egg masses would have much effect on leaf roller populations.

3. Leaf Roller Parasite Relationships

A large complex of parasite species was recovered from leaf rollers in the Okanagan Valley. Thirty-seven species were recovered from A. rosanus and/or A. argyrospila; in Quebec, ten species were recovered from A. argyrospila over a seven year period (Paradis and LeRoux 1965); in Connecticut, twenty-five species were recovered from A. argyrospila and Archips griseus

(Rob.) over a three year period (Prokopy 1968). Apparently, there is a greater number of parasite species attacking leaf rollers in British Columbia than in eastern North America. As the studies done in the east surveyed apple only, it may indicate that there are a number of parasites which parasitize leaf rollers on plants other than apple and not leaf rollers on apple. My results agree with those of Powell (1962), who surveyed leaf rollers on a number of host plants, that the Ichneumonidae and Tachinidae are common parasites while Chalcidoidea are only incidentally associated with leaf rollers.

Larval and pupal parasites of Archips spp. either overwinter away from a host or need an alternative host which overwinters as a larva or pupa. If they need an alternate host for overwintering, because Archips spp. overwinters as an egg, this would apparently have an affect on the incidence of parasitism of Archips spp. Though the life-histories of the significant parasites found during this study are not well known it appears that at least some require hosts other than Archips spp. for overwintering. These parasites would then be limited in their populations by the number of available overwintering sites and would probably attack Archips spp. primarily when the stages of the primary host suitable for parasitizing are not in the field or as supplementary hosts when the primary host level is high and there is a build up of the parasite populations.

Generally, the recorded larval and pupal parasites of leaf rollers exhibit wide host ranges that include several families of Lepidoptera. Many, such as S. albifrons, E. atratus, D. cavus, C. aeneoviridis, and Gelis sp., are hyperparasites as well as primary parasites. None of the

parasite species found in this study appeared to be specific to any species of leaf roller. None of them appeared to be specific to leaf rollers as a group as the named species, generally, had been recorded from at least one other host species. In general, those parasites which were considered important in this study were those that appear to have wide host ranges. New host records are given in Table 12.

With the possible exception of two species it did not appear that any of the parasites were plant host specific. That is, they were found parasitizing leaf rollers on more than one plant species. This was difficult to determine with a number of the species because only low numbers were found. M. epagoges was not found attacking A. rosanus on privet at Summerland though it was reared from this species on nearby apple and rose. The indication is that it does not search privet. H. xanthonotus was not found attacking A. argyrospila on antelope bush at Okanagan Falls though it was reared from this species on nearby apple. The indication is that this species does not search antelope bush.

Incidence of parasitism was not high at any of the collecting sites and ranged from 19.0% to 32.4% on unsprayed apple. Chapman and Lienk (1971) found that the incidence of parasitism on wild apple was fairly constant in New York. The incidence of parasitism did not appear to be density-dependent on the different host plants at each of the sites containing apple. Paradis and LeRoux (1965) in a seven year study of A. argyrospila found that the pupal parasite Itoplectis conquisitor (Say) was apparently acting in a density-dependent manner based on a

Table 12 A list of new parasite host records for A. rosanus, A. argyrospila and P. limitata.

Archips rosanus	Archips argyrospila	Pandemis limitata
Compsilura concinnata	Dibrachys cavus	Apanteles cacoeciae
Apanteles cacoeciae	Habrobracon xanthonotus	Hemisturmia tortricis
Agathis annulipes	Eulophus anomocerus	Pseudoperichaeta erecta
Trichogramma minutum	Dicladocerus westwoodii	Microgaster epagoges
Sympiesis marylandensis	Elasmus atratus	Habrocytus phycidis
Elachertus cacoeciae	Catolaccus aeneoviridis	Itoplectis quadricingulata
Elachertus aeneoniger		Brachymeria ovata ovata
Elasmus atratus		
Habrocytus phycidis		
Catolaccus aeneoviridis		
Hercus pleuralis		
Scambus tecumseh		
Brachymeria ovata ovata		

variable percent parasitism in relation to pupal density. It is doubtful if any of the parasites found in this study were responding to increasing numbers of Archips spp. directly for the following reasons: density-dependent parasites are generally fairly host specific and none of the parasites found in this study were host specific; and they were dependent on other hosts at the times when the right stage of Archips spp. for parasitizing was not present in the field. Some of the significant parasites were found in the dry but not the relatively wet habitat type while the opposite occurred with other species. A combination of factors may account for this: lack of a suitable alternate host; adverse environmental conditions; lack of a suitable host species on a suitable host plant; and/or it had not dispersed into that area.

In this study spraying lowered the incidence of parasitism. At the same time these were the situations which had the highest leaf roller populations. Spraying probably affects parasites either by direct killing action on the parasite and/or by reducing the number of available hosts. Apparently, parasites are exerting a certain level of biological control and in situations where sprays are applied this control is reduced.

Those parasite species that appear to be important attack the later larval instars and the pupal stages. Parasite pressure was greatest after much of the damage to apple fruit had been done.

At present, it does not appear that the parasite complex found in the Okanagan Valley exerts an economically significant pressure on population regulation of the two major pest species, A. rosanus and

A. argyrospila. It may be possible to introduce (i) larval and/or pupal parasites or (ii) egg parasites from outside the Okanagan Valley to control these pests.

(i) Larval and/or pupal parasites. Larval and pupal parasites have been dismissed as potential biological control agents for A. argyrospila in Quebec (Paradis and LeRoux 1965). It is doubtful if there is a fairly host specific larval or pupal parasite of A. rosanus or A. argyrospila present anywhere. But, it would probably not do any harm to release larval and/or pupal parasites of these or closely related species into the Okanagan Valley and may help to control these pests.

(ii) Egg parasites. Study and research on the possible introduction of egg parasites to control A. rosanus and A. argyrospila would probably result in better control of these pests since they spend the better part of the year in this stage and fairly host specific egg parasites are avaiable.

The egg parasite Trichogramma minutum Ril. was recovered from both these species for the first time in the Okanagan Valley during this study. It has a wide host range and is apparently overwintering in Archips spp. eggs in the Okanagan Valley. It was found emerging from eggs in late May at the same general time that leaf roller larvae were hatching. It is not a specific parasite of Archips spp. It needs appropiate egg hosts during the spring and summer when A. rosanus and A. argyrospila are in the larval and pupal stages. Like a number of the larval and pupal parasites it is also dependent on other host species to maintain high populations.

There are two other fairly host specific egg parasites, Trichogrammatoymia tortricis Girault and Trichogramma cacoeciae Marchal, which are potentially useful agents for introduction into the Okanagan Valley for control of Archips spp. T. tortricis is a host specific parasite of A. argyrospila in New York and its life-cycle appears to be integrated with that of A. argyrospila (Chapman, Pearce, and Avens 1941). T. cacoeciae is a European species which has two generations a year on A. rosanus (Marchal 1927).

4. Factors Influencing Abundance of Leaf Rollers on Apple

a) Alternate host plants.

The influence of alternative host plants on leaf roller abundance on apple involves two factors: the species of leaf roller and what other host plants it ultilizes; and larval dispersal.

Different species of apple-feeding leaf rollers feed on different alternate host plants in the Okanagan Valley. This study concentrated on rose, privet, and dogwood as alternate host plants though several other plants were surveyed extensively. Privet was fed on by only A. rosanus; dogwood was fed on by A. rosanus and P. limitata; antelope bush was fed on by only A. argyrospila; and rose was fed on by all apple-feeding leaf rollers with the exception of S. afflictana.

The alternate host plants of each species of leaf roller in order of apparent importance follows. A. rosanus: privet, rose, dogwood; A. argyrospila: rose, antelope bush; P. limitata: rose, dogwood; P. idaeusalis:

rose, willow; S. afflictana: apple only; and A. dorsalana: rose only.

Rose is the significant alternate host-plant of apple-feeding leaf rollers as a group as it was either of first or second importance as an alternate host plant for most species. The importance of other host plants near an orchard can be determined only when it is known what species is present in the orchard. Because the primary host plants of the leaf rollers appears to vary even within the Okanagan Valley, the best procedure would be to survey any plants which are near orchards for apple-feeding leaf rollers.

Larval dispersal is especially important to leaf rollers in the Okanagan Valley which have only one generation a year, as the range can be increased in a short time period. Larvae are capable of being dispersed from an alternate host plant into the orchard and vice versa. The distance varies depending on wind and other environmental factors but is at least twenty feet and probably much more than this in some cases. Larvae can arrive, cause fruit damage, and establish an adult focus one year sooner in an orchard than can result from adult migration. This larval dispersal can be especially important when a commercial orchard has only the spring spray applied to control leaf rollers because the larvae can move into the orchard and cause damage after the effects of the spray have disappeared. This is important with A. rosanus as its larval population peaks and egg hatching dates are later on plants other than apple and the spring spray is timed to hatching date on apple for A. argyrospila.

b) Insecticides and cultivation.

The relative abundance of leaf roller species varied by the amount of care given the apple trees. Summerland was the only site where wild apple, unsprayed-commercial apple, and commercial apple were present. A. rosanus and P. limitata populations comprised 80% and 10% on wild, 27% and 42% on unsprayed-commercial, and 53% and 2% on commercial, respectively. These figures do not show any clear trends but that is probably to be expected as there are a number of factors which would influence the relative abundance of each species of leaf roller. The condition of the leaves would be expected to have an effect and these varied from diseased, scabbed-over leaves on wild apple to healthy-looking leaves on unsprayed-commercial and commercial apple. Each leaf roller species would be affected differently by the condition of the leaves also. Spraying would also be expected to affect the different species of leaf rollers differently for either behavioral or physiological reasons.

A possible explanation for the apparent greater effect of spraying on leaf rollers other than Archips spp. on apple and rose at Summerland may have something to do with their overwintering method. Both these species overwinter as eggs while the others overwinter as larvae.

During the last thirty years pesticides applied at repeated intervals have temporarily controlled leaf rollers in the Okanagan Valley. There is no doubt that spraying is effective in reducing the abundance of leaf rollers. From a pest management view-point one of the major problems with spraying is that repeated applications are needed for good control. Leaf roller populations increased from two to five

times more in commercial apple orchards than in orchards that had not been sprayed for a number of years. It is not clear why populations increased but does indicate that natural enemies are exerting some biological control. One of the problems in determining why leaf roller populations increase is that, as in the case of most Tortricinae, A. argyrospila and A. rosanus populations appear to be cyclic in nature and rise and decline, in part, irrespective of spraying (Chapman and Lienk 1971). Another characteristic is localized outbreaks.

In the future fewer pesticides will be applied and at less frequent intervals due to integrated controls and use of the sterile-male technique to control the codling moth. When this happens it is possible there will be outbreaks of one or more species of leaf roller in the Okanagan Valley.

5. Pest Status

A. argyrospila is a pest in North America, A. rosanus is a pest in Europe, P. limitata has been a pest in North America, and P. idaeusalis has been a sporadic pest in north-eastern United States (Chapman and Lienk 1971). S.afflictana utilizes apple as a primary host though it has never been a pest of apple. A. dorsalana has not been reported as a pest species.

Madsen (1970) and Madsen and Davis (1971) found that direct fruit damage by A. argyrospila on unsprayed apple in the Okanagan Valley varied between 9.1% and 25.0%.. Madsen and Vakenti (unpublished results, 1972) found up to 8.0% direct fruit damage by A.rosanus on unsprayed apple

in the Okanagan Valley. These levels are higher than the grower acceptable economic level of direct fruit damage.

The dominant species found on apple at each different site is probably the major pest species. Further study is needed to determine if this is correct.

6. Management of Leaf Rollers on Alternate Host Plants

Control of leaf rollers on their alternate host plants would lower their populations in the Okanagan Valley and serve to reduce infestation of commercial orchards.

Before attempting to control leaf roller populations on alternate hosts it was necessary to determine if the apple-feeding leaf rollers feeding on alternate hosts were serving as reservoirs for parasites. The results of this study indicate they were not serving as parasite reservoirs. It is possible that non-apple-feeding parasite hosts or reservoirs are present on the alternate host plants of apple-feeding leaf rollers though.

Identification of the pest species present on apple and surveys of the area for alternate host plants are preliminary to manipulation of alternate host plants. A possible pest management program involving removal and spraying of alternate host plants could be utilized to control apple-feeding leaf rollers on these plants.

Removing such alternate host plants as privet should be fairly cheap and simple as it is an introduced, cultivated plant that is usually grown

in urban areas. Removing wild rose would be comparatively expensive and difficult as it is a native plant that grows throughout the Okanagan Valley, and also is used as an ornamental; however, removal could be done on a limited scale near orchards.

Spraying alternate host plants that were not removed could be used in conjuction with removal. This spraying would have to be repeated at intervals - at the minimum, yearly. Spraying of alternate hosts of apple-feeding leaf rollers in urban areas could be increased by an information service aimed at urban residents. This could be in the form of information on the necessity of controlling leaf roller populations on ornamentals in order to reduce the incidence of infestation in commercial orchards. Also, it would be useful to inform commercial apple growers of the necessity of spraying alternate host plants that are located near orchards. Once the farmer is advised of the problem created by alternate host plants and decides to spray them there would probably be little increased cost over normal spraying procedures.

SUMMARY OF CONCLUSIONS

There are seven species of leaf rollers feeding on apple in the Okanagan Valley; A. rosanus, A. argyrospila and P. limitata are the most important.

The density of alternative host plants in the immediate area of apple appears to have an effect on species of leaf roller found on apple.

The abundance of leaf rollers and leaf roller species appeared to vary by habitat type that apple was growing in.

The life-cycles of the two major pest species, A. rosanus and A. argyrospila, closely coincide in time.

Different species of leaf rollers on apple differ primarily in their method of overwintering.

Different species of apple-feeding leaf rollers have different alternate host plants.

Rose is the most important alternate host plant.

In general, the parasites recovered were not host specific to leaf rollers and they were not plant host-specific.

Host plants besides apple need to be considered in a pest management program.

Alternate host plants with apple-feeding leaf roller infestations are not significant parasite reservoirs.

Leaf roller populations increase when spraying is not done regularly.

Reduced incidence of A. rosanus parasitism is coincidental with vehicular traffic.

During the last fifty years some species of leaf rollers in the Okanagan Valley have become absent or rare while other species that were absent or rare have become abundant; this change has been coincidental with increasing urbanization and cultivation of the land.

The relative abundance of the leaf roller species on the different host plants in the relatively wet habitat type at Summerland may be an indication of the future leaf roller fauna of the Okanagan Valley.

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CURRICULUM VITAE

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PERSONAL INFORMATION

Birthdate: 22 November 1943
Married, two children
U.S. Citizen; Canadian Landed Immigrant

EDUCATION

1962 Graduated from Toppenish St. High, Toppenish, Washington

1964 Trade School, Meatcutting, City College, Portland, Oregon

1970 B.S. (Entomology), Washington State University, Pullman, Washington

Special training courses completed: Medical Corpsman, Medical Specialist, Welfare Elegibility Examiner, Pest Control Operator, Vector-borne Disease Control.

WORK EXPERIENCE

1971 to present — Research Assistant and Teaching Assistant. Department of Biological Sciences, Simon Fraser University, Burnaby 2, British Columbia.

1970 — Pest Control Operator. Truly Nolen Exterminating, Inc., 4422 Montant Street El Paso, Texas. Part-time position.

1968 to 1970 — Technician and Research Assistant. Entomology Department, Washington State University, Pullman, Washington.

1965 to 1967 — Combat Medic. Fourth Infantry Division, United States Army.

1965 — Experimental Aide. Entomology Department, Washington State University, Pullman, Washington.

1964 — General Technician. United States Department Agriculture, Entomology Bureau, Nob Hill Street, Yakima, Washington.

Summer Work 1962, 1963, 1968 & 1971	Insect Control Assistant. Entomology Department, Del Monte Corporation, Cannery Road, Toppenish, Washington.

SOCIETY MEMBERSHIP

Entomological Society of America
Entomological Society of British Columbia
Washington State Entomological Society

PAPERS PRESENTED AT SCIENTIFIC MEETINGS

Mayer, D. F. 1973. Bionomics of leaf rollers in the Okanagan Valley of British Columbia. Western Cooperative Spray Conference, Portland, Oregon.

AWARDS

1963	Awarded an athletic scholarship Selected to Dean's List for outstanding scholastic work
1969	President's list in recognition of superior scholarship
1970	High scholarship roll for excellent grades
1970	Nominated to Phi Kappa Phi