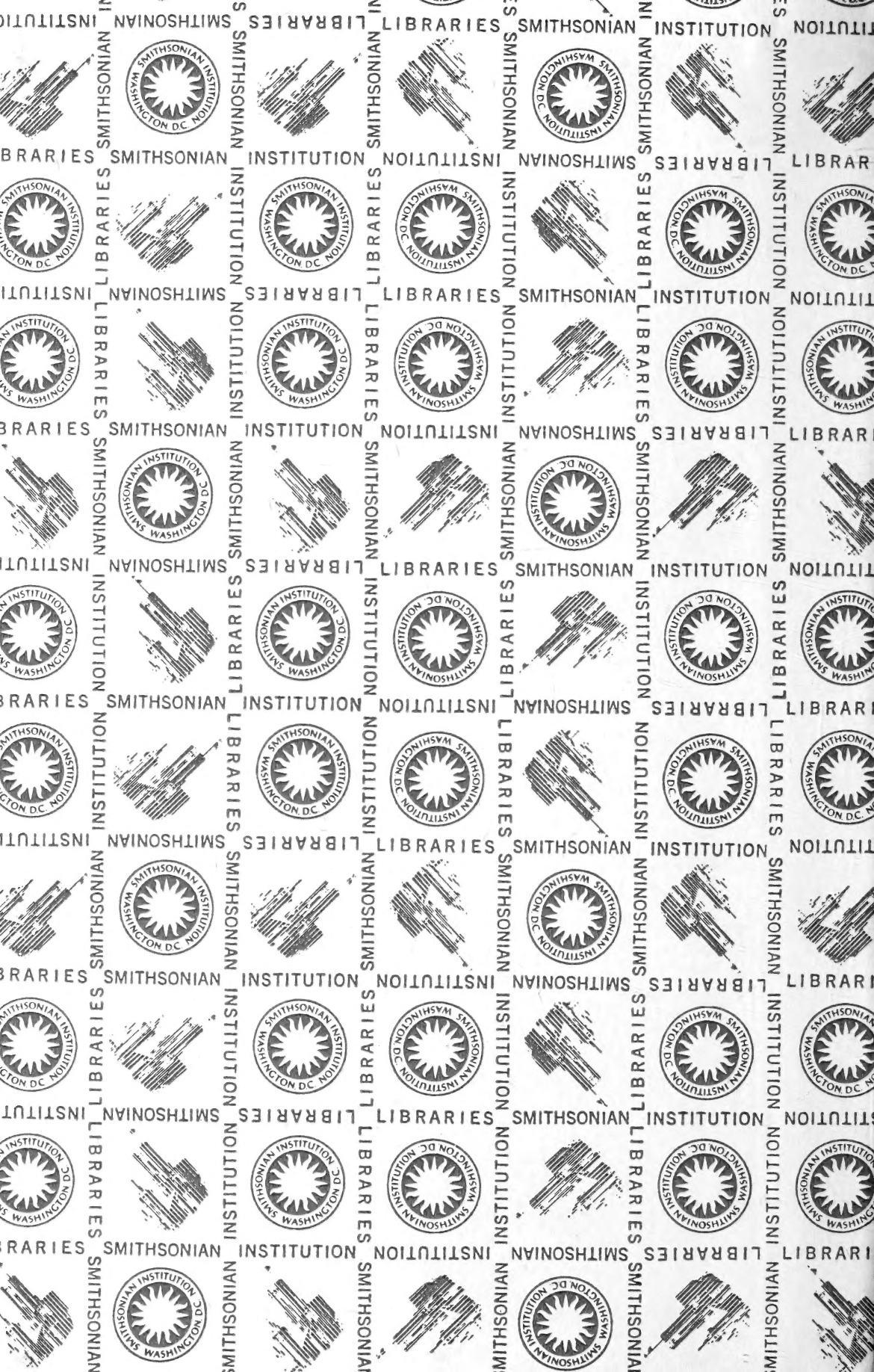
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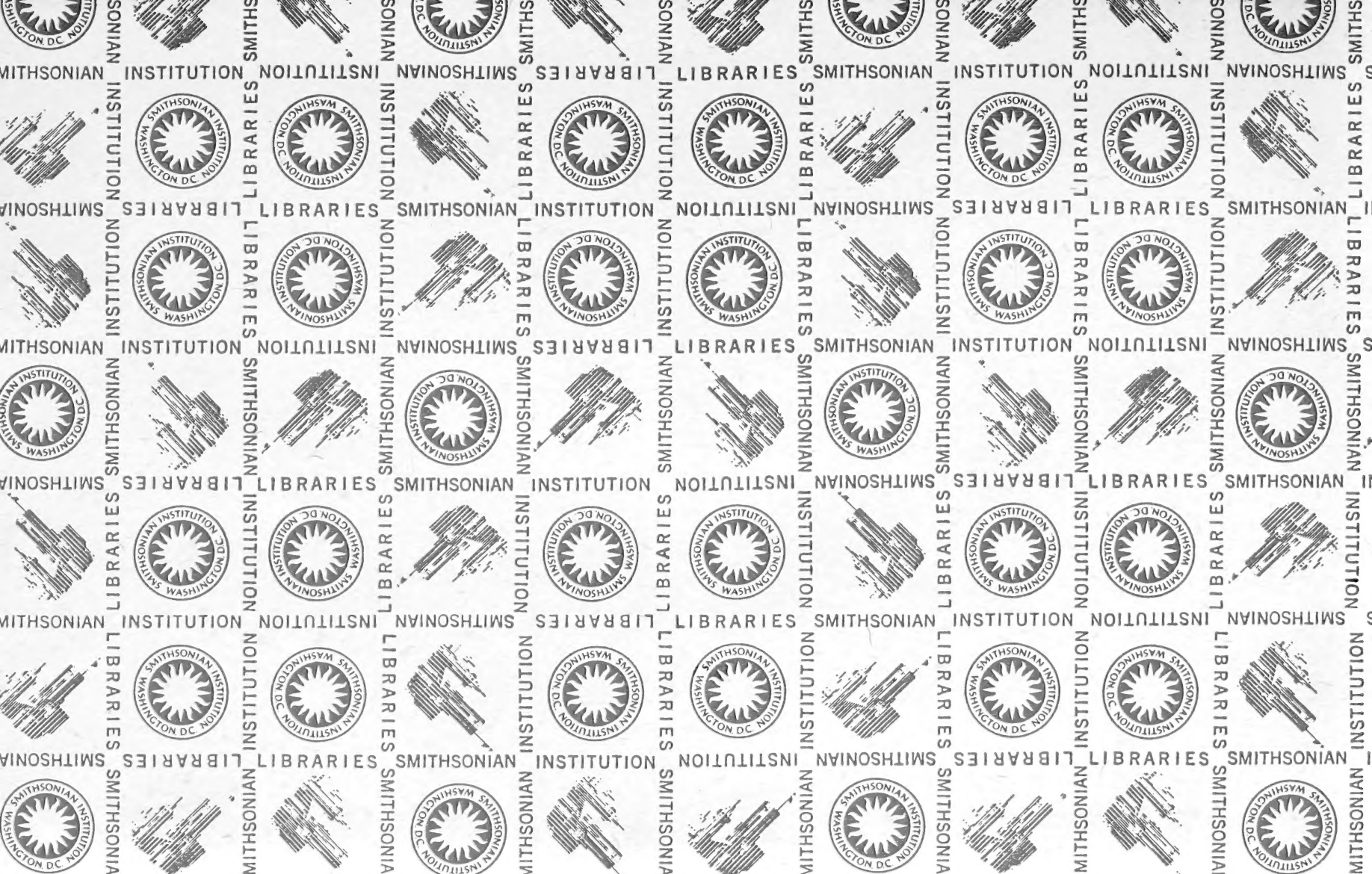
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EVALUATION OF PINE OIL FOR PROTECTING WHITE SPRUCE FROM SPRUCE BEETLE (COLEOPTERA:SCOLYTIDAE) ATTACK[1]

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ABSTRACT

The effectiveness of two formulations of pine oil (Norpine 65 and BBR-2) in protecting white spruce from attacks by spruce beetles was tested in south-central Alaska. Fifty percent of the pheromone-baited trees were protected by Norpine 65 for 1 year after treatment whereas only 33% were protected by BBR-2. Baited trees sprayed with Norpine 65 and BBR-2 were attacked less frequently than were baited check trees and sustained a lower attack density per tree. The percentage of trees protected by Norpine 65 was 13% greater than those protected by BBR-2. Although 85% of the trees treated with Norpine 65 were attacked, the attack density was approximately half that of trees treated with BBR-2.

INTRODUCTION

The spruce beetle *(Dendroctonus rufipennis* [Kirby]) is the most destructive insect of white spruce *(Picea gluaca* [Moench] Voss) in south-central Alaska. Much of the timber loss during the past 10 yeasrs has been in areas with high-value trees, such as recreational and residential areas (Werner and Holsten 1983). Lindane is currently registered in the United States by the Environmental Protection Agency for spruce beetle control; however, forest resource managers and home owners are reluctant to use lindane because of its high toxicity to mammals and its persistent residues. For these and other reasons there is a need to develop methods for protecting high-value, individual white spruce trees from attack by spruce beetles—methods that are effective and acceptable to the public. A naturally occurring compound that appears to repel bark beetles is pine oil. This compound is a by-product of the sulphate pulping process and is a complex mixture of naturally occurring derived secondary and tertiary terpene alcohols and other terpene hydrocarbons.

Norpine 65[4] and BBR-2[5] are two compounds consisting of mixtures of terpene hydrocarbons that have been field tested against ambrosia beetles, *Trypodendron lineatum* Olivier, (Nijholt 1980) and *Dendroctonus* bark beetles (Nijholt and McMullen 1980, Nijholt *et al.* 1981, Richmond 1985, McMullen and Safranyik 1985). Neither compound is currently registered as an insecticide in the United States.

Nijholt *et al.* (1981) recorded a 67% reduction in spruce beetle attacks on white spruce trees treated with Norpine 65. Richmond (1985) reported that Norpine 65 provided 100% protection to lodgepole pine *(Pinus contorta* var. *latifolia* Engelm.) from attack by mountain pine beetle *(D. ponderosae* Hopkins). In comparison, BBR-2 protected 47% of the treated trees. BBR-2 and Norpine 65 protected lodgepole pine where mountain pine beetle populations were low, but the compounds were less effecitve when beetle pressure was high (McMullen and Safranyik 1985).

Field tests were conducted in south-central Alaska to test Norpine 65 and BBR-2 as sprays for protecting white spruce from attack by spruce beetle. The tests were conducted in 1983 and 1984 along Kenai Lake in the Seward Ranger District, Chugach National Forest.

MATERIALS AND METHODS

In 1983, 30 uninfested live white spruce trees with an average diameter at breast height (dbh) of 30.86 ± 6.65 cm and an average height of 17.6 ± 0.60 m were selected in a northeast aspect stand that was heavily interspersed with beetle-infested trees. Fifteen trees were randomly assigned to each of two treatments—BBR-2 and untreated checks. In 1984, 50 uninfested live white spruce were randomly selected in an area adjacent to the 1983 test site. Treatments consisted of 40 trees sprayed with Norpine 65 and 10 untreated check trees. Trees were located a minimum of 30 m from other treatment trees. BBR-2 and Norpine 65 were applied undiluted with a garden-type 8-1 pressure sprayer to the bark surface of the tree bole (2 l per tree) to a height of 3 m until the bark was thoroughly wet.

To test the effectiveness of the two pine oil formulations, treated and untreated check trees were baited with 1 ml of aggregation pheromone frontalin (Werner and Holsten 1984) for 60 days after treatment. The pheromone was dispersed from perforated polyethylene vials attached directly to the south side of the trees at breast height. A 20- by 50-cm piece of wire hardware cloth (mesh size 6.3 by 6.3 mm) coated with Stikem Special® was attached to the bole of each tree directly above the pheromone dispenser to compare the number of spruce beetles visiting the treated and untreated trees.

Treatment efficacy was computed by recording the number of attacks on the lower 3 m of the bole and the number of trees that died after treatment. Trees were examined at 3 months after treatment to record trap catch and attack densities in the sticky traps; tree mortality was recorded at 13 months. Successful attacks were characterized by pitch tubes or entrance holes (Hard *et al.* 1983). Live trees with no attacks or < 10 attacks/3 m of lower bole were considered to be protected by the treatment. Analysis of variance and Waller and Duncan's Bayes LSD test (Duncan 1975) were used to compare beetle attack means and sticky trap catch means.

[1]This article reports the results of research only. Mention of a proprietary product or pesticide does not constitute an endorsement or a recommendation for use by the U.S. Department of Agriculture, nor does it imply registration under FIRFRA, as amended.

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[4]Northwest Petrochemical Corp., Anacortes, Washington.

[5]Safer Agro-chem Ltd., Victoria, British Columbia.

TABLE 1. Effectiveness of pine oil formulations in protecting white spruce from attack by spruce beetle in Alaska.

	BBR-2 (1983)				Norpine-65 (1984)			
	Check		Treated		Check		Treated	
	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
No. trees[1]	14	1	10	5	9	1	20	20
No. trees attacked	14	0	10	1	9	1	20	14
Mean No. beetles/trap[2]	70 ± 38d	15 ± 0b	54 ± 36c	6 ± 5a	83 ± 71d	10 ± 2a	16 ± 12b	4 ± 2a
Mean No. attacks/tree[2]	45 ± 8c	0a	41 ± 15c	0.5 ± 0.9a	48 ± 7c	3 ± 1a	21 ± 11b	4 ± 5a
Percent mortality	93	-	67	-	89	-	50	-

[1]Tree mortality assessed 13 months after treatment.

[2]Mean number of attacks on the lower 3 m of the tree bole. Values followed by the same letter within rows are not significantly different ($P > 0.05$; Waller and Duncan's Bayes LSD (Duncan 1975)).

RESULTS AND DISCUSSION

Spruce beetle populations were extremely high in the study areas during 1983 and 1984. Eleven of the BBR-2-treated trees (or 73%) were attacked compared to 14 (93%) of the untreated check trees. Sixty-seven percent of the treated trees died within 1 year after treatment compared to 93% of the check trees. Thirty-four or 85% of the Norpine 65-treated trees were attacked compared to 10 or 100% of the check trees. Fifty percent of the treated trees died compared to 90% of the check trees. Although significantly more trees treated with Norpine 65 were attacked than those treated with BBR-2, the severity of attack was less. There was no difference between treatments in the percentage of check trees attacked. Those check trees that lived apparently had little beetle pressure as few beetles were caught in traps and beetle attack density was < 3 per 3 m of the lower bole.

Trees treated with Norpine 65 caught significantly fewer beetles and sustained fewer attacks than untreated checks; trees treated with BBR-2 caught fewer beetles than checks but had as many beetle attacks (Table 1). Norpine 65-treated trees that died caught fewer beetles and had fewer attacks than trees that died in the BBR-2 treatment. There was no difference in the number of beetles caught and attack densities between trees treated with Norpine 65 and BBR-2 and that were still living 13 months after treatment.

Norpine 65 provided more protection to white spruce from attack by spruce beetles than did BBR-2. The mode of action of pine oil is unknown but evidence suggests it acts as an olfactory or gustatory repellent. It remains questionable whether phytotoxicity occurs in some species of conifer; phytotoxicity was not evident in this study. Although both Norpine 65 and BBR-2 provided some protection to white spruce from beetle attack, the composition and concentration of active ingredients was unknown. In addition, variation of active ingredients probably occurs among batches of pine oil obtained from different pulping runs, and until the active ingredients are known and bioassayed, care must be taken in interpreting field test results.

ACKNOWLEDGEMENTS

We thank John Hard, Danny Lyon, and Ken Zogas, USDA Forest Service, Fairbanks and Anchorage, Alaska, for their assistance in collecting field data, and George Hudak of the Seward Ranger District, Chugach National Forest, for providing a site for the study. We are also grateful to Dave Duncan, Northwest Petrochemical Corporation, for supplying the Norpine 65 and assisting in the application.

REFERENCES

Duncan, D.B. 1975. *t* tests and intervals for comparisons suggested by the data. Biometrics. 31: 339-359.

Hard, J.S., R.A. Werner, and E.H. Holsten. 1983. Susceptiblity of white spruce to attack by spruce beetles during the early years of an outbreak. Can. Jour. For. Res. 13: 678-684.

McMullen, L.H., and L. Safranyik. 1985. Some effects of pine oil on mountain pine beetle (Coleoptera:Scolytidae) at different population levels. Journ. Entomol. Soc. Brit. Columbia. 82: 29-30.

Nijholt, W.W., and L.H. McMullen. 1980. Pine oil prevents mountain pine beetle attack on living lodgepole pine trees. Can. For. Serv. Bi-Monthly Res. Notes 36: 1-2.

Nijholt, W.W., L.H. McMullen, L. Safranyik. 1981. Pine oil protects living trees from attack by three bark beetle species, *Dendroctonus spp.* (Coleoptera:Scolytidae). Can. Ent. 113: 337-340.

Richmond, C.E. 1985. Effectiveness of two pine oils for protecting lodgepole pine from attack by mountain pine beetle (Coleoptera:Scolytidae). Can. Ent. 117: 1445-1446.

Werner, R.A., and E.H. Holsten. 1983. Mortality of white spruce during a spruce beetle outbreak on the Kenai Peninsula in Alaska. Can. Journ. For. Res. 13: 96-101.

Werner, R.A., and E.H. Holsten. 1984. Scolytidae associated with felled white spruce in Alaska. Can. Ent. 116: 465-471.

THE EUROPEAN WINTER MOTH AS A PEST OF FILBERTS: DAMAGE AND CHEMICAL CONTROL[1]

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ABSTRACT

Different chemicals and two spray timing dates were evaluated for control of the European winter moth, *Operophtera brumata* (L.) in filbert orchards of Oregon. Data showed that endosulfan, carbaryl, phosalone, diazinon and fenvalerate were effective against this pest. A *Bacillus thuringiensis* product, Thuricide HPC was found to be ineffective. The timing of the spray treatment was critical. Sprays applied at 90 - 95% egg hatch (April) were much more effective than the sprays applied at 50 - 60% egg hatch (March). The spray timing seemed to be less critical for fenvalerate treatment, which was equally effective at both treatment dates.

The damage caused by *O. brumata* to filbert trees is described.

INTRODUCTION

The European winter moth, *Operophtera brumata* (L.), is a common pest of tree fruits in most of Europe and parts of Asia. It is widespread across northern Africa, temperate Eurasia from Scandinavia, Britain and France to Japan (Ferguson 1978). It was first recorded from North America in Nova Scotia in 1949 (Smith 1950), although there is strong indication that the pest might have been introduced to that province some time before 1930 (Cunningham *et al.* 1981). In the Pacific Northwest, the first introduction was detected in 1976 on southern Vancouver Island, B.C. (Gillespie *et al.* 1978), and by 1978 near Portland, Oregon. However, a close examination of insect collection records from Oregon indicates that several males of *O. brumata* had been collected in 1958 and later in 1973 from Oregon locations (Ferguson 1978).

The biology of *O. brumata* has been studied by a number of workers including Cumming (1961), Embree (1965, 1970), and Smith (1950) from Nova Scotia, Gillespie *et al.* (1978) from British Columbia, and J.C. Miller (personal communication) from Oregon. Miller has shown that *O. brumata* is well distributed throughout the northern Willamette Valley, Oregon and seems to prefer cultivated filberts (hazelnuts), *Corylus avellanae* L., although large populations were also noticed on *Prunus* (plum), *Malus* (apples), *Pyrus* (pear), and *Quercus* (oak) species. AliNiazee (1981) reported *O. brumata* as a new pest of commercial filberts in the Willamette Valley. Reported here are studies evaluating the effect of spray timing on the efficacy of some commonly used filbert insecticides against *O. brumata*. Damage caused on filbert trees is also described.

MATERIALS AND METHODS

Studies were conducted in a filbert orchard, heavily infested with winter moth, located in Washington County, Oregon. The orchard consisted of two (one with 12-year-old and the other with 30 - 40-year-old) tree blocks, approximately 4 ha each. The present study was conducted in the young tree block (consisting of mostly Barcelona and Daviana varieties) because of its convenience for spraying and sampling. The damage observations were conducted by collecting and examining 50-100 opening buds or terminals at weekly or biweekly intervals throughout the months of April, May and June. In 1981, four insecticide treatments (endosulfan, phosalone, carbaryl, and *Bacillus thuringiensis*) were compared with untreated checks, and in the 1982 season, five insecticides (endosulfan, phosalone, carbaryl, diazinon, and fenvalerate) were tested. Only those compounds which were registered for use in filbert system were selected for this study. The effects of different spray dates on the efficacy of the treatments were determined by applying chemicals at two different times: March 20 and April 3 in 1981; and March 29 and April 21 in 1982. These dates were selected to correspond with approximately 50-60% and 90-95% egg hatch in the field. The experimental plots were set up in a randomized block design with single tree plots separated by an unsprayed guard tree on all four sides to avoid spray drift. Each treatment was replicated four times. Sprays were applied during the early morning hours (6:00-10:00 a.m.) using a power sprayer with hand gun at a pressure of 250-300 p.s.i. Trees were sprayed to the point of drip, and *ca.* 6-8 liters of spray material was applied/tree.

Pre- and post-treatment counts were made by selecting 10 opening buds or terminals/tree at random at a height of 1.5-2.0 m above ground, approximately at the mid-canopy. These terminals were then brought to the laboratory and examined under a binocular microscope for winter moth damage. Data were analyzed using ANOVA and the means were separated using Duncan's Multiple Range Test.

Fig. 1. Shot-hole leaf feeding damage caused by *O. brumata*.

RESULTS AND DISCUSSION

Damage. The damage caused by the winter moth larvae on filbert trees resembles that of other native geometrids, including the western winter moth, *Operophtera occidentalis* (Hulst) and the Danby's winter moth *O. danbyi* (Hulst). However, both of these species are less common on filberts, and were rarely found in the present study. On the contrary, almost all early season damage in the study orchards was caused by *O. brumata*. The seasonal cycle of *O. brumata* appears to be well synchronized with the development of filbert trees, making it the most easily accessible plant for larval damage early in the season.

The larval damage caused by *O. brumata* was visible as early as middle to late March during 1981 and 1982, and continued for another 6-8 weeks. The early damage was caused by indiscriminate larval feeding on opening buds in March. Larvae made holes in and fed on the bud material by boring inside. Both vegetative and fruiting buds were affected. As the season progressed, the larvae started to feed on young and newly opened leaves thus causing a shot-hole effect. (Fig. 1). At this stage, their feeding damage resembled the damage caused by another insect, the Syneta beetle *Syneta albida* Lec., which appears in the orchards slightly later. The winter moth damage became more pronounced as the trees started to grow and form a canopy. Heavily infested trees were generally full of leaves with holes, and were unable to provide any shade. Eventually these leaves withered away and fell, causing defoliation (Fig. 2).

Chemical Control. Data (Tables 1 and 2) show differential susceptiblity of winter moths to different test chemicals. An examination of the results of different treatment dates suggests that timing appears to be a critical factor in chemical control of this pest. For example, in 1981 trials, the first spray applied on March 20 provided inadequate control (Table 1). Although the infestations were noticeably reduced in all treatments except *Bacillus thuringiensis* (formulation Thuricide HPC), the control achieved was inadequate to reduce damage. However, performance of the same insecticides improved substantially when they were applied on April 3, about two weeks after the first treatment (Table 2). Among the chemicals tested in 1981 (Table 2) endosulfan provided excellent control, followed by carbaryl and phosalone. The microbial insecticide *Bacillus thuringiensis* was less effective in both early and late treatments, although its performance also improved in late treatment plots.

In 1982, two additional chemicals, diazinon and fenvalerate were included in the trial and *B. thuringiensis* was deleted because of its ineffectiveness in 1981 trials. Data (Table 3) indicate that endosulfan and fenvalerate both performed extremely well; the infestation was reduced from 15% in control to 0% in treated plots. Other tested chemicals, diazinon, carbaryl and phosalone provided moderate control. However, statistically non-significant differences were found among these treatments. Late

TABLE 1. Efficacy of early treatment (March 20) of some selected insecticides against *Operophtera brumata* in filberts. Washington County, Oregon, 1981.

Chemicals	Dosage lb AI/100 gal	Percent Infestation of terminals after treatment[1,2] 7 days	17 days	24 days
endosulfan 50 WP	0.5	15.0 ab	7.5 ab	0.0 a
carbaryl 50 WP	1.0	7.5 a	2.5 a	2.5 a
phosalone 3 Ec	0.5	15.0 ab	15.0 ab	10.0 ab
Thuricide HPC	1/3 qt[3]/	40.0 b	10.0 ab	10.0 ab
Untreated check	---	27.5 b	27.5 b	15.0 ab

1/ Means followed by same letter are not significantly different (P = .05) using Duncan's Multiple Range Test.

2/ Pooled pre-treatment count conducted on April 3 showed 50 ±5 SD percent of the terminals were infested and that the infestation was very uniform throughout the study blocks.

3/ Actual formulated material.

TABLE 2. Efficacy of late treatment (April 3) of some selected insecticides against *Operophtera brumata* in filberts. Washington County, Oregon, 1981.

Chemicals	Dosage lb AI/100 gal	Percent Infestation of terminals after treatment[1,2] 7 days	17 days	24 days
endosulfan 50 WP	0.5	0.0 a	0.0 a	2.5 a
carbaryl 50 WP	1.0	2.5 ab	2.5 ab	2.5 a
phosalone 3 EC	0.5	10.0 ab	5.0 ab	7.5 ab
Thuricide HPC	1/3 qt[3]/	17.5 b	20.0 bc	22.5 b
Untreated check	---	50.0 c	27.5 c	17.5 ab

1/ Means followed by same letter are not significantly different (P = .05) using Duncan's Multiple Range Test.

2/ Pooled pre-treatment count conducted on April 3 showed 50± 5 SD percent of the terminals were infested and that the infestation was very uniform throughout the study blocks.

3/ Actual formulated material.

TABLE 3. Influence of different treatment dates on efficacy of some selected insecticides against *O. brumata* in filberts. Washington County, Oregon, 1982.

Chemicals	Dosage lb AI/100 gal	$\bar{x}$ Percent infestation on indicated dates [1]/ Early treatment [2]/ Pre-treatment (3-29)	Post-treatment (4-20)	Late treatment [2]/ Pre-treatment (4-21)	Post-treatment (4-29)
endosulfan 50WP	0.5	22.5 a	0.0 a	10 a	0.0 a
carbaryl 50 WP	1.0	27.5 a	2.5 a	15 a	3.0 a
phosalone 3 Ec	0.5	27.5 a	7.5 a	10 a	3.0
Diazinon 50 WP	0.5	17.5 a	2.5 a	10 a	0.0 a
fenvalerate 2.4 Ec	0.2	20.0 a	0.0 a	10 a	0.0 a
Untreated	---	20.0 a	15.0 b	10 a	10.0 b

[1]/ Means followed by same letter are not significantly different (P = 0.05) using Duncan's Multiple Range Test.

[2]/ Early treatment applied March 29, 1982 and late treatment April 21, 1982.

Fig. 2. Defoliation of a filbert tree branch caused by *O. brumata*.

treatment applied on April 21 did reduce the infestation in almost all treated plots; the performance of endosulfan, fenvalerate and diazinon was slightly better than carbaryl and phosalone, although the differences among treatments again were non-significant. The time of the spray application had little affect on fenvalerate treatment. Since this synthetic pyrethroid is extremely effective and long-lasting, the spray timing seems to be less important than it was with the other compounds.

Treatment timing is a critical factor in determining the performance of insecticide sprays in all crop systems. Improper timing causes ineffective control. The early spray in 1981 was applied at about 50% egg hatch, and the late spray at about 90% egg hatch. In 1982, the early spray was applied at about 60-65% egg hatch and the late spray near 100% egg hatch. Most growers with *O. brumata* tend to apply their control treatments as early as possible (preferably in late March and early April), to avoid initial bud damage. Data presented here suggest that although the early treatments would reduce *O. brumata* populations markedly, they would be ineffective in controlling late emerging larvae. It appears, therefore, that spray application during the first two weeks in April (depending upon the spring temperatures), which corresponds to the late treatment date of this study, might provide better control using the same chemicals. This later date would coincide with about 90-95% egg hatch in most years. Since the early damage is generally insignificant, it seems that filbert growers can benefit by waiting until most eggs have hatched before applying chemical treatments for *O. brumata* control.

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REFERENCES

AliNiazee, M.T. 1981. The obliquebanded leafroller and the winter moth: two new pests of Oregon filberts. Proc. Oreg. Wash. and B.C. Nut Grow. Soc. 66: 98-100.

Cunninghan, J.C., N.V. Tonks and W.J. Kaupp. 1981. Viruses to control winter moth, *Operophtera brumata* (Lepidoptera:Geometridae). J. Entomol. Soc. Brit. Columbia. 78: 17-23.

Cumming, F.G. 1961. The distribution, life history and economic importance of the winter moth, *Operophtera brumata* in Nova Scotia. Can. Entomol. 93: 135-142.

Embree, D.C. 1965. The population dynamics of the winter moth in Nova Scotia, 1954-1962. Mem. Entomol. Soc. Can. No. 46, 57 pp.

Embree, D.G. 1970. The diurnal and seasonal patterns of hatching of winter moth eggs, *Operophtera brumata* (Lepidoptera:Geometridae). Can. Entomol. 102: 750-768.

Ferguson, D.C. 1978. Pests not known to occur in the United States of limited distribution. Winter moth, *Operophtera brumata* (L.) (Lepidoptera:Geometridae). U.S. Dept. Agric. Coop. Pl. Pest Rep. 3: 687-694.

Gillespie, D.R., T. Finlayson, N.V. Tonks, and D.A. Ross. 1978. Occurrence of the winter moth, *Operophtera brumata* (Lepidoptera:Geometridae) on southern Vancouver Island, B.C. Can. Entomol. 110: 223-224.

Smith, C.C. 1950. Notes on the European winter moth in Nova Scotia. Can. Dept. Agric. For Biol. Div., Bi-mon. Prog. Rep. 6(2):1.

RESPONSES TO PLANT EXTRACTS OF NEONATAL CODLING MOTH LARVAE, *CYDIA POMONELLA* (L.), (LEPIDOPTERA:TORTRICIDAE:OLETHREUTINAE)

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ABSTRACT

A bioassay was designed to test behavioral responses of neonatal codling moth larvae to chloroform and methanol extracts of 25 plant species. Chloroform extractable materials from absinthe wormwood, *Artemisia absinthium* (L.), rabbitbrush, *Chrysothamnus nauseosus* (Pallas), and tansy, *Tanacetum vulgare* (L.) showed promise as possible feeding deterrents to neonatal codling moth larvae.

INTRODUCTION

In Washington State approximately half the cost of controlling arthropod pests in apples is attributable to the codling moth, *Cydia pomonella* (L.) (Ferro *et al.* 1975). Much of the damage occurs as "stings" made by probing neonatal larvae attempting to penetrate but then not entering the fruit. This "stinging" behavior might be linked to incompletely developed chemoreceptors. Immediately upon eclosion from the egg, larvae may not be able to recognize the fruit as a potential food source. This "non-recognition" phenomenon has been shown by Wiklund (1973) for early instars of *Papilio machaon* (L.) and by Bland (1981) for first instars of acridids. Non-recognition of food by neonates can lead to wandering activities that increase their exposure to abiotic and biotic mortality factors. As a result, in unsprayed apple orchards, death of neonatal codling moth larvae reduces the population by greater proportions than mortalities of any other life stage (Ferro *et al.* 1975, MacLellan 1977). Therefore, new control efforts should be directed to this stage. Disruption of larval feeding behavior by the use of secondary plant compounds may increase wandering and thus mortality.

We surveyed local plants for extracts that might modify the feeding behavior of neonatal codling moth larvae. Extracts that prevented or interrupted feeding activity were considered possible sources for feeding deterrents as defined by Schoonhoven (1982). Twenty-five selected plant species of eastern Washington and northern Idaho were collected in the survey. This study concentrated on neonatal larvae and their feeding behavior rather than on the long-term development of insects fed on artificial diets containing the suspected feeding deterrents.

MATERIALS AND METHODS

Plant Collection and Extraction

Test plants were collected during the summer of 1982. Criteria used to select the plants included strong odor, notable lack of herbivore feeding activity, or literature references concerning their repellent properties. An effort was made to include at least one representative from each of a variety of plant families (Table 1).

Plants chosen appeared healthy and free from visible signs of disease. Entire plants were collected including a moist ball of soil around the roots. The roots were wrapped in moist paper towels and covered with a plastic bag for transport. Plant samples were either frozen or extracted within 1 h of collection.

Ten grams of leaves (and flowers, if present) were weighed, wrapped in plastic, and frozen at ca. -16°C to preserve plant components without changes in chemical composition due to enzymatic activity (Draper 1976).

[1]Washington State Univ., College of Agriculture and Home Economics Research Center, Scientific Paper 7027. Work done under project number 5405.

Frozen or fresh plant material was ground (<4°C) to a slurry in a Sorval Omnimixer® in 30 ml of chloroform and methanol, 2:1 ratio. The slurry was left for 2 h in a covered flask, then filtered through a Büchner funnel. Solvents were transferred to a separatory funnel and the two phases were then collected in vials, flooded with nitrogen, and stored at -16°C until tested.

Bioassay Design

"Transparent" variety apples ($\bar{x}$ diam = 5 cm) were collected in late July, 1982, from an abandoned, unsprayed tree near Viola, Idaho in Latah County. Apples were held at 4°C and used within 6 months. A cork borer was used to remove 20 (0.8 cm diam, 0.5 cm thick) plugs from the same apple for each test. Each plug was held by the epidermis with a suction tube and dipped 3 times in liquid Paraplast® tissue embedding medium (melting point 56-57°C) to coat the plug, excluding the epidermis. Each plug was then placed on a filter paper (2.1 cm) to facilitate handling during test procedures. Twenty freshly-prepared plugs were required for each experiment.

A 9 cm plastic petri dish served as the test arena (Fig. 1). A 1.2 cm hole was drilled in the center of the dish and covered with nylon screen (100 μm mesh) to prevent escape by the larvae. A section of clear plastic tubing (I.D. 2.1 cm, 1.2 cm tall), with four 0.3 cm holes drilled in the base at 90° intervals, was secured over the center hole. A polyethylene tube (O.D. 1.4 cm, I.D. 1.0 cm) for connecting a vacuum line was glued in place over the 1.2 cm hole on the bottom of the dish. Four 0.3 cm holes were drilled at 90° intervals in the center of the side wall of the dish and covered with nylon screen. A thin layer of vacuum grease was applied to the top lip of the petri dish and the lid was secured with 3 rubber bands. Five arenas were placed in a series and vacuum was applied to create an air flow of 24 cc/sec/arena. The air flow permitted test larvae to find the apple plugs by following the odor gradients and also prevented a buildup of odors. Dense smoke demonstrated that the air flow pattern was uniform.

Bioassay Procedure

Three milliliters of chloroform extract were transferred to a pre-weighed round-bottom flask and flash-evaporated to dryness under vacuum at room temperature. The flask and residue were re-weighed and enough 1% Triton-X:water was added to make a 1% (w/v) solution of plant extract. A similar procedure was followed for methanol extracts, but 1% methanol:water was added to the dry residue to obtain a 1% (w/v) solution of plant extract.

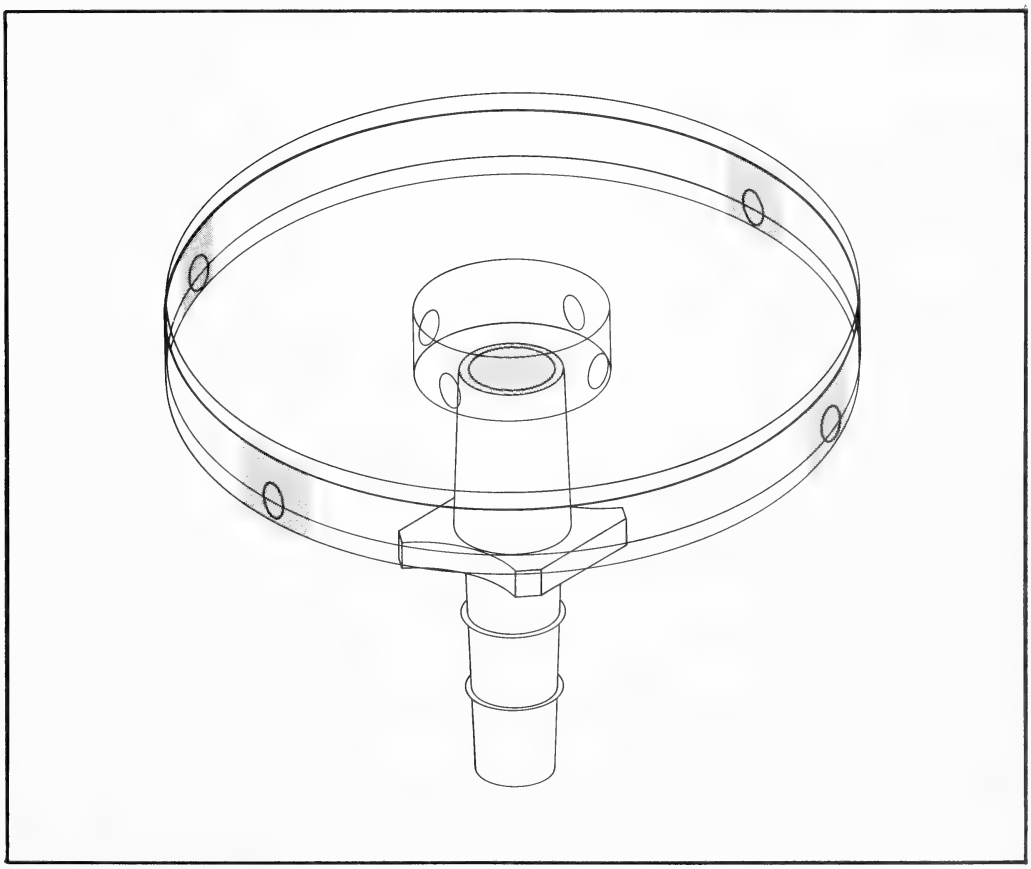

Fig. 1 Modified petri dish used for test arena bioassay.

The epidermis of the apple plugs was immersed in weighed test solutions, and excess fluid was allowed to drain back into the reservoir for several seconds. The amount of 1% solution adhering to each plug was determined by re-weighing the test solution reservoir. Plugs to be used as controls were immersed in 1% Triton-X:water mixture (for chloroform extraction tests) or a 1% methanol:water mixture (for methanol extraction tests). In each arena a plug was placed at each 90° interval with test and control plugs alternating, for a total of 4 plugs.

Test Animals

The codling moths used for this research were collected as larvae from unsprayed apple trees near Viola and reared through two generations on an agar-wheat germ diet (Howell and Clift 1972). All experiments were conducted in a controlled environment with long day (16 h light:8 h dark) illumination from overhead fluorescent lighting, a temperature of 29°C ± 1°, and RH of 55-60%. For each test, 10 larvae (<24 h old) were transferred to each of 5 arenas. After 24 h the location of each larva was recorded. Results were analyzed by one-way analysis of variance (Fisher's LSD $P<0.001$). Mortality and feeding behavior were noted.

Feeding Stations

Initially, experiments were conducted to determine the optimal number of feeding stations necessary to ensure that neonates would find the apple plugs with minimal wandering. This was done by varying the number (1 to 4) of untreated apple plugs in each arena. Four apple plugs resulted in establishment of 90% of the larvae. Therefore, all tests were conducted using 4 stations. In addition, results obtained while using 4 untreated plugs/arena showed an even distribution of larvae on each of the stations with no significant ($P<0.05$) feeding preference for any 1 station. There was also no observed hesitation by the larvae to feed on any of the feeding stations treated with either control solvent, 1% Triton-X:water or 1% methanol:water.

Tests were made of chloroform and methanol extracts of 25 plants (Table 1). Extracts that reduced feeding on treated stations to ≤20% were re-tested (Table 2). Methanol extracts were generally ineffective, and only the alcohol extract of bittersweet, *Solanum dulcamara*, was re-tested. The most promising materials, chloroform extracts from absinthe wormwood, *Artemisia absinthium* (L.), rabbitbrush, *Chrysothamnus nauseosus* (Pallus), and tansy, *Tanacetum vulgare* (L.), were then used in a third series of tests (Table 3).

TABLE 1. Plants from the Palouse area of Washington and Idaho collected and extracted to test for compounds modifying behavior of neonatal codling moth larvae.[a]

Family	Scientific and common name[b]	Date collected
Pinaceae	Abies grandis (Douglas) Grand Fir	VI-23-82
	Pinus monticola (Douglas) Western White Pine	VI-23-82
	Pseudotsuga menziesii (Mirbel) Douglas fir	VI-23-82
Liliaceae	Allium sativum (L.) Garlic	VIII-19-82
	Veratrum californicum (Durand) False Hellebore	VI-23-82
Aristolochiaceae	Asarum caudatum (Lindley) Wild Ginger	VI-23-82
Geraniaceae	Geranium viscossissimum (Rydberg) Sticky Geranium	VII-12-82

Leguminosae	Lupinus argenteus (Pursh) Silky lupine	VI-10-82
Labiatae	Nepeta cataria (L.) Catnip	VI-24-82
Cruciferae	Tropaeolum majus (L.) Nasturtium	IX-19-82
Convolvulaceae	Convolvulus arvensis (L.) Field Bindweed	VI-25-82
Solanaceae	Solanum dulcamara (L.) Bittersweet	IX-13-82
	Capsicum annuum (L.) Pepper	X-14-82
Umbelliferae	Conium maculatum (L.) Poison Hemlock	VI-16-82
Asteraceae	Achillea millefolium (L.) Yarrow	VI-25-82
	Anthemis cotula (L.) Mayweed	IX-17-82
	Artemisia absinthium (L.) Absinthe Wormwood	VI-16-82
	Chicorium intybus (L.) Chicory	VII-26-82
	Chrysothamnus nauseosus (Pallas) Rabbitbrush	IX-23-82
	Erigeron canadensis (L.) Horseweed	IX-15-82
	Madia glomerata (Hooker) Tarweed	VIII-10-82

Matricaria matricarioides (Lessing) Pineapple Weed	VII-7-82
Tanacetum vulgare (L.) Tansy	IX-6-82
Taraxacum officinale (Weber) Dandelion	VIII-16-82
Tragopogon porrifolius (L.) Salsify	VI-15-82

[a]The Pinaceae, Liliaceae, and Aristolochiaceae were collected in Latah County, Idaho; all others were collected in Whitman County, Washington.

[b]Names from Hitchcock and Cronquist (1973).

RESULTS AND DISCUSSION

Because the female codling moth does not always oviposit directly on the young fruit, neonatal larvae are exposed to many environmental hazards. Thus, these newly emerged larvae must search for food, resulting in a depletion of energy resources, an increase in exposure to predation, parasitism, and pathogens and desiccation due to high temperatures and low relative humidity. These latter climatic conditions are especially prevalent in the central basin of Washington. Exposure to these hazardous situations makes the first larval instar the "weak link" in the life cycle of the codling moth.

Among the 25 plant species tested, a number of extracts showed considerable promise as feeding deterrents for neonatal larvae of the codling moth. There were significantly ($P < 0.001$) fewer larvae found on the apple plugs treated with the chloroform extracts of *Artemisia absinthium*, *Chrysothamnus nauseosus*, and *Tanacetum vulgare* than were found on the control plugs treated only with chloroform. *Tanacetum vulgare*, for example, is closely related to the chrysanthemums which are known for their insecticidal properties (Wodehouse 1971). The main components of the volatile oil of *T. vulgare* were identified as bicylic monoterpenoids, borneol (Brewer and Ball 1981), β-thujone and ℓ-camphor (Gibbs 1974). The latter repels moths (Windholz *et al.* 1976), and tansy extracts have proven to be particularly obnoxious to insects (Lewis and Elvin-Lewis 1977). Tansy oil diluted in alcohol has been used as a mosquito repellent (Crockett 1977).

In addition, a polyacetylene (trans-dehydromatricaria ester) has been isolated from *T. vulgare* leaves (Bohlman *et al.* 1973). Polyacetylenes are often associated with composites such as *Chrysothamnus nauseosus* where they have been credited with antifeeding activity against *Leptinotarsa decemlineata* (Rose *et al.* 1980). For example, dihydromatricaric acid is a polyacetylene that is a known defense secretion used by a cantharid beetle, *Chauliognathus lecontei* (Meinwald *et al.* 1968). Seven of the 25 plants tested are known to contain polyacetylenes, including *Matricaria matricarioides* (Lessing) whose generic name implies "a place where something rotten is generated" (Borrer 1960). Extracts from only 2 of the 7 polyacetylene-containing plants tested, *T. vulgare* and *C. nauseosus*, exhibited antifeeding activity against neonatal codling moth larvae. This is not surprising since so many insects feed upon plants of the Compositae. Absinthins, dimeric sesquiterpenoids isolated from *Artemisia absinthium*, inhibited feeding by larvae of *Spodoptera littoralis* (Boisduval) (Wada and Munakata 1971), and chloroform extracts from this plant deterred 90% of the codling moth larvae from feeding on treated apple plugs. Sesquiterpenoids from *Parabenzoin trilobum* (L.) (Wada *et al.* 1968) and *Aneura pinguis* (L.) (Goodwin 1971) have provided antifeedant activity against several insects, but not all sesquiterpene-containing plants deter feeding. *Achillea millefolium*, for instance, is known to contain at least 4 sesquiterpenoid structures (Yoshiaka *et al.* 1973), and yet chloroform extracts of yarrow had no effect on *C. pomonella* larvae.

Two plants which contained chloroform extracted materials that were effective feeding deterrents were *Veratrum californicum* (Durand) and *Allium sativum* (L.). *V. californicum* contains teratogenic steroid alkaloids which cause cyclopian and related cephalic malformations in lambs born to ewes that ate the plants (Binns *et al.* 1963). These defects were also found to occur in other animals eating the plant (Keller 1975). For this reason, *V. californicum* was viewed as containing potentially hazardous materials, and was not investigated further. However, mixed alkaloidal preparations of *Veratrum* and *Schoenocaulon* have been used as insecticides (Kingsbury 1964). *A. sativum*, garlic, although known to be an effective insect repellent (Nasseh 1982) was considered too odoriferous for pre-harvest application to an apple crop.

TABLE 2. Percentage of larvae actively feeding on apple cores treated with chloroform extracts of various plants or found dead within the arena after 24 h.

Plant species	% Feeding on treated apple cores	% Mortality
A. sativum	2	8
A. absinthium	9	10
C. nauseosus	12	10
G. viscossissimum	20	8
M. glomerata	12	8
P. monticola	14	12
S. dulcamara	12	18
T. vulgare	3	16
T. majus	12	10
V. californicum	2	4

[a]When only solvent-treated apple cores were used, 90% of the larvae penetrated the epidermis and mortality averaged 4% for 15 arenas of 10 larvae each.

TABLE 3. Location of 10 larvae placed in each arena after 24 h. Data represent 15 arenas for each plant species.

Location in Arena	Plant Species					
	A. absinthium		*C. nauseosus*		*T. vulgare*	
	$\bar{x}$	S.D.	$\bar{x}$	S.D.	$\bar{x}$	S.D.
Treated Core	2.07a	1.03	2.33a	1.05	1.93a	1.10
Control Core	4.67b	0.90	5.07b	0.96	5.40b	1.12
Wandering	3.27a,b	1.28	2.60a	1.24	2.67a	1.05

Means in the same column followed by the same letter are not significantly different ($P<0.001$).

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KEY WORDS

Codling moth, neonate, plant extracts, feeding deterrents, *Artemisia, Chrysothamnus, Tanacetum*

REFERENCES

Binns, W., L. James, J. Shupe, and G. Everett. 1963. A congenital cyclopian-type malformation in lambs induced by maternal ingestion of a range plant, *Veratrum californicum*. Am. J. Vet. Res. 24: 1164-1174.

Bland, R.G. 1981. Survival and food detection by first instar *Melanoplus femurrubrum* (Orthoptera:Acrididae). Great Lakes Entomol. 14: 197-204.

Bohlmann, F., T. Burkhardt, and C. Zdero. 1973. Naturally Occurring Acetylenes. Academic Press: New York. 547 pp.

Borror, D.J. 1960. Dictionary of Word Roots and Combining Forms. Mayfield: Palo Alto, CA. 134 pp.

Brewer, G.J. and H.J. Ball. 1981. A feeding deterrent effect of a water extract of tansy *(Tanacetum vulgare*, Compositae) on three lepidopterous larvae. J. Kansas Entomol. Soc. 54: 733-736.

Crockett, L.J. 1977. Wildly Successful Plants, A Handbook of North American Weeds. MacMillan: New York. 268 pp.

Draper, S.R. 1976. Biochemical Analysis in Crop Science. Oxford Univ. Press: Oxford, England. 130 pp.

Ferro, D.N., R.R. Sluss, and T.P. Bogyo. 1975. Factors contributing to the biotic potential of the codling moth, *Laspeyresia pomonella* (L.) in Washington. Environ. Entomol. 4: 385-391.

Gibbs, R.D. 1974. Chemotaxonomy of flowering plants. Vol. I, p. 89, McGill Queens-Univ. Press: Montreal.

Goodwin, T.W. 1971. Aspects of Terpenoid Chemistry and Biochemistry. Academic Press: London. 441 pp.

Hitchcock, C.L. and A. Cronquist. 1973. Flora of the Pacific Northwest. Univ. Washington Press: Seattle. 730 pp.

Howell, J.F. and A.E. Clift. 1972. Rearing codling moth on an artificial diet in trays. J.Econ. Entomol. 65: 888-890.

Keller, R. 1975. Teratogenic effects of cyclopamine and jervine in rats, mice, and hamsters. Proc. Soc. Exp. Biol. Med. 149: 302-306.

Kingsbury, J. 1964. Poisonous Plants of the United States and Canada. Prentice Hall: Englewood Cliffs, NJ. 626 pp.

Lewis, W.H. and M.P.F. Elvin-Lewis. 1977. Medical Botany. John Wiley and Sons: New York. 515 pp.

MacLellan, C.R. 1977. Trends of the codling moth (Lepidoptera:Olethreutidae) populations over 12 years on two cultivars in an insecticide free orchard. Can. Entomol. 109: 1555-1562.

Meinwald, J., Y.C. Meinwald, A.M.Chalmers, and T. Eisner. 1968. Dihydromatricaria acid: Acetylene acid secreted by soldier beetles. Science 160: 890-892.

Nasseh, M.O. 1982. The effect of crude extracts of garlic on *Syrphus corollae* (F.), *Chrysopa carnea* (Steph.), and *Coccinella septempunctata* (L.) Z. Agnew. Entomol. 94: 123-126.

Rose, A.F., B.A. Butt, and T. Jermy. 1980. Polyacetylenes from the rabbitbrush, *Chrysothamnus nauseosus*. Phytochemistry 19: 563-566.

Schoonhoven, L.M. 1982. Biological aspects of antifeedants. Entomol. Exp. Appl. 31: 57-69.

Wada, K., Y. Enomoto, K. Matsui, and K. Munakata. 1968. Insect antifeedants from *Parabenzoin trilobum*. Two new sesquiterpenes, shiromodiol-diacetate and monoacetate. Tetra Letters 45: 4673-4676.

Wada, K. and K. Munakata. 1971. Insect feeding inhibitors in plants. III. Feeding inhibitory activity of terpenoids in plants. Agr. Biol. Chem. 35: 115-118.

Windholz, M., S. Budavari, L.Y. Stroumtsos, and M.N. Fertig. 1976. The Merck Index, 1735, p. 220, 9th Edition. Merck: Rahway, NJ. 1313 pp.

Wiklund, C. 1973. Host plant suitability and the mechanism of host selection in larvae of *Papilio machaon*. Entomol. Exp. Appl. 16:232-242.

Wodehouse, R.P. 1971. Hayfever Plants. Hafner: New York. 280 pp.

Yoshiaka, H., T.J. Mabry, and B.N. Timmermann. 1973. Sesquiterpene lactones chemistry, NMR and plant distribution. Univ. of Tokyo Press: Tokyo. 544 pp.

MORTALITY AND TOP-KILL IN DOUGLAS-FIR FOLLOWING DEFOLIATION BY THE WESTERN SPRUCE BUDWORM IN BRITISH COLUMBIA

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ABSTRACT

Surveys of mortality and top-kill caused by the western spruce budworm, *Choristoneura occidentalis* Freeman, in 65 stands of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco are reported. Top-kill was detected in 85% of the stands and 25% of the trees surveyed. Mortality amounted to 8% and less than 1% of the trees examined in the Vancouver and Kamloops Forest Regions, respectively. Both frequency of top-kill and mortality were related to the number of years defoliation in the stand and were higher on suppressed trees than on dominant or codominant trees. Younger stands sustained a higher incidence of top-kill than older stands. Tree mortality was higher on steep slopes than on flat terrain. These results suggested that top-kill or mortality were the results of physiological stress on the trees, in addition to the debilitating effects of defoliation.

INTRODUCTION

The western spruce budworm, *Choristoneura occidentalis* Freeman, is a recurrent defoliator of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, in British Columbia (B.C.). The earliest documented infestation in B.C. occurred on southeastern Vancouver Island during the period 1909-1911 (Harris *et al.* 1985). Since then, six other infestations have occurred, mainly in the Pemberton, Fraser Canyon and Ashcroft areas.

The effects of budworm defoliation on tree growth in B.C. are recorded (Alfaro *et al.* 1982, 1984, 1985; Thomson *et al.* 1982; Van Sickle *et al.* 1983). Noticeable loss in diameter growth starts in the second year of defoliation; annual tree rings become progressively smaller with increasing duration of defoliation (Alfaro *et al.* 1982). Growth rate recovery to pre-infestation levels does not occur immediately after the decline of the infestation, but takes several years. Height growth is severely affected as well; repeated defoliation results in shorter or missing internodes or even in dieback or top-kill of the crown (Shepherd *et al.* 1977; Van Sickle *et al.* 1983). Depending on the severity of the top-kill (length and basal diameter of the dead part of the stem), large defects may develop in the bole, thus reducing its merchantability. The combined effect of height and diameter growth loss results in tree volume loss (Alfaro *et al.* 1985). Mortality is most frequent in trees of small diameter (Alfaro *et al.* 1982) and appears to be randomly distributed in the stand (Alfaro *et al.* 1984).

These previous studies were generally based on small samples in terms of the number of stands evaluated. Therefore, it was not possible to develop damage models of wide applicability. This report interprets damage surveys of top-kill and tree mortality on 65 Douglas-fir stands affected by the latest western spruce budworm epidemic in B.C. This infestation began in 1967, reached a maximum infestation area in 1976 and, on a reduced scale, continued in 1985. The surveys were conducted in 1979 by the Forest Insect and Disease Survey (FIDS) of the Canadian Forestry Service (Fiddick and Van Sickle 1979). Emphasis is on the study of the relationship between tree mortality or top-kill frequency on a stand basis *versus* defoliation history and stand characteristics.

METHODS AND MATERIALS

The areas of defoliation by the western spruce budworm were obtained from FIDS maps, then 65 stands of different duration and severity[1] of defoliation were selected throughout the infested area (Table 1). Thirty-seven and twenty-eight stands were in the Vancouver and Kamloops Forest Regions, respectively. About 100 trees were examined in each stand as follows: five sampling points, 20 m apart, were established along a transect line; at each point, about 20 trees, closest to the point, were selected. A total of 6594 trees were examined in all stands.

Each tree was examined to determine whether it was dead or alive. All trees that had died in recent years (as opposed to old kills and snags) were assumed to have been killed by the budworm. The length of top-kill, or severity, in each tree was estimated with the naked eye or with the aid of binoculars. Severity was classified as 0 (no top-kill), > 0 to 1 m, > 1 to 3 m, > 3 to 5 m, > 5 m. The percentage of dead trees (percent mortality) and percent-

[1]Aerial observers in B.C. classify defoliation severity according to the following criteria: *light*: discolored foliage barely visible from the air, some branch tip and upper crown defoliation apparent; *moderate*: pronounced discoloration, noticeably thin foliage, top third of many trees severely defoliated, some completely stripped; *severe*: bare branch tips and completely defoliated tops common, most trees more than 50% defoliated.

age of trees top-killed were calculated for each stand. The factors of slope, age, aspect, elevation, site quality (from forest cover maps) and number of years of defoliation were recorded for each stand.

Covariance and regression analysis were used to study the relationship between percent mortality and top-kill in the stand and the stand factors. For the analysis, the percent mortality and top-kill per stand were transformed to the arcsin (in radians) $\sqrt{p}$.

Regression model selection was based on examination of the data and residual plots, and on comparison of correlation coefficients. Only statistically significant correlation coefficients were reported. Differences in mean percentage top-kill and mortality by aspect and site quality were tested by covariance analysis (Dixon and Massey 1957), adjusting the means by the difference in number of years of defoliation among aspects or sites. One stand with high mortality (94% of the trees dead) was dropped from the analysis of top-kill data. The qualitative variables, site and aspect, were introduced in the regression as indicator or "dummy" variables (Wesolowsky 1976).

RESULTS AND DISCUSSION

Top-kill

Top-kill was detected in 85% of the stands. Forty-one percent of the stands had between 1 and 20% of the trees top-killed, 23% had frequencies between 21 and 40%, 12% had 41-60%, and 10% sustained greater than 60% top-kill (Fig. 1). Twenty-five percent (range 0 to 91%) of all trees examined in all stands showed top-kill.

Most of the damaged trees were in the $>$ 0 to 1 m top-kill class (16% of the trees) (Table 2), 5% had top-kill in the $>$1 to 3 m length class, 3% in the $>$3 to 5 m class, and 1% in the $>$ 5 m class. The proportion of trees in the different top-kill classes varied significantly among crown classes (Table 2) (χ^2 test, $P<0.01$). Percent top-kill was about the same among dominant and codominant trees, at 20 and 21%, respectively, but it was significantly higher (χ^2 test, $P<0.01$) for intermediate trees, at 25%, and much higher for suppressed trees, which had a 41% top-kill frequency. The higher incidence of top-kill among the suppressed trees is probably due to these

TABLE 1. Characteristics of 65 Douglas-fir stands defoliated by the western spruce budworm.

	Mean	Minimum	Maximum
Elevation (m)	782	300	1128
Slope (%)	21	0	80
Age (yrs.)	76	20	141
No. yrs. defoliation			
Light	3	0	5
Moderate	1	0	5
Severe	1	0	5
All Classes	5	2	8

TABLE 2. Percentages of Douglas-fir trees top-killed, listed by crown class and top-kill severity class (length of crown killed), in stands defoliated by the western spruce budworm.

Crown Class	Top-kill severity class (m)[1]				
	> 0 - 1	> 1 - 3	> 3 - 5	> 5	All classes
Dominant	8	6	5	1	20 a
Codominants	10	6	4	1	21 a
Intermediate	20	4	1	0	25 b
Suppressed	37	3	0	1	41 c
All crown classes	16	5	3	1	25

[1] The percentage of top-killed trees varied significantly by top-kill severity and crown class (χ^2, $P<0.01$). Percentages within column followed by the same letter were not statistically different (χ^2, $P>0.05$)

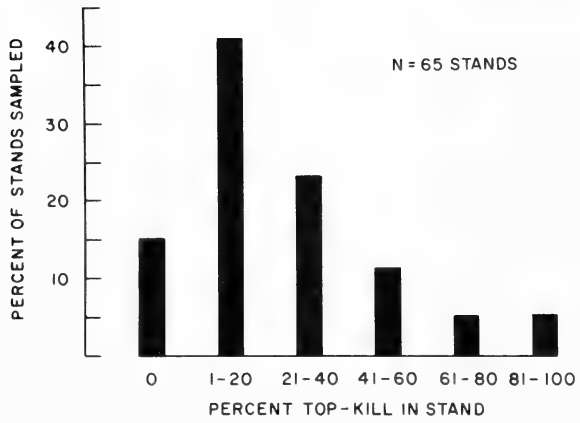

Fig. 1. Percentage of stands sampled by top-kill frequency class.

having smaller nutrient reserves than dominant or co-dominant trees and, therefore, being less able to withstand insect defoliation. Scott *et al.* (1980) arrived at a similar conclusion when studying top-kill frequency in Douglas-fir and Grand fir, *Abies grandis* (Dougl.) Forbes, in central Washington.

Percent top-kill in stands increased with the number of years of defoliation (Fig. 2). Regression analysis yielded the following model:

(1) ARCSIN $(PTop\text{-}kill)^{1/2} = -0.16 + 0.12$ [No. years of defoliation]
$R^2 = 0.24$ and Se = 0.29, F = 20.0
where PTop-kill = percent top-kill in the stand/100.

This model indicated that, on average, with 2 to 7 years of defoliation, the expected top-kill levels in the stand were 1, 4, 10, 18, 28 and 39% respectively. Although the regression coefficient was significant, a considerable proportion of the variance remained unexplained. The regression did not improve when the number of years of severe defoliation in the stand was included instead of the number of years of defoliation.

Analysis of covariance indicated that, in addition to the number of years of defoliation, stand aspect and age explained a significant portion of the variability of top-kill percentage. Stands on North, West or South aspects had significantly lower percent top-kill (13 to 24%) than East (28%) aspects (Table 3). The reasons for this increased top-kill on East aspects are not clear. Top-kill had a significant negative correlation with stand age.

Although stands on poor sites had nearly double the percent top-kill (38%) of stands on medium (20%) or good sites (21%) (Table 4) the differences were not statistically significant. Stand elevation or slope did not influence the percent top-kill in the stand.

Average percentage top-kill was 27 and 18% in the Vancouver and Kamloops Regions, respectively. However, after adjustment by the difference in number of years of defoliation between the two regions, these two means were not statistically different (Table 5).

Mortality

Mortality was evident in 26 of the 65 stands sampled (40%) and averaged 4.9% of the trees in all stands sampled (range 0 to 94%). However, mortality was significantly higher in stands located in the Vancouver District, at 8%, than in stands located in the Kamloops District, which had less than 1% average mortality. Only three of the 28 stands in the Kamloops District sustained

TABLE 3. Percent top-kill and tree mortality, listed by aspect, in 65 Douglas-fir stands defoliated by the western spruce budworm.

Aspect	No. Stands	No. years defoliation	Top-kill[1] (%)	Tree mortality[1] (%)
North	8	4.4	13 (19)a	0 (2)a
West	4	5.0	23 (22)a	0 (0)a
South	42	5.2	24 (20)a	7 (6)a
East	11	3.9	28 (39)b	2 (5)a
All aspects	65	4.9	25	4.9

[1] Shown in brackets is the mean top-kill or mortality percent by aspect after removal of the effect of differences in number of years of defoliation by covariance analysis. Top-kill or mortality percentages within columns followed by the same letter were not statistically different.

TABLE 4. Percent top-kill and tree mortality, listed by site quality, in 65 Douglas-fir stands defoliated by the western spruce budworm.

Site	No. Stands	No. years defoliation	Top-kill[1] (%)	Tree mortality[1] (%)
Good	10	4.5	22 (25)a	1 (2)a
Medium	45	4.9	20 (20)a	5 (5)a
Poor	10	5.1	38 (37)a	7 (6)a
All classes	65	4.9	25	4.9

[1] Shown in brackets is the mean top-kill or mortality percent by site quality after removal of the effect of differences in number of years of defoliation, by covariance analysis. Top-kill or mortality percentages were not statistically different by site quality.

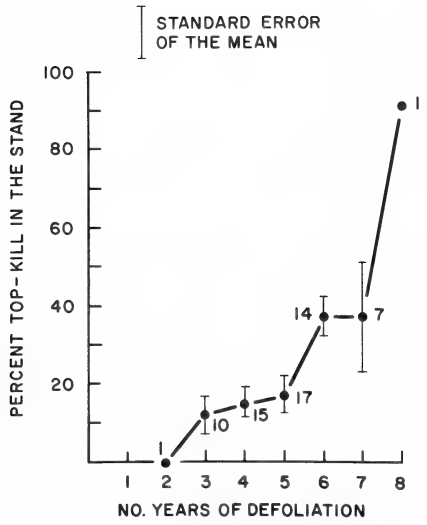

Fig. 2. Relationship between the percent top-kill in a Douglas-fir stand and number of years of defoliation by the western spruce budworm. Number of stands indicated beside each point.

mortality. The areas sampled in the Vancouver District included the steep slopes of the Fraser River Canyon which often coincide with poor sites and shallow soils. Trees growing under these conditions are probably under stress and are more prone to mortality.

Percent mortality also varied by crown class (χ^2 test, $P<0.01$, Table 6); suppressed trees suffered a significantly higher average mortality (8.4%) than other classes. Differences in mortality among intermediate (3.7%) co-dominant (4.7%) and dominant (5.2%) trees were not statistically significant. Increased mortality in both suppressed and intermediate classes was reported in 1982 by Alfaro *et al.* As with top-kill, the higher mortality in the suppressed trees is probably due to the fact that these trees are stressed from competition and are therefore unable to withstand defoliation.

The following models were developed:

(2) ARCSIN $(PMORT)^{1/2} = -0.24 + 0.075$ [No. years of defoliation]
$R^2 = 0.20$ and Se = 0.20, F = 15.6
where PMORT = percent top-kill in the stand/100.

This equation indicated that mortality was expected if the stand was defoliated for more than 3 years. With 4 to 7 years of defoliation, the expected levels of tree mortality in the stand were 0.4, 1.8, 4.3 and 7.9%, respectively. This equation crosses the x-axis at No. years of defoliation = 3.2, therefore it is not defined for durations of defoliation less than or equal to 3 years. Although this relationship was significant, it explained only 20% of the variability in tree mortality in the stand. The correlation improved significantly when the number of years of severe defoliation was used as a predictor variable.

(3) ARCSIN $(PMORT)^{1/2} = -0.004 + 0.133$ [No. years of severe defoliation]
$R^2 = 0.47$ and Se = 0.16, F = 56.9

This equation predicted that, with 1 to 7 years of severe defoliation, the levels of tree mortality were 2, 7, 15, 25, 38, 51 and 64%, respectively.

Percent mortality appeared to be higher on South (7%) or East aspects (2%) than on North or West aspects (negligible mortality) and also higher on medium (5%) or poor (7%) sites than on good sites (1%) (Tables 3, 4). However, after removal of the effects of different number of years of defoliation by covariance analysis, percent mortality did not differ statistically by site or aspect.

Stepwise multiple regression analysis between percent tree mortality in the stand and stand elevation, slope, aspect, age and number of years of defoliation, detected a significant effect only of slope and number of years of defoliation. Tree mortality was higher in stands with the steepest slopes.

CONCLUDING DISCUSSION

The fact that 85% of the stands and 25% of the trees sampled sustained top-kill suggests that top-kill is a major cause of growth loss and a source of stem defects in

TABLE 5. Percent top-kill and tree mortality in Douglas-fir stands defoliated by the western spruce budworm in two forest regions of British Columbia.

Region	No. Stands	No. Years Defoliation	Top Kill (%)	Mortality (%)
Vancouver	37	5.5	27	8.0
Kamloops	28	4	18	0.8
Total	65	4.9	25	4.9

TABLE 6. Percentage of Douglas-fir trees killed by western spruce budworm, listed by crown class, in stands defoliated by the western spruce budworm.

Crown Class	Total No. trees	No. dead trees	Tree mortality (%)[1]
Dominant	1394	72	5.2 a
Codominant	2208	103	4.7 a
Intermediate	2131	79	3.7 a
Suppressed	861	72	8.4 b
All trees	6594	326	4.9

[1] Mortality percentages within columns followed by the same letter were not statistically different (χ^2 test, $P>0.05$)

Douglas-fir defoliated by western spruce budworm. The negative correlation of top-kill with age, indicative of a higher susceptibility to top-kill in younger trees, is of particular importance since large defects in the lower bole may render any growth above the damaged point non-merchantable. Douglas-fir mortality averaged about 8% in the Vancouver District, with 5.2 and 4.7% of the dominant and codominant trees, respectively, killed by budworm (Table 6). Since these trees represent the future crop, mortality caused by budworm, although not so spectacular as that in eastern forests caused by the eastern spruce budworm, *Choristoneura fumiferana* (Clem.), should also be of concern to the western forest manager. Higher mortality was recorded among the supressed trees but because most of these trees would probably die before harvest, this volume loss can be considered unimportant.

The models presented could be used as a basis for the hazard rating of stand susceptibility to western spruce budworm damage and to calculate the possible outcome of infestations of different durations on particular stands. The high proportion of the variance that remained unexplained is not surprising in a study of this nature and suggests that other important factors are at work. Tree susceptibility to top-kill or mortality appears to be related to a stress condition. Other factors causing stress on trees, such as stand density, presence of other insects or diseases and climate during defoliation could also be important. Although this study did not provide statistical proof of top-kill or mortality variation by aspect or site quality, the data suggested that trees on steep, South and East slopes, and on poor sites are more susceptible (Tables 3 and 4). Further sampling is recommended to clarify this point.

ACKNOWLEDGEMENTS

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LITERATURE CITED

Alfaro, R.I., G.A. Van Sickle, A.J. Thomson and E. Wegwitz. 1982. Tree mortality and radial growth losses caused by the western spruce budworm in a Douglas-fir stand in British Columbia. Can. J. For. Res. 12: 780-787.

Alfaro, R.I., T.L. Shore and E. Wegwitz. 1984. Defoliation and mortality caused by western spruce budworm: variability in a Douglas-fir stand. J. Entomol. Soc. Brit. Columbia 81: 33-38.

Alfaro, R.I., A.J. Thomson and G.A. Van Sickle. 1985. Quantification of Douglas-fir growth losses caused by western spruce budworm through stem analysis. Can. J. For. Res. 15: 5-9.

Dixon, W.J. and F.J. Massey, Jr. 1957. Introduction to statistical analysis. McGraw-Hill Book Co., 488 p.

Fiddick, R.L. and G.A. Van Sickle. 1979. Forest insect and disease conditons. British Columbia and Yukon/1979. Can. For. Serv. Pac. For. Res. Cent. Inf. Rep. BC-X-200.

Harris, J.W.E., R.I. Alfaro, A.G. Dawson and R.G. Brown. 1985. The spruce budworm in British Columbia 1909-1983. Can. For. Serv. Pac. For. Res. Cent. Inf. Rep. BC-X-257.

Scott, D.R.M., P.M. Crimp and R.L. Johnsey. 1980. Growth impacts on host trees due to western spruce budworm defoliation on the east slope of the Washington Cascades. Canada-U.S. Spruce Budworms Research Program (CANUSA). Final report for 1979-1980. 111 pp.

Shepherd, R., J.W.E. Harris, G.A. Van Sickle, L. Fiddick and L. McMullen. 1977. Status of western spruce budworm on Douglas-fir in British Columbia. Can. For. Serv. Pac. For. Res. Cent., Pest Report.

Thomson, A.J., R.I. Alfaro, and G.A. Van Sickle. 1982. Evaluating effects of western spruce budworm on Douglas-fir volume growth. Can. For. Serv. Res. Notes 4: 24-25.

Van Sickle, G.A., R.I. Alfaro, and A.J. Thomson. 1983. Douglas-fir height growth affected by western spruce budworm defoliation. Can. J. For. Res. 13: 445-450.

Wesolowsky, G.O. 1976. Multiple regression and analysis of variance. John Wiley & Sons. 292 pp.

EVALUATION OF THREE TYPES OF BARRIERS TO TRAP WINTER MOTH (LEPIDOTPERA:GEOMETRIDAE) ADULTS

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ABSTRACT

Three types of barrier traps, Tanglefoot®, fiberglass and fiberglass sprayed with the insecticide Raid®, were tested at three locations, on eight trees each per treatment and location for a total of 72 trees, to determine their efficiency in preventing the flightless winter moth females from crawling higher up the tree to oviposit. The efficiency of the barrier was evaluated by counting the number of female winter moth adults caught 10-15 cm above the test barrier. Tanglefoot® was the most effective barrier. An average of 67.1 winter moth females managed to crawl over the fiberglass barrier compared to 3.6 females over the fiberglass barrier sprayed with Raid® and 1.1 females over the Tanglefoot® barrier. The differences among the average catches were significant ($P<0.01$) for the fiberglass barrier but not between the fiberglass barrier with Raid® and the Tanglefoot® barrier. We recommend that Tanglefoot® applied over a polyethylene strip, after the bark crevices have been plugged, be used to prevent winter moth females from crawling under the barrier. The Tanglefoot® barrier has the added advantages that it is cheap, non-toxic and, since it reduces or eliminates the need for insecticide application, it is fully compatible with biological control measures.

RESUMÉ

Trois barrières (Tanglefoot®, de fibre de verre et de fibre de verre vaporisé d'insecticide Raid®) ont été mises à l'essai à trois endroits, chacune sur huit arbres à chaque endroit, pour un total de 72 arbres. Le but de ces essais consistait à déterminer dans quelle mesure ces barrières pouvaient empêcher les arpenteuses tardives femelles, aptères, de grimper dans les arbres pour y pondre. L'efficacité des barrières a été évaluée en fonction du nombre de femelles adultes capturées à 10 à 15 cm au-dessus de l'obstacle. C'est la barrière Tanglefoot® qui a été jugée la plus efficace. En moyenne, 67,1 arpenteuses ont réussi à franchir la barrière de fibre de verre; 3,6 la barrière vaporisée au Raid®; et 1,1 la barrière Tanglefoot®. L'écart entre ces moyennes était significatif ($P<0,01$) pour la barrière de fibre de verre, mais non pour les deus autres barrières. Nous recommandons que la barrière Tanglefoot® repose sur une bande de polyéthylène, après obturation des crevasses de l'écorce pour empêcher les arpenteuses de s'y faufiler. La barrière Tanglefoot® possède également les avantages d'être bon marché, non toxique et, puisqu'elle réduit ou élimine la nécessité d'appliquer un insecticide, d'être tout à fait compatible avec les moyens de lutte biologique.

INTRODUCTION

The winter moth, *Operophtera brumata* (Linnaeus) (Lepidoptera:Geometridae), an important defoliator of deciduous forest, shade and fruit trees in Europe, was accidentally introduced into Nova Scotia in the early 1930s (Embree 1966) and on southern Vancouver Island before 1972 (Gillespie *et al.* 1978). By 1977, the winter moth had reached outbreak proportions on the Saanich Peninsula of Vancouver Island, causing severe defoliation on many shade and fruit trees.

In British Columbia, winter moth adults start emerging from pupae in the ground in November and may be found until early January. Male moths have functional wings and locate and mate with the flightless females on the trunks of trees. Females climb up the trunks and lay eggs singly or in small clusters under lichens, in bark crevices, on twigs or similar concealed places. Each female can produce up to 220 eggs (Embree 1966). The eggs hatch from late March to April and newly hatched larvae disperse by spinning silken threads and drifting on the wind. The larvae feed on leaves of a wide range of deciduous host plants. Fully developed larvae drop from the trees in late May to early June to pupate in the ground.

One method of winter moth control is to prevent the females from crawling up the trunk of trees to oviposit. For years, Tanglefoot bands applied around the tree trunks have been used (Embree 1966) and other types of

banding and combinations thereof have been tried. The trees, however, can still be infested by the young larvae as they disperse on silken threads from tree to tree by wind.

In British Columbia, a program was jointly initiated in 1978 by the federal and provincial governments to investigate control measures against the winter moth.

Biological control has been the main thrust of the program. The same two species of parasitoids, *Agrypon flaveolatum* (Gravenhorst) (Hymenoptera:Ichneumnidae) and *Cyzenis albicans* (Fallén) (Diptera:Tachiidae), that are credited with the control of the winter moth in Nova Scotia were introduced into British Columbia (Embree and Otvos 1984). Both species became established in British Columbia and appear to be spreading (I.S. Otvos unpubl. data).

Other controls evaluated were the use of a bacillus, or of petrochemical insecticides alone (Tonks *et al.* 1978) or in combination with insecticidal soap (Puritch and Condrascholl 1985) against the feeding larvae (N.V. Tonks unpubl. data) besides various barriers to trap adult females thus preventing them from ovipositing higher in the tree. The efficacy of some barrier tests is reported here.

MATERIALS AND METHODS

Three types of barriers (treatments) were tested: a) Tanglefoot band, b) fiberglass insulation alone, and c) fiberglass insulation sprayed with commercially available Raid.[1] At each of the three locations in Greater Victoria (Cattle Point, Summit Park Reservoir, and Burnside Rd. at Mackenzie Ave.) eight randomly selected Garry oak trees, *Quercus garryana* Dougl., received an upper band of Tanglefoot and a lower band of one of the three treatment barriers (Fig. 1) for a total of 24 trees per location. The diameter of the trees at breast height averaged 27.8 cm and ranged from 16.2-43.6 cm.

On all trees receiving the Tanglefoot barrier, an inexpensive, butyl-flex caulking compound was applied to the bark crevices, in a band around the circumference of the tree with a caulking gun. Then a 6 mil. thick, 20-25 cm wide polyethylene strip was pulled tightly around the tree over the caulking and fastened with staples. Care was

[1]For convenience of the public, brand or trade names are used in this paper, identified by capitalization. Their use does not constitute an endorsement of the product nor a suggestion that like products are not effective.

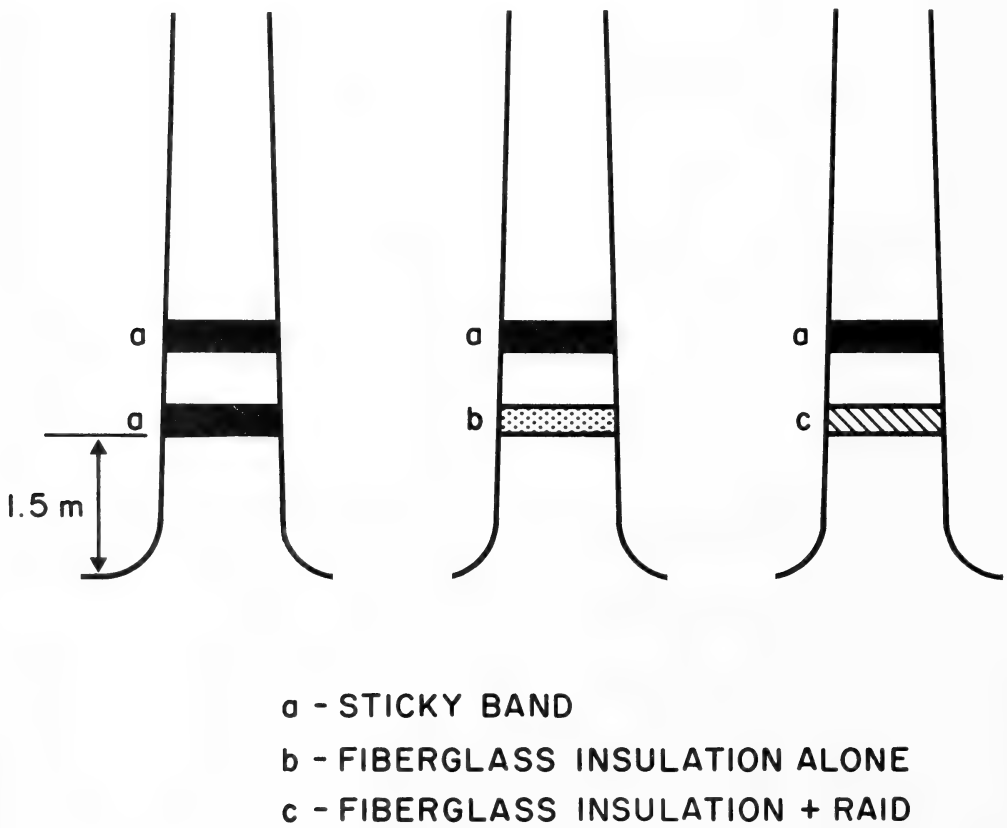

Fig. 1 Schematic drawings of the three types of barriers and Tanglefoot bands applied to the sample trees.

taken to "fill" all the crevices to prevent winter moths from crawling underneath the polyethylene. Tanglefoot was applied on the polyethylene with a spatula in a band 10-15 cm. wide.

In the second treatment, a band of commercially available fiberglass insulation without paper backing (about 20 cm wide by 7.6 cm thick) was secured by string to the trees.

In the last treatment, a similar fiberglass barrier was sprayed until dripping with Raid every 4-5 days. The commercially available Raid in pressurized cans, manufactured for house and garden use, according to the label contained: pyrethrins 0.176%, tetramethrin 0.09%, technical piperonyl butoxide 1.25%. All treatment barriers were 1.5 m above the ground.

All trees received a sticky band in an identical manner to the first treatment, 10-15 cm. above the first barrier (Fig. 1). In order to prevent adults from crossing the bands by "walking" over the bodies of the trapped moths, the sticky bands were replaced whenever the number of winter moth adults caught came close to saturating the band.

TABLE 1. Means and standard errors of the numbers of winter moth females caught on sticky bands above the barrier treatments (n = 8).

Location	Barrier treatments		
	Tanglefoot	fibreglass	fibreglass with Raid
	$\bar{x} \pm$ S.E.	$\bar{x} \pm$ S.E.	$\bar{x} \pm$ S.E.
Cattle point:	1.4 ± 0.5 (752)[a]	45.3 ± 12.9	2.0 ± 0.8
Summit Park:	1.1 ± 0.5 (578)[a]	49.8 ± 11.7	2.9 ± 0.9
Burnside Rd.	0.8 ± 0.3 (606)[a]	106.4 ± 21.3	6.0 ± 1.1
Total	1.1 ± 0.2 (1936)[a]	67.1 ± 10.5	3.6 ± 0.6

[a] Total numbers of moths caught on the treatment (lower) Tanglefoot bands.

All treatments were put in place between November 16 and 19 just as adult winter moth emergence started. The traps were left in place until January 10, 1985, by which time emergence had been completed. The numbers of winter moth females caught in the upper sticky band as well as those caught in the lower band of (treatment a) were counted on November 22, 28, December 3, 12, 19 and January 10.

The counts of winter moth adults, trapped in the upper sticky bands, were transformed to $\log_{10}$ (count + 1) to stabilize the variance. The transformed data were subjected to analyses of variance and Student-Newman-Keul's multiple range test (Zar 1974).

RESULTS AND DISCUSSION

There was high density of winter moth adults at all three test areas. Totals of 752, 578 and 606 female moths were trapped on the lower band of the Tanglefoot treatment at Cattle Point, Summit Park and Burnside Road, respectively (Table 1). Preventing these females from crawling up the tree trunks to oviposit reduced potential larval numbers considerably when one considers that a female lays up to 220 eggs (Embree 1966).

Tanglefoot was the most effective treatment. Based on counts from the upper sticky band, significantly higher mean numbers of winter moth females (Table 1) managed to crawl over the fiberglass barriers (67.1) than over the fiberglass barrier sprayed with Raid (3.6) or the Tanglefoot barriers (1.1) ($P < 0.01$). The difference in the average number of winter moth females caught on the sticky bands above the latter two barriers was not statistically significant at the 5% level. Nevertheless, the sticky barrier in this test (treatment a) let through two-thirds fewer females than the fiberglass barrier sprayed with Raid (treatment c) (Table 1).

When the moth flight was over, all the traps were easily removed. Tanglefoot application to the polyethylene had an advantage over application directly to the bark because it facilitated the removal of the sticky bands. Caulking bark crevices eliminated the need for smoothing or scraping of the bark prior to applying the Tanglefoot and the caulking was easily removed from the crevices, thus restoring the bark to its natural condition.

The Tanglefoot band applied to polyethylene strips secured to the tree over caulked bark crevices is the recommended, and the most efficient of the barriers tested in preventing winter moth females from crawling up the trunks of trees to oviposit. Although the Tanglefoot is somewhat messy to apply, it is non-toxic to humans and pets, and is easily removed with paint thinner. Only 17 of the 96 sticky bands used needed to be replaced and this was easily done by placing a second band of polyethylene strip over the first.

The fiberglass barrier sprayed with commercially available Raid was easier to apply than the sticky band but it appeared somewhat less effective and was more costly. Raid had to be reapplied at intervals of 4-5 days during the whole trapping season and it might need to be applied more frequently still following heavy rain.

The cost of plastic, Tanglefoot and caulking applied to a tree was $0.84 vs. $0.98 for Raid applied to a fiberglass barrier.

None of the three barriers tested here is harmful to the introduced parasitoids as they are in the host pupae in the soil until the following spring when they emerge to lay their eggs.

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REFERENCES

Gillespie, D.R., T. Finlayson, N.V. Tonks and D.H. Ross. 1978. Occurrence of the winter moth, *Operophtera brumata* (Lepidoptera:Geometridae), on southern Vancouver Island, British Columbia. Can. Ent. 110: 223-224.

Graham, A.R. 1958. Recoveries of introduced species of parasites of the winter moth, *Operophtera brumata* (L.) (Lepidoptera:Geometridae), in Nova Scotia. Can. Ent. 90: 595-596.

Ebree, D.G. 1966. The role of introduced parasites in the control of the winter moth in Nova Scotia. Can. Ent. 98: 1159-1168.

Embree, D.G. and I.S. Otvos. 1984. *Operophtera brumata* (L.), winter moth (Lepidoptera:Geometridae). Ch. 61, pp. 353-357. *In* J.S. Kelleher and M.A. Hulme (eds.). Biological Control Programmes Against Insects and Weeds in Canada 1969-1980. Commonwealth Agricultural Bureaux, Farnham Royal, England.

Puritch, G.S. and S.F. Condrashoff. 1985. Insecticide mixture containing fatty acids. Canadian patent no. 1187409.

Tonks, N.V., P.R. Everson and T.L. Theaker. 1978. Efficacy of insecticides against geometrid larvae. *Operophtera* spp., on southern Vancouver Island, British Columbia. J. Entomol. Soc. Brit. Columbia 75: 6-9.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall, Englewood Cliffs, N.J. 620 pp.

THE SPRUCE BUDWORM, *CHORISTONEURA FUMIFERANA* (LEPIDOPTERA:TORTRICIDAE), IN BRITISH COLUMBIA

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ABSTRACT

The spruce budworm, *Choristoneura fumiferana* (Clements), causes severe defoliation, primarily of white spruce, *Picea glauca* (Moench) Voss, eastern larch, *Larix laricina* (Du roi), K. Koch, and alpine fir, *Abies lasiocarpa* (Hook.) Nutt, in the Liard River area of northern British Columbia. Less preferred hosts are black spruce, *Picea mariana* (Mill.) B.S.P., and lodgepole pine, *Pinus contorta* Dougl. Infestations last for many years with variable defoliation intensity. Defoliation causes extensive top-killing of trees but little mortality. In addition, mature spruce trees (104 to 144 years old) defoliated from 1959 to 1976 lost an estimated 3 to 4.4% of diameter growth. Tree ring analysis suggested that *C. fumiferana* defoliated trees in the Liard River area at least five times since 1869. Infestations recurred every 14 to 28 years.

RESUMÉ

La tordeuse des bourgeons de l'épinette *(Choristoneura fumiferana* [Clemens]*)* est à l'origine d'une grave défoliation frappant principalement l'épinette blanche *(Picea glauca* [Moench] Voss*)*, le mélèze laricin *(Larix laricina*[Du Rio] K. Koch*)* et le sapin subalpin *(Abies lasiocarpa* [Hook.] Nutt.*)* dan la région de la rivière Liard, dans le nord de la Colombie-Brittanique. D'autres hôtes sont moins toucheés: l'epinette noire *(Picea mariana* [Mill.] B.S.P.*)* et le pin tordu *(Pinus contorta* Dougl.*)*. Les infestations durent de nombreuses anées et l'intensité de la défoliation est variable. Le dépérissement terminal des arbres causé par la défoliation est important, mais la mortalité est faible. On a estimé que des épinettes matures (de 104 à 144 ans) défolées de 1959 à 1976 ont eu une diminution de 3 à 4,4% de leur accroissement en diamètre. L'analyse des cernes indique que *C. fumiferana* a défolié les arbres de la région de la rivière Liard au moins 5 fois depuis 1869. Les infestations sont réapparues tous les 14 à 28 ans.

INTRODUCTION

The spruce budworm, *Choristoneura fumiferana* (Clements), is a major defoliator of balsam fir, *Abies balsamea* (L.) Mill., and white spruce, *Picea glauca* (Moench) Voss, in eastern Canada and the United States (Schmitt *et al.* 1984). The *Choristoneura* species found on coniferous trees in British Columbia was initially thought to be *C. fumiferana*. However, three new northwestern species of *Choristoneura* were described by Freeman (1967). It is now considered that this genus has four species which are pests of commercial coniferous trees in British Columbia: *C. occidentalis* - the western spruce budworm, *C. biennis* - the 2-year-cycle budworm, *C. orae* (no common name) and *C. fumiferana* - the spruce budworm (Freeman 1967; Dang 1985).

Since it was first reported in 1957 by the Forest Insect and Disease Survey (FIDS) of the Canadian Forestry Service, there has been a recurrent infestation of budworm in the Liard River Basin in the northeastern corner of British Columbia[1]. This budworm has since been confirmed as *C. fumiferana* (Dang, 1985).

Detailed population and defoliation records were kept by FIDS on this infestation from 1959 to 1969. Since 1969, reports have been more qualitative than quantitative, due both to the relative remoteness of the location and to the apparently minor economic significance of this pest in B.C.

While the spruce budworm in eastern Canada and the U.S.A. has been well described in the literature, very little information has been reported on its existence in western Canada (Furniss and Carolin 1977). This report brings together information collected by FIDS over the past 35 years in order to describe the distribution, biology and damage caused by *C. fumiferana* in British Columbia.

[1]Records of this infestation can be found in the annual reports of the Forest Insect and Disease Survey, Canadian Forestry Service, Pacific Forestry Centre, Victoria, B.C., which were summarized by Erickson R.D. and J.F. Loranger. 1983. "History of the population fluctuations and infestations of important forest insects, in the Prince George Forest Region 1942-1982." File Report, Canadian Forestry Service, Pacific Forest Research Centre, Victoria, B.C., 60 pp.

MATERIALS AND METHODS

The Forest Insect and Disease Survey has maintained a national data bank of insect and disease collections from 1949 to date (Harris 1976). Collection records were examined to determine the relative abundance and host preference of *C. fumiferana* in B.C.

Detailed monitoring of the spruce budworm infestation in the Liard River area was conducted by FIDS at several locations between kilometres 795 and 866 of the B.C. section of the Alaska highway from 1959 to 1969. Each year, 5 to 25 locations were sampled to estimate defoliation intensity. Average percent current defoliation was visually estimated from the ground using binoculars on ten dominant or codominant white spruce trees at each sampling point.

Surveys conducted after 1969 were less detailed. Based on ground or aerial examination, defoliation was classed as light (discolored foliage barely noticeable from a distance), moderate (pronounced foliage discoloration, noticeably thin foliage, top third of many trees severely defoliated, some completely stripped) and severe (bare branch tips and completely defoliated tops, most trees more than 50% defoliated).

In 1976, 10 spruce trees were randomly selected for growth determination at each of three locations along the Alaska highway (kilometres 827, 858 and 874). The sample included 29 white spruce and one black spruce, *Picea mariana* (Mill.) B.S.P. The ring width pattern of the single black spruce, in plot 2, was similar to that of the remaining white spruce in the sample from the area and was included in the average. Two cores were collected

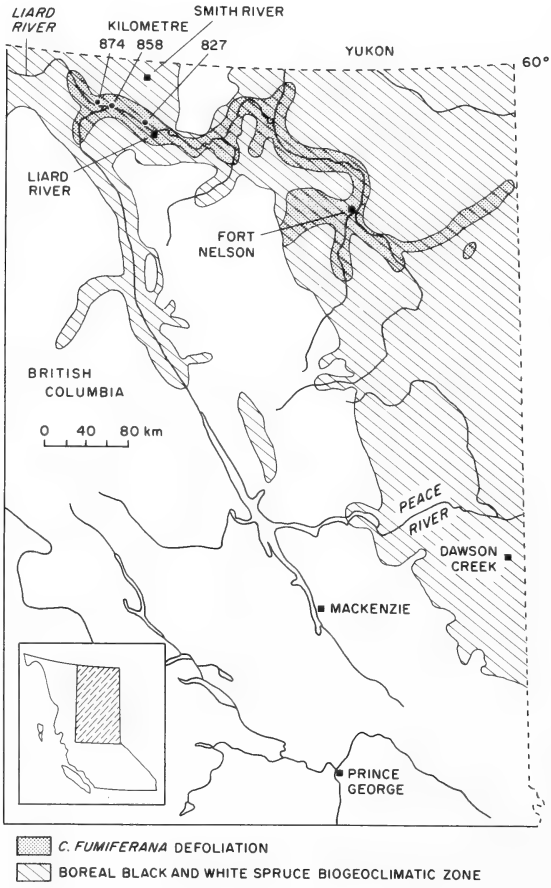

Fig. 1. Maximum extent of spruce budworm infestation and Boreal White and Black Spruce Biogeoclimatic Zone in British Columbia.

from each tree at breast height, using an increment borer. The cores were dated using dendrochronological methods (Stokes and Smiley 1968) and ring widths were measured using an ADDO-X instrument[2]. A ring width series *versus* year was constructed by averaging the data from the two cores from each tree. Each ring width series was smoothed using a centered three- or five-year moving average. The resultant data were plotted and examined to describe the effect of budworm defoliation on tree growth and to determine a possible history of infestations in the area (Alfaro *et al.* 1982, Blais 1983).

Increment cores were also collected from intermediate trees of the non-host species trembling aspen, *Populus tremuloides* Michx., and white birch, *Betula papyrifera* Marsh. To aid in the interpretation of the tree ring series, weather information for the area was obtained from the Smith River Airport weather station (Fig. 1) (Anon. 1957-1985).

RESULTS AND DISCUSSION

Description of the Infestation

The spruce budworm in British Columbia follows a similar life cycle, including the timing of each stage, to that in eastern Canada. Wood (1965)[3] described the life cycle as follows. Eggs are laid in July, in masses on the needles and hatch in about 12 days. Young larvae overwinter in hibernaculae under bark scales, lichen or other protective coverings. In the following May the larvae emerge and first mine old needles or attack the opening buds. Subsequent larval feeding is mainly on the current year's growth; if, however, this becomes depleted, larvae will move onto older foliage to feed. Pupation occurs in late June or early July with the moths emerging in 12-18 days.

The maximum extent of defoliation, as recorded from ground and aerial observations, was entirely within the Boreal White and Black Spruce Biogeoclimatic Zone (Krajina 1965; Annas 1983) (Fig. 1). This zone is limited to the northeast corner of the province occupying the lower elevations of the main valleys west of the Rocky Mountains. It occurs north of approximately 54°N latitude and at elevations ranging from 165 to 1150 m and is characterized by very cold winters and a relatively short growing season (Annas 1983).

Defoliation occurred in the area from 1959 (when first reported) until 1979; however, its intensity was highly variable over the years. It remained low (23-35%) from 1959 until 1962 (Fig. 2), then increased sharply in 1964 and 1965, when defoliation averaged 90% of the total foliage. In 1966 there was a reduction in damage (< 10% defoliation). However, defoliation gradually increased again until 1969, the last year of detailed record-keeping, when it averaged 40%. From 1970 until 1975, defoliation in the area was classified as moderate to severe, with the exception of 1974, when it was light. Light defoliation occurred from 1976 to 1978. No visible defoliation was reported again until 1984 and 1985 (light to moderate).

Based on the percentage of samples containing *C. fumiferana* (Fig. 3a) and on the average numbers of larvae and pupae per positive collection (Fig 3b), white spruce appeared to be the preferred host followed by eastern larch, *Larix laricina* (Du Roi) K. Koch, and alpine fir, *Abies lasiocarpa* (Hook.) Nutt. Less preferred hosts were black spruce and lodgepole pine, *Pinus contorta* Dougl.; however, these two species are also defoliated when mixed with white spruce.

[2]Parker Instruments, Organistan 18, S-21617 Malmo, Sweden.

[3]Wood R.O. 1965. "The one-year cycle spruce budworm, *Choristoneura fumiferana* (Clem.), in northeastern British Columbia." Unpublished report, Canadian Forestry Service, Forest Insect and Disease Survey, Pacific and Yukon Region, 8 pp.

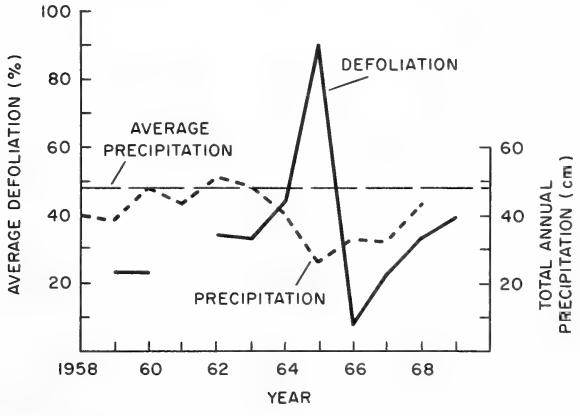

Fig. 2. Average defoliation of the current year's foliage based on ground observation of dominant and codominant white spruce trees in the Liard River area. Total annual and 30-year average precipitation as measured at the Smith River Airport weather station.

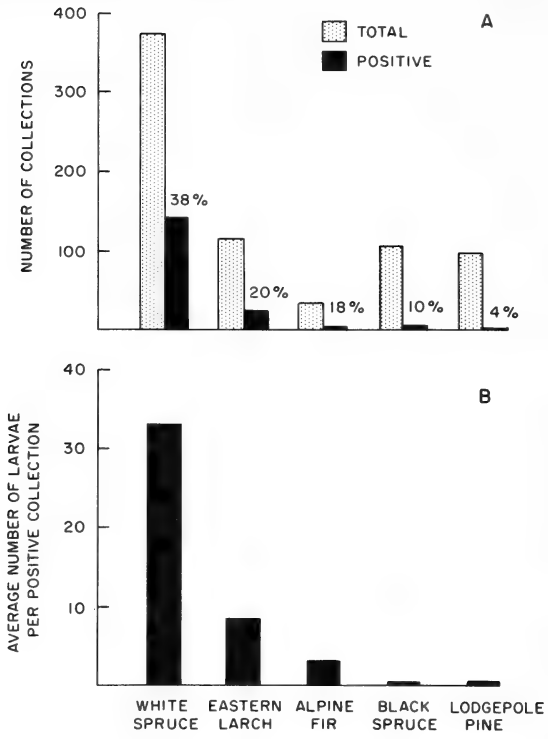

Fig. 3. Incidence of spruce budworm on five tree species in northeastern British Columbia. A) Number of positive (containing at least 1 budworm larva or pupa) and total number of collections of larvae and pupae by host tree. Percentages refer to the percentage of total collections that were positive. B) Average number of larvae and pupae per positive collection by host tree.

Weather records for these infestation years show little variation in mean annual high and low temperature but considerable variation in total annual precipitation. The years 1964 to 1968 were below the 30-year precipitation average (Fig. 2), with the year of lowest precipitation, 1965, coinciding with the year of greatest defoliation. Examination of the deviations from normal precipitation on a monthly basis for these infestation years showed that 1965 had an unusually dry March through August, a situation apparently favorable to the development of budworm infestations (Wellington *et al.* 1950; Greenbank 1956; Morris 1963; Thomson *et al.* 1984).

Effects of defoliation on annual diameter growth

Average ring widths for 1939 to 1976 for the 10 spruce trees in each locality are shown in Fig. 4. The first defoliation records for this area date to 1959. However, ring width declined in 1957 and 1958. Because of a one to two year lag in ring width reduction after defoliation (Kleinschmidt *et al.* 1980, Alfaro *et al.* 1982), it is possible that defoliation in the area started in 1956. Alternatively, it is possible that some climatic factor such as drought stressed the trees prior to, or concurrent with, defoliation. Similar decline in birch, a non-host, in plot 2 (Fig. 4), supports the second hypothesis. Also, weather data from the area indicate 1957 to 1959 as years of below normal precipitation (Anon. 1957 to 1959).

Both non-host trees (one birch and one aspen) showed marked increases in ring width commencing one to two years after the first year of recorded defoliation for the host (1959). This suggests a release effect on the non-host, possibly because of increased light resulting from the defoliation of the host.

Based on the average ring width series for each plot, loss in diameter was calculated by assuming that growth during 1957 to 1976 should have been equal to the mean growth of the 6 years preceding defoliation (1951-1956). We assumed that the decline in ring width during the loss period was entirely due to *C. fumiferana* defoliation and disregarded any effects of the coincident precipitation deficits on growth. It is possible that defoliation and precipitation deficit might have additive effects. We also disregarded the natural trend of tree ring widths to decline with age (the rate of ring width decline was very slow in

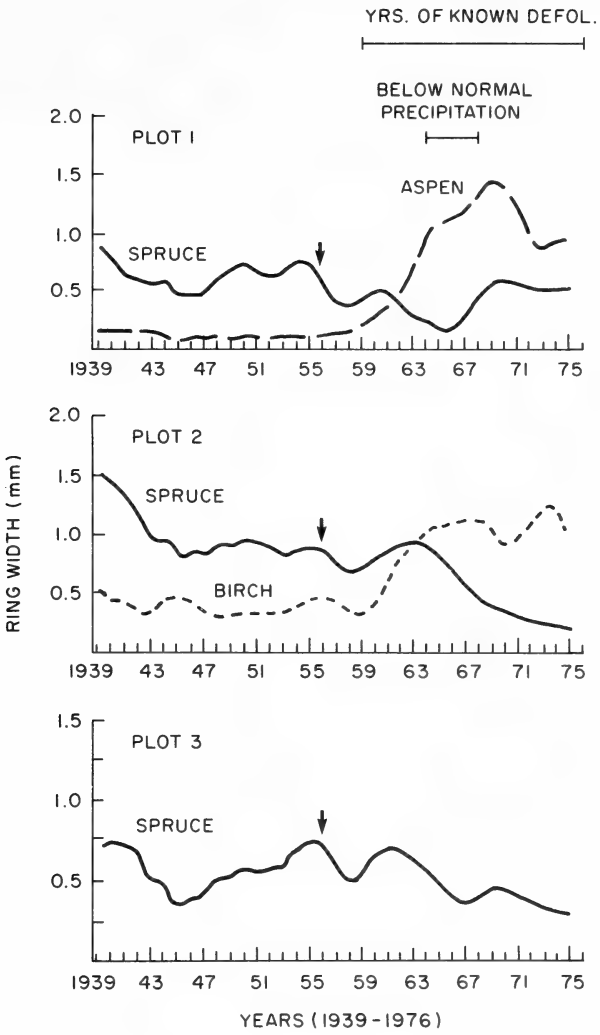

Fig. 4. Average annual ring width of 10 spruce trees from three plots in the Liard River area. Also shown for comparison are ring widths of one aspen and one birch tree. Suspected first year of defoliation (1956) is shown by the arrow.

these mature trees). Thus, our loss estimates must be considered as a "worst case scenario." Absolute losses averaged 10.6, 13.2 and 7.7 mm in plots 1, 2 and 3 respectively; thus percentage losses, relative to the average diameter the trees could have reached by 1976, were 3.8, 4.4 and 3.0% respectively (Table 1).

Examinations conducted in 1977 of wind fallen trees in areas affected by the severe defoliation of 1965 indicated that nearly all of the trees had sustained top-kill averaging 30 to 60 cm in length. Leader recovery from the top-kill in the form of multiple leaders was evident in most trees. The significance of defects in the main stem due to top-kill is greater in young than in mature trees, because defects can result in a reduction in the merchantable height of the tree. Tree mortality as a result of persistent budworm defoliation was rarely found, unlike the situation in eastern North America (MacLean *et al.* 1984).

Possible outbreak chronology for the Liard River area.

Examination of the annual ring width series disclosed a distinct pattern of alternating periods of growth increase and decline (Fig. 5) which recurred every 14 to 28 years (Table 2). These periods were evident in many trees from this area (Table 2) and could be attributed to periodic environmental conditions adverse to growth, to the effects of recurrent *C. fumiferana* (or some other pest) or to both. No pest records exist for this area prior to 1956. A similar pattern of ring width reduction for the years 1956 to 1976, the years of known defoliation (Figs. 4, 5),

Embree, D.C. 1965. The population dynamics of the winter moth in Nova Scotia, 1954-1962. Mem. Entomol. Soc. Can. No. 46, 57 pp.

Embree, D.G. 1970. The diurnal and seasonal patterns of hatching of winter moth eggs, *Operophtera brumata* (Lepidoptera:Geometridae). Can. Entomol. 102: 750-768.

Ferguson, D.C. 1978. Pests not known to occur in the United States of limited distribution. Winter moth, *Operophtera brumata* (L.) (Lepidoptera:Geometridae). U.S. Dept. Agric. Coop. Pl. Pest Rep. 3: 687-694.

Gillespie, D.R., T. Finlayson, N.V. Tonks, and D.A. Ross. 1978. Occurrence of the winter moth, *Operophtera brumata* (Lepidoptera:Geometridae) on southern Vancouver Island, B.C. Can. Entomol. 110: 223-224.

Smith, C.C. 1950. Notes on the European winter moth in Nova Scotia. Can. Dept. Agric. For Biol. Div., Bi-mon. Prog. Rep. 6(2):1.

RESPONSES TO PLANT EXTRACTS OF NEONATAL CODLING MOTH LARVAE, *CYDIA POMONELLA* (L.), (LEPIDOPTERA:TORTRICIDAE:OLETHREUTINAE)

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ABSTRACT

A bioassay was designed to test behavioral responses of neonatal codling moth larvae to chloroform and methanol extracts of 25 plant species. Chloroform extractable materials from absinthe wormwood, *Artemisia absinthium* (L.), rabbitbrush, *Chrysothamnus nauseosus* (Pallas), and tansy, *Tanacetum vulgare* (L.) showed promise as possible feeding deterrents to neonatal codling moth larvae.

INTRODUCTION

In Washington State approximately half the cost of controlling arthropod pests in apples is attributable to the codling moth, *Cydia pomonella* (L.) (Ferro *et al.* 1975). Much of the damage occurs as "stings" made by probing neonatal larvae attempting to penetrate but then not entering the fruit. This "stinging" behavior might be linked to incompletely developed chemoreceptors. Immediately upon eclosion from the egg, larvae may not be able to recognize the fruit as a potential food source. This "non-recognition" phenomenon has been shown by Wiklund (1973) for early instars of *Papilio machaon* (L.) and by Bland (1981) for first instars of acridids. Non-recognition of food by neonates can lead to wandering activities that increase their exposure to abiotic and biotic mortality factors. As a result, in unsprayed apple orchards, death of neonatal codling moth larvae reduces the population by greater proportions than mortalities of any other life stage (Ferro *et al.* 1975, MacLellan 1977). Therefore, new control efforts should be directed to this stage. Disruption of larval feeding behavior by the use of secondary plant compounds may increase wandering and thus mortality.

We surveyed local plants for extracts that might modify the feeding behavior of neonatal codling moth larvae. Extracts that prevented or interrupted feeding activity were considered possible sources for feeding deterrents as defined by Schoonhoven (1982). Twenty-five selected plant species of eastern Washington and northern Idaho were collected in the survey. This study concentrated on neonatal larvae and their feeding behavior rather than on the long-term development of insects fed on artificial diets containing the suspected feeding deterrents.

MATERIALS AND METHODS

Plant Collection and Extraction

Test plants were collected during the summer of 1982. Criteria used to select the plants included strong odor, notable lack of herbivore feeding activity, or literature references concerning their repellent properties. An effort was made to include at least one representative from each of a variety of plant families (Table 1).

Plants chosen appeared healthy and free from visible signs of disease. Entire plants were collected including a moist ball of soil around the roots. The roots were wrapped in moist paper towels and covered with a plastic bag for transport. Plant samples were either frozen or extracted within 1 h of collection.

Ten grams of leaves (and flowers, if present) were weighed, wrapped in plastic, and frozen at ca. -16°C to preserve plant components without changes in chemical composition due to enzymatic activity (Draper 1976).

[1]Washington State Univ., College of Agriculture and Home Economics Research Center, Scientific Paper 7027. Work done under project number 5405.

TABLE 2. Percentage of trees sampled showing annual growth ring reductions attributed to *C. fumiferana* defoliation in the Liard River area of British Columbia based on examinations of increment cores from 10 spruce trees in each plot.

Year of ring			Percent of trees showing growth reduction		
Earliest Decline	Minimum	Latest Recovery	Plot 1	Plot 2	Plot 3
1873	1876	1890	70	86[2]	80
1892	1896	1909	70	100[3]	70
1920	1923	1937	100	80	50
1942	1945	1954	80	90	100
1956	____[1]	____[1]	100	100	100

[1] Infestation was still in progress when cores were collected in 1976.
[2,3] Based on only 7 and 8 trees, respectively.

REFERENCES

Alfaro, R.I., G.A. Van Sickle, A.J. Thomson and E. Wegwitz. 1982. Tree mortality and radial growth losses caused by the western spruce budworm in a Douglas-fir stand in British Columbia. Can. J. For. Res. 12: 780-787.

Annas, R.M. 1983. Boreal White and Black Spruce Zone. pp. 254-258. *In* Watts S.B. (ed.) Forestry Handbook for British Columbia. The Forestry Undergraduate Society, Faculty of Forestry, University of British Columbia, 611 pp.

Anonymous. 1957-1985. Monthly Record, Meteorological observations in Canada. Environment Canada, Atmospheric Environment Service.

Blais, J.R. 1983. Trends in the frequency, extent and severity of spruce budworm outbreaks in eastern Canada. Can. J. For. Res. 13: 539-547.

Dang, P.T. 1985. Key to Adult Males of Conifer-Feeding Species of *Choristoneura* Lederer (Lepidoptera:Tortricidae) in Canada and Alaska. Can. Ent. 117: 1-5.

Freeman, T.N. 1967. On coniferophagous species of *Choristoneura* (Lepidoptera:Tortricidae) in North America I: Some new forms of *Choristoneura* allied to *C. fumiferana*. Can. Ent. 99: 449-455.

Furniss, R.L. and V.M. Carolin. 1977. Western Forest Insects. U.S.D.A. For. Serv. Misc. Pub. 1339, 654 pp.

Greenbank, D.O. 1956. The role of climate and dispersal in the initiation of outbreaks of the spruce budworm in New Brunswick. Can. J. Zool. 34: 453-476.

Harris, J.W.E. 1976. Storage and retrieval of quantitative British Columbia-Yukon Forest Insect and Disease Survey records. Can. For. Serv., Pac. For. Res. Cent. Inf. Rep., BC-X-120, 30 pp.

Kleinschmidt, S.M., G.L. Baskerville and D.S. Solomon. 1980. Reduction of volume increment in Fir-spruce stands due to defoliation by spruce budworm. Fac. of Forestry, U. of N. Brunswick. 37 pp.

Krajina, V.J. 1965. Biogeoclimatic zones and classification of British Columbia. *in* Ecology of Western North America 1: 1-17. Kragina V.J. (editor) Univ. of British Columbia Dept. of Botany.

MacLean, D.A., A.W. Kline and D.R. Lavigne. 1984. Effectiveness of spruce budworm spraying in New Brunswick in protecting the spruce component of spruce-fir stands. Can. J. For. Res. 14: 163-176.

Morris, R.F. (editor). 1963. The dynamics of epidemic spruce budworm populations. Memoirs Ent. Soc. Can. No. 31, 332 pp.

Schmitt, D.M., Grimble, D.G. and Searcy, J.L. 1984. Managing the Spruce Budworm in Eastern North America. U.S.D.A. Forest Service. Agriculture Handbook No. 620.

Stokes, M.A. and T.L. Smiley. 1968. An introduction to tree-ring dating. U. of Chicago Press, Chicago 73 pp.

Thomson, A.J., R.F. Shepherd, J.W.E. Harris and R.H. Silversides. 1984. Relating weather to outbreaks of western spruce budworm *Choristoneura occidentalis* (Lepidoptera:Tortricidae) in British Columbia. Can. Ent. 116: 375-381.

Wellington, W.R., J.J. Fettes, K.B. Turner and R.M. Belyea. 1950. Physical and biological indicators of the development of outbreaks of the spruce budworm. Can. J. Research 28: 308-331.

CARNUS HEMAPTERUS (DIPTERA:CARNIDAE) AN AVIAN NEST PARASITE NEW TO BRITISH COLUMBIA

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Carnus hemapterus Nitzsch is an ectoparasite of bird nestlings found throughout Europe and scattered locations in North America. (Bequaert 1942, Capelle and Whitworth 1973). Although Sabrosky (1965) lists it only from New Brunswick in Canada, Bequaert (1951) did state that *C. hemapterus* was also "found in British Columbia...the details...to be published later by the discoverers." As far as I know, those details were never published.

While checking a nest of the Northern Saw-whet Owl *Aegolius acadicus)* near Osoyoos, B.C. on April 17, 1985, I noticed several small flies crawling over the newly-hatched nestlings. I collected a few specimens on April 17, 19, and 21, and on April 25 I took 50 flies off two nestlings. They were identified as *C. hemapterus* by S.G. Cannings and J.F. McAlpine; voucher specimens are now at the University of British Columbia, Canadian National Collection, and the University of Guelph.

C. hemapterus has been collected from the nests of a wide variety of birds, but primarily from those of raptors and hole-nesting species. I found it to be common in the Osoyoos area, being present in all of 13 nests of the European Starling *Sturnus vulgaris* and two other Northern Saw-whet Owl nests that I checked. Further details of the infestations are being published elsewhere (Cannings, in press).

REFERENCES

Bequaert, J. 1942. *Carnus hemapterus* Nitzsch, an ectoparasitic fly of birds, new to America (Diptera). Bull. Brook Ent. Soc. 37: 140-149.

Bequaert, J. 1951. *Carnus hemapterus* Nitzsch on a screech owl in Arizona (Diptera). Psyche 58: 157.

Cannings, R.J. in press. Infestations of *Carnus hemapterus* Nitzsch (Diptera:Carnidae) in Northern Saw-whet Owl nests. Murrelet.

Capelle, K.J. and T.L. Whitworth. 1973. The distribution and avian hosts of *Carnus hemapterus* (Diptera:Milichiidae) in North America. J. Med. Ent. 10: 525-526.

Sabrosky, C. 1965. Milichiidae. P. 728-733 *In* A. Stone, C.W. Sabrosky, W.W. Wirth, B.H. Foote, and J.R. Coulson (Eds.), A catalog of the Diptera of America north of Mexico. USDA Agric. Res. Serv., Washington, DC, 1696 pp.

HOST DISCRIMINATION IN *RHAGOLETIS BERBERIS* (DIPTERA:TEPHRITIDAE)

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ABSTRACT

Following oviposition, females of *Rhagoletis berberis* Curran (Tephritidae), appear to deposit host marking pheromones on the surface of their host fruit, *Mahonia* (Berberacidae), and discriminate against such marked hosts when choosing oviposition sites. Marking is accomplished by dragging the ovipositor on the fruit surface, resulting in the deposition of a fluid trail. In addition to these findings, females were observed feeding on the juice of host fruit through punctures made with their ovipositors. Therefore, the incidence of fly feeding was compared with successful and unsuccessful oviposition.

INTRODUCTION

Host discrimination is defined as the ability to detect conspecifics (Salt, 1934) and is demonstrated in several entomophagous and phytophagous parasitic insects (Prokopy, 1982). In some members of the tephritid fruit fly genus, *Rhagoletis*, for example, host discrimination is mediated by the deposition of host marking pheromones (HMPs) which are laid down in a fluid trail over the fruit surface following egg-laying. Females foraging for suitable oviposition sites detect the presence of HMPs through contact with receptors on their foretarsi and generally reject such marked hosts (Prokopy, 1981). The present study examines the host discrimination behaviour of females of the tephritid species, *Rhagoletis berberis* Curran, as part of a long term study on the population dynamics of *R. berberis* and its host *Mahonia* (Berberacidae) in British Columbia.

Rhagoletis berberis is found in the Okanagan Valley, on Vancouver Island and in Lower Mainland regions of B.C. The species is easily distinguished from other members of the genus by its entirely black body, distinctive karyotype and wing pattern. Its narrow host range includes several species of northwestern *Mahonia*, notably *M. aquifolium* and *M. nervosa*, commonly known as mountain grape and Oregon grape respectively (Bush, 1961). Adult flies emerge in early summer and can be found at host sites for several weeks. During this period, mated females lay eggs in nearly ripe fruit. The pupating larvae drop from rotting fruit and overwinter in the soil beneath the host. In the following summer, adults emerge from the soil, initiating a new cycle of insect-host interaction. Our rationale for studying host discrimination in *R. berberis* is based upon the following:

First, *R. berberis* larvae are unable to move between host fruit. Therefore their success as larvae is dependent upon the choice of host fruit by their mothers. As food and space within hosts is limited, competition among larvae within the fruit may be important to larval survival. Thus, females that mark hosts and avoid laying eggs in already-occupied fruit may enhance their reproductive fitness.

Second, HMPs are known to operate in at least ten other species of the *Rhagoletis* genus (Prokopy, 1981).

Third, certain species of fruit infesting tephritids are among the world's most damaging agricultural pests (Prokopy & Roitberg, 1984). Although not an economic pest, *R. berberis* is closely related to the cherry fruit fly, *R. cerasi*, a current pest in B.C. and the apple maggot fly *R. pomonella*, a pest present in Washington State and feared to be spreading to B.C. Thus, knowledge gleaned from this system may be utilized in management of those related deleterious pests.

Finally, elucidation of the oviposition behaviour of *R. berberis* should promote our understanding of the population dynamics of this fly-fruit system. In addition to host discrimination behaviour, we report observations of related behaviour.

METHODS

The present research consisted of field observations and laboratory experiments for which we utilized two groups of *R. berberis* females: wild flies, reared and observed in nature and flies of wild origin, reared and observed in the lab.

Field Observations

Three field sites, located in two suburbs of the B.C. Lower Mainland, were chosen based on host and fly presence. At each site, we followed wild females individually as they moved among fruit clusters, documenting their search, oviposition and fruit surface-dragging behaviour with a tape recorder and stop watch. Visited fruit were dissected in the lab. From the dissections we tabluated the number of successful ovipositions (egg(s) found), unsuccessful ovipositions (no egg found) and the number of eggs found per fruit. In addition, we noted the number of fruits dragged upon following oviposition.

Lastly, we picked a random sample of fruit in the field. Individual infested fruit from this sample and their emergent flies were assigned paired numbers. In each pair, the weight, head capsule width and pronotal width of the fly were compared with the diameter of the fruit.

Lab Experiments

Flies of wild origin were reared in the lab. We obtained larvae, from rotting fruit picked the previous summer, in the following manner: gathered ripe fruit clusters were brought into the lab and spread out on wire mesh screens set over trays of moist vermiculite and fine sand. Pupating larvae dropped from the rotting fruit into the vermiculite mixture. Collected larvae, stored at 3°C overwintered until required for the summer's experimentation. Following a warming period, emergence and a maturing period (*ca.* 8 days), mated females were separated from males and placed collectively in a 25 x 25 cm plexiglass-mesh cage. The flies were fed on a diet of water, sucrose and yeast hydrolysate (Prokopy, 1971) and were maintained under fluorescent light, 16L:8D. We conducted lab experiments 6 hours after lights-on to approximate the time females would forage for oviposition sites in nature. Lab-reared flies were used for the experiments because wild flies collected at our field sites did not acclimatize to lab conditions.

Females were pre-tested prior to the experiments to ensure their readiness and motivation for egg-laying. To qualify for the experiments each fly was required to lay a single egg in each of two uninfested fruits. We transferred pre-tested females to individual plastic, numbered Dixie®-cup cages. Each qualified female was offered, randomly, three types of *M. aquifolium* fruit atached singly to the end of a coded probe and placed inside her cage. The three types offered were: 1. Uninfested fruit (– –), 2. Egg-infested fruit with surface dragging (+ +) and 3. Egg infested fruit without surface dragging (+ –) which we obtained by removing females from the fruit surface immediately following oviposition. This was a necessary step because our field observations indicated that females will generally drag the fruit surface after oviposition (see Results).

During the experiments, females that rejected a random fruit, i.e., left without attempting oviposition, were offered an uninfested fruit to ensure that rejection occurred due to fruit quality and not the motivational state of the fly. If the uninfested fruit was rejected as well, the previous data for the fly were eliminated. Females rested 5 minutes between each experiment. We dissected the offered fruit after each experiment.

We recorded the females' search times on all three fruit types. We observed that occasionally, females would feed on the juice of the offered fruit through punctures made with their ovipositors. The incidence of fly feeding was therefore compared with successful and unsuccessful ovipositons.

RESULTS

Field Observations

Females were active in the field from 1100 to 1400 hours and made short flights to nearby fruit clusters or longer flights to distant bushes. Males, by contrast, were present from 900 to 1700 hours. They stationed themselves on fruit within single clusters and apparently waited for females. Sightings of both sexes were considerably fewer on overcast or rainy days as compared to days of full sunlight. Females did not attempt to oviposit on every fruit they encountered. Females that did attempt oviposition followed one of two sequences, both of which began with a search of the fruit surface. After searching, flies either left the fruit or initiated oviposition. Following oviposition, they either dragged their ovipositor over the fruit surface or left. We documented 25 ovipositions, the mean duration of which was 123.9 s (S.E. = 8.17 s). The mean duration of ovipositor dragging was 21.6 s (S.E. = 3.7 , N = 17). On occasion, we observed a fine, thread-like, fluid trail on the fruit surface after dragging occurred.

Results of the fruit dissections (Table 1) show ovipositor dragging following in 80.6% of successful ovipositions (egg found). Conversely, ovipositor dragging following in 40% of unsuccessful ovipositions (no egg). In only one of the 15 successful ovipositions was a fruit found to contain more than one egg.

Females in the field oviposited in a wide range of fruit sizes (range: 7.0 - 13.0 mm diameter). No significant

TABLE 1. Comparison by fruit dissection of successful and unsuccessful oviposition attempts and their associations with HMP dragging by *R. berberis* in the field.

OVIPOSITION	POST-OVIPOSITION BEHAVIOUR			
	Drag	No Drag	Total	
Successful (egg)	13	2	15	G-test
Unsuccessful (no egg)	4	6	10	$p < .02$
Total:	17	8	25	

This species is a member of the subfamily Emesinae. *B. fraterna* has an angular or spiniform process on the clypeus, the pale stripe on the ventral surface of the head is as wide as the interocular space and is without a dark spot ventrally on each side behind the eye. The upper margin of the pygophore has a broad squarish process, but there is no erect spine within the upper border.

It is distributed throughout the western, southwestern and northern United States, Mexico, Cuba, Jamaica, Colombia and Ecuador (Wygodzinsky 1966).

B.C. material examined: 1♀, Lytton, 26.vii.1931 (G.J. Spencer); 1♀, *id.*, 23.viii.1931; 5♂ 5♀, Peace River, Hwy. 29, 32 km W of Charlie L, 5.viii.1982 (G.G.E.Scudder); 1♂, Vancouver, University Endowment Lands, nr. S.W. Marine Drive and 41st Ave., 29.viii.1984 (G.G.E.S.) [UBC].

FAMILY CORIXIDAE

Sagara alternata (Say)

Corixa alternata Say 1825, J. Acad. Nat. Sci. Phil. 4: 329
Sigara (Vermicorixa) alternata, Hungerford 1948, Univ. Kans. Sci. Bull. 32: 653.

S. alternata has the hemelytra with the postnodal pruinose area and the claval pruinose area of equal length, and the thorax with the mesoepimeron narrow (Hungerford 1948).

The species occurs from Nova Scotia to Alberta, and across most of the United States.

B.C. material examined: 1♂, Delta, Burns bog, 2.x.1984 (J. Lancaster); 1♂ 1♀, Vancouver, Van Dusen Botanic Gardens, ornamental pond, 16.iv.1985 (G.G.E. Scudder) [UBC].

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REFERENCES

Barber, H.G. 1949. A new genus in the subfamily Blissinae from Mexico and a new *Nysius* from the Northwest (Lygaeidae: Hemiptera-Heteroptera). Bull. Brooklyn Ent. Soc. 44: 141-144.

Barber, H.G. 1958. A new species of *Nysius* from Alaska and Alberta, Canada. Proc. Ent. Soc. Wash. 60: 70.

Froeschner, R.C. 1960. Cynidae of the Western Hemisphere. Proc. U.S. Nat. Mus. 111: 337-680.

Hungerford, H.B. 1948. The Corixidae of the Western Hemisphere (Hemiptera). Univ. Kans. Sci. Bull. 32: 1-827.

Kelton, L.A. 1978. The Anthocoridae of Canada and Alaska. Heteroptera:Anthocoridae. The Insects and Arachnids of Canada, Part 4. Can. Dept. Agric. Publ. 1639, 101 pp.

McDonald, F.J.D. 1974. Revision of the genus *Holcostethus* in North America (Hemiptera:Pentatomidae). J. N.Y. Ent. Soc. 82: 245-258.

McPherson, J.E. 1982. The Pentatomoidea (Hemiptera) of northeastern North America with emphasis on the fauna of Illinois. Southern Illinois Univ. Press, Carbondale and Edwardsville, 240 pp.

Rolston, L.H. 1983. A revision of the genus *Acrosternum* Fieber, subgenus *Chinavia* Orian, in the Western Hemisphere (Hemiptera:Pentatomidae). J. N.Y. Ent. Soc. 91: 97-176.

Scudder, G.G.E. 1981. Two new species of Lygaeinae (Hemiptera:Lygaeidae) from Canada. Can. Ent. 113:747-753.

Slater, J.A. 1964. A catalogue of the Lygaeidae of the World. Univ. of Connecticut, Storrs, 2 vols., 1668 pp.

Slater, J.A. and Baranowski, R.M. 1978. How to know the true bugs (Hemiptera-Heteroptera). Wm. C. Brown Co., Dubuque, Iowa, 256 pp.

Stoner, D. 1920. The Scutelleridae of Iowa. Univ. Iowa Stud. Nat. Hist. 8: 1-140.

Wygodzinsky, P.W. 1966. A monograph of the Emesinae (Reduviidae, Hemiptera). Bull. Amer. Mus. Nat. Hist. 133: 1-614.

ERRATUM

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TABLE 4. Response of *R. berberis* females to fruit surface punctures following oviposition attempts.

OVIPOSITION	FEED	NO FEED	
Successful (egg)	5	26	G-test
Unsuccessful (no egg)	14	6	$p = < .001$

about and placed their mouth parts into the puncture. Data from feeding observations (Table 4) show that 70% of unsuccessful ovipositions were followed by feeding while only 18% of successful ovipositions were followed by feeding.

DISCUSSION

First, both field observations and lab experiments indicate that *R. berberis* females generally follow egg-laying with ovipositor dragging of the host fruit surface. Most importantly, lab results indicate that it is not the presence of an egg but rather the dragging that enables females to discriminate. Thus, it follows that females detect a substance deposited on the fruit during dragging. Several factors give weight to this conclusion: firstly, evidence for the existence of this substance comes from our observation of a fine, thread-like trail on the fruit, visible briefly, following ovipositor dragging. Secondly, the fact that all pre-tested females readily climbed onto and searched each fruit type equally, indicates that physical contact with the fruit surface is necessary for determination of its quality. Thirdly, contact pheromone markers are used by several species within the *Rhagoletis* genus including *R. pomonella, R. cerasi, R. completa, R. fausta, R. cingulata, R. indifferans, R. mendax, R. cornivora, R. tabellaria* and *R. basiola* (Prokopy, 1981). Thus, we conclude that *R. berberis* employs a contact marking pheromone to aid in host discrimination.

The usage of host marking pheromones is functionally significant in several ways. HMPs appear to be the only means by which *R. berberis* females can detect the presence of an egg after it has been laid. HMPs signal egg presence to other foraging females enabling them to avoid conspecific competition and thereby enhancing their reproductive fitness. Recent theoretical studies (Roitberg & Prokopy, 1986) however, suggest the functional significance of HMPs is that they signal to the female that laid the egg initially that it has already exploited a particular fruit. Therefore, additional eggs should not be laid in the same fruit to avoid sibling competition for limited food and space. In either case, as our data suggest, single *M. aquifolium* fruits support only one larva, so that rejection of marked fruit should enhance the fitness of parents through increased offspring survival. In addition, Price (1970), suggested that females' response to HMPs enhances foraging efficiency via dispersal of females away from areas already heavily exploited.

Second, our lack of correlation between fruit diameter and fly size indicates that competition between larvae may be far more deleterious than variation in fruit size. Thus, it is not surprising that females do not appear to discriminate between different sized fruit for oviposition sites.

Third, results suggest that the females' feeding behaviour, at fruit surface punctures, has a single functional significance, that of obtaining nutrients. If this phenomenon were related to offspring survival we might expect to observe a high correlation between oviposition and feeding. In fact, feeding rarely followed oviposition.

Finally, we hope knowledge of this HMP system will help us to reach an overall understanding of tephritid marking systems. Such an understanding will aid in future management of both harmless and damaging *Rhagoletis* species. Already, recent computer simulation studies (Roitberg & Angerilli, 1986) show employment of HMPs in orchards, in conjunction with traps, may provide effective population control at rates comparable to chemical biocides.

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REFERENCES

Bush, G.L. 1961. *Rhagoletis* in North America. Bulletin of the Museum of Comparative Zoology. 134, No. 11: 508-511.

Price, P.W. 1970. Trail odours: Recognition by insects parasitic on cocoons. Science. 170: 546-547.

Prokopy, R.J. and E.F. Boller. 1971. Artificial egging system for the European cherry fruit fly. Journal of Economic Entomology. 63: 1413-1417.

Prokopy, R.J. 1981. Oviposition deterring pheromone system of apply maggot flies in: (E.R. Mitchell, Ed.) *Management of Insect Pests with Semiochemicals*. Plenum Publishing Corporation 477-494.

Prokopy, R.J., Roitberg, B.D. and A. Averill. 1982. Chemical mediation of resource partitioning in insects in: (R. Carde and W. Bell, Eds.) *Chemical Ecology of Insects*. Chapman and Hall. London. 301-330.

Prokopy, R.J. and B.D. Roitberg. 1984. Foraging behaviour of true fruit flies. American Scientist. 72: 41-49.

Roitberg, B.D. and N. Angerelli. 1986. Management of temperate orchard pests: Applied behavioural ecology. Agricultural Zoology Reviews. 1: (in press).

Roitberg, B.D. and R.J. Prokopy. 1986. Marking pheromones. Bioscience. (in press).

Salt, G. 1934. Experimental studies in insect parasitism. II. Superparatisism. Proceedings of the Royal Society of London. Series B. 114: 455-476.

TRYPODENDRON LINEATUM (COLEOPTERA:SCOLYTIDAE) BREEDING IN BIG LEAF MAPLE, *ACER MACROPHYLLUM*

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The striped ambrosia beetle, *Tyrpodendron lineatum* [Olivier], is a holarctic species which normally breeds in coniferous wood (Lekander *et al.* 1977; Bright 1976; Wood 1982). Occasionally it is found in hardwoods, and in the literature it is recorded from *Alnus, Betula,* and *Malus* (Bright 1976; Nijholt 1981; Wood 1982). This paper describes successful attack and brood production in bigleaf maple, *Acer macrophyllum*.

The attacked maple was found at the MacMillan-Bloedel Ltd. Mesachie Lake dryland sorting area, situated just southwest of Cowichan Lake on Vancouver Island. The tree was wind thrown during the winter 1984-1985, and attacked in the spring of 1985. The tree was 40-45 years old, the diameter was 50 cm (dbh), and growth was fairly vigorous (6.3 ± 2.1 mm per year) over the last 5 years. The attack density was 22.5 ± 8.2/0.1 m^2 at midbole. Brood production was moderate as judged by the number of pupal galleries. Approximately 300 brood beetles were collected in an emergence trap from six 30 cm sections taken 3-4 m from the butt end of the tree. The sections were collected on October 2, and emergence continued until late October. It is likely that most brood beetles had already emerged at the time the sections were collected. Galleries penetrated the wood to a maximum depth of 7 cm. The ambrosia fungus appeared normal as judged by the color of the galleries and apparent health of the brood.

The population of *T. lineatum* at the Mesachie Lake dryland sort is fairly moderate. The attacked maple was not in the vicinity of any coniferous timber, but there were two pheromone-baited Lindgren funnel traps (Lindgren 1983) within 5 m of the tree. It is possible that the pheromone from these traps attracted the beetles and induced the attack. However, the successful brood production would suggest that the condition of the wood was favorable for the beetles. Therefore it appears that the attack was natural, demonstrating the adaptability of this ambrosia beetle.

Specimens of the ambrosia beetles collected in this study are kept in the insect collection at the Pacific Forestry Centre, Victoria, B.C.

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REFERENCES

Bright, D.E. 1976. The bark beetles of Canada and Alaska. Canada Department of Agriculture Publication 1576, 241 pp.

Lekander, B., B. Bejer-Petersen, E. Kangas and A. Bakke. 1977. The distribution of bark beetles in the Nordic countries. Acta Ent. Fenn. No 32, 36 pp + 78 distribution maps.

Lindgren B.S. 1983. A multiple funnel trap for scolytid beetles (Coleoptera). Can. Ent. 115: 299-302.

Nijholt, W.W. 1981. Ambrosia beetles in alder. Can. For. Serv. Res Notes 1 (2): 12

Wood, S.L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera:Scolytidae), a taxonomic review. Great Basin Naturalist No. 6, 1359 pp.

ERRATUM

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A SIMPLE REARING METHOD FOR FUNGUS GNATS *CORYNOPTERA* SP. (DIPTERA:SCIARIDAE) WITH NOTES ON LIFE HISTORY[1]

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ABSTRACT

A method of rearing fungus gnats of *Corynoptera* sp. (Diptera:Sciaridae) is described, based on a diet of bean seed and horticultural peat. The gnats completed development from egg to adult in 13-15 days at 24 ± 2° C. Oviposition and longevity were increased by a honey supplement to the adults.

INTRODUCTION

Various species of fungus gnats (Diptera:Sciaridae) are common pests in greenhouse crops (Lindquist, Faber and Casey 1985; Wilkinson and Daugherty 1970a, b). Larvae reportedly damage the roots of seedlings and mature plants (Wilkinson and Daugherty 1970a; Dennis 1978), and adults are a source of annoyance and irritation to workers and consumers. The species most commonly reported causing damage in greenhouses is *Bradysia coprophilia* (Lintner) (Lindquist, Faber and Casey 1985). Wilkinson and Daugherty (1970a) reported *B. impatiens* (Johannsen) feeding on roots of soybean plants in a greenhouse.

In the fall of 1982 larvae of a species of Sciaridae were noted feeding on and around the roots of *Gerbera jamesonii* in a greenhouse. These were collected, reared and subsequently identified as *Corynoptera* sp. This species was successfully placed in continuous rearing. The following reports rearing techniques for this species which may be adaptable to other species of Sciaridae. The life history of *Corynoptera* sp. is described.

MATERIALS AND METHODS

Rearing

The rearing mixture was prepared by first soaking 100 g of dried pinto or small red beans in water for 24 h. These were rinsed under cold running water and ground with 500 ml of water in a blender. The ground beans were then added to 2 ℓ of sieved (16 mesh) horticultural peat and sufficient water was added to produce a moist mixture. This was stored in the refrigerator at 2°C until needed.

Cylindrical plastic 1 ℓ refrigerator containers coated on the outside with black paint were used as rearing containers. A hole of 2.5 cm diam. in the lid was covered with 80 mesh screen to provide ventilation. Approximately 100 ml of the rearing mix was added to these containers and packed firmly into the bottom. A small quantity of honey was then smeared on the lid. Twenty-five to 50 1- to 2-day-old gravid female fungus gnats and an equal quantity of males were briefly anesthetized with CO_2 and placed in the container. Colonies were renewed by anesthetizing freshly emerged adults in the original container and then placing the appropriate number into a new container.

Life History

Eggs for life history studies were collected by placing large numbers of female and male *Corynoptera* sp. in sealed containers with moist paper towelling. Eggs were rinsed from the towelling after 24 h and collected on a 200 mesh screen. Approximately 2000 freshly laid eggs were put into each of five containers as described above, with 200 ml of rearing mix. These were held at 24 ± 5°C. On the following day and each day thereafter a 10 ml sample of mix was taken from each container. Samples were teased apart with dissecting needles. Fungus gnats at all stages were extracted from the medium by gentle agitation in a 40% sucrose solution as suggested by Fordyce and Cantelo (1981). They were removed from the solution as they floated to the surface. This activity was maintained until no further individuals could be extracted. All fungus gnats extracted from each sample were counted and identified by stage, i.e. egg, larva, pupa or empty pupal case (= adult).

Adult Fecundity and Longevity

The effects of carbohydrate supplement on fecundity and adult longevity were tested. One freshly-emerged unmated female and one male were placed in each of 30 inverted, vented petri dishes. Blotting paper discs on the bottom of the dishes were kept moist throughout. A small portion of rearing mixture was provided to focus egg laying. In 15 of the dishes a drop of honey (approximately 0.1 ml) was placed on the blotting paper as a carbohydrate supplement. Oviposition was assessed daily. Data were analysed by t-test (= 0.05).

[1]Contribution No. 290. Saanichton Research and Plant Quarantine Station, 8801 East Saanichton Rd., Sidney, B.C.

RESULTS

Rearing

The method described was effective for rearing *Corynoptera* sp. Cultures have been maintained continuously for three years with occasional supplementing from wild stocks collected in greenhouses. Yield of individual culture vessels ranged from 500 to 1000 insects. A culture normally took 16 to 18 days to cycle at lab temperatures 18 to 24°C). The rearing mixture developed a luxuriant covering of mold that rapidly disappeared when the larvae hatched and began feeding. After the visible fungus had been consumerd, the larvae turned to the larger bean pieces left in the mixture as well as the mixture itself. By the time larval development was complete, the mixture had been reduced to a rich compost.

Life History

Overall development required slightly less than 13 days to 50% emergence of adults (Fig 1). The egg stage lasted between 1 and 2 days. Larval development required 7 days and the pupal stage lasted about 4 days. Emergence of adults was essentially complete by day 15. Males began emerging 1 day before the females (Table I). The male:female ratio was 1:1.3.

Adult Fecundity and Longevity

Females lived for 7.3 ± 1.72 days and laid 149.6 ± 42.39 eggs when provided with a honey supplement. In contrast, females lived only 3.8 ± 0.68 days and laid 111.1 ± 47.18 days without the honey supplement. Males lived 10.6 ± 2.12 days with honey supplement and 4.5 ± 0.53 days without honey supplement. All differences are significant (t-test, $p<0.01$).

In a separate experiment, all females without mates laid eggs on the day of death and these eggs were infertile. Eggs from the mated females in the previous experiment were generally fertile although the level of fertility was not checked.

Most of the eggs were laid on day 3 of the experiment in both honey and no honey treatments (Table II). Without honey, all oviposition took place in a 3-day span whereas with honey, oviposition occurred during an 8-day span.

DISCUSSION

The rearing system described above is similar to that of Wilkinson and Daugherty (1970a). In their studies, *Bradysia impatiens* was reared on finely ground soybeans mixed in distilled water. A mixture of ground beans and distilled water proved too odoriferous for use in a laboratory environment, particularly when large numbers were being reared in vented containers. Other rearing methods for *B. coprophilia* used ingredients ranging from a sterilized manure/straw mixture inoculated with mushroom spawn (Thomas 1929) to sterilized, blended grass cuttings on agar slants (Kennedy 1973). Horticultural peat was chosen because it closely simulates the substrate used by fungus gnats in greenhouses. In addition, it and the beans are more readily available than the exotic ingredients.

Fig. 1 Development of *Corynoptera* sp. over time in a rearing mixture of peat and ground beans.

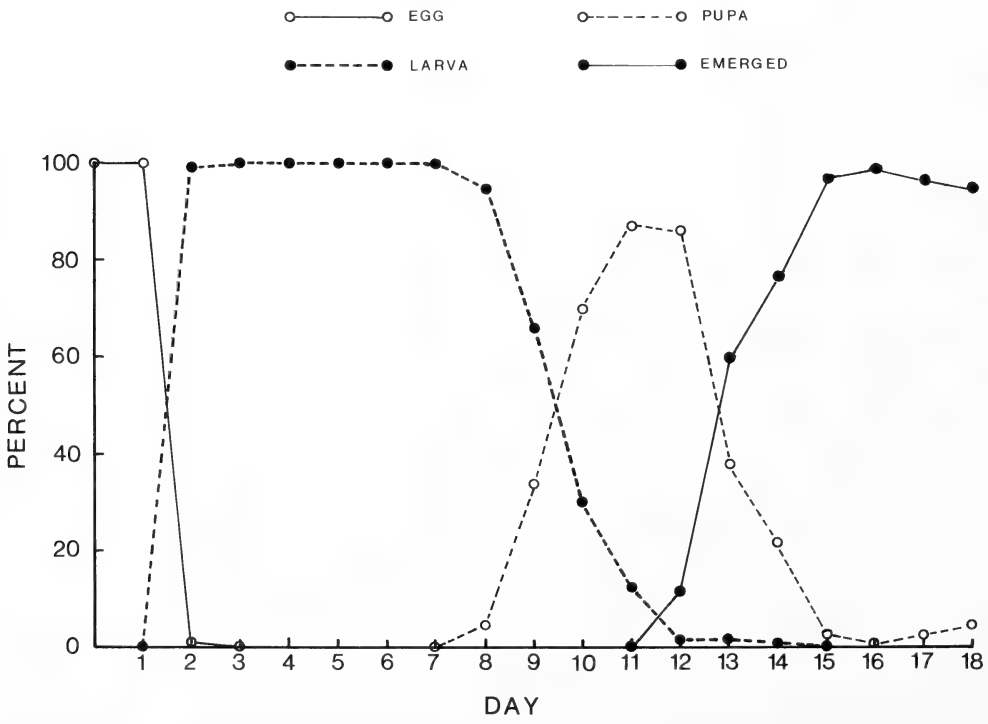

TABLE I. Cumulative percent emergence of *Corynoptera* sp. adult males and females from a rearing mixture of peat and ground beans.

Day	Males	Females
11	0	0
12	33.2	.2
13	71.0	55.5
14	93.7	92.5
15	97.9	95.8
16	98.9	98.4
17	99.8	99.4
18	100.0	100.0

TABLE II. Mean daily egg production (S.D.) of *Corynoptera* sp. females with and without honey supplement.

Day	With Honey N=14	Without Honey N=15
1	0	0
2	1.1 (4.01)	2.4 (6.51)
3	74.1 (63.18)	83.4 (57.28)
4	19.4 (28.10)	25.2 (46.36)
5	33.8 (57.65)	0
6	8.4 (19.08)	0
7	3.9 (8.70)	0
8	5.6 (7.88)	0
9	3.6 (13.63)	0
10	0	0
Grand X	149.6 (42.39)	111.1 (47.18)

The life cycle of *Corynoptera* sp. is considerably shorter under our conditions than that of *B. coprophilia* as described by Wilkinson and Daugherty (1970b). They found the optimum for that species to be approximately 20 days at 18.9-30.0°C as opposed to 13 days for *Corynoptera* sp. at 24 ± 2°C. The apparent increase in numbers of pupae after day 16 (Fig. 1) was probably spurious and due perhaps to waterlogging or disintegration of empty pupal cases.

Kennedy (1973) observed adults of *B. impatiens* apparently feeding on "ooze" from rearing cultures, although Wilkinson and Daugherty (1970a) did not observe feeding by adults of this species. I have many times observed fungus gnat females of undetermined species apparently feeding on honeydew deposits from *Trialeurodes vaporariorum* (Homoptera:Aleyrodidae). It appears from the feeding experiment that this behavior could increase the oviposition and lifespan of females, perhaps to the degree that in cases of whitefly outbreak, fungus gnat populations should be monitored carefully.

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REFERENCES

Dennis, D.J. 1978. Observations of fungus gnat damage to glasshouse curcubits. N.Z.J. Exp. Agric. 6: 83-84.

Fordyce, C., Jr. and W.W. Cantelo. 1981. Techniques to extract immature stages of *Lycoriella mali* from mushroom growing media. J. econ. Ent. 74: 253-254.

Kennedy, M.K. 1973. A culture method for *Bradysia impatiens* (Diptera:Sciaridae). Ann. Entomol. Soc. Am. 66: 1163-1164.

Lindquist, R.K., Faber, W.R., and Casey, M.L. 1985. Effect of various soiless root media and insecticides on fungus gnats. HortScience 20: 358-360.

Thomas, C.A. 1929. A method for rearing mushroom insects and mites. Entomol. News. 40: 222-225.

Wilkinson, J.D. and Daugherty, D.M. 1970a. The biology and immature stages of *Bradysia impatiens* (Diptera:Sciaridae). Ann. Entomol. Soc. Am. 63:656-660.

Wilkinson, J.D. and Daugherty, D.M. 1970b. Comparative development of *Bradysia impatiens* (Diptera:Sciaridae) under constant and variable temperatures. Ann. Entomol. Soc. Am. 63:1079-1083.

APPLE MAGGOT IN THE WESTERN UNITED STATES: A REVIEW OF ITS ESTABLISHMENT AND CURRENT APPROACHES TO MANAGEMENT[1]

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INTRODUCTION

The apple maggot, *Rhagoletis pomonella* (Walsh) has been a serious pest of apples in the eastern United States and Canada for over 100 years. (Dean and Chapman, 1973). It is native to the northeastern United States where it originally infested fruit of hawthorn, *Crataegus* spp. It has been found throughout the east coast from Quebec in the north to as far south as Florida and from the Altantic sea coast to parts of the Dakotas, Iowa, and eastern Texas, but not the western United States. In 1979, however, the apple maggot was reported for the first time from a backyard tree in Portland, Oregon (AliNiazee and Penrose, 1981).

Many tourists from the eastern U.S. and Canada visit the western U.S. every year. California quarantine inspection records indicate that apple maggot infested fruit has been occasionally intercepted at border stations for at least 30 years. These infested fruits had originated from many different parts of the United States. An examination of the Oregon Department of Agriculture (ODA) tephritid fly collection indicated that an apple maggot fly had been collected in 1951 at Rowena, near Hood River, Oregon, on a yellow sticky trap. The specimen had been identified as the snowberry maggot, *R. zephyria* Snow, by the ODA but has recently been re-identified as *R. pomonella* AliNiazee and Westcott, 1986). It is probable that the apple maggot has been accidentally introduced to the West many times during the past decades.

EARLY INTRODUCTION AND ESTABLISHMENT

The 1979 Portland infestation was found in a backyard apple tree of unknown variety. Infested fruit was brought to an extension agent's office and later identified as apple maggot based on adult taxonomic characters. Fruit from this site was heavily infested suggesting that the maggots had been present for a few years prior to initial detection. Conversation with the property owner failed to establish any connection with recent fruit movement from the midwest or eastern U.S.

A survey conducted in 1980 by the ODA to determine the apple maggot distribution in Oregon showed that the apple maggot was limited to the northern Willamette Valley and an isolated find in the Rogue River Valley near Phoenix, Oregon (AliNiazee and Penrose, 1981). A small number of traps placed in southwestern Washington indicated that apple maggot occurred in and around Vancouver, Washington. The unexpected wide distribution of apple maggot in 1980 suggested that it had been in Oregon for some time.

It is impossible to trace the spread of apple maggot throughout the west, but some inferences can be made from its present distribution. The discontinuous distribution initially observed in Oregon (AliNiazee and Penrose, 1981) in part reflects the discontinuous distribution of host material and low trap densities used in most surveys. Where host material is continuous, natural dispersal of apple maggot had undoubtedly occurred. However, natural dispersal seems limited to between a few yards and a few miles annually (Maxwell and Parsons 1968, Maxwell 1968, Phipps and Dirks 1933, Neilson 1971). Given this constraint, the discontinuity of host material in many areas of the West, and the present distribution pattern of apple maggot (Table 1), it is highly probably that much of the dissemination has resulted from the transport of infested fruit. This mode of dispersal has probably been the source of isolated infestations in areas like Spokane and along the Oregon coast.

Climatic conditions of the western United States differ substantially from those in the East and Midwest, and the apple maggot has had to adapt to these environmental constraints. A recently completed study indicates that environmental conditions of the Willamette Valley and Oregon coast only marginally satisfy the requirements for diapause development, and this prolongs emergence of adults over a long period (AliNiazee, unpublished date). Fifty percent of the pupae emerged during the first year, compared with over 80% during the first year in the eastern U.S. (Dean and Chapman, 1973).

Hot and dry summers are common to many parts of the western U.S. Relative humidities range from 15-50% during the daytime with little rainfall occurring during the months of July, August and September. The impact of these conditions on adult longevity, oviposition and hatch are not clearly understood. One of us (M.T. AliNiazee) observed that during hot, dry periods the flies were easily agitated and spent considerable time and energy in short flights. Such conditions would encourage rapid dispersal, as agitated flies would be more likely to fly to surrounding trees.

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[1]Scientific paper No. 7081, College of Agriculture Research Centre, Washington State University, Pullman, WA 99164. Oregon Agricultural Experiment Sta. Tech. Paper, No. 7976.

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TABLE 1. Current distribution of *R. pomonella* in the western United States.

States	Distribution	Hosts	References
California	Wide Northern California	Apple, Hawthorn	Joos et al. (1985)
Utah	Moderately wide Central and Northern Utah	Cherries, Hawthorn	Miller and Bianco (per. comm.) Jorgensen (per. comm.)
Idaho	Localized Southeastern Idaho	?	Westcott (per. comm.)
Colorado	Localized Western Colorado	Cherries	Stahl (per. comm.)
Washington	Wide Southwestern Washington (Isolated at Spokane)	Apples, Hawthorn	Brunner (unpb. data)
Oregon	Wide Willamette Valley, Southern Oregon (Isolated along the coast and Columbia River Gorge)	Apples, Hawthorn Plum, Prunes	AliNiazee and Westcott (1986)

CURRENT STATUS

At present the apple maggot distribution in the West includes most of the Willamette Valley of Oregon, part of southern Oregon, a six-county area of northern California, southwestern Washington, and parts of northcentral Utah. Scattered isolated populations also occur near Spokane, Washington (15 sq. miles), at a number of coastal locations in Oregon and California, along the Columbia River Gorge, in southern Idaho and near Grand Junction, Colorado (Table 1).

Oregon – Apple maggot surveys have been continued since 1980 by the ODA to determine its distribution in the state. By 1984 the apple maggot had been recorded in almost all western Oregon counties (Westcott, personal communication). It was not, however, uniformly distributed throughout its range in western Oregon. Although the Willamette Valley seemed to be generally infested, there was an allopatric distribution along the coast, confined mostly to urban areas.

In Oregon the two areas of major concern were the Hood River and Rogue River valleys. The former is the major apple growing area and the latter the major pear growing area of the state. Surveys of 1980 indicated the presence of apple maggot in Cascade Locks, about 32 km west of Hood River (AliNiazee and Penrose, 1981) and at Phoenix in southern Oregon. Attempts were made to eradicate these infestations by weekly spray applications of phosmet. Surveys in 1981 and 1982 indicated that the apple maggot had been eradicated from both these sites; however, other sites in the same general area have since been found to be infested. Recent trap data showed that flies are now present at both these sites. For the first time in 1984 the flies were trapped in the commercial apple orchards of the Willamette Valley.

In Hood River Valley apple maggot infestations are localized. The intensive spraying of commercial apple orchards, the small number of unsprayed apple trees and low probability of movement into the area by either natural or human means may account for this condition. In southern Oregon, however, the apple maggot is widely distributed. A relative abundance of unsprayed apple trees increases the potential for successful establishment in this area. In addition, the volume of people moving along the principal north-south route through southern Oregon increases the probability of apple maggot being spread by human transport of infested fruit.

Washington – The Washington infestation of apple maggot is perhaps as old as that of Oregon. Vancouver (Clark County) directly across the Columbia River from Portland, was found to be infested in 1980 (AliNiazee and Penrose, 1981). Surveys conducted in 1981 by the Washington State Department of Agriculture (WSDA) found the apple maggot throughout southwestern Washington and into Skamania County at Stevenson. In 1982, an expanded survey by WSDA detected apple maggots at additional locations along the Columbia River Gorge and near Spokane, WA. During 1983 and 1984, catches in increased trap densities indicated the apple maggot distribution was larger than had been previously assumed.

The infestations near White Salmon and Spokane are of greatest concern to Washington since they occur near commercial fruit growing areas. Efforts to eradicate localized populations at these two locations, using a combination of host removal and insecticide applications, are continuing. In 1984 apple maggot flies were trapped for the first time in commercial apple orchards in southern Washington. Preventive spray programs were implemented in response to the detections and no infested fruits were found. Apple maggot detections north of Vancouver suggest that there is a slow rate of natural spread.

California – The California Department of Food and Agriculture (CDFA), concerned about Oregon's apple maggot infestation, increased their monitoring program in northern California counties bordering Oregon in 1981 using Pherocon® Am traps at a density of 0.8/km^2 in urban high hazard areas. No flies were trapped during 1981 and 1982.

On August 24, 1983, one apple maggot adult was trapped near Smith River, Del Norte County, California. Flies subsequently were found in a number of northern California counties. The surveys indicated a widespread, low density infestation on apple and hawthorn at several locations along the Klamath River as well as the north coastal area near the Oregon border. A total of 103 adult flies and 38 larval-infested sites were found in 1983 (Joos *et al.* 1984). In 1984 the apple maggot was detected in three additional counties. The movement of fruit *via* back roads is common in this general area and probably facilitated the spread of apple maggot.

Utah – Apple maggots were first collected in Utah in 1976 from Malaise traps near Willard Basin of Box Elder Co. (Jorgensen *et al.* 1986). However, no flies or fruit infestations were later reported from the state. In 1983, adult flies were detected in traps maintained as part of a cherry fruit fly monitoring program. Flies were detected on July 6, 1983, in Utah County near Mapleton (Miller, personal communication). After flies were detected in the Mapleton area, trap density was increased from 3.8 to 10/km^2, and over 200 flies were trapped in the Mapleton area during 1983. Apple maggot flies also were detected in Cache and Davis Counties, but no flies were detected in other areas, despite heavy trapping (Miller, personal communication).

Jorgensen (personal communication) reported that apple maggots had been reared from infested sweet and sour cherries during 1984 but had not as yet been reared from apple. Jorgensen *et al.* (1986) later reported rearing flies from infested fruit of native hawthorn, *Crataegus douglasii*.

Colorado – Four specimens of apple maggots were detected near Palisade in a sweet cherry orchard during 1985 (F. Stahl, personal communication). Although the distribution of the apple maggot in the state is not well documented, these findings are of concern to the major tree fruit growing areas near Grand Junction, Colorado.

FUTURE OUTLOOK

Based on the distribution pattern discussed above, it appears that the apple maggot is now well established in the western United States. It is very difficult to precisely determine the date of introduction and establishment. Based on its current distribution and the one fly caught in 1951 from Rowena, Oregon, it appears that apple maggot probably has been in Oregon for at least 30-40 years. A changing trend in the emergence rates and a shift of opiine parasitoids from *R. zephyria* to *R. Pomonella* (AliNiazee 1985a) also suggests the presence of apple maggot in the western U.S. for many years. Further spread of this pest in the West will depend on a number of factors including the movement of infested fruit and quarantine restrictions placed on fruit shipments from infested areas. Unrestricted movement of infested fruit greatly increases the possibility of rapid spread. The occurrence of the pest in many different environments of the West indicates that it is capable of surviving in most areas where commercial apples are produced. Its widespread infestation of cherries (Jorgensen, personal communication) suggests development of new host races in the West. Major efforts are currently underway in Washington, Oregon and California to restrict the movement of the apple maggot and protect the major apple producing areas.

MANAGEMENT APPROACHES

Eradication – The eradication of apple maggot from the entire western U.S. seems impractical if not impossible. It may be too late to attempt even area-wide eradication on a statewide basis. For example, in western Oregon and Washington infestations are widespread and largely confined to hawthorn and abandoned apple trees. These apple maggot hosts are abundant, with many infested sites being inaccessible.

In northern California along the Klamath River and coastal areas, complete eradication will be difficult. Localized eradication seems feasible and may be a viable option, particularly if the infestations are near major apple growing areas. Localized infestations near Hood River and Cascade Locks were thought to be eradicated two years ago, but flies were detected again in 1984. In Washington, successful local eradication was thought to have been achieved within the town of Klickitat, but apple maggot was detected again in 1984. It is encouraging that apple maggot populations in areas where local eradication is being attempted have steadily declined. Total eradication of the apple maggot is probably only feasible where geographic barriers isolate local populations from more generally infested areas.

Containment – Containment of apple maggot populations in a given area by creating insecticide treated and/or host-free buffer zones is an attractive idea. However, the practical feasibility of such an approach is difficult to evaluate. Although a half-mile flight range has been suggested for the apple maggot (Dean and Chapman, 1973), it is possible that under certain conditions flies may travel longer distances, thus complicating containment programs. A prerequisite to any containment effort would be the determination of fly distribution in a given area. Such distribution maps are not currently available for all infested areas in the West. Delimiting surveys are being conducted in California and parts of Oregon, Washington and Utah. The most likely means of apple maggot dispersal will be by transport of infested fruit. The imposition of strict quarantines, primarily on non-commercial fruit, will be critical to the success of containment programs. Survey programs should be implemented in areas of the western U.S. where apple maggot has not yet been detected.

Management – Apple growers in generally infested areas, such as the Willamette Valley of Oregon, must learn to live with the apple maggot. Fortunately, apple maggot control is easily accomplished through application of a number of insecticides (Hoyt *et al.* 1982). The biology of the apple maggot (number of generations, damage, etc.) in the western United States is similar to that described by several authors in the eastern United States. However, distinct phenological differences exist between the eastern and the western population. In Oregon and Washington the apple maggot begins emerging in early July. Peak emergence occurs in late August or early September (AliNiazee and Wescott 1986, Tracewski *et al.* 1985). Flies are found as late as November, and larvae have been found in late December. During some years, larvae might be able to survive the entire winter in more moderate areas. Sprays applied for control of codling moth, *Cydia pomonella* L., will provide partial control of the apple maggot. However, complete dependence on these sprays will not provide adequate protection (AliNiazee 1986), and one or two additional sprays will be required for commercially acceptable control.

Naturally occurring biological control could play an important role in management of apple maggot in Oregon. Two opiine parasitoids, *Opius downesi* Gahan and *O. lectoides* Gahan have shifted from the showberry maggot to the apple maggot population in hawthorn and have caused reductions in pest density at two study sites in Oregon (AliNiazee 1985). The life cycle of these parasitoids is well synchronized with that of the apple maggot. More detailed studies are needed, however, to determine the potential of these and other natural enemies under commercial orchard conditions. Studies on apple maggot trapping, sampling and monitoring are also needed.

ACKNOWLEDGEMENTS

Sincere thanks are expressed to Drs. R.L. Westcott, Timothy Miller, Edward Bianco, Clive Jorgensen, Donald Davis, John Joos, Robert Dowell, Stan Hoyt and Peter Westigard for their assistance in the preparation of this manuscript.

REFERENCES

AliNiazee, M.T. 1985. Opiine (Hymenoptera:Braconidae) parasitoids of *Rhagoletis pomonella* and *R. zephyria* (Diptera:Tephritidae) in the Willamette Valley, Oregon, Can. Entomol. 117: 163-166.

AliNiazee, M.T. 1986. Managing the apple maggot, *Rhagoletis pomonella* in the Pacific Northwest: An evaluation of possible options. Proc. 10 BC/WPRS Symp. on "Fruit Flies of Economic Importance." Hamburg, West Germany, 1984. Pp. 175-182.

AliNiazee, M.T. and R.L. Penrose. 1981. Apple maggot in Oregon: A possible threat to the Northwest apple industry. Bull. Entomol. Soc. Amer. 27:245-246.

AliNiazee, M.T. and R.L. Westcott. 1986. Distribution of the apple maggot, *Rhagoletis pomonella* in Oregon. J. Ent. Soc. Brit. Columbia. 83:52.

Dean, R.W. and P.J. Chapman. 1973. Bionomics of the apple maggot in eastern New York. Search Agriculture 3:1-64.

Hoyt, S.C., J.R. Leeper, G.C. Brown, and B.A. Croft. 1982. Basic biology and management components for insect IPM. pp. 93-152. *In:* B.A. Croft and S.C. Hoyt (ed.). Integrated Management of Insect Pests of Pome and Stone Fruits. John Wiley and Sons, New York.

Joos, J.L., W.W. Allen and R.A. VanSteenwyk. 1984. Apple maggot: A threat to California's apple industry. Calif. Agric. 38:9-11.

Jorgensen, C.D., D.B. Allred, and R.L. Westcott. 1986. Apple maggot *(Rhagoletis pomonella)* adaptation for cherries in Utah. Great Basin Natur. (in press).

Maxwell, C.W. 1968. Apple maggot adult dispersion in a New Brunswick apple orchard. J. Econ. Entomol. 61:103-106.

Maxwell, W.T.A. 1971. Dispersal studies of a natural population of apple maggot adults. J.Econ. Entomol. 64:648-653.

Phipps, C.R. and C.O. Dirks. 1933. Dispersal of apple maggot. J. Econ. Entomol. 25:576-582.

Tracewski, K.T., J.F. Brunner, S.C. Hoyt and S.R. Dewey. 1985. Occurrence and development of *Rhagoletis pomonella* (Walsh) in hawthorns in the Pacific Northwest. J. Econ. Entomol. Submitted.

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DISTRIBUTION OF THE APPLE MAGGOT, *RHAGOLETIS POMONELLA* (DIPTERA:TEPHRITIDAE)IN OREGON

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ABSTRACT

Data from a four-year (1981-1984) distributional study suggest that, in Oregon, the apple maggot *Rhagoletis pomonella* (Walsh) is established in the interior valleys (especially the Willamette Valley) along the Columbia River Gorge and at isolated locations along the Oregon coast. An analysis of the general distribution pattern and some earlier records suggests that the apple maggot may have been in Oregon for nearly four decades.

INTRODUCTION

After the chance discovery of the apple maggot *Rhagoletis pomonella* (Walsh) (Diptera:Tephritidae) near Portland, Oregon in 1979, a number of questions arose regarding the distribution and pest status of this insect in the Pacific Northwest. It was obvious that the entire western apple growing area, from British Columbia to California, was threatened by this maggot find. An initial survey to delimit the distribution was started by the Oregon Department of Agriculture (ODA) in 1980 and the results of early surveys were discussed by AliNiazee and Penrose (1981), and Westcott (1982). A review of the apple maggot situation in the western United States was presented by AliNiazee and Brunner (1986). Reported here is the current distribution of the apple maggot in Oregon.

METHODS

The distribution studies were conducted by employing Zoecon's Pherocon® AM standard traps and periodic inspection of host fruit for larval finds. During 1980, trapping studies were mostly confined to a small area in Portland, but eventually expanded to other areas, especially in the northern Willamette Valley.

During 1981 an urban grid system was employed in and around larger inland towns and the coastal cities of Astoria, Coos Bay and Brookings, providing a maximum density of 4 traps/mi^2. Transects were run in the Willamette Valley along portions of Interstate 5 and highways to the west, from Wilsonville south to Eugene; along I-5 from Eugene to Grants Pass; and along the coast, all at a rate of 1 trap/mi^2. However, in practice this rate was greatly reduced in some areas due to lack of hosts. In southwestern Oregon, from Grants Pass southward, the rate was increased to 2/mi^2. In eastern Oregon, major cities in Klamath, Malheur, Umatilla, Union and Wasco counties were trapped using the urban grid system. Approximately 70 traps were placed in native hawthorns, *Crataegus* spp., from Wasco county to Umatilla and Baker counties, to test the hypothesis that a hawthorn race of apple maggot might be native to the state.

During 1982 the grid trap density was increased to 10 traps/mi^2. Western Oregon areas chosen for trapping included previously untrapped or scantily trapped localities in the vicinity of I-5, from Eugene southward, and in Coos and Curry counties. In eastern Oregon, the trapping studies were conducted for the first time in the major cities of Crook, Deschutes, Grant and Jefferson counties, and again in Malheur, Union, Umatilla, and Wasco counties.

In 1983 efforts were largely confined to areas where the presence of apple maggot is of concern to commercial production of apples. In 1984 a similar trapping program was continued. The rediscovery of apply maggots in Hood River and the first detection near The Dalles, Oregon, effected an increase in trap density in these general areas.

RESULTS AND DISCUSSION

Fig. 1 shows the current distribution of the apple maggot in Oregon. Although different symbols are used for each year, the progression of detections should not be interpreted to reflect the dispersal rate of *R. pomonella*, either natural or artificial. Rather, it is a reflection of changing trapping patterns and density. Nevertheless, these data suggest that apple maggot is now well established throughout the interior valleys of western Oregon and parts of southern Oregon. It is also found in the Columbia River Gorge and, disjunctly, along the coast; the latter strongly suggesting fly dispersal by movement of infested fruit.

Although apple maggot has been recorded from Oregon only since 1979, its widespread and sometimes abundant occurrence in western Oregon and some adjacent areas in Washington suggests an earlier time of establishment. Distributional studies conducted during 1980 and 1981, even, provided a clear picture of this, when a high percentage of positive trapped sites and observed fly abundance in the northernmost Willamette Valley (partic-

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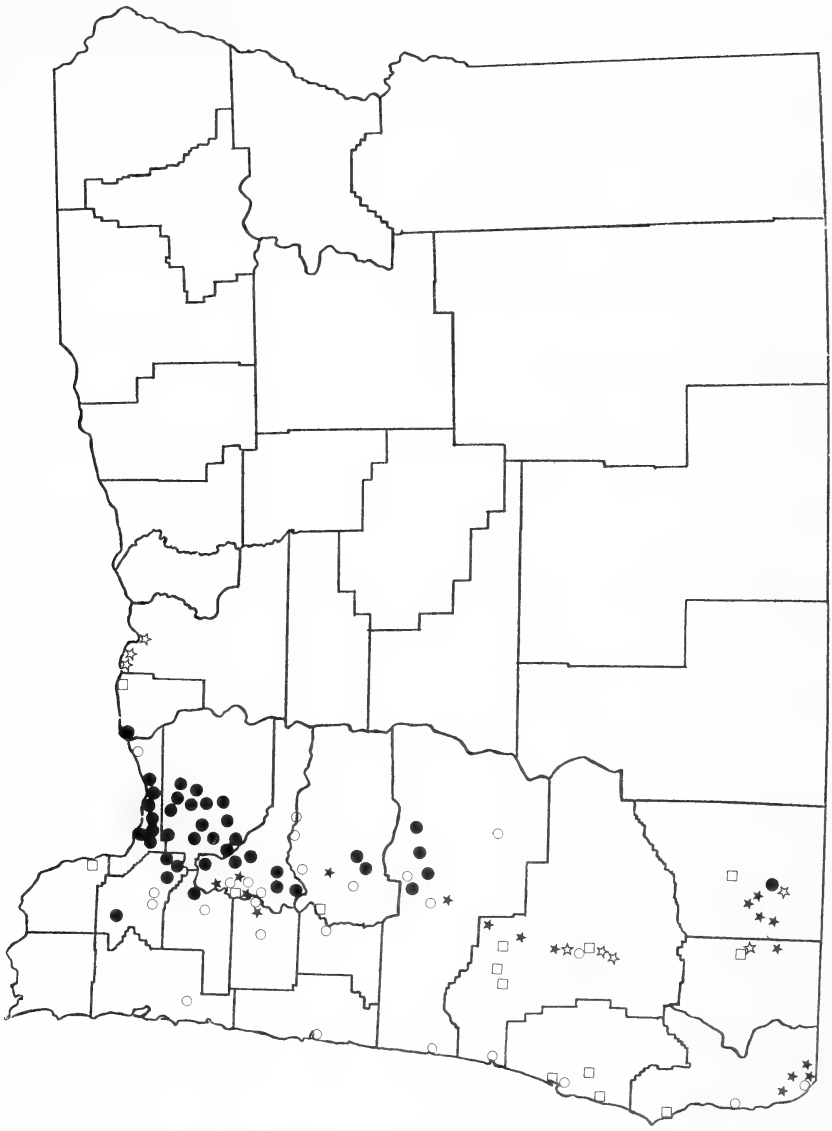

Fig. 1. Present distribution of apple maggot in Oregon. Solid circles, 1980; rectangles, 1981; hollow circles, 1982; solid stars, 1983; hollow stars, 1984.

ularly the greater Portland area) strongly suggested this region as the point of origin. Given the large human population in this region and the ease with which infested apples may be transported *via* the automobile, this fly population does not necessarily stem from one source.

It is difficult to ascertain how long the apple maggot has been in Oregon. A close examination of Oregon Department of Agriculture (ODA) records shows that in September 1947, a California border quarantine station intercepted some apples, allegedly from a backyard tree in Portland, which were claimed to be infested with apple maggot. Shortly thereafter, all remaining apples from the alleged site were inspected and no evidence of apple maggot was found. During 1948 ODA personnel placed traps in the suspected host and in apple trees on 33 nearby properties (40 traps total). Two flies identified as *R. pomonella*, apparently by Alan Stone, were recorded. However, Stone considered the snowberry maggot, *R. zephyria* Snow to be a synonym of *R. pomonella*, and a snowberry bush infested with *R. zephyria* was found across the street from a site where one of the flies was captured. The specimens in question cannot be located.

From an area "approximately 1/2 mile x 1 mile" around the suspect host from 1947, 1174 apples were examined.

All were negative except one report as follows: "One apple contained tunnels that might have been made by apple maggots. No maggots found. No evidence of codling moth at the core." In our opinion this report, although submitted as "definitely negative in regard to finding of apple maggots" does not completely rule out the presence of apple maggots at this site in southeast Portland. Indeed, this report coupled with the fact that this area is currently heavily infested with apple maggot, and given the difficulty of detection of an incipient infestation even with methods available today, would seem to raise more questions.

Another important fact relates to a specimen in the ODA collection which had been misidentified as *R. zephyria*. This specimen was collected on a yellow sticky board trap in 1951 near Rowena, in the Columbia River Gorge area of Wasco county, and has been determined by one of us (R.L.W.) to be *R. pomonella* (with an ovipositor length of 1.15 mm). In our study, apple maggot was first detected in this area during 1984, the fourth year of sampling.

The widespread distribution of *R. pomonella* in Oregon (Fig. 1), the earlier record as discussed above, and the abundance and excellent host/parasitoid synchrony of opiine parasitoids (AliNiazee 1985) which probably shifted over to *R. pomonella* from *R. zephyria*, suggest that apple maggot has been in Oregon for many years.

REFERENCES CITED

AliNiazee, M.T. 1985. Opiine parasitoids (Hymenoptera:Braconidae) of *Rhagoletis pomonella* and *R. zephyria* (Diptera:Tephritidae) in the Willamette Valley, Oregon. Can. Entomol. 117: 163-166.

AliNiazee, M.T. and R.L. Penrose. 1981. Apple Maggot in Oregon: a possible new threat to the Northwest apple industry. Bull. Entomol. Soc. Amer. 27: 245-246.

AliNiaze, M.T. and J.F. Brunner. 1986. Apple maggot in the western United States: a review of its establishment and current approaches to management. J. Ent. Soc. Brit. Columbia. 83: 49.

Westcott, R.L. 1982. Differentiating adults of apple maggot, *Rhagoletis pomonella* (Walsh) from snowberry maggot, *R. zephyria* Snow (Diptera:Tephritidae) in Oregon. Pan Pacific Entomol. 58: 25-30.

MORPHOLOGY OF *MYRMECOPHILA MANNI*, A MYRMECOPHILOUS CRICKET (ORTHOPTERA:GRYLLIDAE)[1]

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ABSTRACT

Scanning electron microscopy showed that the myrmecophilous cricket, *Myrmecophila manni* Schimmer, retains many structural features common to typical gryllids and has few of the morphological features often associated with myrmecophily. However, the mouth parts, particularly the labrum and epipharynx, are highly modified for strigilation and trophallaxis. The structure of the ovipositor is unique in that it can expand greatly to permit the passage of large eggs. This cricket also differs from typical gryllids in having stemmata instead of compound eyes, a feature probably related to its life inside dark ant nests where it does not need good vision. Behavioral, rather than morphological, attributes are probably more important in adapting the crickets for life with ants.

INTRODUCTION

Four species of *Myrmecophila* Latreille, small (2.3-4.0 mm), apterous crickets, are found in North America (Hebard 1920). *Myrmecophila* are the only myrmecophilous crickets known. Inquilines, especially myrmecophiles, often share a number of characteristics that enable them to live in the hostile but energy-rich environment of the ant nest. Often these adaptations include a myrmecoid body shape, a hard cuticle, reduction of certain appendages, and the use of glandular secretions appeasing to the ants. The degree of morphological change in myrmecophiles is probably directly related to the degree with which they have integrated into the colony (Wilson 1971). *Myrmecophila manni* Schimmer retains many of the structural features commonly found in the family Gryllidae and does not possess many of the adaptations often associated with myrmecophily.

The purpose of this study was to examine the morphological features of *M. manni* and to relate these finding to the crickets' relationship with their ant hosts.

MATERIAL AND METHODS

Eight *M. manni* were examined by scanning electron microscopy (SEM). Live specimens were fixed in 2% osmium tetroxide (OsO_4) for 1 h, and then 3% glutaraldehyde for 2 h at 4°C. Standard procedures for SEM preparation followed using an Omar SPC 1500 critical point dryer, Hummer V gold coater and EPTEC SEM, equipped with 55 P/N film. Field and laboratory observation of *M. manni* behavior were made to support interpretations of the functional morphology revealed by SEM.

[1]Scientific Paper Number 7085, Washington State University, College of Agriculture and Home Economics Research Center, Pullman. Work conducted under project 0037.

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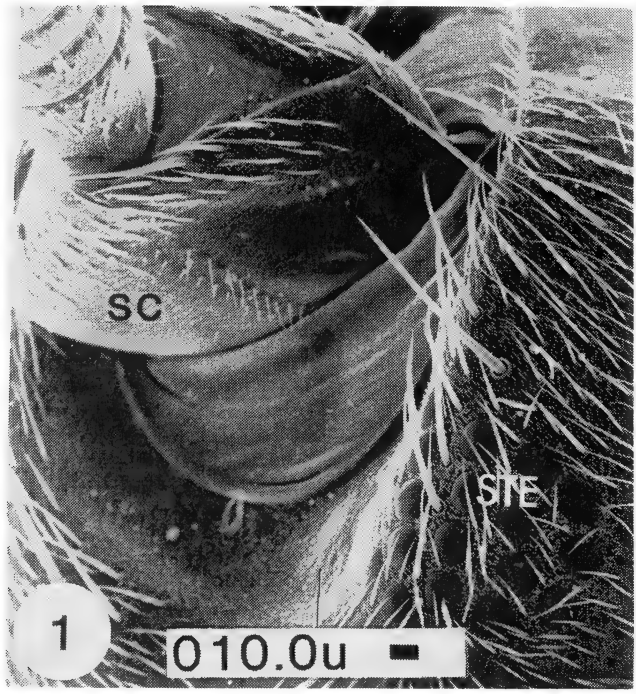
RESULTS AND DISCUSSION

Sensory Apparatus

The SEM showed that *M. manni* has morphological features commonly found in the family Gryllidae. However, some pecularities of *M. manni* may be adaptations to myrmecophily. The antennae of *M. manni* are as long as the body and have a proportionately large scape. The row of hairs along the scape may help the cricket detect the source of a stimulus (Fig. 1). That is, when crickets are in a fixed position it can be demonstrated that they will follow a visual object with their antennae. The hairs on the scapes signal the angle the antennae are deflected, helping pinpoint the stimulus. The sensilla of the antennae occur in a repetitive fashion along the 44 + segments. Numerous filiform hairs cover the entire surface of the antennae and probably perceive sound or respond to air displacement vibrations (Haskell 1960) (Fig. 2). Coelomic pegs, considered to serve a chemosensory function, occur at the rate of about 1 per segment.

The cerci, like the antennae, are large in *M. manni* (Fig 2). They are usually held away from the body giving the cricket a larger surface area for perception. Their entire surface is covered with various-sized trichoid sensilla. The thinner hairs, which are also the longest, are bent by the slightest breeze. Cercal hairs of grasshoppers respond to sound frequencies of 30-1000 Hz and can be stimulated by air moving at 4 cm/sec (Haskell, 1961).

Reduction of appendages is common for myrmecophiles. However, *M. manni* retains its elaborate sensing structures, suggesting a beneficial function in the ant-cricket relationship. Behavioral studies show that *Myrmecophila* are often attacked by the host (Wheeler 1900, Henderson 1985). However, rarely is a cricket caught off guard and captured by an ant. The antennae and cerci probably warn the cricket of approaching ants. The cricket also uses its antennae to mimic the conspecific antennation used by ants preceeding mutual grooming



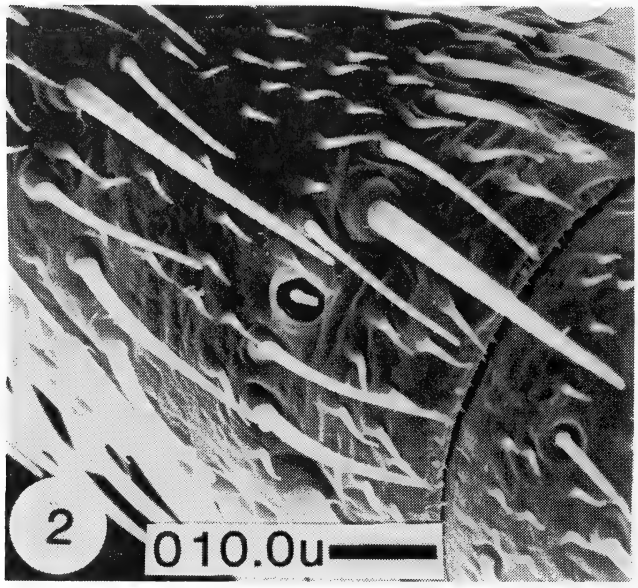
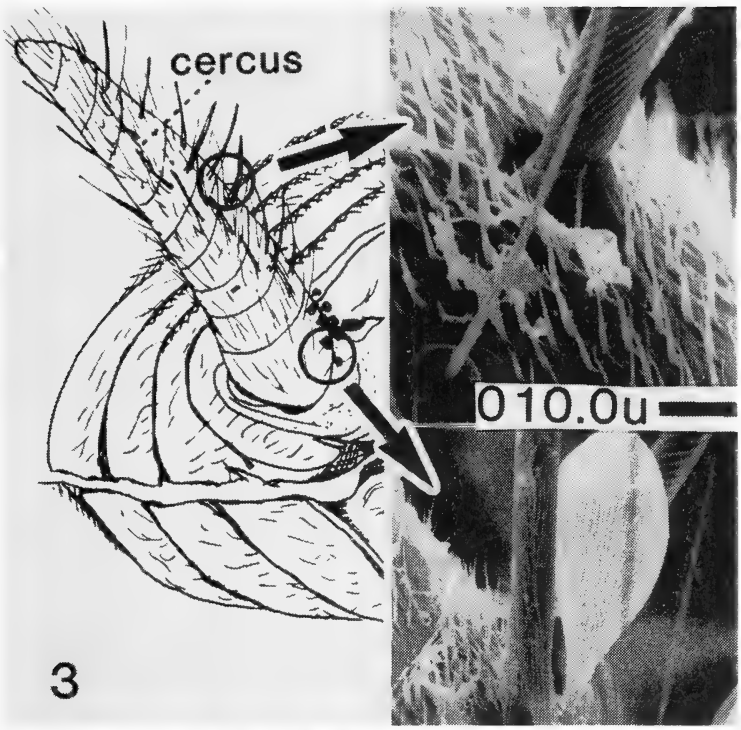


Fig. 1. Highly magnified SEM showing scape (sc) of the antenna and stemmata (ste). Note the row of hairs along the scape.

Fig. 2. Typical arrangement of sensory hairs that are found on each of the 44 + segments of the antennae. The hair in the centre is a coelomic peg, and its chemosensory function is well documented. The trichoid hairs surrounding the peg are mostly tactile sensing hairs.



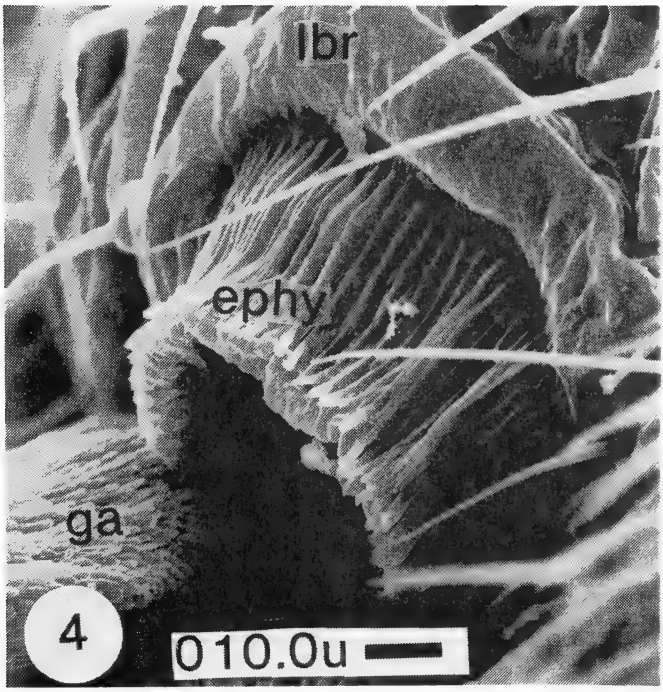
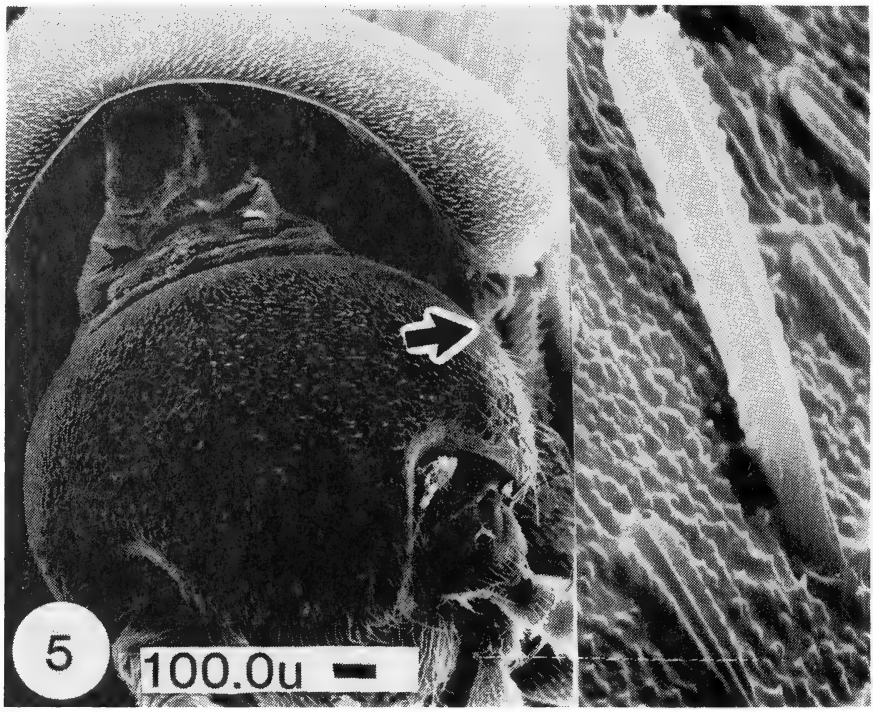


Fig. 3. Diagram showing the orientation of the cercus to the rest of the body. Two major types of hairs are located here. The top insert shows filamentous hairs that detect sound or vibration. These hairs are located over most of the cercal surface. The second type of hair, located only along the first two basal segments, are balloon hairs which help the insect orient to gravity (Bishof 1974).

Fig. 4. The feeding mechanism of *M. manni* is modified to increase the efficiency of its feeding habits. Labrum (lbr), Ephipharynx (ephy), Galea (ga).



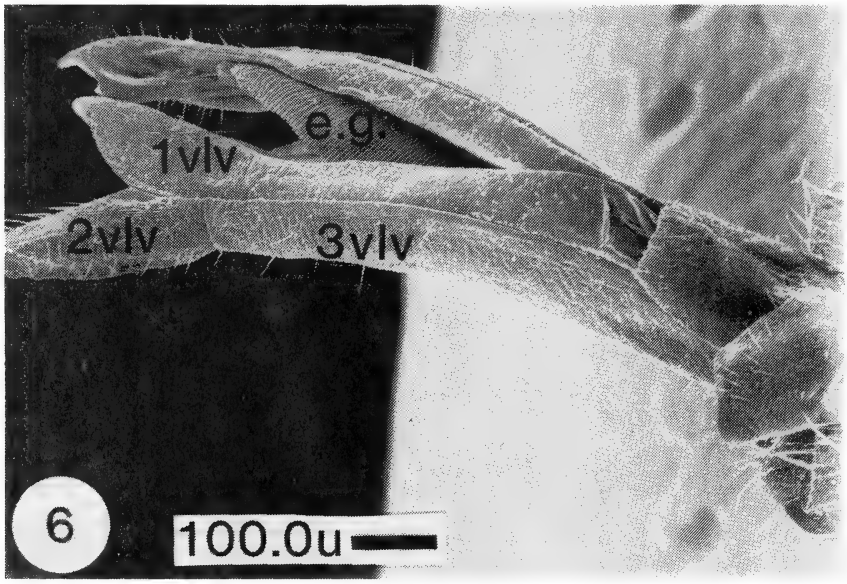


Fig. 5. SEM shows the top of the head, cervix, and pronotum of *M. manni*. The arrow points to a single hair scale, its serrated nature is shown, greatly enlarged, to the right.

Fig. 6. SEM reveals the expanding nature of the ovipositor of *M. manni*. This allows for oviposition of large eggs. The first valvulae (1 vlv) can spread apart and the spiraled egg guide (e.g.) can unspiral, increasing the total surface area. The third valvulae (3 vlv) are fused and wrap around the sclerotized tips of the second valvulae (2 vlv).

and trophallaxis. The length of the antennae aids the cricket in mimicking these signals which allows the cricket, in a sense, to parasitize its host. In addition, observations show that *M. manni* uses its antennae and cerci in elaborate displays during mating and intraspecific aggression (Henderson 1985). Cercal shaking has also been observed in field crickets and may aid in directing the female into proper position for copulation (Alexander 1961).

The eyes of *M. manni* are not compound, as in most crickets, but are composed of 18 to 20 stemmata located above each antenna. Visual perception for this type of eye is believed to be of a coarse mosaic that can only differentiate shapes and sharply contrasting images (Dethier 1943, Meyer Rochow 1974). Morphological regression of the eyes is associated with myrmecophily (Wilson 1971), and although stemmata are not a regressed form of compound eye, the end result is much the same. Fine visual acuity is probably not necessary since the crickets spend most of their lives inside a dark nest.

Locomotory Apparatus

M. manni are both saltatorial and cursorial, thus they retain the jumping and running abilities typical of Gryllidae. With *M. manni* retaining sensilla to allow for perception of approaching ants, it follows that they should retain their speed and jumping ability to allow for escape. Wheeler (1900) believed that the complicated zig-zag path of *Myrmecophila* was the major factor in allowing them to live with ants. Observations in the laboratory revealed that *M. manni* also retains the ability to lose a hind leg if seized by an ant. Steiner (1968) was the first to recognize this adaptation in field crickets as well as some grasshoppers as a possible means of escape. *M. manni* appeared to function normally with a leg missing and lived as long as intact *Myrmecophila* (Henderson 1985).

Feeding Apparatus

The mouth parts of *M. manni* are of the general orthopteran type with a large number of chemosensory sensilla on the tips of the labial and maxillary palpi. However, SEM revealed that the epipharynx and labrum are modified in *M. manni*. The labrum is reduced and the epipharynx protrudes from beneath it in finger-like projections, fused proximally and slightly separate distally (Fig. 4). Epipharyngeal projections of this type are sometimes found in aquatic insects (Haliplidae, Coleoptera, pers. observ.) and are probably used for scraping food loose from various substrates.

M. manni strigilate ants and engage them in trophallaxis. The brush-like epipharynx appears to be a adaptation for taking this food.

The protruding epipharynx increases the surface area that comes in contact with the ball of liquid regurgitated by the ant. The surface tension of the liquid is easily broken and adheres to the mouth parts of the cricket. Also, the mandibles are recessed behind the labrum, and when the cricket scrapes the integument of the ant the epipharynx may act as a scoop. The galeae, used to pull food into the mandibular area, have a reticulated surface and are positioned to sweep any particles scraped by the mandibles into the epipharynx. Highly modified mouth parts also occur among those inquilines which are well integrated into ant colonies (e.g., Pselaphidae, Akre and Hill 1973).

Odor Camouflage

M. manni are attacked by ants, but they are also found at the very heart of the ant nest, the brood chamber (Henderson 1985). One means by which the cricket attains entrance into the chamber is through behavioral mimicry. Odor camouflage may be another means. *M. manni* are covered with serrated scales on the dorsum of the head, thorax, and abdomen that may be used to acquire odors (Figs. 5). Acquisition of the nest odor by myrmecophiles through mechanical means is common. Host odors are transferred by histerid beetles associated with army ants by rubbing their tibial brushes on the ants (Rettenmeyer 1961, Akre 1968). The myrmecophilous beetle *Myrmecaphodius excavaticollis* (Blanchard) (Scarabaeidae) has recently been found to acquire species-specific hydrocarbons from its host by contact, by grooming behavior, and by ingestion of regurgitated ant postpharyngeal gland contents (Vander Meer and Wojick 1982). The serrated scales on *M. manni* might scrape particles off the walls and galleries of the ant nest during the cricket's travels. Wheeler (1900) reported that the walls and galleries of ant nests are covered with cuticular lipids deposited by the constant travel of the ants. Although attacks by ants on their cricket guests suggest that host hydrocarbon acquisition is not fully effective, acquisition of even a small amount of host hydrocarbons may help in the cricket's commensal existence.

Reproductive Morphology

Schimmer (1909) found that the ovipositor of *Myrmecophila* has unique articulation as a result of elongation and fusion of the eighth and ninth terga plurally. Gorokhov (1980) suggested that the column gave the ovipositor the ability to extend and retract; a necessary ability since the insect oviposits eggs nearly one-third as long as its body. SEM showed that the membranous egg guide is spiraled (Fig 6). The spiraling permits expansion of the egg guide, and we suggest that this also is an adaptation for laying proportionately large eggs. As the egg travels down the egg guide the spiral opens up giving the egg the area it needs while still providing a smooth pathway.

Summary

M. manni is morphologically well equipped for myrmecophily. The antennae and cerci are densely clothed with sensory hairs that quickly detect approaching ants. This early warning system, coupled with the propensity of the crickets to run in zig-zag patterns and to jump when escape by running is impossible, ensures that few crickets are caught by ants. In addition, the large hind legs readily detach when they are seized by attacking ants, and crickets lacking one hind leg are apparently able to continue to function normally. These slight morphological modifica-

tions, coupled with appropriate behavior, permit these crickets to integrate into the colonies of their host ants without much difficulty. Also important is their small size (2.3 to 4.0 mm) which makes them difficult to catch even with a determined attack by an ant.

Well integrated myrmecophiles frequently have greatly modified mouth parts to take advantage of food within the ant colony, and these crickets are no exception. Their brush-type epipharynx probably helps sweep food into the buccal cavity when the cricket is strigilating an ant. During trophallaxis the large and irregular surface of the epipharynx may aid in the transfer of the regurgitated liquid. Much more importantly, it appears that the mimicking of recognition signals of the ants enables the cricket to tap a nearly unlimited resource, the contents of the crops of foraging workers.

These small crickets have used a minimum of morphological adaptations and a maximum of behavioral modifications to integrate themselves into colonies of their host ants. The number of crickets in these colonies (one nest harbored over 300 crickets) suggests that they are at least as successful as myrmecoid inquilines.

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REFERENCES CITED

Akre, R.D. 1968. The behavior of *Euxenister* and *Pulvinister*, histerid beetles associated with army ants (Formicidae: Ecitonini). Pan-Pac Ent. 44: 87-101

Akre, R.D., and Wm. B. Hill. 1973. Behavior of *Adranes taylori*, a myrmecophilous beetle associated with *Lasius sitkaensis* in the Pacific Northwest. (Coleoptera: Pselaphidae; Hymenoptera, Formicidae). J. Kansas Ent. Soc. 46: 526-536.

Alexander, R.D. 1961. Aggressiveness, territoriality and sexual behavior in field crickets (Orthoptera: Gryllidae). Behaviour 17: 130-225.

Bishof, H.F. 1974. The club-shaped sensilla on the cerci of *Gryllus bimaculatus* as gravity receptors (Orth., Gryllidae). J.Comp. Physiol. 98: 277-288.

Dethier, V.G. 1943. The dioptric apparatus of lateral ocelli. II. Visual capacities of the ocellus. J. Cell. Comp. Physiol. 22: 115-126.

Gorokhov, A.V. 1982. Morphological peculiarities of crickets of the genera *Myrmecophilus* Berth. and *Eremogryllodes* Chop. and systematic position of the tribe Bothriopylacini (Orthoptera, Gryllidae). Entomol. Obozr. 59: 287-293.

Haskell, P.T. 1960. The sensory equipment of the migratory locust. Symp. Zool. Soc. Lond. 3: 1-23.

Haskell, P.T. 1961. Insects sounds. H.F. and G. Witherby: London. 189 pp.

Hebard, M. 1920. A revision of North American species of the genus *Myrmecophila* (Orthoptera; Gryllidae; Myrmecophilinae). Trans. Am. Entomol. Soc. 49: 91-111.

Henderson, G. 1985. The Biology of *Myrmecophila manni* Schimmer (Orthoptera: Gryllidae). M.S. Thesis, Washington State University. 83 pp.

Meyer-Rochow, V.B. 1974. Structure and function of the larval eye of the sawfly, *Perga*. J. Insect Physiol. 20: 1565-1591.

Rettenmeyer, C.W. 1961. Arthropods associated with Neotropical army ants with a review of the behavior of these ants (Arthropoda: Formicidae: Dorylinae). Ph.D. Dissertation, Univ. Kansas. 605 pp.

Schimmer, F. 1909. Beitrag zu einer Monographie der Gryllodeengatung *Myrmecophila* Latr. Zeitschr. Wissensch. Zool. 93: 409-534.

Steiner, A.L. 1968. Behavioral interactions between *Liris nigra* Van Der Linder (Hymenoptera: Sphecidae) and *Gryllus domesticus* L. (Orthoptera: Gryllidae). Psyche 75: 256-273.

Vander Meer, R.K. and D.P. Wojcik 1982. Chemical mimicry in the myrmecophilous beetle *Myrmecaphodius excavaticollis*. Science 218: 806-808.

Wheeler, W.M. 1900. The habits of *Myrmecophila nebrascensis* Brunner. Psyche 9: 111-115.

Wilson, E.O. 1971. The insect societies. Belknap/Harvard: Cambridge, MA 548 pp.

ADDITIONAL HETEROPTERA NEW TO BRITISH COLUMBIA

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ABSTRACT

The following 11 species are recorded from British Columbia: *Amnestus pallidus, Holcostethus piceus, Neottiglossa trilineata, Acrosternum hilare, Melanopleurus perplexus, Nysius fuscovittatus, Nysius paludicolus, Zeridoneus costalis, Anthocoris confusus, Barce fraterna*, and *Sigara alternata.*

INTRODUCTION

Research on the Heteroptera of British Columbia has led to the discovery of eleven species new to the province. These are listed, together with notes on their identification and distribution. The genera can be keyed in Slater and Baranowski (1978). Material is deposited in the Canadian National Collection, Ottawa [CNC] and the Spencer Entomological Museum at the University of British Columbia [UBC].

FAMILY CYDNIDAE

Amnestus pallidus Zimmer

Annectus [sic] pallidus Zimmer 1910, Can. Ent. 42: 166.

A member of the subfamily Amnestinae, which can be recognized by having the clavi meeting behind the scutellum, forming a commissure about 1/3 to 1/4 the length of the scutellum. This small (2-3 mm) pale ferruginous bug characteristically has the juga each with 5 marginal pegs, the rostrum not extending beyond the middle coxae and with segment 3 less than twice as long as segment 1.

The species ranges from Quebec and Ontario and Massachusetts south to Georgia, and west to Washington and California (Froeschner 1960; McPherson 1982). It has been collected on *Antennaria plantaginifolia* (Compositae) (Stoner 1920).

B.C. material examined: 1♂, Westbank, soil sample, *Hypericum* area, 24.vi.1955 (Wilson, Wakefield) [CNC].

FAMILY PENTATOMIDAE

Holcostethus piceus (Dallas)

Pentatoma? piceus Dallas 1852, List Hem. B.M. 1: 236.
Holcostethus piceus, Kirkaldy 1909, Cat. Hem.: 48.

The genus *Holcostethus* can be keyed in McPherson (1982), and has been reviewed for North America by McDonald (1974). *H. piceus* has a black connexivum bordered by a narrow yellow margin, abdominal venter fuscous, antennal segments fuscous except at joints, scutellum with distinct yellow tip and broadly rounded at the apex, and juga not contiguous in front of tylus.

The species has been recorded from Quebec west to Alberta, and south to Illinois and Colorado (McPherson 1982). Nothing is known about the life history.

B.C. material examined: 1♀, Quesnel, 10.vii.1949 (G.J. Spencer) [UBC].

Neottiglossa trilineata (Kirby)

Pentatoma (Neottiglossa) trilineata Kirby 1837, *in* J. Richardson, Fauna Boreali-Americana 4: 276.

Neottiglossa trilineata can be keyed in McPherson (1982). The species has a triangular-shaped head, nontumescent juga, with head dorsally black, without a median yellow line, but with deep punctures.

The range of *N. trilineata* extends from Nova Scotia, Quebec, northern Michigan and Nebraska west to British Columbia and California (McPherson 1982). Nothing is known about the life history.

B.C. material examined: 1♀, Prince George, 30 mi E, 18.viii.1970 (G.G.E. Scudder) [UBC]; 1♂, Summerland, 26.ix.1932 (A.N. Gartrell) [CNC]; 1♂, Summit Lake, mi 392 Alaska Hwy., 4200', 31.vii.1959 (R.E. Leech) [CNC]: 1♀, Telegraph Creek, Sawmill Lake, 1100', beside lake, 28.viii.1960 (R. Pilfrey) [CNC].

Acrosternum hilare Say

Pentatoma hilaris Say 1831, Hem. Het. N. Amer. New Harmony: 5.
Rhapigaster sarpinus Dallas 1851, List Hem. B.M. 1: 276.
Nezara hilaris, Ulher 1878, Proc. Boston Soc. Nat. Hist. 19 (4): 380.
Acrosternum hilare, Parshley 1915, Psyche 22: 175.

Rolston (1983) has recently reviewed the genus *Acrosternum* in the Western Hemisphere, and shown that all species belong to the subgenus *Chinavia* Orian. *H. hilare* can be keyed in McPherson (1982) and Rolston (1983). This large (13-19 mm) green pentatomid has the lateral margins of the pronotum straight or nearly so, the jugae equal to tylus in length, and the rostrum reaches at least to the hind coxae.

H. hilare occurs in Ontario and Quebec, and ranges apparently throughout the United States (Rolston 1983). The species has been collected from a wide range of host plants (see list in McPherson (1982)), and is of some economic importance (Rolston 1983), having been collected on cotton, peach, pear, apple, apricot, corn, asparagus, grape, cow-pea, cherry, strawberry, plum, tomato,

orange, etc. This species is evidently univoltive in the northern part of the range, overwintering as an adult.

B.C. material examined: 1♀, Oliver, 4 km N, 6.vi.1981 (S.G. Cannings); 1♂, *id.*, ex. *Urtica*, 18.v.1984 [UBC]. 1♂ 1♀ Osoyoos, Haynes Ecol. Res., on choke cherry *(Prunus virginiana)*, 12.v.1983 (S.G. Cannings) [UBC]; 1♂, Vaseux L., on mock orange *Philadelphus lewisii)*, 27.viii.1986 (G.G.E. Scudder) [UBC].

FAMILY LYGAEIDAE

Melanopleurus perplexus Scudder

Melanopleurus perplexus Scudder 1981, Can. Ent. 113: 751.

This small (4-6 mm) species can be keyed in Scudder (1981), being recognized by having a pale spot on the vertex, black ostiolar peritreme, and dusky hemelytra with a distinct golden pubescence.

Described originally from Alberta, Manitoba and Saskatchewan, the species is now known from British Columbia.

B.C. material examined: 1♀, Peace River, Hwy. 29, 32 km W of Charlie L., 5.viii.1982 (G.G.E. Scudder) [UBC].

Nysius fuscovittatus Barber

Nysius fuscovittatus Barber 1958, Proc. Ent. Soc. Wash. 60: 70.

This rather large species (♂ 4.7 (range 4.4-5.3) mm; ♀ 5.4 (range 4.7-6.3) mm), characteristically has the rostrum extending onto the abdomen, the abdominal sterna being black. It was described from Alaska and Alberta (Jasper) (see below). The species also occurs in British Columbia and the Yukon. I have found *N. fuscovittatus* to be associated with *Dryas drummondii* Rich. (Rosaceae), and can be collected on the dried seed heads, usually in large number.

Material examined: BRITISH COLUMBIA: 27♂ 16 ♀, Golden, 7 mi E, 1.vii.1982 (G.G.E. Scudder); 4♂ 28♀, Liard River, 8.7 km S, 31.vii.1982 (G.G.E.S.); 2♀, Muncho Lake Prov. Park, Strawberry Flats, 31.vii.1982 (G.G.E.S.); 5♀, Muncho Lake Prov. Park, Trout R., 31.vii.1982 (G.G.E.S.); 8♂ 7♀, Parson, 11 mi N, 1.viii.1982 (G.G.E.S.); 1♂ 3♀, Peterson Cr., Muncho L., 20 km S, 1.viii.1982 (G.G.E.S.); 2♂ 4♀, Racing R., km 670 Alaska Hwy., 1.viii.1982 (G.G.E.S.); 1♂ 1♀, Stewart, 13.5 km E, Bitter Cr., 23.vii.1983 (G.G.E.S.); 11♂ 15♀, Stewart, 43 km E, Stromm Cr., 22.vii.1983 (G.G.E.S.); 10♂ 9♀, Stone Mt. Prov. Park, Summit L., 10.5 km N, 1.viii.1982 (G.G.E.S.) [UBC]. YUKON: 9♂ 4♀, Campbell Hwy., Lapie Canyon, 19.vii.1983 (G.G.E.S.); 6♂ 7♀, Kluane L., mi 1054 Alaska Hwy., 20.vii.1979 (G.G.E.S.); 73♂ 49♀, *id.*, 16.vii.1982; 1♂ 1♀, Long's Cr., 4 km N, km 1863 Alaska Hwy., 22.vii.1979 (G.G.E.S.); 16♂ 33♀, Ogilvie R., km 293 Dempster Hwy., 65° 55' N 137° 22' W, 22.vii.1982 (G.G.E.S.); 119♂ 109♀, Pine L., km 1626 Alaska Hwy., 9.vii.1983 (G.G.E.S.); 13♂ 14♀, South Canol Rd., km 218, Lapie Cr., 19.vii.1983 (G.G.E.S.) [UBC].

Nysius paludicolus Barber

Nysius paludicola Barber 1949, Bull. Brooklyn Ent. Soc. 44: 144.

This species lives in salt marshes, feeding on *Salicornia* (Barber 1949). It can be recognized by the rather large size (5.3 mm), long antennae, long bucculae and the contracted part of the costal margin which equals the length of the unicolorous scutellum.

While originally described from Washington and Alberta, the Alberta material from Jasper was subsequently included in the type material of *N. fuscovittatus* (Barber 1958).

B.C. material examined: 15♂ 27♀, Tsawwassen Beach, 21.vii.1962 (G.G.E. Scudder); 1♂ 4♀, *id.*, 27.vi.1965 [UBC].

Zeridoneus costalis (Van Duzee)

Perigenes costalis Van Duzee 1909, Can.Ent. 41: 373.
Zeridoneus costalis, Barber 1918. J.N.Y. Ent. Soc. 26: 45.

This large (6.5-8 mm) ground dwelling Myodochine Lygaeid is illustrated by Slater and Baranowski (1978). It lacks a stridulatory area on the abdomen, has only a shallow constriction between the lobes of the pronotum, and has the first tarsomere of the hind tarsus 3X the combined length of the terminal two tarsomeres.

This species is recorded from Alberta to Quebec, and from Maryland to North and South Dakota (Slater 1964).

B.C. material examined: 1♂ 1♀, Attachie, 4 km E, 5.viii.1982 (G.G.E.Scudder) [UBC]: 1♀, Hudson Hope, 5.viii.1982 (G.G.E.S.) [UBC]; 1♂ 1♀, Peace River, 32 km W of Charlie Lake on Hwy. 29, 5.viii.1982 (R.A. Cannings) [UBC]; 1♀, Wasa, 7.viii.1970 (L.A. Kelton) [CNC].

FAMILY ANTHOCORIDAE

Anthocoris confusus Reuter

Anthocoris confusus Reuter 1884, Monogr. Anthoc.:71.

This species can be keyed in Kelton (1978). It has the clavus, corium, inner part of embolium and inner angle of the cuneus pruinose; the rest of the cuneus and costal part of the embolium is shiny.

The species is a European introduction and in Canada is most abundant on *Fagus, Acer, Tilia, Dentaria* and *Rosa*. It has been reported from Nova Scotia, Ontario, Prince Edward Island, Maine and Tennessee (Kelton 1978).

B.C. material examined: 1♀, Vancouver, 1.v.1977 (G.G.E. Scudder) [UBC].

FAMILY REDUVIIDAE

Barce fraterna Say

Ploiaria fraterna Say 1831, Hem. Het. N. Amer. New Harmony : 33.
Barce flaterna, Banks 1909, Psyche 16 (3): 47.

This species is a member of the subfamily Emesinae. *B. fraterna* has an angular or spiniform process on the clypeus, the pale stripe on the ventral surface of the head is as wide as the interocular space and is without a dark spot ventrally on each side behind the eye. The upper margin of the pygophore has a broad squarish process, but there is no erect spine within the upper border.

It is distributed throughout the western, southwestern and northern United States, Mexico, Cuba, Jamaica, Colombia and Ecuador (Wygodzinsky 1966).

B.C. material examined: 1♀, Lytton, 26.vii.1931 (G.J. Spencer); 1♀, *id.*, 23.viii.1931; 5♂ 5♀, Peace River, Hwy. 29, 32 km W of Charlie L, 5.viii.1982 (G.G.E.Scudder); 1♂, Vancouver, University Endowment Lands, nr. S.W. Marine Drive and 41st Ave., 29.viii.1984 (G.G.E.S.) [UBC].

FAMILY CORIXIDAE

Sagara alternata (Say)

Corixa alternata Say 1825, J. Acad. Nat. Sci. Phil. 4: 329
Sigara (Vermicorixa) alternata, Hungerford 1948, Univ. Kans. Sci. Bull. 32: 653.

S. alternata has the hemelytra with the postnodal pruinose area and the claval pruinose area of equal length, and the thorax with the mesoepimeron narrow (Hungerford 1948).

The species occurs from Nova Scotia to Alberta, and across most of the United States.

B.C. material examined: 1♂, Delta, Burns bog, 2.x.1984 (J. Lancaster); 1♂ 1♀, Vancouver, Van Dusen Botanic Gardens, ornamental pond, 16.iv.1985 (G.G.E. Scudder) [UBC].

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REFERENCES

Barber, H.G. 1949. A new genus in the subfamily Blissinae from Mexico and a new *Nysius* from the Northwest (Lygaeidae: Hemiptera-Heteroptera). Bull. Brooklyn Ent. Soc. 44: 141-144.

Barber, H.G. 1958. A new species of *Nysius* from Alaska and Alberta, Canada. Proc. Ent. Soc. Wash. 60: 70.

Froeschner, R.C. 1960. Cynidae of the Western Hemisphere. Proc. U.S. Nat. Mus. 111: 337-680.

Hungerford, H.B. 1948. The Corixidae of the Western Hemisphere (Hemiptera). Univ. Kans. Sci. Bull. 32: 1-827.

Kelton, L.A. 1978. The Anthocoridae of Canada and Alaska. Heteroptera:Anthocoridae. The Insects and Arachnids of Canada, Part 4. Can. Dept. Agric. Publ. 1639, 101 pp.

McDonald, F.J.D. 1974. Revision of the genus *Holcostethus* in North America (Hemiptera:Pentatomidae). J. N.Y. Ent. Soc. 82: 245-258.

McPherson, J.E. 1982. The Pentatomoidea (Hemiptera) of northeastern North America with emphasis on the fauna of Illinois. Southern Illinois Univ. Press, Carbondale and Edwardsville, 240 pp.

Rolston, L.H. 1983. A revision of the genus *Acrosternum* Fieber, subgenus *Chinavia* Orian, in the Western Hemisphere (Hemiptera:Pentatomidae). J. N.Y. Ent. Soc. 91: 97-176.

Scudder, G.G.E. 1981. Two new species of Lygaeinae (Hemiptera:Lygaeidae) from Canada. Can. Ent. 113:747-753.

Slater, J.A. 1964. A catalogue of the Lygaeidae of the World. Univ. of Connecticut, Storrs, 2 vols., 1668 pp.

Slater, J.A. and Baranowski, R.M. 1978. How to know the true bugs (Hemiptera-Heteroptera). Wm. C. Brown Co., Dubuque, Iowa, 256 pp.

Stoner, D. 1920. The Scutelleridae of Iowa. Univ. Iowa Stud. Nat. Hist. 8: 1-140.

Wygodzinsky, P.W. 1966. A monograph of the Emesinae (Reduviidae, Hemiptera). Bull. Amer. Mus. Nat. Hist. 133: 1-614.

ERRATUM

In Wilkinson, P.R. 1984. Hosts and distribution of Rocky Mountain wood ticks *(Dermacentor andersoni)* at a tick focus in British Columbia rangeland, Vol. 81: 57-71, table 2, footnote 1: the entry "1 muskrat on July 20", should be "1 weasel on July 20". The name *Mustela* was somehow transposed into muskrat.

THE APHIDS (HOMOPTERA:APHIDIDAE) OF BRITISH COLUMBIA
14. FURTHER ADDITIONS

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ABSTRACT

Twelve species of aphids and new host records are added to the taxonomic list of the aphids of British Columbia.

INTRODUCTION

Ten previous lists of the aphids of British Columbia (Forbes, Frazer and MacCarthy 1973; Forbes, Frazer and Chan 1974; Forbes and Chan 1976, 1978, 1980, 1981, 1983, 1984, 1985; Forbes, Chan and Foottit 1982) recorded 368 species of aphids collected from 810 hosts or in traps and comprises 1529 aphid-host plant association. The present list adds 12 aphid species (indicated with an asterisk in the list) and 56 aphid-host plant associations to the previous lists. Twenty-six of the new aphid-host plant associations are plant species not recorded before. The additions bring the number of known aphid species in British Columbia to 380. Aphids have now been collected from 836 different host plants and the total number of aphid-host plant associations is 1585.

The names of aphids are in conformity with Eastop and Hille Ris Lambers (1976) and are arranged alphabetically by species. Eleven new collection sites are tabulated in Table 1. The location of each collection site can be determined from Table 1 or from the tables of localities in the previous lists. The reference points are the same as those shown on the map which accompanies the basic list.

TABLE 1. Collection sites of aphids, with airline distances from reference points.

Locality	Reference Point	Distance		
		Dir	km	mi
Apex Mountain	Kelowna	SW	70	44
Buckley Bay	Vancouver	W	135	84
Chuwhels Mountain	Kamloops	SW	22	14
Falkland	Kamloops	SE	59	37
Mill Bay	Victoria	NW	27	17
Port Alberni	Victoria	NW	139	87
Qualicum Beach	Vancouver	W	96	60
Silver Star Prov. Park	Kelowna	NE	64	40
Tamarac Park	Kelowna	E	40	25
Westwold	Kamloops	SE	48	30
Whonnock	Vancouver	SE	53	33

LIST OF SPECIES

***ACERIS (Linnaeus), PERIPHYLLUS**

Acer sp.: Agassiz, Jul 13/13 (Wilson 1915).

ADIANTI (Oestlund), SITOBION

Matteuccia struthiopteris: Vancouver (UBC), Apr30/84.

Polypodium glycyrrhiza: Vancouver (UBC), Apr30/84.

AETHEOCORNUM Smith & Knowlton, MACROSIPHUM

Geranium viscosissimum var. *viscosissimum:* 108 Mile House, Jul26/83.

ALBIFRONS Essig, MACROSIPHUM

Lupinus arcticus: Apex Mountain, Jul2/83, Jul10/84; Chuwhels Mountain, Jun29/83, Jul7/84; Cowichan Lake, May 21/84, Jul12/83, Jul16/84; Diamond Head, Jul20/83, Jul30/84; Mill Bay, Jul 12/83; Nanaimo, May 21/84, Jul12/83, Jul16/84; Port Alberni, Jul16/84; Princeton, Jul2/83; Silver Star Provincial Park, Jun30/83; Vancouver (UBC), Aug14/84.

Lupinus polyphyllus: Buckley Bay, Jul16/84; Burnaby, May 24/84, Sep5/84; Burnaby (SFU), Mar8/84, Jun13/83, Aug28/84, Nov28/83; Cloverdale, Jul12/83, Jul16/84; Qualicum Beach, Jul16/84; Tamarac Park, Jul1/83, Jul10/84; West Vancouver, May 12/84, Jun12/83, Sep13/84, Oct4/83.

Lupinus sericeus: Falkland, Jun30/83; Westwold, Jun30/83.
Lupinus sp.: Burnaby, May31/84, Sep13/84; Manning Park, Jul2/83, Jul10/84; Pender Island, Aug3/84.

ALNIFOLIAE (Williams), PROCIPHILUS
Amelanchier canadensis: Vancouver (UBC), Jun14/85.

ALPINA (Gillette & Palmer), KAKIMIA
Mimulus cardinalis: Vancouver (UBC), Aug20/84.

ASCALONICUS Doncaster, MYZUS
Potentilla pensylvanica: Vancouver (UBC), May11/83.

AVENAE (Fabricius), SITOBION
Hordeum jubatum: Vancouver, Jun25/84.
Luzula nivea: Vancouver (UBC), Jun29/84.
Malus domestica: Vernon, Jul16/13 (Wilson 1915).

BERBERIDIS (Kaltenbach), LIOSOMAPHIS
Mahonia aquifolium: Vancouver, Jun14/85.

CARDUI (Linnaeus), BRACHYCAUDUS
Carduus sp.: Vernon, Jul16/13 (Wilson 1915).

***CARNOSUM (Buckton), MICROLOPHIUM**
Urtica dioica: Vernon, Jul16/13 (Wilson 1915).

CERASI (Fabricius), MYZUS
Galium aparine: Vancouver (UBC), Jun15/84.
Prunus sp.: Vancouver, Jul12/13 (Wilson 1915).

CERASIFOLIAE (Fitch), RHOPALOSIPHUM
Prunus virginiana: Vernon, Jul16/13 (Wilson 1915).

CERTUS (Walker), MYZUS
*Catharanthus roseus:*Vancouver (CDA), May 16/85.
Dianthus barbatus: Vancouver (CDA), MAY 16/85.
Dianthus 'Scarlet Luminette': Vancouver (UBC), Aug 20/84.

***CHANI Robinson, UROLEUCON**
Grindelia nana: Vancouver (UBC), Oct1/82 (Robinson 1985).

CIRCUMFLEXUM (Buckton), AULACORTHUM
Matteuccia struthiopteris: Vancouver (UBC), Apr30/84.

CITRICOLA van der Goot, APHIS
Stranvaesia davidiana: Vancouver (UBC), Jul10/84.

COWENI (Cockerell), TAMALIA
Arctostaphylos uva-ursi: Vancouver (UBC), Jul18/85, Aug23/84.

CREELII Davis, MACROSIPHUM
Medicago sativa: Kamloops, Jun 10/85, Jul3/84, Jul8/85.

DAPHNIDIS Borner, MACROSIPHUM
Daphne laureola: Vancouver (UBC), Jul10/84.

DORSATUM (Richards), SITOBION
Gaultheria shallon: Vancouver (UBC), May 15/85.

EQUISETI Holman, SITOBION
Equisetum arvense: Vancouver, Jun19/85.

FAGI (Linnaeus), PHYLLAPHIS
Fagus sp.: Agassiz, Jul13/13 (Wilson 1915).

FIMBRIATA Richards, FIMBRIAPHIS
Fragaria virginiana ssp. *glauca:* Vancouver (CDA), Aug1/85.
Rosa 'Zephirine Drouhin': Vancouver (UBC), May9/85.

FOENICULI (Passerini), HYADAPHIS
Lonicera etrusca: Vancouver (UBC), Jul25/85.
Oenanthe sarmentosa: Pender Island, Aug2/84.

FRAGAEFOLII (Cockerell), CHAETOSIPHON.
Fragaria virginiana ssp. *glauca:* Vancouver (CDA), Aug1/85.

FRAGARIAE (Walker), SITOBION
Hordeum jubatum: Vancouver, Jun25/84.
Rubus discolor: Whonnock, May10/84.

***FRIGIDAE (Oestlund), OBTUSICAUDA**
Artemisia sp.: Vernon, Jul16/13 (Wilson 1915).

GERANII Gillette & Palmer, AMPHOROPHORA
Geranium viscosissimum var. *viscosissimum;* 108 Mile House, Jul26/83.

***GROSSULARIAE (Schule), ERIOSOMA**
Ulmus americana: Burnaby, Jul7/84.

HELICHRYSI (Kaltenbach), BRACHYCAUDUS
Cotula australis: Vancouver (UBC), Jun4/85.
Prunus domestica: Vancouver, May31/85.

HUMULI (Schrank), PHORODON
Prunus domestica: Vancouver, Jul25/84.

LACTUCAE (Linnaeus), HYPEROMYZUS
Ribes nigrum 'Wellington XXX': Vancouver (UBC), Nov16/84.

LUDOVICIANAE (Oestlund), MACROSIPHONIELLA
Artemisia ludoviciana: Vernon, Jul16/13 (Wilson 1915).

LYTHRI (Schrank), MYZUS
Prunus emarginata: Vancouver (UBC), Aug8/85.

MACROSIPHYM (Wilson), ACYRTHOSIPHON
Amelanchier laevis: Vancouver (UBC), Jul10/84.

MILLEFOLII (de Geer), MACROSIPHONIELLA
Achillea millefolium 'Cerise Queen': Vancouver (UBC), Jun21/85.
Achillea millefolium var. *lanulosa:* Vancouver (UBC), Jun21/85, Jul26/85.

NEGUNDINIS (Thomas), PERIPHYLLUS
Acer negundo: Agassiz, Jul13/13 (Wilson 1915).

NYMPHAEAE (Linnaeus), RHOPALOSIPHUM
Capsella bursa-pastoris: Vancouver (CDA), Jun7/85.
Catharanthus roseus: Vancouver (CDA), Jun7/85.

OBLIQUUS (Cholodkovsky), MINDARUS
Picea sp.: Prince George, Sep18/84.

ORNATUS Laing, MYZUS
Ratibida columnifera: Vancouver (UBC), Nov16/84.

***PALLIDUM (Oestlund), MACROSIPHUM**
Aster sp.: 108 Mile House, Jul27/83.
Erodium cicutarium ssp. *cicutarium:* Vancouver (UBC), Jun4/85.

PLATANI (Kaltenbach), TINOCALLIS
Ulmus americana: Vancouver, Jul13/84.

***POPULEUM (Kaltenbach), PTEROCOMMA**
Populus sp.: Vernon, Jul16/13 (Wilson 1915).

POPULIFOLII (Essig),CHAITOPHORUS
Populus sp. Vernon, Jul16/13 (Wilson 1915).

POPULIFOLII NEGLECTUS Hottes & Frison, CHAITOPHORUS
Populus nigra 'Italica': Vancouver (UBC), Jun11/85, Jun20/85, Jun25/85.

PRUNI (Geoffroy), HYALOPTERUS
Prunus sp.: Vernon, Jul16/13 (Wilson 1915).
Typha latifolia: Pender Island, Aug3/84.

PTERICOLENS (Patch), SITOBION
Pteridium aquilinum: Pender Island, Aug3/84.

PTERIDIS (Wilson), SITOBION
Pteridium aquilinum: Pender Island, Aug3/84.

PUNCTIPENNIS (Zetterstedt), EUCERAPHIS
Betula sp.: Agassiz, Jul13/13 (Wilson 1915).

RIBISNIGRI (Mosley), NASONOVIA
Lapsana communis: Vancouver, Jun25/85.

ROSAE (Linnaeus), MACROSIPHUM
Rosa centifolia 'Cristata': Vancouver (UBC), Aug7/85.
Rosa sp.: Vancouver, Jul12/13 (Wilson 1915).

ROSARUM (Kaltenbach), MYZAPHIS
Potentilla fruticosa: Vancouver (UBC), Oct31/84.
Potentilla fruticosa ssp. *floribunda*: Vancouver (UBC), Jul26/85.

RUBICOLA (Oestlund), ILLINOIA
Rubus sp.: Vancouver, Jul12/13 (Wilson 1915).

***RUDBECKIAE (Fitch), UROLEUCON**
Solidago sp.: Vernon, Jul16/13 (Wilson 1915).

RUSSELLAE (Hille Ris Lambers), UROLEUCON
Helichrysum virgineum: Vancouver (UBC), Sep2/83.

***SANDILANDICUS (Robinson), HYPEROMYZUS**
Crepsis sp.: 108 Mile House, Jul26/83.

SANGUICEPS Richards, PTEROCOMMA
Salix exigua: Vancouver (UBC), Apr16/85, May16/85.

SMITHIAE (Monell), PTEROCOMMA
Populus sp.: Vernon, Jul16/13 (Wilson 1915).

SOLANI (Kaltenbach), AULACORTHUM
Pleione formosana: Vancouver (UBC), Apr16/85.

***SOLIDAGINIS (Fabricius, UROLEUCON**
Solidago sp.: Agassiz (Glendenning 1929).

SONCHI (Linnaeus), UROLEUCON
Sonchus arvensis: Abbotsford, Jul25/85.

***SORBI (Kaltenbach), DYSAPHIS**
Malus domestica: Agassiz, Jul13/13 (Wilson 1915).

SPYROTHECAE Passerini, PEMPHIGUS
Populus nigra 'Italica': Vancouver (UBC), May 22/85.

STANLEYI Wilson, MACROSIPHUM
Sambucus cerulea: Vancouver, Jul14/13 (Wilson 1915).
Sambucus racemosa sp. *pubens* var. *melanocarpa*: Vancouver (Glendenning 1929).

TANACETARIA (Kaltenbach), MACROSIPHONIELLA
Tanacetum vulgare: Cloverdale, Aug24/84.

TILIAE (Linnaeus), EUCALLIPTERUS
Tilia americana: Vancouver (UBC), Jun14/85.

TRIRHODUS (Walker), LONGICAUDUS
Aquilegia vulgaris: Vancouver, Jul24/85.

ULMI (Linnaeus), ERIOSOMA
Ulmus americana: Burnaby, Jul17/84.

***VANCOUVERENSE Robinson, UROLEUCON**
Solidago canadensis var. *salesbrosa*: Vancouver (UBC), Sep13/78 (Robinson 1985).

VARIANS Patch, APHIS
Epilobium angustifolium: 108 Mile House, Jul26/83.
Ribes nigrum 'Wellington XXX': Vancouver (UBC), Aug20/84, Sep11/84.

WAKIBAE (Hottes), FIMBRIAPHIS
Rosa 'Agnes': Vancouver (UBC), May9/85, May28/85.

*Aphid species not in the previous lists.

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The authors gratefully acknowledge the following for valuable aid and advice in identifications: R.L. Blackman and V.F. Eastop, British Museum (Natural History), London, England; R. Danielsson, Dept. of Systematics, Zoological Institute, Lund, Sweden; and A.G. Robinson, Dept. of Entomology, University of Manitoba, Manitoba; and M. Cohen of Simon Fraser University providing us with his collection data for *M. albifrons*.

REFERENCES

Eastop, V.F., and D. Hille Ris Lambers. 1976. Survey of the world's aphids. Dr. W. Junk b.v., Publisher, The Hague.

Forbes, A.R., and C.K. Chan. 1985. The aphids (Homoptera:Aphididae) of British Columbia. 13. Further additions. J. ent. Soc. Brit. Columbia 82: 56-58.

Forbes, A.R., and C.K. Chan. 1984. The aphids (Homoptera:Aphididae) of British Columbia. 12. Further additions. J. ent. Soc. Brit. Columbia 81: 72-75.

Forbes, A.R., and C.K. Chan. 1983. The aphids (Homoptera:Aphididae) of British Columbia. 11. Further additions. J. ent. Soc. Brit. Columbia 80: 51-53.

Forbes, A.R., and C.K. Chan. 1981. The aphids (Homoptera:Aphididae) of British Columbia. 9. Further additions. J. ent. Soc. Brit. Columbia 78: 53-54.

Forbes, A.R., and C.K. Chan. 1980. The aphids (Homoptera:Aphididae) of British Columbia. 8. Further additions and corrections. J. ent. Soc. Brit. Columbia 77: 38-42.

Forbes, A.R., and C.K. Chan. 1978. The aphids (Homoptera:Aphididae) of British Columbia. 6. Further additions. J. ent. Soc. Brit. Columbia 75: 47-52.

Forbes, A.R., and C.K. Chan. 1976. The aphids (Homoptera:Aphididae) of British Columbia. 4. Further additions and corrections. J. ent. Soc. Brit. Columbia 73: 57-63.

Forbes, A.R., C.K. Chan and R. Foottit. 1982. The aphids (Homoptera:Aphididae) of British Columbia. 10. Further additions. J. ent. Soc. Brit. Columbia 79: 75-78

Forbes, A.R., B.D. Frazer and C.K. Chan. 1974. The aphids (Homoptera:Aphididae) of British Columbia. 3. Additions and corrections. J. ent. Soc. Brit. Columbia 71: 43-49.

Forbes, A.R., B.D. Frazer and H.R. MacCarthy. 1973. The aphids (Homoptera:Aphididae) of British Columbia. 1. A basic taxonomic list. J. ent. Soc. Brit. Columbia 70: 43-57.

Glendenning, R. 1929. Further additions to the list of aphids of British Columbia. Proc. Entomol. Soc. Brit. Columbia 26: 54-57.

Robinson, A.G. 1985. Annotated list of *Uroleucon (Uroleucon, Uromelan, Satula)* (Homoptera:Aphididae) of America north of Mexico, with keys and descriptions of new species. Canad. Ent. 117: 1029-1054.

Wilson, H.F. 1915. Aphid notes from British Columbia. Proc. Entomol. Soc. Brit. Columbia 5:82-85.

THE APHIDS (HOMOPTERA:APHIDIDAE) OF BRITISH COLUMBIA
15. FURTHER ADDITIONS

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ABSTRACT

Six species of aphids and new host records are added to the taxonomic list of the aphids of British Columbia.

INTRODUCTION

Eleven previous lists of the aphids of British Columbia (Forbes, Frazer and MacCarthy 1973; Forbes, Frazer and Chan 1974; Forbes and Chan 1976, 1978, 1980, 1981, 1983, 1984, 1985, 1986; Forbes, Chan and Foottit 1982) recorded 380 species of aphids collected from 836 hosts or in traps and comprises 1586 aphid-host plant associations. The present list adds 6 aphid species (indicated with an asterisk in the list) and 75 aphid-host plant associations to the previous lists. Twenty-nine of the new aphid-host plant associations are plant species not recorded before. The additions bring the number of known aphid species in British Columbia to 386. Aphids have now been collected from 865 different host plants and the total number of aphid-host plant associations is 1661.

The aphid names are in accordance with Eastop and Hille Ris Lambers (1976) and listed alphabetically by species. Five new collection sites are tabulated in Table 1. The location of each collection site can be determined from Table 1 or from the tables of localities in the previous papers. The reference points are the same as those shown on the map which accompanies the basic list.

TABLE 1. Collection sites of aphids, with airline distances from reference points.

Locality	Reference Point	Distance Dir	km	mi
Alexandria	Williams Lake	NW	64	40
Eisenhower Junction	Kelowna	NE	314	196
Garibaldi Provincial Park	Vancouver	NE	68	42
Rosedale	Vancouver	SE	82	51
Thetis Island	Vancouver	SW	58	36

LIST OF SPECIES

ABIETINUM (Walker), ELATOBIUM
Picea engelmannii: Vancouver (UBC), Mar15/85.

ADIANTI (Oestlund), SITOBION
Athyrium filix-femina: Vancouver (UBC) Jul14/83.

ALBIFRONS Essig, MACROSIPHUM
Lupinus sp.: Vancouver (UBC), Sep2/83.

ASCALONICUS Doncaster, MYZUS
Cerastium fontanum ssp. *triviale* Vancouver, Dec30/59.
Lactuca sativa: Cloverdale, May16/85.
Potentilla 'Gibson's Scarlet': Vancouver (UBC), Nov14/85.
Rumex crispus: Lulu Island, Mar 24/60.
Senecio cruentus: Vancouver, Apr9/57.
Viola septentrionalis: Vancouver (UBC), Apr16/85.

AVELLANAE (Schrank), CORYLOBIUM
Corylus sp.: Vancouver, Jul28/83.

***AZALEAE (Mason), ILLINOIA**
Vaccinium macrocarpon: Vancouver (UBC), Aug29/83.

BERBERIDIS (Kaltenbach), LIOSOMAPHIS
Berberis buxifolia: Vancouver (UBC), Oct1/85.

***BREVISCRIPTUM (Palmer) UROLEUCON**
Aster sp.: Eisenhower Junction, Jul26/67.

CALIFORNICUM (Clarke), MACROSIPHUM
Salix triandra: Vancouver (UBC), May23/86.

CAPILANOENSE Robinson, AULACORTHUM
Rubus spectabilis: Vancouver (UBC), May28/86.

CARAGANAE (Cholodkovsky), ACYRTHOSIPHON
Caragana arborescens: Alexandria, Jul4/48.

CARDUI (Linnaeus), BRACHYCAUDUS
Cirsium vulgare: Thetis Island, Jul1/85.

CASTILLEIAE Sampson, KAKIMIA
Castilleja sp.: Eisenhower Junction, Jul26//67.

CIRCUMFLEXUM (Buckton), AULACORTHUM
Asparagus densiflorus 'Sprengeri': Vancouver (CDA), Jun21/85.

Berberidopsis corallina: Vancouver (UBC), Oct1/85.
Crinodendron patagua: Vancouver (UBC), Aug23/85.
Linnaea borealis: Vancouver (CDA), Mar26/86.

CIRSII (Linnaeus), UROLEUCON
Cirsium arvense: Pender Island, Jul11/85; Richmond, Aug10/65.
Cirsium brevistylum: Pender Island, Jul9/85.

***COWENI Palmer, APHIS**
Veratrum viride ssp. *eschscholtzii*: Garibaldi Provincial Park, Aug9/59.

CYNOSBATI (Oestlund), KAKIMIA
Tellima grandiflora: *Vancouver (UBC), Mar5/77.*

DAPHNIDIS Borner, MACROSIPHUM
Daphne laureola: Vancouver (UBC), May 19/76, Jun28/76.

DIRHODUM (Walker), METOPOLOPHIUM
Rosa rugosa 'Hansa': Vancouver (UBC), Oct18/85.

ELAEAGNI (del Guercio) CAPITOPHORUS
Phaseolus vulgaris: Rosedale, Jun16/58.

EQUISETI Holman, SITOBION
Equisetum arvense: Vancouver, Aug15/85.

EUPHORBIAE (Thomas), MACROSIPHUM
Apocynum androsaemifolium: Vancouver (UBC), Jul13/83.
Capsicum frutescens: Vancouver, May13/59.
Catalpa speciosa: Vancouver, Jun20/83.
Centranthus ruber: Vancouver (UBC), Jul15/83.
Crataegus monogyna 'Alba': Vancouver, May30/83.
Deutzia gracilis: Vancouver (UBC), Jul11/83.
Fumaria officinalis: Vancouver (UBC), Jun17/83.
Hypoestes phyllostachya: Vancouver (CDA), May15/86.
Kolkwitzia amabilis: Vancouver (UBC), Jun24/83.
Lantana camara: Vancouver (CDA), Apr25/86.
Potentilla fruticosa: Vancouver (UBC), Jul19/83.
Rosa gymnocarpa: Vancouver (UBC), Jul12/84.
Rudbeckia hirta: Vancouver (UBC), Jul15/83.
Taraxacum officinale: Vancouver, Mar11/83.
Vaccinium corymbosum: Vancouver (UBC), Jul12/83.
Valeriana officinalis: Vancouver (UBC), Jun23/83.
Verbena x *hybrida 'Springtime'*: Vancouver (UBC), Aug26/83.
Yucca sp.: Vancouver, Aug24/83; Vancouver (UBC), Jul26/83.

FABAE Scopoli, APHIS
Cirsium arvense:Abbotsford, Jul30/51; Agassiz, Jun30/59.
Phaseolus vulgaris: Abbotsford, Jul13/59; Brentwood, Jul4/59; Cordova Bay, Aug6/53.
Senecio sp.: Vancouver, Jul7/56.
Vicia faba: Saanich, Jul4/59.

FIMBRIATA Richards, FIMBRIAPHIS
Rosa nutkana: Vancouver (UBC), Jul11/83.

FOENICULI (Passerini), HYADAPHIS
Coriandrum sativum 'Dark Green Italian': Vancouver (CDA), Apr15/86.

GENTNERI (Mason), FIMBRIAPHIS
Crataegus x *lavallei*: Vancouver (UBC), Jul19/84.
Crataegus monogyna 'Alba': Vancouver, Jun4/83.
Sorbus americana: Vancouver, Jun28/59.

HELICHRYSI (Kaltenbach), BRACHYCAUDUS
Aster sp.: Vancouver, Jun1/58.
Cirsium vulgare: Thetis Island, Jul1/85.

HOLODISCI Robinson, APHIS
Holodiscus discolor; Vancouver, Jun24/85; Vancouver (UBC), Jun11/75.

HUMULI (Schrank), PHORODON
Photinia x *fraseri*: Vancouver, May9/86.

LACTUCAE (Linnaeus), HYPEROMYZUS
Sonchus asper: Vancouver, Jul16/56, Sep5/56.
Sonchus oleraceus: Vancouver, Jul5/56.

LACTUCAE (Passerini), ACYRTHOSIPHON
Lactuca serriola: Vancouver, Sep30/85.

***MACGILLIVRAYAE (Hille Ris Lambers), ILLINOIA**
Chaenomeles japonica: Vancouver, Jul21/76.

MANITOBENSE (Robinson), SITOBION
Cornus sericea: Vancouver (UBC), May28/86.

MILLEFOLII (de Geer), MACROSIPHONIELLA
Achillea 'Coronation Gold': Vancouver (UBC), Jun21/85.

OCHROCENTRI (Cockerell), BIPERSONA
Cirsium sp.: Kamloops, Jul4/53.

ORNATUS Laing, MYZUS
Chaenomeles speciosa: Vancouver, May3/58.
Cirsium arvense: Vancouver (UBC), May23/86.
Crinodendron patagua: Vancouver (UBC), Aug23/85.
Taraxacum officinale: Vancouver, May12/58.

OSMARONIAE (Wilson), MACROSIPHUM
Oemleria cerasiformis: Vancouver (UBC), Apr26/83.

PARVIFOLII Richards, MACROSIPHUM
Vaccinium parvifolium: Vancouver (UBC), Apr5/83.

***PAUCOSENSORIATUM (Hille Ris Lambers), UROLEUCON**
Asper: Chilliwack, May 26/58; Kamloops, May2/57, Jul24/57.

PERSICAE (Sulzer), MYZUS
Aster sp.: Creston, Apr22/59.
Phaseolus vulgarus: Rosedale, Jun16/58.

PISUM (Harris), ACYRTHOSIPHON
Phaseolus vulgaris: Cordova Bay, Aug6/53.
Vicia faba: Saanich, Jul4/59.

POMI de Geer, APHIS
Pyrus communis: Vancouver, May23/58.

PYRIFOLIAE MacDougall, MACROSIPHON
Capsella bursa-pastoris: Vancouver (CDA), Sep2/83.
Rosa 'Beauty Secret': Vancouver (CDA), Sep2/83.
Sorbus aucuparia: Vancouver, Mar27/83. Apr18/83, May 15/83, May20/86, Jun23/83.

RHAMNI (Clarke), SITOBION
Rhamnus purshiana: Ladner, May25/66.

RIBISNIGRI (Mosley), NASONOVIA
Cichorium intybus: Pender Island, Jul11/85.
Lapsana communis: Vancouver, Jul24/85.

ROSAE (Linnaeus), MACROSIPHUM
Rosa centifolia 'Muscosa': Vancouver (UBC), Aug7/85.
Rosa eglanteria: Pender Island, Jul9/85.
Rosa 'Nozomi': Vancouver (UBC), Oct4/86.

ROSARUM (Kaltenbach), MYZAPHIS
Rosa 'Agnes': Vancouver (UBC), Apr19/85.

SCAMMELLI (Mason), ERICAPHIS
Arctostaphylos uva-ursi: Vancouver (UBC), Jul11/78.
Vaccinium corymbosum: Abbotsford, Jul28/83.

SOLANI (Kaltenbach), AULACORTHUM
Catalpa sp.: Vancouver, Jun19/59.
Chaenomeles speciosa: Vancouver, May3/58.
Potentilla pensylvanica: Vancouver (UBC), May11/83.
Primula sp.: Vancouver, May23/59.
Pyrus communis: Vancouver, May23/58.
Senecio cruentus: Vancouver, Apr9/57.
Sinningia speciosa: Vancouver, Jul3/58.

SONCHI (Linnaeus), UROLEUCON
Sonchus arvensis: Sea Island, Jul15/59.
Sonchus asper: Vancouver, Jul1/59.

SPIRAECOLA (Patch), ILLINOIA
Spiraea thunbergii: Vancouver (UBC), Jun13/85.

STAPHYLEAE (Koch), RHOPALOSIPHONINUS
Iris sp.: Vancouver (UBC), Apr18/86.
Penstemon 'Evelyn': Vancouver (UBC), Apr18/86.
Platycodon grandiflorus 'Apoyama': Vancouver (UBC), Apr18/86.

STELLARIAE Theobald, MACROSIPHUM
Capsella bursa-pastoris: Vancouver (CDA), May20/86.
Catharanthus roseus: Vancouver (CDA), May20/86.
Dianthus sp.: Chilliwack, Aug13/85.

TARAXACI (Kaltenbach) UROLEUCON
Taraxacum officinale: Vancouver, Jun17/59.

***THOMASI Hille Ris Lambers, CHAETOSIPHON**
Rosa rugosa 'Hansa': Vancouver (UBC), May1/85, Oct18/85.

TILIAE (Linnaeus), EUCALLIPTERUS
Tilia petiolaris: Vancouver (UBC), Aug22/85.

VARIABILIS Richards, BOERNERINA
Alnus viridis ssp. *sinuata*: Vancouver (UBC), Jun14/85.

WAKIBAE (Hottes), FIMBRIAPHIS
Rosa rugosa 'Alba': Vancouver (UBC), Jun23/83.
Rosa woodsii ssp. *woodsii*: Vancouver (UBC), Sep2/83.

*Aphid species not in the previous lists.

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REFERENCES

Eastop, V.F., and D. Hille Ris Lambers. 1976. Survey of the world's aphids. Dr. W. Junk b.v., Publisher, The Hague.

Forbes, A.R., and C.K. Chan. 1986. The aphids (Homoptera:Aphididae) of British Columbia. 14. Further additions. J. ent. Soc. Brit. Columbia 83 (in press).

Forbes, A.R., and C.K. Chan. 1985. The aphids (Homoptera:Aphididae) of British Columbia. 13. Further additions. J. ent. Soc. Brit. Columbia 82: 56-58.

Forbes, A.R., and C.K. Chan. 1984. The aphids (Homoptera:Aphididae) of British Columbia. 12. Further additions. J. ent. Soc. Brit. Columbia 81: 72-75.

Forbes, A.R., and C.K. Chan. 1983. The aphids (Homoptera:Aphididae) of British Columbia. 11. Further additions. J. ent. Soc. Brit. Columbia 80: 51-53.

Forbes, A.R., and C.K. Chan. 1981. The aphids (Homoptera:Aphididae) of British Columbia. 9. Further additions. J. ent. Soc. Brit. Columbia 78: 53-54.

Forbes, A.R., and C.K. Chan. 1980. The aphids (Homoptera:Aphididae) of British Columbia. 8. Further additions and corrections. J. ent. Soc. Brit. Columbia 77: 38-42.

Forbes, A.R., and C.K. Chan. 1978. The aphids (Homoptera:Aphididae) of British Columbia. 6. Further additions. J. ent. Soc. Brit. Columbia 75: 47-52.

Forbes, A.R., and C.K. Chan. 1976. The aphids (Homoptera:Aphididae) of British Columbia. 4. Further additions and corrections. J. ent. Soc. Brit. Columbia 73: 57-63.

Forbes, A.R., C.K. Chan and R. Foottit. 1982. The aphids (Homoptera:Aphididae) of British Columbia. 10. Further additions. J. ent. Soc. Brit. Columbia 79: 75-78

Forbes, A.R., B.D. Frazer and C.K. Chan. 1974. The aphids (Homoptera:Aphididae) of British Columbia. 3. Additions and corrections. J. ent. Soc. Brit. Columbia 71: 43-49.

Forbes, A.R., B.D. Frazer and H.R. MacCarthy. 1973. The aphids (Homoptera:Aphididae) of British Columbia. 1. A basic taxonomic list. J. ent. Soc. Brit. Columbia 70: 43-57.

A RECORD OF THE SURINAM COCKROACH IN VANCOUVER

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An adult female cockroach was brought to Simon Fraser University for identification in April 1986. It had been collected in an office on one of the upper floors of a highrise block in downtown Vancouver. According to Mr. Rex Case, the district manager of the pest control company that serviced this block and a nearby ground-level shopping centre, these cockroaches had been sufficiently numerous to cause complaint. In the office, the largest population seemed to be in a room containing a photocopier near which there was a neglected planter. We later searched the office but found only fragments of cockroaches. The photocopying room did not contain any food or drink and did not appear to be a suitable habitat for cockroaches.

The specimen was identified as *Pycnoscelis surinamensis* (L.), an Indomalaysian species that in its introduced North American and European forms is parthenogenetic. Another unusual characteristic of this species is that the egg pod is withdrawn into a brood pouch until hatching, making them effectively viviparous. They were evidently first identified in Canada in 1938 as a serious pest girdling the stems of roses in a large greenhouse in Grimsby, Ont. (Anon. 1938), and there is a casual remark by Mallis (1982) that it was seen in large numbers in a bird house at the Toronto zoo.

The Surinam cockroach is about 2cm long, obviously larger than the German cockroach (1 to 1.5cm) and smaller than the American and Australian cockroaches (3 to 4cm), all of which are more commonly found in Vancouver. In the specimens we examined, the pronotum is uniformly dark apart from a narrow anterior yellow line. The posterior margin of the pronotum is sinuate. The tibiae and tarsi are relatively short particularly on the mesothoracic leg and, compared with the commoner species, the tarsal segments are extremely narrow. The tibiae are broad and armed with strong, presumably fossorial, spines. These key characters are shown in Fig. 1. The wings are pale brown and well developed, normally covering the rather stubby cerci. We assume the adults can fly but have neither observed this nor seen any mention of it in the literature.

We believe that these insects have been introduced on indoor plants imported from the United States. Even if the plants are brought in without soil it is very likely that a single small nymph could avoid detection in an appressed axil or loose fibrous material around a stem. A search was made in the warehouse of one of the companies that supplied plants to the shopping centre where the cockroaches were found. None was seen or caught with sticky cockroach traps set around the plants.

We have seen no references to this species as an urban pest but in view of the proliferation of environmental planting in offices and shopping malls entomologists should be aware that it might well become one.

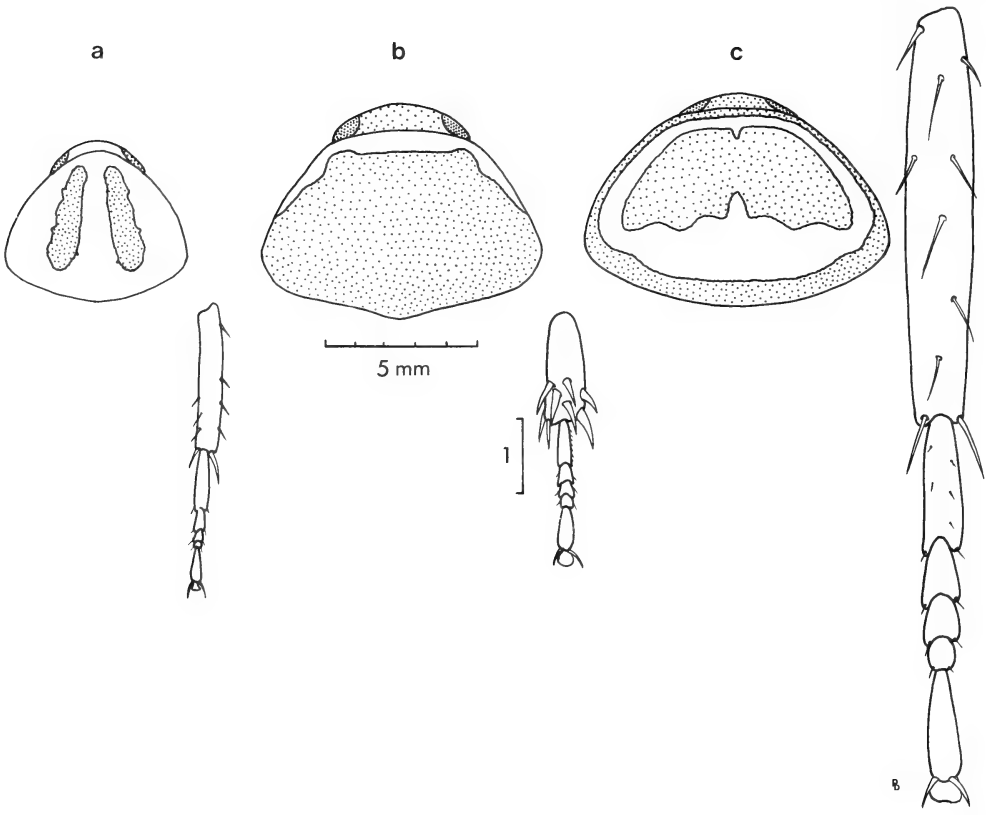

Fig 1. Shape and typical colour patterns (Vancouver area) of a, German; b, Surinam and c, Australian cockroach. Scale 5mm. Right mesotibiae and tarsi are drawn alongside at higher magnification, scale 1mm.

REFERENCES

Anon. 1938. Canadian Insect Pest Review *16* p. 279. Agriculture Canada.

Mallis, A. 1982. Handbook of Pest Control. p. 129. Franzak & Foster, Cleveland, Ohio.

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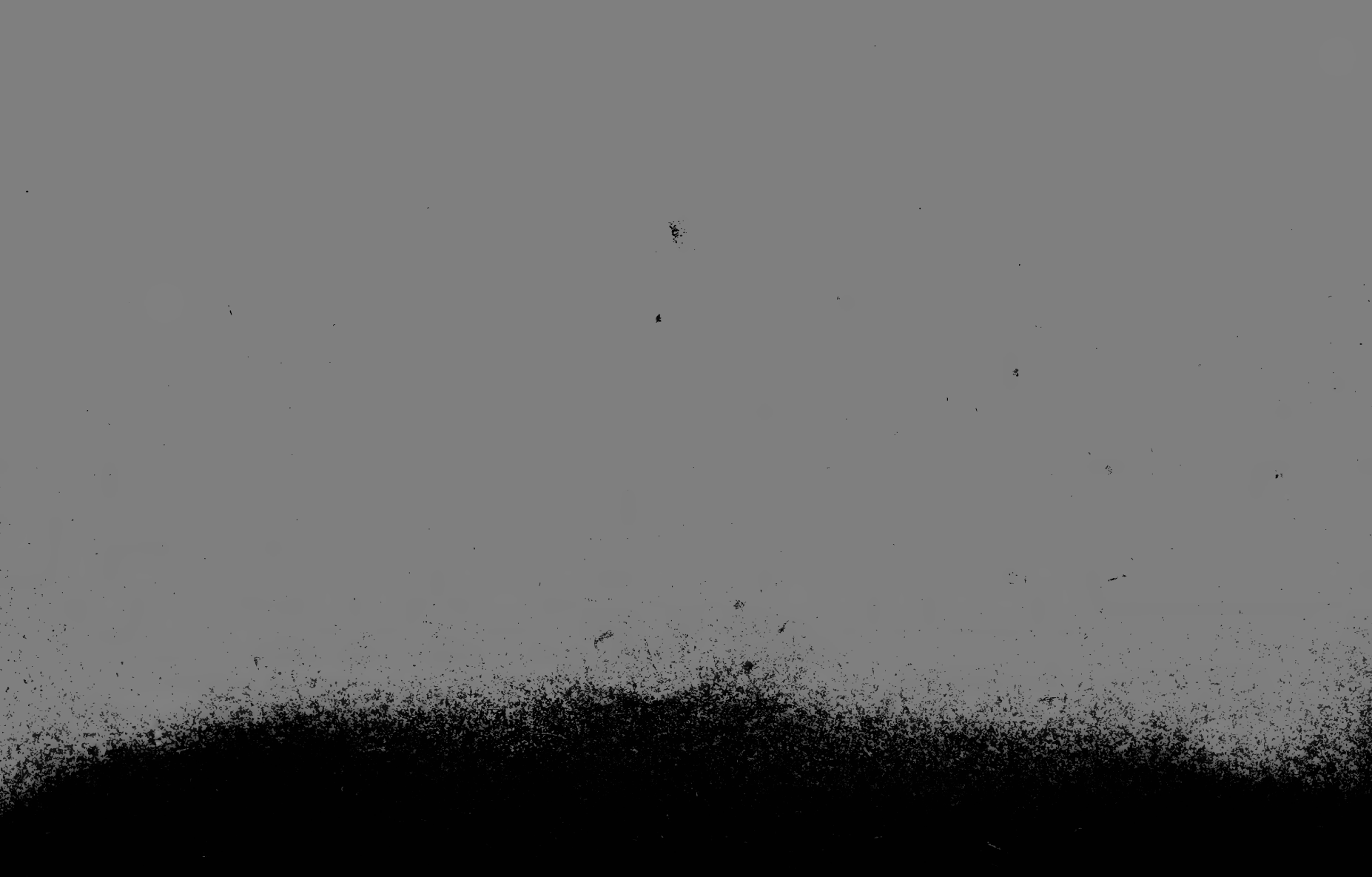

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SOME INFLUENCES OF AREA AND PEST MANAGEMENT ON APPLE MITE POPULATIONS IN THE OKANAGAN VALLEY OF BRITISH COLUMBIA

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Abstract

Biweekly leaf samples were taken from commercial apple orchards in four main growing areas, from north to south of the Okanagan Valley, each about 70 km apart, during the full growing season of 1983. Both phytophagous and predacious mite distribution and abundance were influenced by the area and four management practices. Unsprayed orchards had few mites whereas regularly sprayed orchards tended to have larger mite populations, the species composition and abundance of which varied with area. The numbers of some species of phytophagous mites appeared to be related to the species and abundance of predacious mites present in a given orchard.

Introduction

Integrated mite control has been practiced in apple orchards of the Okanagan and Similkameen Valleys for about 15 years (Downing and Arrand 1976). During that time miticide applications for the control of European red mite (*Panonychus ulmi,* (Koch)), McDaniel spidermite (*Tetranychus mcdanieli,* McG.) and apple rust mite (*Aculus schlectendali* (Nalepa)), have steadily decreased, probably because of the effectiveness of the various species of predacious mites, primarily in the family Phytoseiidae, which are found in many apple orchards. The frequency of insecticide application has also decreased, most notably as a result of the implementation of pest management procedures that have reduced the number of annual sprays for codling moth (*Cydia pomonella* (L)) from four or five to two or three. During this time, growers commented that the integrated mite control program appeared to be most effective toward the southern end of the growing region. It was not clear if this was a result of differences in cultural practices, grower tolerance (or intolerance) to phytophagous mites, or a biogeographical phenomenon related to predator species composition and abundance in different areas.

Previous work by Anderson and Morgan (1958), Anderson *et al.* (1958), and Downing and Moilliet (1971) suggested that of 28 to 30 species of predacious mites found in southern British Columbia, only three or four species occur in relatively large numbers and are common in commercial orchards. These authors did not report which areas of the Okanagan Valley were sampled and there is a suggestion in Anderson and Morgan (1958) that the phytoseiids did not maintain the phytophagous mite populations at acceptable levels. This conclusion may have reflected the miticidal properties of the insecticides available to growers at the time. That is, those compounds may have prevented the development of large and diverse predator populations.

This study was undertaken to determine the effects of area and thus climate, plus pest management on the species distribution and abundance of both phytophagous and predacious mites in Okanagan apple orchards.

Materials and Methods

The growing region was divided into four areas each centered on the principal town: Vernon, at the extreme north end of the growing region; Kelowna, approximately 70 km to the south; Summerland (including Penticton) a further 70 km south; and the Osoyoos-Oliver-Cawston area about the same distance south again and close to the U.S. boundary, referred to here as Oliver/Osoyoos. After discussions with packing house field persons and private pest management consultants, orchards were selected in each of the four areas and classified as abandoned, organic, integrated or traditional. Abandoned orchards usually consisted of a few trees that had not been tended for at least the previous season. No, or few, synthetic chemical sprays were applied to organic orchards, but the frequency of chemical applications in

integrated orchards was limited to those occasions when a pest exceeded a pre-specified threshold. In some of the integrated orchards that we studied, this resulted in no sprays being applied for the year of the study. Traditional orchards were sprayed largely on a calendar basis without reference to the population levels of pest species present. There were at least two orchards in each classification in each region except for a single abandoned orchard in the Vernon area.

Mite populations were sampled every two weeks from mid-May to mid-August, 1983 by randomly selecting 20 leaves per tree from a minimum of 10 trees per orchard. Spur leaves were used early in the season and current year shoots later. The variety "Red Delicious" was used whenever possible. The leaves were then processed with a mite brushing machine as described in Morgan *et al.* (1955) and results were recorded and analyzed on the basis of mites/20 leaves. Phytophagous mites were identified to species by using a stereo microscope during the counting. Every 2nd to 5th phytoseiid predacious mite encountered on the counting plate was mounted in Hoyer's medium and identified to species using a phase-contrast compound microscope.

None of the orchards studied received a miticide application, other than dormant oil, during the season of the study.

The total number (per 20 leaves) of each species of mite found on each sampling occasion for the duration of the study was subject to a two-way Analysis of Variance (using location and pest management method as main effects) and the Least Significant Difference test (SAS, Proc GLM). Data were transformed to log (x+1) when appropriate.

Results and Discussion

Three species of phytophagous mites *(P. ulmi, A. schlectendali* and *T. mcdanieli)* were found in the leaf samples. *T. mcdanieli* was found so infrequently that it was not included in any further analyses. Four species of Phytoseiidae *(Typhlodromus occidentalis* Nesbitt, *T. caudiglans* Schuster, *T. columbiensis* Chant and *Amblyseius* sp. near *herbarius* Wainstein were found reguarly though T. columbiensis was found in only one orchard and in small numbers, and the Amblyseius sp. was very rare, occurring only in integrated control orchards in the southern half of the valley.

Contribution No. 651

Table I. Mean (± standard error) total number of European red mites per 20 leaves after the indicated number of elapsed days sampled from commercial orchards under four pest management systems in four areas of the Okanagan Valley of British Columbia in 1983.

Area	Days	Abandoned	Organic	Integrated	Traditional	Area mean	
Vernon	78	0.7/0.3	58.8/19.9	0.6/0.4	113.4/33.7	43.0/12.3	1
Kelowna	77	1.1/0.5	4.4/1.7	1.6/0.5	2.5/1.3	2.4/0.6	2
Summerland	83	0.1/0.1	0.5/0.3	18.2/6.9	4.8/2.0	5.9/2.1	2
Oliver/ Osoyoos	84	1.6/0.4	0.0	12.9/4.4	5.8/1.6	6.9/2.0	2
Mean		0.9/0.2 a	14.5/5.9 bc	9.9/2.6 bc	26.3/9.8 b		

*Means followed by the same letter or number are not significantly different (LSD, P<0.05)

The ERM population was larger in the Vernon area than in the three other areas (Table I) and populations were higher in traditional, integrated and organic orchards than in abandoned orchards (Table I). The two-way ANOVA showed a significant interaction effect for area and pest management system presumably because of the large number of ERM found in the Vernon orchards. If the Vernon area data are omitted from the analysis there are no significant area affects and the number of ERM found in integrated orchards is significantly higher than in the other 3 types ($p < 0.01$).

There were more rust mites in the Oliver/Osoyoos area than in the three more northerly areas and in traditional and organic orchards than in either abandoned or integrated orchards (Table II).

The phytoseiid population was also larger in the Oliver/Osoyoos area than in the other areas (Table III) but did not appear to differ between orchard types.

As nearly 100% of the growers in the study had applied dormant oil for ERM control at the beginning of the year, ERM population differences between orchards must be due to factors other than the use or non-use of dormant control measures. That is, dormant control using oil probably acts in a density-dependant manner. Only those eggs exposed to the oil fail to hatch, and in large populations more eggs would be in exposed situations than in small populations. Therefore we would expect similar egg survival regardless of the size of the egg population as there are only a limited number of refugia available. Differences in phytoseiid numbers and species, differences in predator efficiency resulting from species or strain differences, and differences in climate that might favour one area over the other in terms of rate of population increase or predation rate could explain differences in ERM populations between orchards. These influences may act in concert or individually at different times.

Table II. Mean (± standard error) total number of apple rust mites per 20 leaves after the indicated number of elapsed days sampled from commercial orchards under four pest management systems in four areas of the Okanagan Valley of British Columbia in 1983.

Area	Days	Abandoned	Organic	Integrated	Traditional	Area mean
Vernon	78	804.8/ 353.6	3755.7/ 1156.1	72.8/ 41.1	606.2/ 409.6	1372.5/ 434.3 1
Kelowna	77	54.3/ 25.8	2521.7/ 811.2	1063.9/ 509.8	2348.4/ 889.9	1475.3/ 358.7 1
Summerland	83	183.7/ 60.7	1089.7/ 790.6	927.7/ 433.7	2379.9/ 857.4	1189.2/ 342.1 1
Oliver/ Osoyoos	84	1892.9/ 642.5	2200.7/ 869.3	1809.9/ 413.1	6116.1/ 1735.7	2627.5/ 449.7 2
Mean		1065.4/ 333.7 a	2190.8/ 466.6 b	1210.6/ 242.6 a	3045.5/ 672.9 b	

*Means followed by the same letter or number are not significantly different (LSD, $P<0.05$)

Table III. Mean (± standard error) total number of Phytoseiids per 20 leaves after the indicated number of elapsed days sampled from commercial orchards under four pest management systems in four areas of the Okanagan Valley of British Columbia in 1983.

Area	Days	Abandoned	Organic	Integrated	Traditional	Area mean
Vernon	78	8.0/1.9	7.0/2.4	0.0	0.5/0.3	3.4/0.9 1
Kelowna	77	1.2/0.7	1.2/0.5	2.8/0.8	10.4/2.0	4.0/0.9 1
Summerland	83	6.5/2.4	1.5/0.7	3.4/1.5	1.1/0.5	3.0/0.8 1
Oliver/ Osoyoos	84	5.7/2.1	4.2/1.3	10.5/2.0	7.4/1.7	8.1/1.1 2
Mean		5.2/1.1	3.4/0.8	6.2/1.1	4.9/1.0	

* Means followed by the same number are not significantly different (LSD, $P<0.05$)

Twenty-nine-year, yearly average maximum and minimum temperatures and yearly precipitation (Table IV) show that there is a cold to warm temperature gradient from north to south and a somewhat similar high to low precipitation gradient. However, the Osoyoos area is intermediate between the Vernon and the other two areas for precipitation. This suggests that mite population growth should be slower at the north end of the valley than at the south end. Temperature dependant phenomena such as phytoseiid predation rates should also be lower in the north than in the south, at least early in the season when temperature differences would be greatest. Therefore, the same number of phytoseiids should consume more prey per unit time in the south end of the valley than in the north end. This would allow a peak number of phytoseiids in the north to be associated with a larger population of ERM than a similar phytoseiid population in the south.

Table IV. Mean yearly minimum temperature, maximum temperature and rainfall (29-year average) for four areas of the Okanagan Valley of British Columbia.

Area	Minimum (C)	Maximum (C)	Rainfall (mm)
Vernon	1.8	12.6	290.4
Kelowna	2.2	13.2	221.9
Summerland	4.0	13.8	213.5
Oliver/Osoyoos	4.6	15.9	245.6

Source: Canadian Climate Normals. 1951-1980. Environment Canada.

Phytoseiid winter mortality is greater in the north than in the south. During the winter of 1985-86 phytoseiid mortality was near 100% in the Kelowna area while it was 80-85% in the Oliver area. Therefore, phytoseiid populations in the north would be lower at the start of the year, and may not be so responsive to prey population increases because of the reduced average temperatures. It is not possible to assess the applicability of this assumption with only one years data.

Although there are temperature differences between the areas, the variation between Vernon and Kelowna, for example, is probably not great enough to completely account for the differences in phytophagous mite populations found. Qualitative differences between predator populations may be important. *T. occidentalis* and *T. caudiglans* were the most abundant phytoseiids found during this survey. *T. caudiglans* comprised only 0.01% of the total predators found in the Vernon area but was found in varying numbers in the other areas. On both an area and a management system basis, *T. caudiglans* was always less abundant than *T. occidentalis* (Tables V and VI).

In abandoned orchards, *T. caudiglans* was the most abundant phytoseiid. It was almost totally absent from organic and traditional orchards, and was present in variable mumbers in integrated orchards (Table VI). This relationship was consistent in two of the three areas in which *T. caudiglans* was present; it was not found in the integrated control orchards that we studied in the Summerland area.

Table V. Percent composition by species of Phytoseiidae in commercial apple orchards in four areas of the Okanagan Valley of British Columbia in 1983.

	Percent composition	
Area	Typhlodromus caudiglans	Typhlodromus occidentalis
Vernon	0.01	99.9
Kelowna	24.1	75.9
Summerland	6.0	94.0
Oliver/Osoyoos	18.7	81.3

It has been reported by Downing and Moilliet (1972) that if organophosphate sprays are terminated, *T. caudiglans* will competitively displace *T. occidentalis* but if the sprays are resumed the reverse occurs. We found an apparent relationship between the relative abundance of *T. caudiglans* and the use of organophosphates (such as phosmet, phosalone, azinphosmethyl) and growing area or no organophosphate use. In effect, organophosphates essentially exclude *T. caudiglans* from orchards in the north but not in the south. *T. caudiglans* was found in 13 orchards; three in the Kelowna area, three in the Summerland area and the balance in the South End. No organophosphates were used in those orchards where it was found outside of the Oliver/Osoyoos area, while phosmet, phosalone or azinphosmethyl were used in five of the seven orchards in that area. A study is currently underway to confirm the possibility that *T. caudiglans* may have developed resistance to organophophates in the southern part of the valley. This could be important if true, because our data and those of others such as Downing and Moilliet (1972) suggest that *T. caudiglans* is superior to *T. occidentalis* for the control of ERM.

Table VI. Percent composition by species of Phytoseiidae in Okanagan (British Columbia) apple orchards subject to different pest management strategies in 1983.

Management strategy	Percent composition	
	Typhlodromus caudiglans	*Typhlodromus occidentalis*
Traditional	1.0	97.9
Integrated	2.6	97.4
Organic	0.2	99.8
Abandoned	52.7	47.3

Further evidence for the superiority of *T. caudiglans* as a predator comes from observations made in an orchard with a very low codling moth population that resulted from the sterile male method of codling moth control of some years earlier. The orchard presented an opportunity for comparison when it became necessary to spray one half of the orchard for codling moth control in 1984. In 1983 *T. caudiglans* made up more than 50% of the phytoseiid population in this orchard and ERM were barely detectable. In 1984, after azinphosmethyl was applied, the phytoseiid population in the unsprayed half of the orchard still consisted primarily of *T. caudiglans* and ERM were still at very low levels. But *T. caudiglans* was virtually eliminated from the sprayed half of the orchard, although *T. occidentalis* survived. ERM levels in the sprayed half exceeded economic threshold values for the first time in 6 years (Table VII).

In conclusion, it appears that different growing areas, with their associated climatic differences and pest management practices can affect the distribution and abundance of both phytophagous and predacious mites.

Table VII. Percent composition by species of Phytoseiidae (*Typhlodromus* spp.), mean number of phytoseiids/20 leaves at peak population levels and European red mite (ERM)/20 leaves at peak population levels in the Herz orchard, Cawston, B.C during 1983 and 1984.

Year	Percent composition		Numbers/20 leaves at peak levels	
	T. caudiglans	*T. occidentalis*	Phytoseiidae	ERM
1983 unsprayed	68.4	31.6	26.0	2.0
1984 unsprayed	97.6	2.4	8.0	3.0
1984 sprayed	0	100.00	4.0	1386.4

Acknowledgements

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References

Anderson, N.H. and C.V. Morgan. 1958. The role of *Typhlodromus* spp. (Acarina: Phytoseiidae) in British Columbia apple orchards. Proc. 10th Int. Cong. Ent. **4**: 659-665.

Anderson, N.H., C.V. Morgan and D.A. Chant. 1958. Notes on occurrence of *Typhlodromus* and *Phytoseius* spp. in southern British Columbia (Acarina:Phytoseiinae). *Can. Ent.* **90**: 275-279.

Downing, R.S. and T.K. Moilliet. 1971. Occurrence of phytoseiid mites (Acarina:Phytoseiidae) in apple orchards in south central British Columbia. *J. Ent. Soc. B.C.* **68**: 33-36.

Downing, R.S. and T.K. Moilliet. 1972. Replacement of *Typhlodromus occidentalis* by *T. caudiglans* and *T. pyri* (Acarina:Phytoseiidae) after cessation of sprays on apple trees. *Can. Ent.* **104**: 937-940.

Downing, R.S. and J. Arrand. 1976. Integrated control of orchard mites on apple in British Columbia. *Can. Ent.* **108**: 77-81.

Morgan, C.V., D.A. Chant, N.H. Anderson and G.L. Ayre. 1955. Methods for estimating orchard mite populations, especially with the mite brushing machine. *Can. Ent.* **87**: 189-200.

EFFICACY AND RESIDUES OF CHLORPYRIFOS APPLIED AGAINST ROOT MAGGOTS ATTACKING COLE CROPS IN BRITISH COLUMBIA

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Abstract

Chlorpyrifos proved to be as effective as chlorfenvinphos, and more effective than fensulfothion and diazinon for cabbage maggot control in root and stem crucifers. For short season crops such as cauliflower, broccoli and cabbage, the granular formulation applied at seeding, followed in 21 days with a single drench of the emulsifiable liquid formulation was adequate. In Brussels sprouts, the slowest of the stem crucifers to mature, a minimum of two drench applications were necessary for acceptable control. In rutabaga, another long season crop, chlorpyrifos 15G applied at seeding followed by 3 drench applications (i.e. at 21 day intervals) after seeding was necessary to produce rutabagas with acceptable damage levels at harvest. In the sandy-clay loam where these studies were undertaken, chlorpyrifos applied at the dosage rates and at the times prescribed for the stem and root crucifers studied did not give rise to appreciable residues at harvest. These studies show that a pre-harvest interval of 32 days would be appropriate for the 5 crops studied.

Introduction

The cabbage maggot, *Delia radicum* (L.), is a chronic and serious pest of cole crops grown in the Fraser Valley and Vancouver Island regions of B.C. If not adequately controlled, maggot feeding may kill, weaken or stunt developing plants and reduce yields considerably. In root crucifers such as rutabaga and turnip, maggots can render the crop unmarketable if more than slight damage caused by their feeding is evident on the roots at harvest. Research into the biology and control of this pest pertinent to this growing region has been reported by King and

Forbes (1954,1958); King *et al.* (1955); Forbes (1962); and Finlayson *et al.* (1967,1980). Since the 1950's, insecticides have been the mainstay of successful maggot control programs in commercial production in B. C. Initially, chlorinated hydrocarbon insecticides were used, until resistant strains of the maggot were identified in the Pacific Northwest in 1959 (Howitt and Cole 1962; Finlayson 1962). At present, control of root maggots attacking the stem crucifers, broccoli, Brussels sprouts, cabbage and cauliflower, relies exclusively on granular and/or drench applications of organophosphates such as chlorfenvinphos, fensulfothion, and diazinon. These chemicals, with the addition of phorate and carbofuran, a carbamate, are also registered for use on root crucifers such as rutabagas and turnips.

Although the arsenal of insecticides currently available against the cabbage maggot seems adequate, there are in fact problems associated with each registrant. Fensulfothion and diazinon, for example, have failed in recent years to provide commercially acceptable maggot control in both the field and seed bed (M. Sweeney, personal communication, Simonet 1981). Although not verified, an increasing tolerance of the pest to these insecticides is suspected. Chlorfenvinphos, although still effective, can, under certain environmental conditions, or if misapplied, reduce germination or stunt seedlings (Mackenzie and Vernon 1984). Phytotoxicity has also resulted from the improper use of fensulfothion. For the root crucifers, carbofuran still appears efficacious, however, chronic use of this material can result in the proliferation of soil bacteria antagonistic to the persistence of this pesticide (Felsot *et al.* 1981,1982). Where this has occurred, as in Illinois (Felsot 1982), the effective longevity of carbofuran has been markedly reduced. Locally, there is some evidence that such "antagonistic" soils are emerging in the muckland soil growing region of Cloverdale. Finally, phorate, available only in the granular formulation, is restricted to a single application at seeding and is prohibited from use in highly organic soils. These considerations cast doubt on the current and future usefulness of these insecticides for cabbage maggot control in B.C. For the B.C. cole crop industry to remain viable, it is essential to expand the chemical control options available to growers.

From 1980 to 1986, a number of insecticides were screened for cabbage maggot control on root and stem crucifers. Of those tested, chlorpyrifos, an organophosphate, appeared to be as efficacious as the insecticides currently registered, or more so and, because chlorpyrifos is registered for root maggot control in onions, it is well suited for expedient registration on cole crops. This paper reports: 1) the efficacy and phytotoxicity of the granular and liquid formulations of chlorpyrifos in comparison with other candidate insecticides for registration; 2) the optimum rates, number and timing of chlorpyrifos applications for effective use under B. C. growing conditions; and 3) residues of chlorpyrifos in marketable produce at harvest.

Methods and Materials

Efficacy and Phytotoxicity

Between 1981 and 1986, 20 field studies were carried out at the Abbotsford research substation of Agriculture Canada. With the exception of one cauliflower experiment, which was transplanted, all crops were direct-seeded in beds of 2 rows spaced 60 cm apart with 120 cm between rows in adjacent beds. The plants were thinned to 30 cm spacings within the row. Treatment plots were beds, i.e. row pairs, 7.5 m in length and replicated 4 times in a randomized block design.

Insecticides were applied to a sandy clay loam either as granules at the time of seeding or as drenches after seeding. The granular formulations were applied in a 15 cm wide band with a custom built geared applicator attached to and driven by a hand-pushed Stanhay precision seeder. Incorporation of the granules to a depth of about 2.0 cm was achieved by the bow-wave method, where the granule delivery tube is positioned directly in front of the seed coulter. During seeding the coulter ploughs the granules to either side of the furrow. The dragging-bar behind the coulter then fills in the furrow and spreads the granules in a band. The rear wheel of the seeder compacts the treated soil to complete the application. Drenches were applied to the soil at low pressure with a Solo back-pack sprayer to 10 cm on both sides of the plants in the row in a volume of 0.7-2 L water/10m row (1,100-3,300 L water/ha). Granular and liquid

formulation rates are expressed as grams of active ingredient (a.i.) applied to 10 m of seeded row. Granular treatments included chlorfenvinphos 10G (10% a.i.); terbufos 15G (15% a.i.); fensulfothion 15G (15% a.i.); diazinon 5G (5% a.i); and chlorpyrifos 15G (15% a.i.). Rates of chlorpyrifos ranged from 0.9-2.2 g a.i./ 10 m of row in efficacy studies, and from 0.9-3.0 g a.i./10 m of row in phytotoxicity studies. Rates of the other insecticide granulars are shown in Table 1 or are mentioned in the Results. Drench treatments included chlorfenvinphos 40 E (40% a.i.), fensulfothion 6 E (60% a.i.) and diazinon 50 E (50% a.i.). Chlorpyrifos drenches were prepared from the 4EC and 4E-HF formulations, both containing 40.7% active ingredient. Rates and post-seeding dates of drench applications are shown in Tables 1 and 2, or are mentioned in the Results.

Treatment efficacy was assessed by rating maggot damage to roots. Plants from each treatment replicate were uprooted, washed free of soil, and the damage assessed visually using the method of King and Forbes (1954). Roots with no damage were assigned a value of 0 (=none); 1 (=slight); 2 (=moderate); 4 (=severe); and 8 (=very severe). The average value for each treatment was the maggot damage index (D.I.) of that treatment. Rutabagas graded with a D.I. higher than 1 were considered unmarketable.

Phytotoxicity was assessed by counting the number of emerged seedlings either along the entire length of seeded row or within a fixed length of row measured mid-way along the total plot length. Other symptoms of phytotoxicity, such as stunting, leaf cupping, discolouration, and burning were noted when apparent.

The data were transformed by the square root of x + .5 before analysis of variance.

Residue Analyses

Preparation of Plant Tissue Samples. Plant tissue was analyzed for residues of chlorpyrifos and its degradative products using the following method. Samples of cabbage, cauliflower, broccoli, Brussels sprouts, and rutabagas were chopped and thoroughly mixed with a food processor according to crop, treatment and sampling date. Aliquots of 20 g of plant tissues were extracted twice with 100 ml of dichloromethane:acetone (3:2, V:V) mixture in a polytron homogenizer. The extracts were filtered through a Buchner funnel lined with a glass fibre filter paper. The combined extracts were transferred quantitatively to 500 ml separatory funnels to allow separation of the two phases. The aqueous phases were separated and re-extracted with dichloromethane after salting out with sodium chloride. The combined organic phases were dried on anhydrous sodium sulfate and then evaporated just to dryness in a flash evaporator at 38 C. The residues were dissolved in 10 ml of dichloromethane for chemical derivatization.

Chemical Derivatization of 3,5,6-trichloro-2-pyridinol. Crude extracts in dichloromethane equivalent to 2 g of tissue were transferred into 10 ml graduated glass stoppered reaction tubes, followed by the addition of 5 drops of etheral solution of diazoethane in a fume hood. They were thoroughly mixed and allowed to react at room temperature for 30 min. Upon completion of reaction, 10 drops of keeper (1% OV-1 methyl silicone in hexane) were added and the unreacted diazoethane was driven off with a stream of nitrogen. To the reaction products 4 ml of hexane was added, and mixed thoroughly for further clean-up on a Florisil column.

Clean-up of tissue extracts. Chromatographic columns (30 x 1.1 cm i.d.) with Teflon stopcocks were packed from bottom to top, with a glass wool plug, 1.5 cm of anhydrous Na_2SO_4, 6 cm of 2% water deactivated Florisil, 1.5 cm anhydrous Na_2SO_4, and another glass wool plug. The packed columns were prewashed with 10 ml of dichloromethane followed by 10 ml of hexane. The reaction products were then passed through the clean-up columns and the resulting eluates were collected. Chlorpyrifos, ethylated 3,5,6-trichloro-2-pyridinol (pyridinol) and 3,5,6-trichloro-2-methoxypyridine (methoxypyridine) were eluted with 25 ml of 25% dichloromethane in hexane. After the addition of 10 drops of keeper the eluates were concentrated to about 2 ml in a flash evaporator at 38 C. After the addition of 2 ml of isooctane the extracts were further concentrated to about 0.5 ml under a stream of nitrogen. The solvent exchange was repeated twice more and the final volumes were appropriately adjusted with isooctane before GLC analysis.

Gas Chromatography. GLC analyses were made with a Hewlett Packard Model 5890 gas chromatograph equipped with an electron capture detector for the ethylated 3,5,6-trichloro-2-pyridinol and 3,5,6-trichloro-2-methoxypyridine; for the chlorpyrifos a Hewlett Packard

Table 1. Efficacy in cauliflower (cv. Elgon) of chlorpyrifos and three insecticides registered for control of cabbage maggot on stem crucifers, as granules and drenches, Abbotsford, B.C., 1982.

Treatment	Dosage (g a.i./10 m)		Maggot damage index[3]		
	Granular	Drench	65 days[1]	85 days	93 days
Chlorpyrifos 15G + 4E (1 drench)	1.3	1.0	0.1a[2]	0.4a	0.6a
Chlorfenvinfos 10G + 40E (1 drench)	1.7	1.0	0.9ab	0.6a	0.3a
Fensulfothion 15G + 6E (1 drench)	1.3	1.3	2.8 cd	3.0b	4.4bc
Diazinon 5G + 50E (2 drenches)	1.9	1.5	1.7abc	4.1b	3.6b
Control	-	-	2.2bc	4.2b	3.7b

[1] Days after seeding.

[2] Values in each column followed by the same letter are not significantly different (Duncan's multiple range test, $P < 0.05$).

[3] Damage index: 0 = none; 1 = slight; 2 = moderate; 4 = severe; 8 = very severe.

Model 5880A gas chromatograph equipped with a flame photometric detector was used. The capillary columns were 10 m x 0.25 mm i.d. containing cross-linked methyl silicone. The operating parameters were: detector temperature 300 C for the electron capture detector and 200 C for the flame photometric detector; helium as carrier gas at 70 kPa; 5% methane in argon at 20 ml/min as makeup gas for the electron capture detector; hydrogen at 100 ml/min, air at 100 ml/min, and nitrogen at 30 ml/min for the flame photometric detector; column temperature program T_1 = 85 C, rate 1 = 30 C/min; T_2 = 165 C, rate 2 = 5 C/min; T_3 = 185 C, rate 3 = 20 C/min; T_4 = 225 C. Under the described chromatographic conditions the absolute retention times for 3,5,6-trichloro-2-methoxypyridine, ethylated 3,5,6-trichloro-2-pyridinol and chlorpyrifos were 3.89, 7.01 and 11.65 min respectively.

Method Evaluation. Plant tissue from the untreated control was fortified with 3,5,6-trichloro-2-methoxypyridine, 3,5,6-trichloro-2-pyridinol and chlorpyrifos at 1.0, 0.1, and 0.01 ppm (fresh wt.). Quadruplicates of the fortified samples at each level were processed and analyzed as described. The percentage recovery ranged from 81.1% to 96.2%.

Results

Preliminary Studies. In eight experiments from 1981 to 1984, the efficacy of chlorpyrifos was compared to the efficacy of one or more of the insecticides chlorfenvinphos, fensulfothion and diazinon, which were registered for stem crucifers. Trends in efficacy observed in these studies (typified by the study in Table 1) were comparable, regardless of the crop (*ie.* cabbage, broccoli or cauliflower).

In the study shown in Table 1, granular formulations of each insecticide were applied at seeding of cauliflower (cv Elgon), followed by a single drench 16 days later. Diazinon plots received a second drench 34 days after seeding. Treatments of chlorpyrifos gave control equivalent to that of chlorfenvinphos, and significantly ($P < 0.05$) better control than either fensulfothion or diazinon (Table 1). In this trial, the two drenches of diazinon plus the granular formulation at seeding did not even reduce the damage below that of untreated plots. Moderate damage was observed when roots were examined only 31 days after the second diazinon drench. Root damage observed in plots treated with chlorpyrifos and chlorfenvinphos was from none to slight, 77 days after the single drench. Similar long-term efficacy was observed in four studies comparing granular or drench applications of chlorpyrifos and chlorfenvinphos on direct-seeded broccoli, cauliflower and cabbage.

In 1982, a study was undertaken to further investigate the observed lack of efficacy with diazinon. Diazinon granules were applied at seeding, to broccoli (cv. Premium Crop), followed by drenches 17 and 31 days after seeding, using up to twice the registered rates, *i.e.* 3.4 and 2.67 g a.i./10 m of row for the 5G and 50E formulations, respectively. Roots examined for maggot damage in diazinon-treated plots 29 days and at harvest 42 days after the last drenches, were not significantly different from those in the untreated plots. Moderate to severe damage was observed in all plots at harvest.

Chlorpyrifos Efficacy. A series of studies aimed at identifying the most effective formulations, dosage, and timing of chlorpyrifos applications were conducted from 1984 to1985. With respect to dosage, chlorpyrifos 15G was tested alone at 0.9, 1.6, and 2.2 g a.i./10 m row, and the 4E formulation was tested alone in a drench at 1.0 and 2.0 g a.i./10 m. Drenches were applied 3 days after seeding broccoli, (cv. Premium Crop). Fifty-four days after seeding, root maggot damage was significantly lower in all plots treated with chlorpyrifos granular or drench as compared to the untreated plots. Root damage indices were 0.6, 0.4, and 0.1 in plots treated with the lowest to highest rates of granular chlorpyrifos, respectively, while indices of 1.2 and 0.1 were assessed in plots receiving the lower and higher drench rates, respectively. A damage index (D.I.) of 3.9 (= severe damage) was recorded in the untreated plots. The importance of chlorpyrifos 15G dosage on root maggot efficacy is also shown in Table 2 for three stem crucifers. Applied at 0.9 or 2.2 g a.i./10 m of row, chlorpyrifos-treated plots had significantly less damage than untreated plots 72, 82 and 88 days after seeding cabbage, broccoli and Brussels sprouts, respectively. Chlorpyrifos 15G, even at the low rate tested, resulted in only slight damage (D.I. = 1.7) as compared to severe damage (D.I. = 6.7) in the untreated plots. In a study conducted in 1981, under an above normal population of cabbage flies, chlorpyrifos 15G applied at 1.3 g a.i./10 m of row did not provide significantly better control compared to untreated plots after 65 days.

The effects of timing and number of chlorpyrifos applications on root maggot efficacy are also shown in Table 2. In these studies, chlorpyrifos 15G and chlorpyrifos 4E-HF (applied in 1-4 drenches) were tested alone or in combination on the stem crucifers cabbage, broccoli and Brussels sprouts, and on the root crucifer, rutabaga. In all crops, maggot damage indices were significantly lower in plots treated with chlorpyrifos than in untreated plots. Damage was from none to slight in cabbage, broccoli and Brussels sprouts plots receiving a granular plus single drench application, or two drench applications alone, as compared to severe damage in the

untreated plots. To maintain rutabagas during the 113-day growing period, in the slight damage category required for marketing, a granular application plus three drench applications was needed. Four drench applications alone gave between slight and moderate damage. In another rutabaga study, a slight D.I. of 0.4 was found in plots treated with as few as three drenches compared to a D.I. of 6.2 in the control. Damage in plots receiving fewer applications, however, was moderate.

Chlorpyrifos Phytotoxicity. In phytotoxicity studies completed in 1985 and 1986, chlorpyrifos 15G did not significantly reduce seedling emergence or reduce vigour when applied at 2.2 g a.i./10 m row to direct-seeded cauliflower, Brussels sprouts, broccoli and rutabaga. In one 1985 study, however, a 30% reduction in cabbage seedling emergence was observed in chlorpyrifos plots treated with 0.9 and 2.2 g a.i./10 m row. When this study was repeated in 1986, no reduction in emergence occurred even at a rate of 3.0 g a.i. Chlorpyrifos 4E, applied to moist soil at 1.0 g a.i./10 m of row in a drench 7 days after seeding did not reduce seedling emergence of the five crops. Three days after drenching, however, the primary leaves of cabbage seedlings showed a moderate cupping and bluish discoloration. Broccoli and rutabaga seedlings suffered milder symptoms, but after 2 weeks no symptoms were noticeable on any of the crops. In another study, chlorpyrifos 4E applied at 1.0 or 2.0 g a.i./10 m row in a drench 3 days after seeding significantly reduced the emergence of broccoli.

Residues. In the study shown in Table 2, rutabaga samples were taken from the experimental plots and analyzed for residues of chlorpyrifos and its degradative products. Total residues in rutabaga tissue sampled from plots treated with four drenches of chlorpyrifos 4E were only 0.06 ppm 17 days after the last application, and 0.05 ppm after 15 days in tissue from plots treated with granular at seeding and three drenches. Samples of broccoli, Brussels sprouts, cabbage and cauliflower tissue were analyzed by the same procedure. No residues of chlorpyrifos or its degradative products were detected in any of the samples of stem crucifers at harvest.

Discussion. The results from these studies clearly indicate that, in B.C., chlorpyrifos and chlorfenvinphos provided better protection against cabbage maggot damage than diazinon and fensulfothion. The possibility that resistance or tolerance to diazinon and fensulfothion is developing in *Delia radicum* locally is a subject that warrants further investigation. Chlorpyrifos proved to be as efficacious as chlorfenvinphos for cabbage maggot control in all the major stem crucifers, and showed excellent promise for use in root crucifers. Phytotoxicity does not appear to be a serious problem with the granular formulation of chlorpyrifos. Applied as a drench, however, chlorpyrifos did cause some seedling mortality when applied 3 days after seeding. At that time, seeds were just germinating and would have been in a very susceptible stage of growth. Drenching with chlorpyrifos 7 days after seeding or thereafter resulted in only mild symptoms of phytotoxicity which were rapidly outgrown. Usually no symptoms were observed. When drench-related symptoms of phytotoxicity did occur, they were associated with conditions of high temperature or drought. In an Ontario study, chlorpyrifos caused no phytotoxic effects when applied after emergence to cabbage, chinese cabbage, broccoli, rutabaga, Brussels sprouts or cauliflower at 1.12 and 2.24 Kg a.i./ha (Harris *et al.* 1975).

Our studies indicate that for direct-seeded crucifers, combined treatments of chlorpyrifos granular and emulsifiable liquid formulations consistently provided excellent maggot control. For short season crops such as cauliflower, broccoli and cabbage, the granular formulation applied at seeding, followed in 21 days with a single drench of the emulsifiable liquid formulation would be adequate. In a heavy cabbage maggot infestation, a granular or single drench application alone would not be sufficient to prevent damage, as was observed in one of the studies. In Brussels sprouts, the slowest of the stem crucifers to mature, a minimum of two applications were necessary for acceptable control. Considering the long growing season requirements of Brussels sprouts, and the potential for late season invasion by cabbage maggots into developing sprouts (Finlayson and Mackenzie 1979), we think that three applications would give adequate protection, even in years when high numbers of flies are

Table 2. Comparison of chlorpyrifos granular and emulsifiable formulations applied at different rates, schedules and numbers of applications on four major crucifers, Abbotsford, B.C., 1982.

Chlorpyrifos treatment	Mean Root Damage Indices							
	Cabbage		Broccoli		Brussels sprouts		Rutabagas	
15G (0.9 g a.i.)	1.0a[1]	75[2]	0.5a	82	1.7a	88	NT[3]	
15G (2.2 g a.i.)	0.2a	75	1.1a	82	1.5a	88	4.6c	113
15G + 4E[4] (1 drench)	0.2a	53	0.0a	60	0.1a	67	3.0b	93
15G + 4E (2 drenches)	NA[5]		NA		NT		2.1ab	69
15G + 4E (3 drenches)	NA		NA		NA		1.0a	44
4E (1 drench)	0.8a	68	0.8a	75	1.6a	80	4.5c	98
4E (2 drenches)	0.1a	45	0.1a	52	0.9a	60	3.0b	82
4E (3 drenches)	NA		NA		0.2a	39	2.3ab	61
4E (4 drenches)	NA		NA		NA		1.6ab	40
Control	6.7b	-	4.6b	-	6.7b	-	6.6d	-

[1] Values followed by the same letter are not significantly different (Duncan's multiple range test, $P < 0.05$).

[2] Days to root examination from last chlorpyrifos application.

[3] NT: Not tested.

[4] Except where noted, granular treatments were applied at a rate of 2.2 g a.i./10 m seeded row, drenches at 1.0 g a.i.

[5] NA: Not applicable since small number of days from seeding to harvest do not permit this many drench applications.

laying eggs. In rutabaga, another long season crop often requiring 110 days to mature, the roots must be virtually free of maggot damage at harvest. Due to the long growing period involved, and the strict damage limits, chlorpyrifos 15G applied at seeding followed by three drenches at 21 day intervals after seeding, would be necessary to produce rutabagas with no more than slight damage.

With respect to dosage, chlorpyrifos 15G provided acceptable control, *i.e.* slight damage, when applied at 0.9-2.2 g a.i./10 m of row. In the U.S., chlorpyrifos 15G is currently recommended for use on stem crucifers at rates of 0.6-1.4 g a.i./10 m of row, which compares favourably with our results. Chlorpyrifos 4E at 1.0 g a.i./10 m of row in a drench was efficacious and economical for post-planting maggot control. In the sandy-clay loam where these studies were undertaken, chlorpyrifos applied at the dosage rates and at the times prescribed for the stem and root crucifers studied, would not result in appreciable residues at harvest. Our studies suggest that pre-harvest intervals of 32 and 28 days would be appropriate for the 4 stem crucifers tested and for rutabagas, respectively. A 32-day pre-harvest interval is currently recommended for use of chlorpyrifos on stem crucifers in the U.S.

Recently, chlorpyrifos 4E was granted registration for use as a drench on the stem crucifers cauliflower, broccoli and cabbage in Canada, and this insecticide is now being used almost exclusively for maggot control in these crops in B.C. Complete registration of chlorpyrifos 4E and 15G formulations, to be applied according to the optimal findings reported herein on stem and root crucifers, is also being sought.

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References

Felsot, A. S., Maddox, J. V., and B. Willis. 1981. Enhanced microbial degradation of carbofuran in soils with histories of Furadan use. *Bull. Environ. Contam. Toxicol.* **26**: 781-788.

Felsot, A. S., Wilson, J. G., Kuhlman, D. E., and K. L. Steffey. 1982. Rapid dissipation of carbofuran as a limiting factor in corn rootworn (Coleoptera: Chrysomelidae) control in fields with histories of continuous carbofuran use. *J. Econ. Entomol.* **75**: 1098-1103.

Finlayson, D. G., M. D. Noble and H. G. Fulton. 1967. Protection of stem crucifers from cyclodiene-resistant maggots in sandy loam and peat soils. *J. Econ. Entomol.* **60(1)**: 132-137.

Finlayson, D. G. and J. R. Mackenzie. 1979. Combination sprays for control of foliar pests of Brussels sprouts. Pesticide Research Report, Expert Committee for Pesticide Use in Agriculture.

Finlayson, D. G., J. R. Mackenzie and C. J. Campbell. 1980. Interactions of insecticides, a carabid predator, a staphylinid parasite, and cabbage maggots in cauliflower. *Environ. Entomol.* **9**: 789-794.

Forbes, A. R. 1962. Oviposition of the cabbage fly, *Hylemya brassicae* (Bouche) (Diptera: Anthomyiidae) in coastal British Columbia. *Proc. Entomol. Soc. Brit. Columbia* **59**: 47-49.

Harris, C. R., H. J. Svec, W.W. Sans, A. Hikichi, S. C. Phatak, R. Frank and H. E. Braun. 1975. Efficacy, phytotoxicity, and persistence of insecticides used as pre- and postplanting treatments for control of cutworms attacking vegetables in Ontario. *Proc. Entomol. Soc. Ont.* **105**: 65-75.

King, K. M., A. R. Forbes, D. G. Finlayson, H. G. Fulton and A. J. Howitt. 1955. Co-ordinated experiments on chemical control of root maggots in rutabagas in British Columbia and Washington, 1953. *J. Econ. Entomol.* **48**: 470-473.

King, K. M. and A. R. Forbes. 1954. Control of root maggots in rutabagas. *J. Econ. Entomol.* **47(4)**: 607-615.

King, K. M. and A. R. Forbes. 1958. Ten years' field study of methods of evaluating root maggot damage and its control by chemicals in early cabbage. Proc. 10th. Int. Cong. of Entomol (Ital). **3**: 307-311.

Mackenzie, J. R. and R. S. Vernon. 1984. Efficacy of soil-applied chlorpyrifos granules against root maggots attacking cole crops. Pesticide Research Report, Expert Committee for Pesticide Use in Agriculture p.84.

Simonet, D. E. 1981. Cabbage maggot control on direct seeded cabbage, 1980. Insecticide and Acaracide Tests. Ent. Soc. of America Pub., K. Sorensen ed. College Park, Maryland. (6)62.

Sweeney, M. District Horticulturist. British Columbia Ministry of Agriculture and Fisheries, Abbotsford, B.C.

SAMPLING THE TWOSPOTTED SPIDER MITE *TETRANYCHUS URTICAE* (ACARI: TETRANYCHIDAE), ON COMMERCIAL STRAWBERRIES

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A simple, quick and unbiased sampling method has been developed for *Tetranychus urticae* Koch on strawberries (Raworth 1986). The method was based on the relationship between the mean number of *T. urticae*/leaflet (mtl) and the proportion of leaflets without *T. urticae* ($\hat{p}_o$). Data from small experimental field plots (7x7m) were used to develop the method. This note describes work conducted to determine if the method could be applied to large scale commercial fields.

Ten commercial strawberry fields, 0.2 – 5 ha in size, located between Ladner and Agassiz, British Columbia were sampled at 1-2 week intervals from 15 May to 8 July 1986. Two people collected a representative sample of mature, fully opened leaflets along non-overlapping, parallel, diagonal transects. One leaflet was picked every third or fifth row depending on field width. Headband magnifiers (1.5x magnification) were used to examine the leaflets for the presence or absence of *T. urticae*. Once 200 leaflets were sampled, $\hat{p}_o$ was calculated and Table 2 from Raworth (1986) was used to determine sample size such that the precision of the estimate of mtl was maintained at 1 S.E. < 0.2(mtl) for most samples. Accordingly, an additional 100 or 200 leaflets were picked and examined if $\hat{p}_o$ exceeded 0.5 or 0.65, respectively. The final estimate of $\hat{p}_o$ was calculated and the time taken to complete the sample was noted.

An estimate of mtl could be derived from $\hat{p}_o$, but only if a valid relationship between mtl and $\hat{p}_o$ still existed given the sampling method described above. To test this assumption, each sample was stored at 4°C and then examined with a stereomicroscope at 10x magnification to determine mtl. The relationship between mtl and $\hat{p}_o$ was compared with Raworth's (1986) relationship derived from small field plots (Fig. 1). In the latter study, mtl and $\hat{p}_o$ were determined by examination of individually bagged leaflets at 15x magnification. There was no statistical difference ($p > 0.05$) between the slopes or intercepts of the two regressions. This suggests that the sampling method described can be used to provide valid estimates of mtl. The overall regression for Figure 1 may be used to generate a table of $\hat{p}_o$, with associated mtl, sample sizes and standard errors as described in Raworth (1986), given: regression residual mean square (RMS)= 0.4167; number of estimates of mtl and $\hat{p}_o$ (NEMP0)=104; mean of $\log_e(-\log_e(\hat{p}_o))$ (MLP0)= –0.3511; sum of squared deviations of $\log_e(-\log_e(\hat{p}_o))$ (SSDLP0)= 173.8; regression intercept Fig. 1 (IMP0)= 2.144; slope Fig. 1 (SMP0)=1.351; intercept of the mean-variance relationship (Raworth 1986) (IMV)= 2.306; slope of the mean-variance relationship (SMV)= 1.644; and an algorithm written in FORTRAN (Appendix 1).

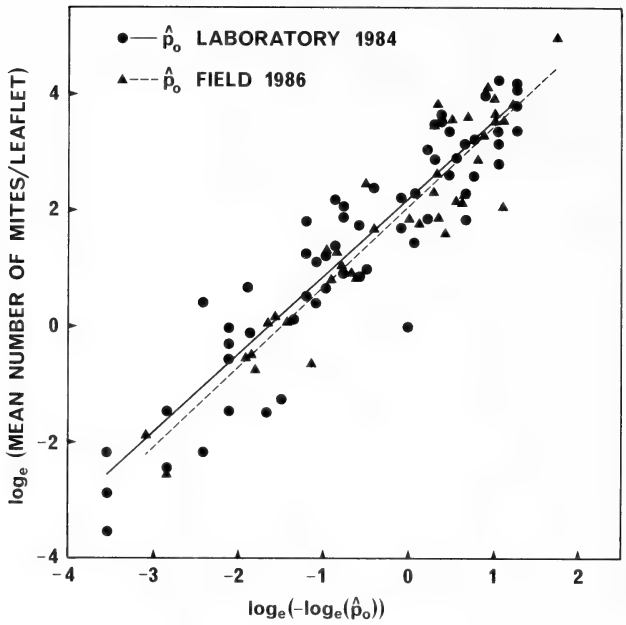

FIG. 1. Mean number of *Tetranychus urticae*/strawberry leaflet (mtl) as a function of the proportion of leaflets without *T. urticae* ($\hat{p}_o$). Overall regression: Y = 2.144 + 1.351 X (r = 0.939, 102df).

The time taken to sample a field to determine $\hat{p}_o$ increased with the number of leaflets examined (Eq. 1). The density of *T. urticae* also affected the sample time significantly ($p<0.05$) (Eq. 2). The higher the density the easier it was to see *T. urticae*, so that less time was used examining each leaflet.

$$Y = -1.48 + 0.150\ X \quad (r=0.858,\ 33df) \qquad [1]$$

$$Y = 4.92 + 0.137\ X - 0.127\ X_1 \quad (R=0.884,\ 32df) \qquad [2]$$

where Y = sample time in minutes
X = total number of leaflets sampled by 2 people
X_1 = mean number of *T. urticae*/leaflet

These data suggest that the density of *T. urticae* may be determined in commercial fields by examining leaflets for the presence or absence of *T. urticae*. The sampling time of about 1h/200 leaflets/person was much less than that needed to collect the leaflets and examine them with a stereomicroscope in the laboratory, a procedure that took up to 10h/200 leaflets/person depending on the density of *T. urticae*.

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Reference

Raworth, D.A. 1986. Sampling statistics and a sampling scheme for the twospotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae), on strawberries. *Can. Ent.* **118**: 807-814.

Appendix 1

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      REAL P0,MEAN,PROP,PROP1,A,B,C,D
     2RMS,NEMP0,MLP0,SSDLP0,IMP0,SMP0,IMV,SMV
      INTEGER NUMS(10)
      READ(5,*)RMS,NEMP0,MLP0,SSDLP0,IMP0,IMV,SMV
      P0=0.05
      DO 100 ITIME=1,19
      MEAN=EXP(IMP0+SMP0*(LOG(–1.0*(LOG(P0)))))
      A=RMS*((1.0/NEMP0)+((((LOG(–1.0*(LOG(P0))))
     2–MLP0)**2)/SSDLP0))
      B=((SMP0**2)*(1.0–P0))/(P0*((LOG(P0))**2))
      C=IMV*(MEAN**(SMV–2.0))
      PROP=0.1
      DO 50 I=1,10
      PROP1=((LOG(PROP*MEAN+MEAN))/LOG(MEAN))–1.0
      D=(PROP1*(LOG(MEAN)))**2
      IF(D.GT.A)GOTO 10
      NUMS(I)=999999
      GOTO 20
10    NUMS(I)=IFIX((B+C)/(D–A))
20    PROP=PROP+0.1
50    CONTINUE
      WRITE(6,90)P0,MEAN,NUMS
90    FORMAT(' ',F5.2,F8.3,I10,I8,8I5)
      P0=P0+0.5
100   CONTINUE
      STOP
      END
```

MECHANICAL PENCILS FOR MICRODISSECTION

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Abstract

Replacing the lead of a 'fine line' mechanical pencil with an entomological pin produces a convenient, adjustable probe for microdissection work.

The range of fine lead (0.5 mm) mechanical pencils currently on the market offer an excellent alternative to homemade handles for microdissection probes. Replacing the lead with an entomological pin of appropriate size results in a comfortable, well-balanced tool with a probe length which is readily adjustable to suit the user or application (Fig. 1).

The cheapest all-plastic leadholders may require up to a No. 5 pin for the chuck to grip adequately, but a moderately-priced pencil with a metal ferrule can grip a No. 2 or even No. 1 pin firmly. Because the pin is retractible (unless bent) probes may be handled easily and safely when not in use. It is not usually necessary to clip the head from the pin unless an extra long reach is desired.

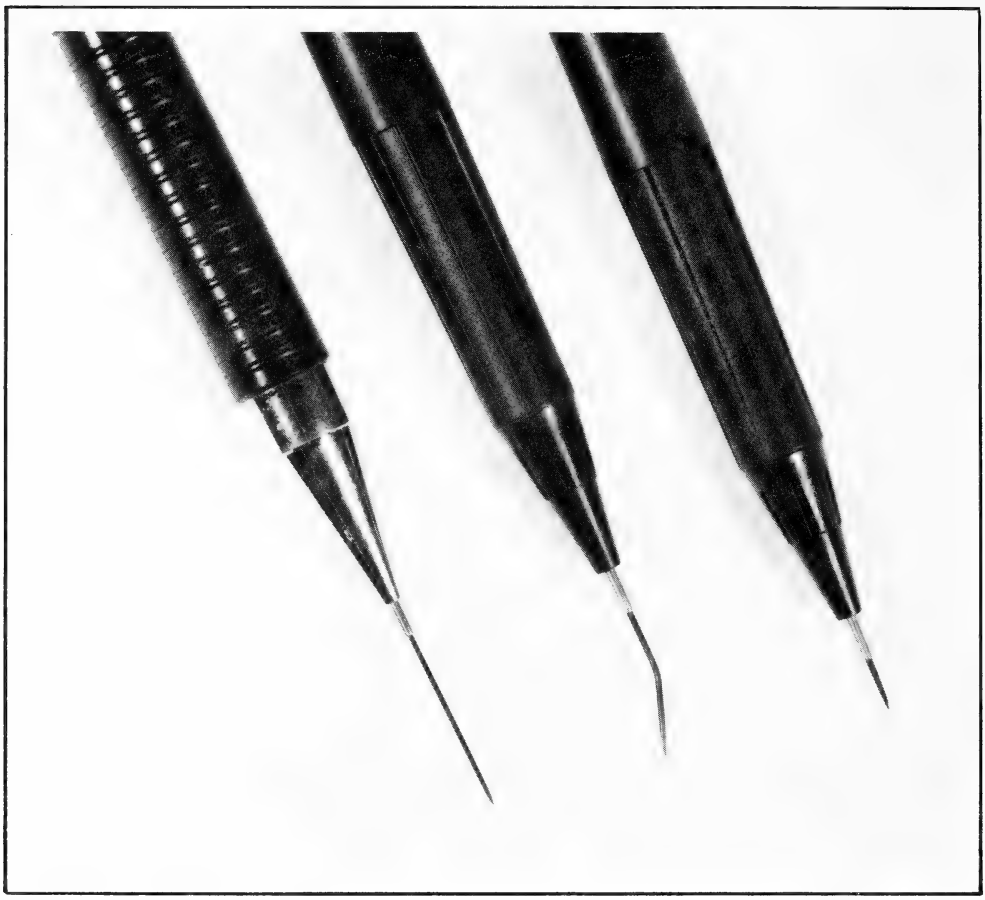

Fig. 1. Heads of three mechanical pencils with lead replaced by Nos. 1 (left) and 4 (middle and right) entomological pins. Left hand probe adjusted for long working length.

These probes have been used effectively at Simon Fraser University both by professional entomologists and undergraduate entomology students in laboratories requiring microdissection.

Acknowledgements

I thank J. H. Borden for his helpful comments on both the probe and manuscript.

PATTERNS OF LANDING OF SPRUCE BEETLES, *DENDROCTONUS RUFIPENNIS* (COLEOPTERA: SCOLYTIDAE), ON BAITED LETHAL TRAP TREES

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Abstract

The distribution of spruce beetles (*Dendroctonus rufipennis* [Kirby]) landing on lethal trap trees was studied in each of 2 years. A wire basket and sticky boards on each tree were used to trap beetles. Significantly more beetles landed on the north side of the boles than on the other three aspects. The density of beetles that landed increased sharply to about 1.6-2.4 m above ground and then decreased. A three- parameter empirical model was used to describe the relationship. On average, about ¾ of all the beetles that landed did so below the maximum height of insecticide treatment (4 m). The proportion of beetles from the lower 4 m of the bole that were trapped in the wire baskets ranged from 11% to 57% and averaged 33%. High correlations between numbers of beetles trapped in wire baskets at the paired trap trees each year, and between beetles trapped in wire baskets and on corresponding sticky boards showed that catches in the baskets were good indicators of the total numbers of beetles that landed on trap trees.

Relative heat accumulation in the stand in degree-hours above a base temperature of 13.3°C during the day was a good indicator of the relative numbers of beetles that landed on the sticky boards. On typical days, beetles began to land on trap trees in mid-morning; landings peaked between 1500 hours and 1600 hours and ceased by 2000 hours.

Résumé

La répartition des dendroctones de l'épinette *(Dendroctonus rufipennis* [Kirby]) se posant sur des arbres pièges létaux a été étudiée au cours de deux années. Sur chaque arbre, les dendroctones ont été capturés au moyen d'un panier métallique et de pièges collants. On a constaté qu'ils se posaient en nombres significativement plus éléves sur le côté nord des troncs que sur les trois autres côtés. La densité des dendroctones augmentait de façon marquée jusqu'à environ 1,6-2,4 m de hauteur puis diminuait. Un modèle empirique comportant trois paramètres a permis de décrire la fonction. En moyenne, les trois quarts environ de tous les dendroctones qui se sont posés l'ont fait au-dessous de la hauteur maximale d'application d'insecticide (4 m). La proportion des dendroctones qui ont été capturés dans les paniers métalliques à 4 m ou moins de hauteur variait de 11 à 57%, la moyenne étant de 33%. Les corrélations élevées observées entre, d'une part, les nombres de dendroctones capturés dans les paniers métalliques sur les paires d'arbres pièges chaque année et, d'autre part, les dendroctones capturés dans les paniers métalliques et sur les panneaux collants correspondants ont montré que les captures dans les paniers étaient de bons indices des nombres totaux de dendroctones se posant sur les arbres pièges.

La chaleur accumulée relative dans le peuplement au cours de la journée en degrés-heures au-dessus d'une température de base de 13,3°C s'est révélée un bon indicateur des nombres relatifs de dendroctones se posant sur les panneaux collants. Ordinairement, les arrivées des dendroctones sur les arbres pièges commençaient au milieu de la matinée, atteignaient un maximum entre 15 et 16 h et cessaient vers 20 h.

Introduction

The spruce beetle *(Dendroctonus rufipennis* [Kirby]), an indigenous species throughout the natural range of spruce *(Picea* sp.) in Canada and the United States, is a highly destructive pest of mature spruce forests, killing millions of trees during outbreak periods (Dyer 1973). Beetles of both sexes aggregate at host trees in response to pheromones released by females following the start of egg gallery excavation. A synthetic pheromone, frontalin, was found to be effective in inducing attacks on living spruce trees (Dyer and Chapman 1971) and has good potential for monitoring and manipulating beetle populations. Under endemic conditions pheromone-baited living trees are usually successfully attacked and treatment with insecticide

is necessary to save them and to kill the attacking beetles (Dyer 1973, 1975). For monitoring beetle flight activity and population trends, these lethal trap trees are fitted with wire baskets at the bases to catch the killed beetles (Dyer 1973). It is assumed that the numbers of beetles in the baskets are closely related to the numbers that landed.

Spruce beetle broods must overwinter as adults prior to emergence in the late spring or early summer when they fly and attack new host material (Schmid and Frye 1977). Flight and attack generally begin when maximum shade temperatures have exceeded the approximate flight threshold of 14.5°C (Werner and Holsten 1985) to 16°C (Dyer 1973) for several days. The diurnal flight pattern and flight activity in relation to heat accumulation above the flight threshold have not previously been investigated.

The objectives of this study were to describe (a) the distribution over time and height of spruce beetles arriving at lethal trap trees, (b) the relationship between catches in screen baskets and the numbers of beetles landing on the treated portion of the tree bole, and (c) the diurnal and directional patterns and the intensity of landing in relation to temperature.

Materials and Methods

Field Procedures. The experiments were carried out in 1979 and 1980 in a stand of mature spruce (*P. glauca* (Moench) Voss x *P. engelmannii* Parry hybrid population), in the Naver Forest about 65 km southeast of Prince George, British Columbia. Two spruce trees were prepared as lethal trap trees each year: on 22 May 1979 and on 6 May in 1980. The trap trees, 41.9 cm to 64.3 cm in dbh, were typical of mature trees in the area and located about 2 km apart, 10-25 m inside the stand. Nearby clearcuts were harvested during the winter of 1974-75 and the slash was no longer suitable for breeding by spruce beetles. One of the trap trees (EA) was used in both years; the other (EI in 1979) was successfully attacked by spruce beetles above the treatment height later in the season and was replaced in 1980 with another tree (EH).

The trees were sprayed to run-off with 1% lindane in water to a height of 4 m. Tree diameter was measured at the maximum spray height in order to estimate the treated bark area. A basket made from aluminum fly screen was placed around the stem of each tree at a height of 30 cm to catch insects killed by the insecticide. The rim of the basket projected about 60 cm above ground and 35 cm from the bole of the trees. A 5-ml polyethelene Boston Bottle (from Bel-Art Products, Pequannock, N.J.) containing 1 ml of a mixture of ⅓ frontalin and ⅔ alpha-pinene (Dyer and Safranyik 1977) was attached to each tree at 1.35 m. Hardboard panels (20 cm wide, factory-painted a light tan colour on one side, and uniformly coated with Stikem Special (from Michel and Pelton Co., Emeryville, CA.) were nailed to the north side of each trap tree. In 1979, the sticky boards extended from 0.6 m (rim of the basket) to the height of insecticide treatment on tree EI and to 6.0 m on tree EA. In 1980, the sticky boards were extended from 0.6 m to 6.0 m on both trap trees. The boards were marked at 30-cm intervals to facilitate tallying of trapped beetles by height level. In 1980, 30 cm x 20 cm sticky boards, treated as described earlier, were also affixed at the three other cardinal directions at 1.5 m to study the distribution of spruce beetles around the tree bole.

All baskets were checked and cleared of dead beetles thrice weekly. Insects were collected and preserved in vials containing 70% alcohol for later identification and counting. Sticky boards were cleaned and spruce beetles were tallied by 30-cm height intervals each time the baskets were cleared. In addition, on days when maximum temperatures were expected to exceed the flight threshold, spruce beetles landing on the sticky boards were tallied hourly throughout the daily flight period. A few Douglas-fir beetles *(D. pseudotsugae* Hopk.) may have been included in the tallies as cross attraction is possible (Dyer and Lawko 1978), but the absence of any Douglas-fir trees within a kilometre should have made the numbers inconsequential. In 1979, hourly records were made on 19 days between 3 June and 6 July and in 1980 on 15 days between 30 May and 15 July.

Temperature was measured with two thermographs inside standard Stevenson screens. One was set up in a clearcut area, about 50 m from a stand edge and 1 km distant from the farthest trap tree (EA). The second was located 30 m inside the stand, 80 m from the other screen.

Analysis. The variation in the numbers of spruce beetles trapped at 1.5 m in the 4 cardinal directions in the two trap trees was studied by analysis of variance in a randomized block split-plot design with the daily catches being the replicates. Mean catches per cardinal direction were compared by Duncan's Multiple Range Test. The data were converted to $\sqrt{x+1}$ prior to analysis.

Based on visual inspection of graphs showing numbers of trapped spruce beetles (Y) on the mid-points of height intervals (X = 0.75 m, 1.05 m etc.) on the bole, the following empirical model was selected to describe the relationship:

$$Y = CX^{B}\exp[-AX] \quad (1)$$

Where Y is the total number of spruce beetles trapped per 30 cm x 20 cm area; X is the height in m of mid-points of height intervals on the bole; A,B and C are regression constants to be estimated. Eq. 1 was fitted by the method of least squares in the following linearized form:

$$\ln Y = C' + B' \ln X - A'X \quad (2)$$

Maximum height of landing by spruce beetles was assumed to be at the greater of the two points (X_{max}) corresponding to an estimated 0.1 trapped beetles per 30 cm x 20 cm area from Eq. 1. Calculation of X_{max} was required to predict total numbers of landings, and the proportion of landings below the maximum height of treatment. The total numbers of beetles landing on a trap tree (T_{all}) during the trapping period was estimated in two ways: (Method 1) by assuming that the density of beetles trapped at a given height level on the north side is the same as that on the other three aspects; and (Method 2) by assuming that the densities of beetles trapped per aspect at 1.5 m relative to the density trapped at the same height on the north aspect held for all heights up to X_{max}. In 1979, estimates were made using method 1; the 1980 estimates were made using both methods. Estimates of T_{all} were calculated by multiplying the density of trapped beetles on the north aspect in each 30-cm height interval i($\hat{Y}i$, Eq. 1, first method) or the weighted density of trapped beetles ($\bar{Y}wi$, second method) by the estimated bark area corresponding to that height interval and summing these products over all height intervals to X_{max}. $\bar{Y}wi$ is computed as in Eq. 3.

$$\bar{Y}wi = \hat{Y}i(\bar{Y}_{all}/Yn) \quad (3)$$

where $\bar{Y}_{all}$ is the mean density of trapped beetles on the four aspects at 1.5 m, Yn is the density of trapped beetles on the north aspect at 1.5 m, and $\hat{Y}i$ and $\bar{Y}wi$ are as defined earlier.

The total numbers of spruce beetles that landed below the maximum height of insecticide treatment (Tp) was computed in a similar manner to that described for T_{all}. The proportion of the beetles that landed below the maximum height of insecticide treatment (Ps) was estimated by the ratio Tp/T_{all} and the proportion of beetles trapped in the wire screen basket (Pb) was estimated as the ratio of the total catch in the basket (Nb) to Tp. The relationship between the numbers of beetles trapped in the basket and the numbers of beetles trapped on the sticky boards below the maximum height of insecticide treatment was analyzed by correlation analysis.

In selecting the flight threshold temperatures, based on temperature records in the clearcut area and inside the stand, we compared hourly temperature records with corresponding beetle activity as reflected by the beetles trapped on the sticky boards. The highest temperatures at which no beetles were trapped in the clearcut (tc) and in the stand (ts) on days following the first recorded flight were designated as the flight thresholds in open areas and in the stand, respectively. The relationships between the numbers of beetles trapped on sticky boards (Ns) and (1) heat accumulation in degree hours (Dh) above the flight threshold temperature, and (2) successive trapping periods during the day, were examined using regression analysis. Prior to analysis, both Dh and Ns were expressed as proportions of the corresponding daily totals in order to compensate for large daily variation in numbers of trapped beetles due to temperature differences among the overwintering sites.

Results

Analysis of variance indicated significant differences among blocks (days) ($p < 0.01$) and aspects ($p < 0.01$) in the mean numbers of spruce beetles trapped/day on 20 cm x 30 cm sticky boards at 1.5 m on the bole (Table 1). The catch ranged between 0 and 140.0 and averaged 78.9 beetles. The catch on the north aspect was significantly larger ($p < 0.01$) than those on the other aspects and there were no differences among the east, south and west aspects (Table 2). There were no significant differences ($p > 0.05$) in the daily catches of beetles between trees or in the interaction between trees and aspects.

The numbers of spruce beetles trapped on the north sticky boards increased from a height of 0.75 m to near 2.0 m and then declined (Table 4). However, the height at which the largest numbers of beetles were trapped varied among trees and ranged between 1.35 m and 2.25 m. The empirical model (Eq. 1) gave excellent fit to the relationship between numbers of spruce beetles trapped per 20 cm x 30 cm area of sticky board and the corresponding mid-point of 30-cm height intervals on the bole (Table 4, Fig. 1). For tree EA, parameters A and B (parameters that control the shape of the function) were nearly the same in both years. The height level of estimated maximum catches (Y_{max}, Table 3) for both trees in 1979 agreed closely with the data (Table 4), but in 1980 Y_{max} for both trees was about one height class greater than in the field. The estimated maximum height on the bole for landing by spruce beetles ranged between 8.0 and 13.7 m; for tree EA, the maximum was about the same each year.

Table 1. Analysis of variance of the numbers of spruce beetles trapped per day on 30 cm x 20 cm sticky boards attached to the four aspects at 1.5 m of two spruce trees baited with pheromone and treated with insecticide to 4 m on the bole in 1980. Data were transformed to $\sqrt{x+1}$ prior to analysis.

Source of variation	d.f.	Sum Squares	Mean Squares	F
Blocks (days)	9	169.032	18.781	8.691**
Trees (T)	1	6.527	6.527	3.020^{ns}
Error I	9	19.449	2.161	
Whole units	19	195.008		
Aspects (A)	3	29.941	9.980	5.812**
A x T	3	3.495	1.165	$<1^{ns}$
Error II	54	92.748	1.717	
Sub units	60	126.184		
Total	79	321.190		

** Significant at the 99% probability level; ns = not significant ($p > 0.05$)

Table 2. Mean numbers per day and tree ($\bar{x}$), sample size (n), and standard deviation (sd) of spruce beetles trapped in 10 days on 30 cm x 20 cm sticky boards attached to the four aspects of two spruce trees at 1.5 m on the bole in 1980.

Aspect	n	$\bar{x}$[1/]	sd
North	20	18.55[a]	34.18
East	20	4.20[b]	8.41
South	20	8.25[b]	17.79
West	20	8.55[b]	17.33
Grand mean	80	9.86	17.18

The estimated number of spruce beetles that landed on the trap trees in the two years, calculated using method 1, which assumes that there was no difference by aspect in the relative frequency of landing, ranged from 7,628 to 32,356 (column 9, Table 3). For tree EA in 1979, the estimated number of landed beetles was more than twice that in 1980. Using method 2, which assumes that beetles landed on the four aspects with the relative frequencies observed at 1.5 m, in 1980 the estimated total landings were reduced by as much as 65% (column 10, Table 3) compared to the estimates made using method 1.

Assuming that equation 1 is a reliable descriptor of the density gradient of landing beetles up the bole, and that beetles land with equal frequency on all aspects, an estimated average of 77% (range 73% - 86%) landed below the maximum height of insecticide treatment (4 m). Based on the same assumption, an estimated average of 33% (range 11% - 55%) of the beetles that landed below the maximum height of insecticide treatment (4 m) were caught in the screen baskets (column 2 as a percentage of column 3, Table 5). On the other hand, based on the assumption of unequal frequencies of landings on the four aspects, the estimated number of beetles that landed below 4 m on the bole in 1980 (column 4, Table 5) was less (by 37%) than the number of beetles caught in the screen basket for tree EA and for tree EH the estimate was only 14% higher than the numbers caught in the screen basket.

Catches of spruce beetles in screen baskets and on the sticky boards at the two trap trees were significantly correlated ($p < 0.01$) in both years with the exception of tree EH in 1980 (Table 6). For this tree, the correlation between trapped beetles in the screen basket and on the sticky board was not significant ($p > 0.05$).

The highest temperatures at which no spruce beetles landed on the sticky boards in the two seasons were 14.4°C in the slash and 13.3°C in the stand. The regressions of relative numbers of beetles trapped on sticky boards during 1 to 2 hr collecting periods (Y) on the relative numbers of heat units for the collecting period (X) are given by Eq. 4 (Fig. 2) for stand temperatures and Eq. 5 for slash temperatures.

Table 3. Statistics for fitting eq. 1 to the total numbers of spruce beetles trapped on 30 cm x 20 cm sticky boards (Y) and height on the tree bole (X).

Tree and Year	Sample size	Equation parameters[1] A	B	C	R^2	Ymax[2]	Max. ht. landing[3] (X_{max})	No. landed beetles (T_{all}) Est. 1[4]	Est. 2[5]
EA-1979	18	-1.132	2.581	473.800	0.724	2.28	13.4	32 347	-
EI-1979	13	-2.290	4.000	2227.300	0.998	1.75	8.0	32 356	-
EA-1980	18	-1.066	2.555	217.699	0.901	2.39	13.7	13 333	4702
EH-1980	18	-1.788	3.372	333.276	0.861	1.88	8.8	7 628	4127

[1] $Y = CX^B \exp[-AX]$ (Eq. 1).

[2] Ymax = -(B/A) from Eq. 1, the height (m) at which the estimated maximum catch occurred.

[3] The greater of two heights (m) on bole corresponding to an estimated 0.1 beetles trapped per 30 cm x 20 cm sticky board surface during the trapping period (Eq. 1)

[4] Estimated numbers of spruce beetles that landed on the trap trees, assuming the same relative frequency of landings on all aspects as on the north aspect.

[5] Estimated numbers of spruce beetles that landed on trap trees assuming that the relative frequencies of landings on the four aspects at all heights were the same as those observed at 1.5 m.

Table 4. The vertical distribution of trapped spruce beetles on 20-cm-wide sticky boards attached to the north aspects of two spruce trees baited with pheromone and treated with insecticide in 1979 (trees EA and EI) and 1980 (trees EA and EH). Figures represent total catches over 19 days in 1979 and 15 days in 1980.

Midpoint of Height interval (m)	Tree and Year			
	EA-1979	EI-1979	EA-1980	EH-1980
	spruce beetles trapped			
0.75	81	203	41	27
1.05	143	332	96	75
1.35	235	362	101	120
1.65	365	312	179	97
1.95	356	387	186	97
2.25	461	277	154	79
2.55	437	236	142	85
2.85	199	168	151	54
3.15	249	129	108	33
3.45	252	83	105	35
3.75	166	78	114	25
4.05	88	41	125	22
4.35	79	–	99	24
4.65	106	–	74	26
4.95	132	–	70	19
5.25	106	–	44	10
5.55	72	–	45	6
5.85	87	–	42	1
Totals	3614	2608	1876	835

Table 5. Total numbers of spruce beetles caught in screen baskets (Nb), and the estimated numbers of spruce beetles that landed (Tp) on the boles of trap trees between the rim of the basket and the maximum height of insecticide treatment (4 m).

Tree and year	Tot. no. beetles		
	Baskets (Nb)	Landed(1)[1/] (Tp)	Landed(2)[2/] (Tp)
EA-1979	4 511	25 119	-
E1-1979	2 857	24 694	-
EA-1980	5 359	9 788	3 379
EH-1980	2 832	6 562	3 276
Totals	15 559	66 433	6 655

[1/] Estimates based on the same relative frequency of beetles landing on all aspects of the bole as on the north side.

[2/] Estimates based on the same relative frequencies of beetles landing at the various aspects on the bole at a given height as those observed at 1.5 m.

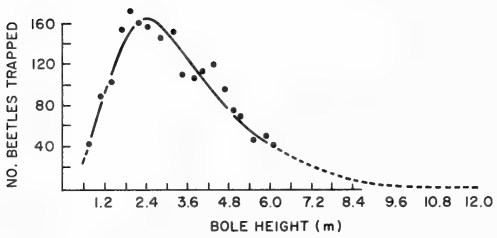

FIG. 1. Relationship between total numbers of spruce beetles caught on 20 cm x 30 cm sticky board areas and height on the bole for trap tree EA in 1980. Solid line is the graph for a three-parameter model (Table 3) fitted to the data (dots).

Table 6. Linear correlations (r) between corresponding catches of spruce beetles in screen baskets at two baited and insecticide-treated spruce trees in 2 years and between numbers of beetles caught in screen baskets and on 20-cm-wide and 6.0-m-high sticky boards attached to the north sides of the bole[1/]

Comparisons	r[1/]	n
1979:		
Tree EA & EI baskets	0.64**	18
EA basket & EA board	0.75*	9
EI basket & EI board	0.84**	9
EA board & EI board	0.89**	18
1980		
Tree EA & EH baskets	0.88**	21
EA basket and EA board	0.98**	10
EH basket & EH board	0.11^{NS}	10
EA board & EH board	0.56**	21

[1/] Beetles trapped on sticky boards below maximum insecticide treatment height (4 m) were used in calculating r-values.

[2/] ** = significant at $p \leq 0.01$, * = significant at $p \leq 0.05$, ns = not significant.

$$Y = -0.0036 + 1.037X \quad (4)$$

$$n = 142,\ r^2 = 0.689,\ Sy.x = 0.039$$

$$Y = 0.0484 + 0.194X \quad (5)$$

$$n = 142,\ r^2 = 0.125,\ Sy.x = 0.065$$

where Y = [No. beetles trapped/tree/collecting period]/[Tot. no. beetles trapped/day]

X = [No. degree hours above threshold temp./collecting period]/[Cumulative degree hours/day].

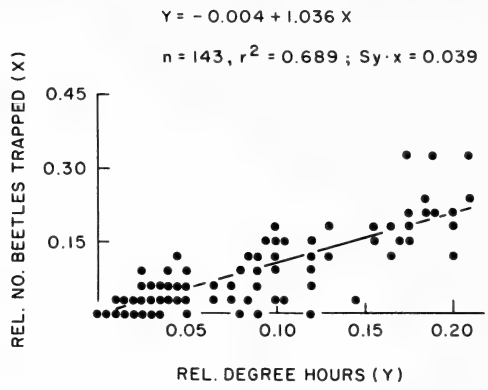

FIG. 2. Relationship between the relative numbers of spruce beetles trapped during 1-2 hr trapping periods (Y) and the relative numbers of degree-hours above a base temperature in the stand of 13.3°C (X).

The intercept of Eq. 4 was not significantly different from 0 ($p > 0.05$) and the intercept of Eq. 5 was highly significant ($p < 0.01$). Eq. 4 was forced through the origin and had the following form (Eq. 6):

$$Y = 1.005X \quad (6)$$

On three typical days, spruce beetle landing on the sticky boards started at mid-morning, peaked between 1500 and 1600 hours and ceased about 2000 hours (Fig. 3).

Discussion

The large variation in the daily catches on sticky boards and in screen baskets is directly related to the effects of temperature on emergence and flight activity. Emergence from hibernating sites and flight began after shade temperatures exceeded the approximate flight threshold of 16°C (Dyer 1973) for several days. The spruce beetles trapped in the experimental area originated mainly from windfelled trees inside the stand and along the margins. Hence, variation in the temperature conditions of the microsites undoubtedly affected the onset, magnitude and duration of daily beetle emergence and flight activity.

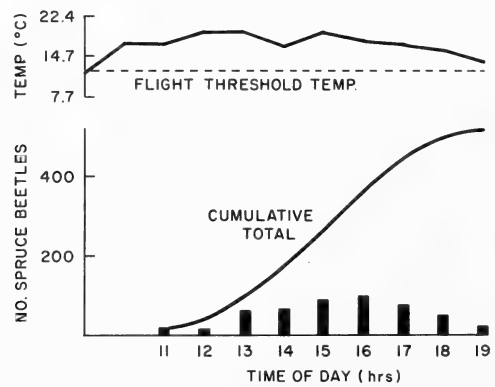

FIG. 3. Average hourly (bars) and cumulative numbers of spruce beetles trapped on sticky boards on June 04, 12, and 14, 1980 at trap tree EA. Temperature was average for the 3 days; flight threshold shown = 13.3°C.

Flying beetles generally follow attractive odours upwind to the source (Borden 1982). As the wind movement during the daily flight periods was predominantly from the south and southwest, the significantly greater numbers of beetles trapped on the north aspect at the 1.5 m level in comparison with the other aspects is partly explained by the search and attack behaviour of the beetles. The preference for landing on (Shepherd 1960) and attacking the shady sides of the host material (Dyer and Taylor 1971; Schmid 1977) could also have increased the catches on the north aspect of the bole. For these reasons, estimates of total numbers of beetles that landed on a trap tree, and on the boles below the spray height, using method 1, based on equal relative frequencies of landings on the four aspects (column 9, Table 3; column 3, Table 5) are likely to be maximum estimates. Conversely, corresponding estimates, using method 2, based on the observed frequencies of landings on the four aspects at 1.5 m (Column 10, Table 3; Column 4, Table 5) are low. This statement is supported by the observation that at Tree EA in 1980 14% more beetles were caught in the wire baskets (5359) (Table 5) than the estimated total for all landed beetles (4702) (Table 3). The beetles could crawl slowly in the stickem, and if some escaped from the small boards, lower predicted total numbers would result. Given the frequency of examination, and the fact that no stickem-coated beetles were found on the boles or in the baskets, it is unlikely that any escaped.

Vertical distributions of landings similar to those observed here (Table 4) have been reported for other bark beetles. Payne and Richerson (1977) found that the vertical distribution of landing *D. frontalis* Zimmermann generally increased to 3-5 m and then decreased with increased trap height on unbaited loblolly pines *(Pinus taeda)*. Avis (1971) found that the density of *D. ponderosae* landing on sticky boards or those caught in barrier traps on unbaited lodgepole pines *(P. contorta)* increased to a maximum between 2 and 4 m and then decreased with increasing trap height. Baiting of the host tree can affect the vertical distribution of landing beetles (Coster *et al.* 1977; Payne and Richerson 1979), but we had no indication that this occurred. At 1500 hours on 28 June, 1979, the pheromone bait was removed from tree EA. During the rest of the same afternoon, a total of 394 spruce beetles were trapped on the sticky board; the highest density (52) were taken at 2.25 m, the same height level where the maximum numbers were trapped when the bait was attached to the tree. The possibility that a few female beetles had penetrated the bark and produced pheromones was considered but no attacks were found.

The similarity of estimated parameters A and B of Eq. 1 for tree EA and the similarity of estimated attack height in both years, despite a large difference in the numbers of trapped beetles (Table 4), indicate that the vertical density gradient of landing by spruce beetles may be largely controlled by tree parameters, or by the character of the immediately surrounding stand, or by both. Beetles searching for suitable host materials tend to fly in the clear bole zone where there is minimum interference from tree crowns and ground vegetation. The estimated maxima for height of landing were not related to tree diameter and agreed closely with reported maxima for height of attack by the spruce beetle (Frye *et al.* 1977; Schmid and Frye 1977). However, as attack density, in general, is inversely related to height on the bole (Schmid and Frye 1977), and as attack density rarely exceeds 8 per 20 cm x 30 cm area, large numbers of beetles must leave the trees for lack of suitable attack sites. This is especially true of the bole zone where the highest numbers of beetles landed.

Our results show that on average about ¾ of the beetles that landed on a trap tree treated with insecticide up to 4 m, landed on the treated bole surface. Of these about ¼ were caught in the screen basket (15 559/66 443, Table 5). This is a conservative estimate owing to the method of estimating the total numbers of landed beetles discussed earlier. A main reason for this low proportion of beetles being caught in the wire baskets is that many of the beetles that were affected by the insecticide fell outside the baskets (Dyer *et al.* 1975). There was also evidence that the proportion of the total beetles that were caught in the wire basket was inversely related to the total beetles that landed on the bole (Table 5, C2÷C3). This indicates that, perhaps due to increased interference among the beetles or failure to find attack sites, or both, proportionately more beetles abandoned trees before they were incapacitated by the pesticide on trees with a high incidence of landings. Although not considered in our

experiment, some beetles that fell from bark surfaces located above maximum treatment height could also have landed in the wire baskets. However, we think that such events were rare.

Spruce beetle emergence during the day was directly related to accumulated heat (degree-hours) inside the stand above a threshold temperature of 13.3°C (Fig. 2) and did not vary significantly within and between years. Beetle emergence during the day was poorly related to heat accumulation in the slash above a slash temperature threshold of 14.4°C (Eq. 5). Dyer (1973) reported a flight and attack threshold shade temperature of 15.6°C. We found that some beetles landed on the sticky boards at stand temperatures as low as 13.9°C and a slash temperature of 15.0°C. In the experimental area the only major source of beetles was from scattered windfall inside the stand. There was a difference in the diurnal pattern of temperature changes between the stand and slash. In the morning (0900 hours to 1200 hours), temperatures in the slash were up to 4°C higher than in the stand; by late afternoon the temperatures in the two locations were about the same but by 1900 to 2000 hours temperature in the stand was higher than in the slash. These are the main reasons why daily heat accumulation above the threshold temperature in the stand was more strongly related to the numbers of beetles trapped during the day than heat accumulation in the slash. During a typical day in the experimental area, landing by beetles began between 0900 hours and 1000 hours, reached its peak between 1500 hours and 1600 hours and ended by about 1900 hours (Fig. 3).

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References

Avis, R.W. 1971. Flight and attack patterns of the mountain pine beetle, *Dendroctonus ponderosae* Hopk. (Coleoptera: Scolytidae). Grad. Thesis submitted to the Faculty of Forestry, University of British Columbia, Vancouver, Canada, March 3, 1971. 58 pp.

Borden, J.H. 1982. Aggregation Pheromones. pp. 74-139. *In* Bark Beetles in North American Conifers. J.B. Mitton and K.B. Sturgeon (Eds.) Univ. of Texas. 527 p. Austin, Tx.

Coster, J.E., T.L. Payne, E.R. Hart and L.J. Edson. 1977. Aggregation of the southern pine beetle in response to attractive host trees. *Environ. Entomol.* **6**: 725-731.

Dyer, E.D.A. 1973. Spruce beetle aggregated by the synthetic pheromone frontalin. *Can. J. For. Res.* **3**: 486-493.

Dyer, E.D.A. 1975. Frontalin attractant in stands infested by the spruce beetle, *Dendroctonus rufipennis* (Coleoptera: Scolytidae). *Can. Entomol.* **107**: 979-988.

Dyer, E.D.A. and J.A. Chapman. 1971. Attack by the spruce beetle induced by frontalin on billets with burrowing females. *Can. Dep. Fish. For. Bi-mon. Res. Notes* **27**: 10-11.

Dyer, E.D.A. and C.M. Lawko 1978. Effect of seudenol on spruce beetle and Douglas-fir beetle aggregation. *Can. For. Serv. Bi-Monthly Res. Notes* **34(5)**, 30-31.

Dyer, E.D.A. and L. Safranyik. 1977. Assessment of the impact of pheromone- baited spruce trees on a spruce beetle population (Coleoptera: Scolytidae). *Can. Entomol.* **109**: 77-80.

Dyer, E.D.A. and D.W. Taylor. 1971. Spruce beetle brood production in logging slash and wind-thrown trees in British Columbia. Can. For. Serv. Pac. For. Res. Cent. Inf. Rep. BC-X-62.

Frye, R.H., J.M. Schmid, C.K. Lister and P.E. Buffam. 1977. Post-attack injection of Silvisar 510 (cacodylic acid) in beetle infested spruce trees. *Can. Entomol.* **109**: 1221-1225.

Payne, T.L. and J.V. Richerson. 1979. Management implications of inhibitors for *Dendroctonus frontalis* (Coleoptera: Scolytidae). *Bulletin de la Sociaetae Entomologique Suisse.* **52**: 323-331.

Schmid, J.M. 1977. Guidelines for minimizing spruce beetle populations in logging residuals. USDA For. Serv., Rocky Mtn. For. Range Expt. Stn., Ft. Collins, CO, Res. Pap. RM-185. 8 pp.

Schmid, J.M. and R.H. Frye. 1977. Spruce beetle in the Rockies. USDA Forest Service, Rocky Mtn For. Range Expt. Stn., Fort Collins, CO, Gen. Tech. Rept. RM-49. 37 pp.

Shepherd, R.F. 1960. Distribution of the Black Hills Beetle over the host tree and factors controlling the attraction and behaviour of the adult. Ph.D. Thesis, Univ. of Minnesota, St. Paul, 81 pp.

Werner, R.A. and E. Holsten. 1985. Effects of phloem temperature on development of spruce beetles in Alaska. pp. 155-163. *In* L. Safranyik (Ed.), Proceedings, IUFRO Conference on the Role of the Host in the Population Dynamics of Forest Insects, Sept. 4-7, 1983, Banff, Canada. 240 pp.

EFFECT OF DIATOMACEOUS EARTH, MALATHION, DIMETHOATE AND PERMETHRIN ON *LEPTOGLOSSUS OCCIDENTALIS* (HEMIPTERA: COREIDAE): A PEST OF CONIFER SEED[1]

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Abstract

Leptoglossus occidentalis Heidemann (Hemiptera:Coreidae) were exposed to diatomaceous earth, and sprays of dimethoate (0.1 and 1.0% a.i.) and permethrin (0.1% and 0.01% a.i.) in both laboratory and field tests and to malathion (0.1% a.i.) in a laboratory test. In field tests, permethrin and dimethoate caused significant ($P < .05$) mortality for two weeks after the sprays were applied and permethrin continued to be effective for a third week. Diatomaceous earth was not effective in field tests or in one of two laboratory tests. Malathion, dimethoate and permethrin caused significant mortality in both laboratory tests.

Seed bugs *(Leptoglossus* spp.; Hemiptera:Coreidae) severely reduce conifer seed crops by feeding on young conelets or mature seeds (Bradley *et al.* 1981; DeBarr 1979; Hedlin *et al.* 1980; Koerber 1963; Ruth 1980). In British Columbia (B.C.), the western conifer seed bug *(Leptoglossus occidentalis* Heidemann) has caused seed losses of between 36% and 41% on Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) (Hedlin *et al.* 1980; Ruth 1980). While seed bug populations and damage have not been monitored routinely in Douglas-fir seed orchards, the bugs are commonly noticed by seed orchard staff around cone harvest. The high value of seed orchard seed and the potential seed losses to *L. occidentalis* make the presence of these insects in orchards of concern.

While numerous insecticides have been tested against seed bugs in the southern United States (DeBarr 1978; DeBarr and Nord 1978; Nord *et al* 1984; Nord *et al* 1985), none has been tested against *L. occidentalis* in B.C. (Miller 1980). This paper reports the results of some initial insecticide screening trials against this insect.

Methods and Materials

A large colony of *L. occidentalis* at the Pacific Forestry Centre in Victoria, B.C. was reared from several years of collections around Victoria and Lake Cowichan, B.C. Adult and fifth-instar seed bugs were selected from this colony for these tests in August and September, 1986. To facilitate handling, the insects were placed in a 0°C cold room for between 30 min and 3 h prior to distribution to the various treatments.

Initial screening tested diatomaceous earth (D.E.) (Diacide Natural Insect Powder®, International Diatoms Ltd., Waterdown, Ont., a.i. [active ingredient(s)] = diatomaceous earth, pyrethrin 0.1%, piperonyl butoxide 1.25%) at full strength; malathion (Malathion 50 EC®, Chipman Inc., Stoney Creek, Ont.) at 0.1% a.i.; dimethoate (Lagon 2E®, Laters Chemicals, Richmond, B.C.) at 1.0% and 0.1% a.i.; and permethrin (Ambush 50 EC®, Chipman Inc., Stoney Creek, Ont.) at 0.1% and 0.01% a.i. All liquids were applied with a 500 ml hand sprayer. D.E. was applied from its original container: a plastic squeeze duster.

[1] Trade names and commercial enterprises or products are mentioned solely for information. No endorsement by the B.C. Ministry of Forests and Lands or the Canadian Forestry Service is implied, nor does it imply that the uses discussed have been registered. All use of pesticides must be registered by appropriate federal and provincial agencies before they can be recommended.

Small, potted Douglas-fir trees were either sprayed to run-off or dusted to the point where a light film was just visible on the foliage. After the sprays had dried, small twigs with foliage were clipped off and the clipped end of each twig was put in a small vial containing moist tissue. The vials were then placed in 1 L plastic containers. Packages of Douglas-fir seed, covered with gauze, were placed within the foliage to provide food for the insects during the trial and screened lids were placed on the containers after the insects were introduced. Five containers with about 20 insects each made up a treatment group for each insecticide. A final treatment (D.E. direct) consisted of dusting the insects, canister and foliage through the screened lid. Insects on untreated foliage served as checks.

Following the initial test, both rates of permethrin and dimethoate were tested again. The procedure was the same as above except that foliage was clipped from open grown Douglas-fir in the Pacific Forestry Centre arboretum and then sprayed. Concurrently, these insecticides were applied to lodgepole pine *(Pinus contorta* Dougl.) branches in the arboretum. One branch on each of five trees was sprayed with each mixture. *L. occidentalis* (about 20/branch) were caged on the branches the next day in nylon mesh bags. One unsprayed branch on each tree served as checks. Insects used in the arboretum were replaced at weekly intervals for two more weeks to test for residual activity of permethrin and the 1.0% rate of dimethoate. All mesh bags were thoroughly washed between uses.

D.E. was tested further after obtaining a new package. Containers and insects were prepared as before. D.E. was applied by dusting over open containers and allowing the subsequent dust cloud to settle as a light film over the contents. This treatment was applied over either insects and foliage (D.E. direct) or over foliage, with the insects being added afterward (D.E. residual).

In the arboretum, a mechanical duster was used to dust two lodgepole pine trees and one Douglas-fir tree with D.E. On each tree, five branches showing a light film of the insecticide were selected and about 20 *L. occidentalis* were caged on in mesh bags. Five branches on one untreated pine served as a check.

Depending on the test, counts of dead and moribund insects were made at two or more of the following intervals: 24 h, 48 h, 96 h, 1 week, 2 weeks. Except for D.E., tests were terminated after one week or when all of the treated insects were dead. On D.E. treated branches, *L. occidentalis* remained caged for a second week. At the end of each test, tallies were made of live and dead *L. occidentalis* in each replicate and counts were pooled by treatment. Results for each assessment period were analysed by chi-square tests and where the overall tests were significant, pairwise comparisons were made using the overall degrees of freedom to determine significance (Fleiss 1981). *L. occidentalis* is a very active insect and when escapees made the counts inconsistent, that replicate(s) was not used in the analysis.

Results and Discussion

Cooling the seed bugs at 0°C to ease handling did not appear to harm them. Mortality was low in all of the checks. This was not unexpected in that late instar and adult *L. occidentalis* have been overwintered in the rearing colony outdoors where the temperature occasionally dips below 0°C.

In the initial screening, all sprays caused significant mortality ($P < .05$) within 24 h after application (Table 1). Malathion was not so effective as either permethrin or dimethoate in providing an initial knockdown, however after one week there was no difference between the sprayed insecticide treatments. Permethrin at 0.01%, had a hlgh initial knockdown within 24 h but some *L. occidentalis* had recovered by 48 h. This situation was reversed again by one week after treatment. This did not occur in the second test (Table 1) where both permethrin and dimethoate again caused significant mortality ($P < .05$).

D.E. did not cause significant mortality in the initial tests (Table 1) but did in the second (Table 2). After discussions with the local distributor, it was concluded that the product used initially may have absorbed too much moisture and had thus become ineffective. The results with the fresh product used in the second test seem to bear this out. It caused 85.7% to 97.1%

Table 1: Percent mortality* of *Leptoglossus occidentalis* exposed to insecticide treated foliage in containers.

Treatment	Mortality in First test n**	24 h	48 h	1 week	Mortality in Second test n	24 h	48 h	1 week
check	100	1.0c	1.0c	2.0b	100	2.0c	2.0b	3.0
D.E. residual	100	0c	0c	1.0b	-	-	-	-
D.E. direct	100	6.0c	6.0c	13.0b	-	-	-	-
malathion 0.1%	61	68.3b	73.7b	86.8a	-	-	-	-
permethrin .01%	80	95.0a	82.4b	93.8a	99	85.9b	91.9a	89.9a
permethrin .10%	100	100 a	100 a	100 a	100	100a	100a	100a
dimethoate 0.1%	103	99.1a	100 a	100 a	100	90a	100a	100a
dimethoate 1.0%	100	100a	100 a	100 a	100	95ab	100a	100a

* Based on counts of live and dead insects, percentages followed by the same letter in a column are not significantly different, $P < .05$; chi-square test.

** N = number of insects exposed.

mortality within 24 h. Curiously, D.E. application to the insects directly was less effective than relying on residual activity alone (Table 2). Reasons for this are unclear but it may be because the cooled immobile insects placed in the "D.E. residual" containers had to move through the insecticide on the container floor as they "woke up", as well as through the insecticide on the foliage where they tended to congregate. The *L. occidentalis* in the "D.E. direct" treatment were mobile and many were on the foliage already. These may have been protected from initial exposure and did not make so much contact as those having to move around on the container floor. Either way, D.E. caused an acceptable level of control in the second laboratory test.

D.E. was not effective outside in the arboretum (Table 3). Mortality in all cases remained at less than 7.5%. Reasons for this failure are not known but at least two factors may have been involved. Diatomaceous earth acts as a desiccant (Ross 1981) so the greater humidity outside

Table 2: Percent mortality* of *Leptoglossus occidentalis* exposed to D.E. in containers.

Treatment	n	24 h	48 h	1 week & 2 weeks
check	100	0a	0a	1.0a
D.E. direct	98	85.7b	86.7b	88.7b
D.E. residual	104	97.1c	95.2c	95.2c

* Based on counts of live and dead insects, percentages followed by the same letter in a column are not significantly different, $P < .05$; chi-square test.

Table 4: Percent mortality* of *Leptoglossus occidentalis* exposed to insecticide treated branches. Groups of insects were placed on branches one day, one week and two weeks after insecticides were applied.

Treatment	Mortality During First Week n**	24 h	96 h	Mortality During Second Week n**	24 h	48 h	7 days	Mortality During Third Week n**	24 h	96 h	7 days
check	95	11.3c	12.6b	103	1.0b	1.0b	2.9b	99	0a	0c	1.0c
dimethoate 1.0%	98	89.8a	100a	98	0b	5.1b	94.9a	98	0a	46.9b	70.4b
dimethoate 0.1%	98	64.3b	100a	-	-	-	-	-	-	-	-
permethrin 0.1%	98	91.1a	100a	99	91.9a	93.9a	100a	100	98.0b	100a	100a
permethrin 0.01%	99	80.0a	100a	100	96.0a	100a	100a	100	100b	100a	100a

* Based on counts of live and dead insects, percentages followed by the same letter in a column are not significantly different, $P < .05$; chi-square test.

** N = number of insects exposed.

Table 3: Percent mortality* of *Leptoglossus occidentalis* exposed to D.E. treated branches outdoors.

Treament	n	24 h	48 h	1 week	2 weeks
check	94	1.1a	1.1a	2.1a	3.2a
D.E.	72	0 a	0 a	0 a	7.5a
D.E.	59	1.7a	3.4a	5.1a	6.8a
D.E.	74	1.4a	1.4a	2.7a	6.8a

* Based on counts of live and dead insects, percentages followed by the same letter in a column are not significantly different, $P < .05$; chi-square test.

compared to that in the laboratory may have reduced the effectiveness. Also heavy dew formed each night and 17.2 mm of rain (Environment Canada 1986) fell during the test. A second factor which may have reduced the efficacy of D.E. is the amount contacting the insects. Although all of the branches had a visible coating of material on them, this may not have been enough for the insects to pick up a lethal dose. In the laboratory, the seed bugs were more confined to treated surfaces.

Both rates of permethrin and dimethoate caused high mortality when *L. occidentalis* was exposed to them on branches outside (Table 4). Many insects were moribund on the bottom of the bags on permethrin treated branches less than 2 h after exposure. Both insecticides caused 100% mortality in less than 96 h (Table 4).

The residual effectiveness of permethrin did not decrease over the three weeks of the test (Table 4). Both rates caused more than 90% mortality within 24 h and 100% mortality in less than 96 h in the second and third weeks. This residual activity was aided by the dry weather. There was little rain (18.3 mm) during the test and most of it (12.4 mm) fell just two days before the end of the third week. Nord *et al.* (1984) also reported that permethrin has a long residual life.

Dimethoate lost some of its effectiveness with time and by the second week of the tests it was taking longer than permethrin to kill *L. occidentalis* (Table 4). By the third week dimethoate did not provide an acceptable level of control.

Conclusions

Our results show that dimethoate and permethrin are effective against *L. occidentalis* at the rates used and that permethrin will continue to be effective for more than three weeks after application. While D.E. was effective against seed bugs in laboratory tests, it was ineffective outdoors. Increasing the amount of D.E. used or using it under very dry conditions may improve its efficacy.

Future research should test permethrin and dimethoate in a more operational context. Demonstrating an increase in filled seeds on cones from trees protected from *Leptoglossus occidentalis* could help further quantify both seed bug damage and the efficacy of these insecticides.

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Literature Cited

Bradley, E.L., B.H. Ebel and K.0. Summerville. 1981. *Leptoglossus* spp. Observed on Eastern White Pine and Fraser Fir Cones. USDA For. Serv. Res. Note SE-310.

DeBarr, G.L. 1978. Southwide Tests of Carbofuran for Seedbug Control in Pine Seed Orchards. USDA For. Serv. Res. Pap. SE-185.

DeBarr, G.L. 1979. Importance of the Seedbugs *Leptoglossus corculus* (Say) (Hemiptera:Coreidae) and *Tetyra bipunctata* (H.-S.) (Hemiptera: Pentatomidae) and Their Control in Southern Pine Seed Orchards. *In*:Bonner, F. (Ed.) Proceedings: A Symposium on Flowering and Seed Development in Trees. Mississippi State University, May 15-18, 1978. I.U.F.R.0. 380 p.

DeBarr, G.L. and J.C. Nord. 1978. Contact Toxicity of 34 Insecticides to Second-Stage Nymphs of *Leptoglossus corculus* (Hemiptera:Coreidae). *Can. Entomol.* **110**: 901-906.

Environment Canada. 1986. Weather Record. *Times Colonist.* Victoria, B.C. Canada. Sept. 5-25, 1986.

Fleiss, J.L. 1981. Statistical Methods for Rates and Proportions. John Wiley and Sons. N.Y. 321 p.

Hedlin, A.F., H.O. Yates III, D.C. Tovar, B.H. Ebel, T.W. Koerber and E.P. Merkel. 1980. Cone and Seed Insects of North American Conifers. Can. For. Serv./USDA For. Serv./Secr. Agric. Recur. Hidraul., Mexico, Victoria, B.C. 122 p.

Koerber, T.W. 1963. *Leptoglossus occidentalis* (Hemiptera:Coreidae), a newly discovered pest of coniferous seed. *Ann. Ent. Soc. Amer.* **56**: 229-234.

Miller, G.E. 1980. Pest Management in Douglas-fir Seed Orchards in British Columbia: A Problem Analysis. Pest Management Papers No. 22, April 1980. Simon Fraser University, Burnaby, B.C., Canada.

Nord, J.C., G.L. DeBarr, N.A. Overgaard, W.W. Neel, R.S. Cameron and J.F. Godbee. 1984. High-volume Applications of Azinphosmethyl, Fenvalerate, Permethrin , and Phosmet for Control of Coneworms (Lepidoptera:Pyralidae) and Seed Bugs (Hemiptera:Coreidae and Pentatomidae) in Southern Pine Seed Orchards. *J. Econ. Entomol.* **77**: 1589-1595.

Nord, J.C., G.L. DeBarr, L.R. Barber, J.C. Weatherby and N.A. Overgaard. 1985. Low-volume applications of azinphosmethyl, fenvalerate and permethrin for control of coneworms (Lepidoptera:Pyralidae) and seed bugs (Hemiptera:Coreidae and Pentatomidae) In southern pine seed orchards. *J. Econ. Entomol.* **78**: 445-450.

Ross, T.E. 1981. Diatomaceous Earth as a Possible Alternative to Chemical Insecticides. *Agric. and Environ.* **6**: 43-51.

Ruth, D.S. 1980. A Guide to Pests in Douglas-fir Seed Orchards. Environ. Can. C.F.S. BC-X-204.

EFFECTS OF FENVALERATE INSECTICIDE ON POLLINATORS[1]

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Abstract

Susceptibility to fenvalerate sprays was greatest for the alfalfa leafcutting bee, *Megachile rotundata* (Fabr.); least for the honey bee, *Apis mellifera* L.; and intermediate for the alkali bee, *Nomia melanderi* Cock. Low temperatures increased the residual toxic effects of fenvalerate to honey bees. Fenvalerate at 0.22 kg AI/ha had low residual hazard to bees after one day under Pacific Northwest conditions. Field tests of fenvalerate on blooming alfalfa, pollen shedding corn, and blooming red raspberry resulted in reduced bee visitation and low to moderate adult bee mortality.

Introduction

Fenvalerate (Pydrin) (cyano (3-phenoxyphenyl) methyl 4-choloro-alpha-(1-methyl ethyl) benzeneacetate) is a synthetic pyrethroid available as an emulsifiable concentrate. It kills as a contact or stomach poison, and is registered for insect control on a relatively large number of agricultural crops.

This paper reports results of our research conerning the effects of fenvalerate insecticide on honey bees (*Apis mellifera* L.), alkali bees (*Nomia melanderia* Cock.), and alfalfa leafcutting bees (*Megachile rotundata* (Fabr.)). Also, we report results of field tests of fenvalerate effects on honey bees when applied to blooming alfalfa and pollen shedding corn and effects on honey bees and bumble bees when applied to blooming red raspberry.

Small-Scale Bioassay

Material and Methods. Tests were conducted with fenvalerate on honey bees, alkali bees, and alfalfa leafcutting bees in 1975 and 1985 (Tables 1 and 2). Fenvalerate was applied to 0.004-hectare plots of alfalfa with a Solo backpack boom sprayer, using 1758 g/cm^2 pressure and 234 liters of water/ha. Field-weathered fenvalerate residual test exposures were replicated four times with four foliage samples per treatment and time interval. Foliage samples consisting of ca. 500-cm^2 taken from the upper 15-cm portions of plants were cut into 2.5- to 5-cm diameter plastic petri disk and a circular insert formed from a strip of metal screen (6.7 meshes/cm) 45 cm long and 5 cm wide. In one test, foliage residues were held in the lab in the dark at 10°C and 29°C, and outdoors in 18-35°C variable day-night temperatures and daily sunlight. Residual toxicity of fenvalerate combined with Bond, (Loveland Industries, Inc., Loveland, CO) or Biofilm (Kalo, Overland Park, KS), was also tested. Active ingredients in Bond are synthetic latex and primary aliphatic oxyalkylated alcohol. Active ingredient in Biofilm is alkylaryl polyoxyethylenate.

Worker honey bees were obtained from top supers of colonies and anesthetized with CO_2 to facilitate handling. Leafcutting bee and alkali bee prepupae in leaf piece cells and soil cores, respectively, were incubated at 29.5° to 31°C and 60% relative humidity. Emerging adults were trapped in canisters fitted with screen funnels and chilled to facilitate handling. Residual test exposures were replicated four times by caging 60 to 75 worker honey bees, 25 to 40 leafcutting bees, and 15 to 20 alkali bees with each of four foliage samples per treatment and time interval. Bees were maintained in cages at 29.5°C/60% RH and fed syrup prepared from 50% sucrose and water in a cotton wad (5 by 5 cm). Bee mortality was determined after 24-hours.

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Results and Discussion. Table 1 presents the combined means of tests done in 1975 and 1985. The honey bee was more tolerant of fenvalerate than the other species. The mortality sequence was typical, in that alfalfa leafcutting bees were most susceptible, alkali bees were intermediate in susceptibility, and honey bees least susceptible to fenvalerate. Bee susceptibility is a function of size or surface/volume ratio which is related to chance adherence of residues to the body of a foraging bee (Johansen *et al.*, 1983). The mortality of bioassay bees in 24 hours continuous contact with foliage samples decreased as the age of residues increased. One day was required for residues of the 0.22 rate to degenerate to result in low mortality to honey bees.

Table 1. Mortalities of honey bees, alfalfa leafcutting bees, and alkali bees exposed to different age residues and rates of fenvalerate 2.4 EC applied to 0.004-ha plots of alfalfa. Bees confined with treated alfalfa for bioassay mortalities. Pullman and Prosser, WA. 1975, 1985.

Materials	Rate kg AI/ha	24 hr % mortalities of bees Caged with treated foliage, Age of residues		
		2 hr	8 hr	24 hr
			Alkali Bees	
Fenvalerate	0.11	64a	18a	--
Fenvalerate	0.43	100 b	96 b	--
Untreated check	--	8 c	5 c	--
			Honey Bees	
Fenvalerate	0.11	57a	17a	--
Fenvalerate	0.22	41 b	25 b	22a
Fenvalerate + Bond	0.22 + 8 oz	37 b	7 c	9 b
Fenvalerate + Biofilm	0.22 + 2 oz	44 b	14a	18a
Fenvalerate	0.43	100 c	97 d	--
Untreated check	--	1 d	2 c	1 c
			Leafcutting Bees	
Fenvalerate	0.11	82a	39a	--
Fenvalerate	0.22	92ab	63 b	--
Fenvalerate + Bond	0.22 + 8 oz	87ab	67 b	--
Fenvalerate	0.43	100 b	96 c	--
Untreated check	--	6 c	7 c	--

Means within a column for each test followed by the same letter are not significantly different (P = 0.05; Duncan's [1951] multiple range test).

The addition of a proprietary sticker did not reduce honey bee mortality in the 2-hour residue tests, but did in the 8 hour tests. Adding Bond significantly reduced honey bee mortality. Mayer *et al.* (1987) showed that Bond also reduces bee mortality when combined with other insecticides.

The effects of temperature and sunlight on activity of fenvalerate against honey bees are shown in Table 2. Two and eight hour residues held at 10°C and 29°C caused significantly more mortality than residues held in variable day-night temperatures (18°C-35°C) and daily sunlight. Therefore, fenvalerate residues may be more toxic to honey bees for a longer period of time when used under cool, cloudy conditions.

Field Test — Alfalfa

Materials and Methods. In 1978, fenvalerate was tested for been toxicity and effects on honey bee foraging activity on blooming alfalfa in a 4-ha field near Pullman, WA. Fenvalerate 2.4 EC was applied by airplane at 0.22 kg AI/ha/93.4 liters of water/ha at 6 a.m. A separate

Table 2. Mortalities of honey bees exposed to different age residues of fenvalerate 2.4 EC (0.22 kg AI/ha) applied to 0.004-ha plots of alfalfa and foliage held at different environmental conditions. Bees confined with treated foliage for bioassay mortalities. Prosser, WA. 1986.

	24 hr % mortalities of bees Caged with treated foliage Age of residues		
Treatment	2 hr	8 hr	24 hr
Fenvalerate			
10°C - dark	70a	96a	9a
29°C - dark	76a	58 b	5a
18°-35°C daily sunlight	49 b	40 c	9a
Untreated check	5 c	2 d	1a

Means within a column for each test followed by the same letter are not significantly different (P = 0.05; Duncan's [1951] multiple range test).

4-ha field several km away served as an untreated check. Two honey bee colonies with Todd dead bee traps were located adjacent to each field. The number of dead honey bees was recorded daily before and after application. Numbers of honey bees/23 m2 of foraging alfalfa were counted after the application. Colony conditions were evaluated before and after the application.

Results and Discussion. Table 3 presents the results of fenvalerate on blooming alfalfa. The application reduced numbers of foraging honey bees to zero, 5 h after application though numbers returned to normal 32 h after application. The application caused no increase in the number of dead bees and no harm to the colonies.

Moffett *et al.* (1982) found fenvalerate at 0.11 kg AI/ha did not cause any honey bee mortality, and bee visits to alfalfa flowers were 70% less on the afternoon after the applications. They also reported that fenvalerate applied at 0.4 kg AI/ha to a blooming alfalfa field did not seriously affect honey bee colonies.

Field Tests — Raspberries

Materials and Methods. In 1985, field tests of fenvalerate were conducted on honey bees on blooming red raspberries near Vancouver, WA. Fenvalerate 2.4 EC was applied at 0.22 kg AI/ha by ground with a hooded-boom sprayer at 8 p.m. Foliage samples taken after application

Table 3. Effect on honey bees of early morning application by air of fenvalerate 2.4 EC (0.22 kg AI/ha) applied to a 4-ha field of blooming alfalfa. Pullman, WA 1978.

Material	Number dead bees/colony				Number HB/23 m^2 sightings		
	Pre-treatment	Post-treatment			Post-treatment		
		24 hr	48 hr	72 hr	5 hr	10 hr	32 hr
Fenvalerate	36	22	23	35	0	6	20
Untreated check	34	70	14	43	19	21	18

were used to bioassay bee mortality. A battery-operated vacuum aspirator (Clinch, 1971) was used to collect 40 honey bees and 40 bumble bees foraging raspberry bloom in the plots. They were captured from the plots at different times after application and confined in the standard small cages for mortality determinations. Bee numbers and behavior in the plots were assessed at different times during the days after application. A stopwatch was used to determine the amount of time 100 individual bees spent working a berry flower before and 17 hours after the fenvalerate application. Test 1 was used to determine the amount of time 100 individual bees spent working a berry flower before and 17 hours after the fenvalerate application. Test 1 was on a 0.02-ha plot of 'Meeker' red raspberry and a separate 0.02-ha plot was left untreated. Two honey bee colonies were placed adjacent to the field seven days before application. Test 2 was on a 0.2-ha field of 'Amity' raspberry which was the only variety blooming during that time. In Test 2, honey bee mortality was assessed using Todd dead bee traps in two colonies placed adjacent to the field several days before application.

Results and Discussion. In Test 1, fenvalerate had no effect on the number of foraging honey bees, based on bee counts 14 h post-treatment (Table 4). In Test 2, foraging honey bees were reduced 19% 14 h after application though numbers returned to normal by 16 h. A mean of 40

Table 4. Effect of evening ground application of fenvalerate 2.4 EC (0.22 kg AI/ha) to blooming red raspberry on honey bees and bumble bees. Test 1 on 0.02-ha plot of 'Meeker.' Test 2 on 0.2-ha plot of 'Amity.' Vancouver, WA. 1985.

	% bees in treated plots compared to untreated at indicated hours after application				
	12 hr	14 hr	16 hr	20 hr	24 hr
Test 1 honey bees	--	125	112	115	--
Test 2 honey bees	33	81	120	91	130
bumble bees	17	33	47	39	8

Table 5. Mortalities of bees exposed to different age residues of fenvalerate 2.4 EC applied (0.22 kg AI/ha) to blooming red raspberry. Test 1 on 0.02-ha plot of 'Meeker.' Test 2 on 0.2-ha plot of 'Amity.' Bees confined with treated foliage for bioassay mortalities. Vancouver, WA. 1985.

		24 hr % mortalities of bees Caged with treated foliage Age of residues					
		Honey bees					Bumble bees
	Material	12 hr	15 hr	18 hr	24 hr	48 hr	18 hr
Test 1	fenvalerate	--	83a	36a	--	24a	--
	untreated check	--	2 b	2 b	--	2 b	--
Test 2	fenvalerate	30a	--	17a	15a	--	100a
	untreated check	1 b	--	1 b	0 b	--	25 b

Means within a column for each test followed by the same letter are not significantly different (P = 0.05; Duncan's [1951] multiple range test).

dead bees per day were captured in the Todd traps before application. At one and two days after application, 31 and 21 dead bees were caught respectivly — well below normal die-off levels (mayer and Johansen, 1983). In Test 2, bumble bee foragers were greatly reduced by the application for up to one day. On the 'Amity' raspberry, individual bees spent a mean of 14.8 (range 7 to 35) sec collecting nectar from a flower pre-treatment; at 17 h post-treatment, the mean dropped to 8.9 (range 4 to 23) sec. We have seen this decrease in the amount of time individual bees spend working blossoms following insecticide applications (unpublished data), but the mechanism involved in such behavior is not known.

Raspberry foliage showed honey bee mortality decreased as residual time increased, but there was significant mortality at one day post-treatment (Table 5). Honey bees in the cages showed an aversion to treated raspberry by clumping together as far away from the treated foliage as possible. We have not observed this repellent type behavior with other insecticides in caged trials with alfalfa treated foliage or with fenvalerate treated alfalfa foliage. Bumble bees did not show this behavior. However, bumble bee poisoning was acute; the 18 hr residues caused 100% mortality.

Foraging honey bees captured in the fenvalerate treated plots had significant mortality up to 20 h post-treatment, but bumble bees captured from field treated plots showed no mortality (Table 6).

Field Tests — Corn

In 1980 and 1986, fenvalerate was tested for bee toxicity on pollen-shedding 'Jubilee' corn in 0.5-ha fields near Prosser, WA. In 1980, fenvalerate 2.4 EC was applied by helicopter before 7 a.m. on four different dates, using 0.22 kg AI/ha in 45 liters of water. In 1986, fenvalerate 2.4 EC was applied by airplane before 7 a.m. on four different dates, using 0.22 kg AI/ha in 51 oz of water (ULV rates). In both years, 0.5-ha fields 0.5 km away served as the untreated check. A daily record was maintained on the number of bees foraging in the field based on one to two 8-min counts on 365 m of row recorded between 10 a.m. and 1 p.m. Two strong, healthy, honey bee colonies with Todd dead bee traps attached, were placed adjacent to each field three days before the first application. The numbers of dead honey bees were recorded daily before and after the applications. Colony conditions were evaluated during the test.

Table 6. Mortalities of bees foraging on blooming red raspberry with different age residues of fenvalerate 2.4 EC applied (0.22 kg AI/ha). Test 1 on 0.02-ha plot of 'Meeker.' Test 2 on 0.2-ha plot of 'Amity.' Foraging bees collected from flowers and confined without foliage in small cages for mortality determinations. Vancouver, WA. 1985.

		24 hr % mortalities of bees Age of residues					
						Bumble bees	
	Material	13 hr	15 hr	20 hr	96 hr	14 hr	20 hr
Test 1	fenvalerate	--	20a	40a	0	--	--
	untreated check	--	10 b	20 b	0	--	--
Test 2	fenvalerate	77a	--	35a	--	0	0
	untreated check	25 b	--	10 b	--	0	0

Means within a column for each test followed by the same letter are not significantly different (P = 0.05; Duncan's [1951] multiple range test).

Results and Discussion. Bee mortality and bee foraging numbers for the sweet corn trials are shown in Table 7. Pre-application and one day post-application comparisons revealed dead bee counts increased two-fold with fenvalerate, but were still considered low based on the range of normal bee die-off (Mayer and Johansen, 1983). Fenvalerate applications reduced the number of honey bees foraging the corn for pollen.

Discussion

It is evident from these studies that fenvalerate is toxic to varying degrees to the bee species studies. Others have reported similar findings. For example, honey bee colonies exposed to beeswax foundation impregnated with 1,000 ppm fenvalerate had poor egg hatch and very low survival through the sealed brood stage (Stoner *et al.*, 1985). However, in a study by Stoner *et al.*, (1984), where fenvalerate was fed at the rate of 100 ppm to honey bee colonies, noticeable toxicity was observed, but not sufficient to pose a serious threat to honey bees. Atkins *et al.*, (1981) reported fenvalerate was highly toxic to honey bees present in the field during applications, though there was no residual toxicity at 1 day post-treatment. In our studies, the residual degradation time in hours (RT) required to bring bee mortality down to 25% in cage test exposures to field-weathered spray deposits applied at standard rates, was slightly more than 8 h for the four bee species we evaluated. Materials with an RT 25 of 8 h or less are useful in terms of bee safety, if applied judiciously, *i.e.* if applied during the late evening or at night.

Table 7. Effect on honey bees of early morning applications by air of fenvalerate (0.22 kg AI/ha) applied to a 0.5-ha field of pollen shedding corn. Prosser, WA. 1986.

Treatment	No. HB/365 m of row Post-treatment		Number dead bees/colony Pre-treatment	Post-treatment	
	24 hr	48 hr		24 hr	48 hr
1980[1]					
Fenvalerate	111	115	--	24	15
Untreated check	428	361	--	16	11
1986[2]					
Fenvalerate	6	--	30	66	42
Untreated check	12	--	3	26	3

[1]fenvalerate applied 29 July and 3, 7, 11 August.
[2]fenvalerage applied 29 July and 1, 4, 7 August.

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References

Atkins, E.L., D. Kellum, and K.W. Atkins. 1981. Reducing pesticide hazards to honey bees: Mortality prediction techniques and integrated management strategies. Univ. Calif. Leaflet 1883. 23 pp.

Clinch, P.G. 1971. A battery-operated vacuum device for collecting insects unharmed. *NZ Entomol.* **5**: 28-30.

Duncan, D.B. 1951. A significant test for differences between marked treatments in an analysis of variance. *VA J. Sci.* **2**: 171-189.

Johansen, C.A., D.F. Mayer, J.D. Eves, and C.W. Kious. 1983. Pesticides and bees. *Environ. Entomol.* **12(5)**: 1513-1518.

Mayer, D.F. and C.A. Johansen. 1983. Occurrence of honey bee (Hymenoptera: Apidae) poisoning in eastern Washington. *Environ. Entomol.* **12(2)**: 317-320.

Mayer, D.F., C.A. Johansen, J.D. Lunden, and Lora Rathbone. 1987. Chemical stickers and bee mortality. *Amer. Bee J.* (In press).

Moffett, J.O., A. Stoner, and R.M. Ahring. 1982. Effect of fenvalerate applications on honey bees in flowering alfalfa. *Southwest. Entomol.* **7(2)**: 111-115.

Stoner, J.P., W.T. Wilson, and J.O. Moffett. 1984. Effect of long-term feeding of low doses of fenvalerate or fluvalinate in sucrose syrup on honey bees in standard-size field colonies. *J. Georgia Entomol. Soc.* **19(4)**: 490-498.

Stoner, A., W.T. Wilson, and Jack Harvey. 1985. Honey bee exposure to beeswax foundation impregnated with fenvalerate or carbaryl. *Amer. Bee. J.* **125(7)**: 513-516.

SECOND BROODS OF *PISSODES STROBI* (COLEOPTERA: CURCULIONIDAE) IN PREVIOUSLY ATTACKED LEADERS OF INTERIOR SPRUCE

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Abstract

Oviposition and successful brood production by spruce weevil, *Pissodes strobi*, were observed below the previous year's attacked, dead leader in as many as 19.5 percent of current attacked trees in a 15-year-old plantation of interior spruce. This occurrence may have significant impacts upon weevil survey and control programmes and, ultimately, the regime under which the stand will be managed.

During the establishment of a trial investigating the feasibility of silvicultural control of spruce weevil, *Pissodes strobi Peck* (Coleoptera: Curculionidae), unusual oviposition behaviour and brood development of this weevil was observed in leaders which had been attacked in the previous year. These observations were made in a 15-year-old plantation of interior spruce (*Picea glauca x engelmannii)*, located approximately 50 km east of Prince George, British Columbia. Clearcut harvesting of the area took place in 1969. The plantation was established in the spring of 1971, using 2+1 bareroot interior spruce stock, following a broadcast burn in the fall of 1970.

The spruce weevil attacks and kills the terminal shoot of young spruce trees ranging in height from 1 - 15 m, and occasionally to over 25 m. Lateral branches are then forced to compete for apical dominance. This commonly results in multiple or crooked stems which can represent losses to merchantable tree volume and value. The overtopping of attacked trees by healthy coniferous trees and competing deciduous trees may result in mortality from competition (Stevenson 1967; Wood and McMullen 1983).

Table I. Occurrence of re-infestation of previously infested spruce leaders by *Pissodes strobi*, expressed in relation to current attacks, in a 15-year-old interior spruce plantation, 50 km east of Prince George, B.C.

Attack year	Previously uninfested leaders		Reinfested leaders	
	n[1]	Av. emerging adults per leader (range)	n[1]	Av. emerging adults per leader (range)
1984	50	3.98 (0-14)	1	3.00 (-)
1985	71	5.72 (0-24)	5	4.00 (0-8)
1986	59	3.12 (0-19)	16	6.25 (0-31)
TOTAL	180	5.26 (0-24)	22	5.82 (0-31)

1 'n' will not be consistent with the attacks represented in Table I since some trees were too tall to determine adult emergence and some leaders were heavily damaged by birds feeding upon maturing brood.

Adult spruce weevils emerge from their overwintering locations in the duff soon after the snow disappears and the site is warmed to above 6°C (Sullivan 1959). The weevils crawl up potential host trees, to begin feeding, immediately after their emergence from hibernation. Stevenson (1967) observed that feeding on stems that had been attacked the previous year occurred only in the uppermost living tissues. Overhulser and Gara (1975) reported that weevils were found initially only on brood trees. However, with the first day of temperatures conducive to adult flight, weevils were also observed on trees attacked two years earlier and on those trees being attacked for the first time. They also noted that flight occurred from the previous year's dead leader on brood trees towards leaders which promised suitable feeding and oviposition sites. Spruce trees have not generally been considered as available for reattack by the spruce weevil for at least two years after their terminals have been killed. This is the time necessary for the tree to produce a new leader with characteristics attractive to the weevil (Alfaro 1982). Commonly, the longest, thickest leaders presenting a vertical silhouette have been found to be the most likely to be attacked (VanderSar and Borden 1977; Kline and Mitchell 1979; Wood and McMullen 1983). It has been documented by several authors (Silver 1968; VanderSar and Borden 1977; Alfaro 1982; Alfaro and Borden 1985) that spruce trees, once initially attacked, appeared to be pre-disposed to further attacks on the resultant multiple terminals. The favoured feeding, mating and oviposition site has been determined to be the tip of the previous year's leader(s) below the terminal bud (Gara *et al.* 1971; Overhulser and Gara 1975; VanderSar and Borden 1977; Wood and McMullen 1983).

The author observed, in 1984, 1985 and 1986, abnormal infestation behaviour of spruce weevils. In addition to the occurrence of spring feeding below the previous year's dead leader, oviposition sites were evident in several of the trees examined (1984 - 2 trees; 1985 - 7 trees; 1986 - 16 trees) (Table I). Current year's feeding and oviposition locations were identified by fresh resin flow from the area of activity below the dead leader. The oviposition punctures were distinguished from feeding punctures, which are normal on such leaders, by the presence of a fecal cap over those in which oviposition occurred (Stevenson 1967; Silver 1968). Further confirmation of oviposition was by the presence of adult exit holes below the oviposition punctures in question (Fig. 1). Hulme *et al.* (1986) determined that the lethal temperature for *P. strobi* in sitka spruce, *Picea sitchensis* (Bong.) Carr., to be near –16°C. Earlier observations (unpublished data) had demonstrated that spruce weevil brood would not overwinter successfully in leaders in the geographic area of the study plots. The emerging adults thus could not be progeny of the previous year's attack. Dissection of similarly attacked leaders collected from outside of the study plots revealed an area between the successive year's attacks in which no larval activity was evident. Average brood production from re-infested leaders was slightly more than that from normally infested leaders; 5.82 adults per leader (range 0–31) vs. 5.26 adults produced per normally attacked leader (range 0–24) (Table II). Total brood production per re-infested leader was almost 250% of that of a singly infested leader; 12.6 adults emerging per leader (range 0–39) vs. 5.26 adults emerging per singly infested leader (range 0–24) (Table III).

Table II. Adult *Pissodes strobi* emergence from previously uninfested and reinfested spruce leaders in a 15-year-old interior spruce plantation, 50 km east of Prince George, B.C.

Attack year	Total number of trees examined	Total number of current attacks	Number of attacks on previously unattacked leaders	Number of attacks below previously attacked leaders	Percent reattack
1984	5383	87	85	2	2.3
1985	5383	92	85	7	7.6
1986	5383	82	66	16	19.5

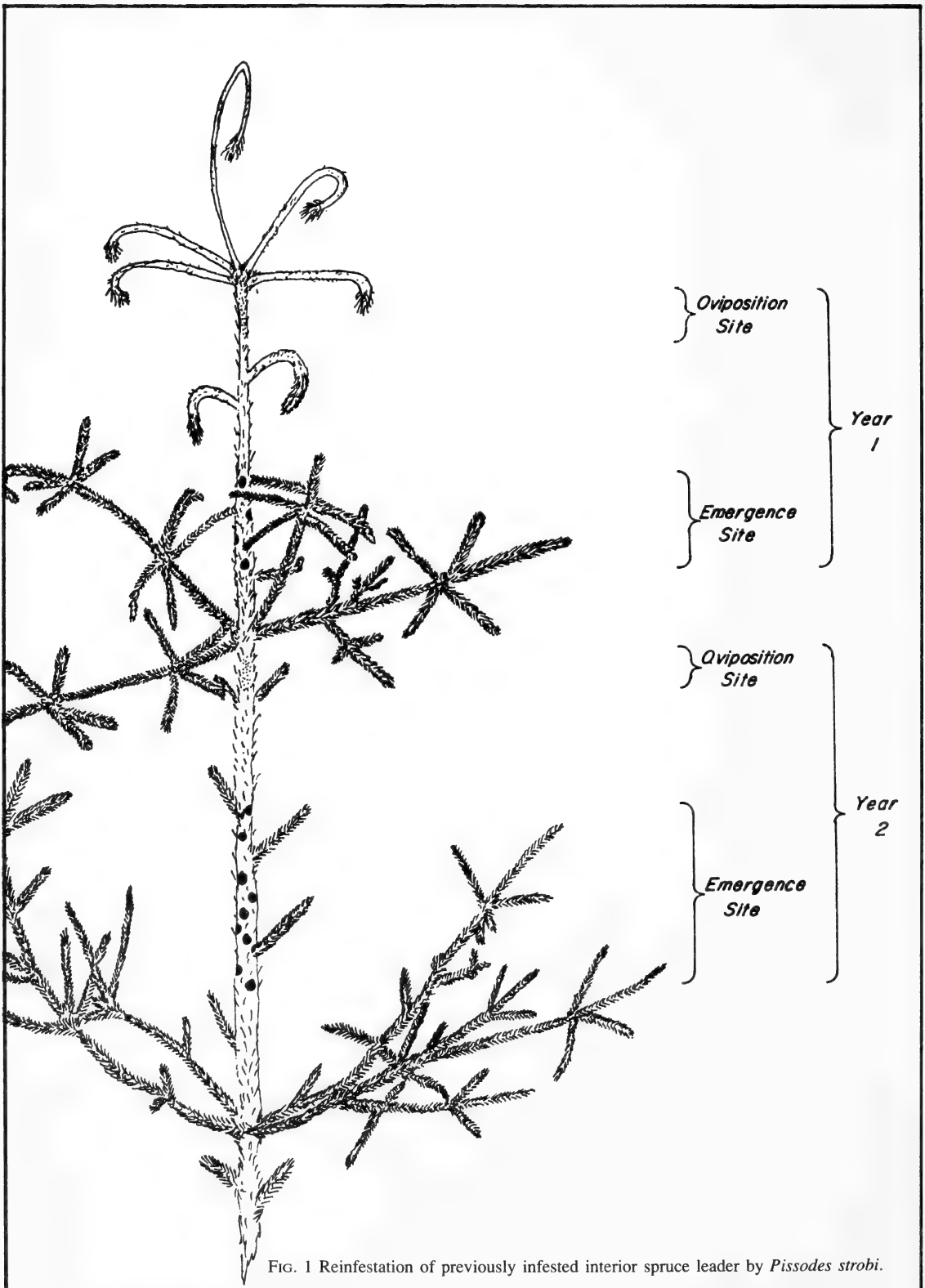

FIG. 1 Reinfestation of previously infested interior spruce leader by *Pissodes strobi*.

Table III. Average emergence from single infestations and multiple infestations of spruce leaders by *Pissodes strobi* in a 15-year-old interior spruce plantation, 50 km east of Prince George, B.C.

Single infestations		Re-infested leaders			
n[1]	Av. emerging adults (range)	n[1]	Av. emerging adults		
	(range)		Initial infestation	Re-infestation	Total
180	5.26 (0–24)	20	6.4 (0–24)	6.2 (0–31)	12.6 (0–39)

[1] 'n' will not be consistent with the attacks represented in Table I since some trees were too tall to determine adult emergence and some leaders were heavily damaged by birds feeding upon maturing brood. 'n' will not be consistent with the attacks represented in Table II since it was necessary to determine adult emergence from both the initial infestation and re-infestation.

The occurrence of successful re-infestation by the spruce weevil is of significance in both survey and control activities. Based on the information from these observations, up to 20 percent of the previous year's infested leaders may be re-infested. Since the identification of currently infested spruce trees is by the drooping or dead current leader, depending upon the time in the year of examination, nearly 20 percent of current attacks may well be overlooked by conventional detection methods. This could result in the non-recognition and non-treatment of sufficient numbers of potential adults to perpetuate a reduced but active weevil population in a young spruce stand. Therefore, a major decision must be made prior to the start of any survey or control programme: either all previous year's infested trees must be inspected carefully for re-infestation, and subsequently treated; or, the exclusion of any re-infested leaders from control treatment must be accepted in conjunction with the potential consequences of the decision. This decision must be made by the forest manager with full realization and acceptance of both the immediate and possible long term effects upon stand development.

References

Alfaro, R.I. 1982. Fifty year-old spruce plantations with a history of intense weevil attack. *J. Entomol. Soc. British Columbia* **79**: 62-65.

Alfaro, R.I. and J.H. Borden. 1985. Factors determining the feeding of the white pine weevil (Coleoptera: Curculionidae) on its coastal British Columbia host, Sitka spruce. *Proc. Ent. Soc. Ont. Suppl.* **116**: 63-66.

Gara, R.I., R.L. Carlson and B.F. Hrutfiord. 1971. Influence of some physical and host factors on the behaviour of the Sitka spruce weevil, *Pissodes sitchensis*, in southwestern Washington. *Ann. Ent. Soc. Amer.* **64**: 467-471.

Hulme, M.A., A.F. Dawson and J.W.E. Harris. 1986. Exploiting cold hardiness to separate *Pissodes strobi* (Peck) (Coleoptera: Curculionidae) from associated insects in leaders of *Picea sitchensis* (Bong.) *Carr. Can. Ent.* **118**: 1115-1122.

Kline, L.N. and R.G. Mitchell. 1979. Insects affecting twigs, terminals and buds. In *Forest Insect Survey and Control. ed.* J.A. Rudinsky. O.S.U. Book Stores Inc. 472 pp.

Overhulser, D.L. and R.I. Gara. 1975. Spring flight and adult activity of the white pine weevil, *Pissodes strobi* (Coleoptera: Curculionidae), on Sitka spruce in western Washington. *Can. Ent.* **107**: 251-256.

Silver, G.T. 1968. Studies on Sitka spruce weevil, *Pissodes sitchensis*, in British Columbia. *Can. Ent.* **100**: 93-110.

Stevenson, R.E. 1967. Notes on the biology of the Engelmann spruce weevil *Pissodes engelmanni* (Curculionidae: Coleoptera) and its parasites and predators. *Can. Ent.* **99**: 201-213.

Sullivan, C.R. 1959. The effect of light and temperature on the behaviour of adults of the white pine weevil, *Pissodes strobi Peck. Can. Ent.* **91(4)**: 213-231.

VanderSar, T.J.D. and J.H. Borden. 1977. Visual orientation of *Pissodes strobi Peck* (Coleoptera: Curculionidae) in relation to host selection behaviour. *Can. J. Zool.* **55**: 2042-2049.

Wood, R.O. and L.H. McMullen. 1983. Spruce weevil in British Columbia. Environment Canada. Canadian Forestry Service. Pacific Forest Research Centre. Forest Pest Leaflet #2. 4pp.

CHIONEA MACNABEANA ALEXANDER, A MICROPTEROUS CRANE FLY (DIPTERA: TIPULIDAE) NEW TO CANADA

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Abstract

The flightless crane fly, *Chionea macnabeana* Alexander, is reported from Canada for the first time: several specimens were collected in Engelmann spruce-subalpine fir forest in the North Cascade Mountains of Manning Park, British Columbia.

Introduction

The genus *Chionea* is a fascinating group of flightless crane flies best known for their winter appearances, when they stride over the snow at dusk when the temperature hovers around 0°C. The North American species were recently treated by Byers (1983) in an excellent and thorough revision. Byers (1983) records five species in Canada: *C. albertensis* Alexander, *C. obtusa* Byers and *C. alexandriana* Garrett from the west and *C. scita* Walker and *C. valga* Harris in the east. In his monograph, Byers suggests that two additional species, *C. macnabeana* Alexander and *C. nivicola* Doane, may range into southern British Columbia.

On 6 March 1983, while on a skiing trip up Fat Dog Creek, Manning Park, B.C., I collected a single male specimen of a *Chionea* species unfamiliar to me. Although it superficially resembled *C. alexandriana* in the shape of the ninth tergum, it was yellowish in colour rather than brown like *C. alexandriana,* and its antennae had ten rather than three or four flagellomeres. Its legs were covered in stout, black setae. It occurred to me that this might be the undescribed male of *C. macnabeana,* so I sent it to Dr. Byers for confirmation. He assured me that it was *C. macnabeana,* but he had just described the male from a specimen collected in Oregon (Byers 1983). On 31 December 1983 and 1 January 1984, eleven additional specimens were collected from the same area.

Material Examined

BRITISH COLUMBIA: Manning Provincial Park, Fat Dog Creek, 40°08′N 120°49′W, 1400-1450 m, 6.iii.1983, 1 male, S. G. Cannings (Canadian National Collection, Ottawa); *ibid.,* 1400-1500 m, 31.xii.1983, 1 male, 1 female, H. and A. Brock (Snow Entomological Museum, U. of Kansas, Lawrence); *ibid.,* 2 males, 1 female, R. J. Cannings (Spencer Entomological Museum, UBC); *ibid.,* 3 males, 2 females, S.G. Cannings (UBC); Manning Provincial Park, Big Ben Trail [headwaters of Similkameen R.], 1.i.1984, S. G. Cannings (UBC).

Discussion

C. macnabeana is an apparently rare species of the coastal mountains of the Pacific Northwest. Only three specimens had been collected previously; these were found near Tillamook, Oregon, in the Sentinel Hills, Oregon, and on the Olympic Peninsula of Washington State, all on the other slopes of the northern Coast Ranges. Two were found at low elevations in coastal forest and one was in subalpine forest at 5200-5500′.

The Manning Park individuals were crawling across snow in a subalpine forest of Engelmann spruce *(Picea engelmanni)* and subalpine fir *(Abies lasiocarpa)* at 1400-1500 m. The first one found was on a shady, steep, north-facing slope; the sky was clear with a temperature of 2°C. Most of the others were captured on the same slope on an overcast day when the temperature was about –1°C, but one was low on an east-facing slope. The common *Chionea* of the immediate area is *C. alexandriana; C. albertensis* is also present, but in much lower numbers.

This area is on the crest of the North Cascade Mountains, so the habitat is somewhat of a hybrid between coast and interior subalpine forests. It is colder and drier than coastal subalpine areas, but is still strongly affected by moist Pacific air masses and receives about 3-4 m of snow annually.

As is typical for the genus, the individuals seem to vary greatly in size, although the small sample size limits the ranges seen: males range from 6.0 to 8.5 mm long with hind femora from 3.8 to 5.8 mm, whereas females are from 7.6 to 8.7 mm long with hind femora from 3.6 to 4.0 mm.

Entomologists in the southern interior of British Columbia should watch for *C. nivicola,* a species which resembles somewhat the brown, slender-legged *C. albertensis* but differs from that species by its shorter antennae of only eight or nine segments (six or seven flagellomeres). In Washington and Oregon, *C. nivicola* inhabits open forests from about 740 to 1850 m elevation (Byers 1983).

Acknowledgements

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Reference

Byers, G. W. 1983. The crane fly genus *Chionea* in North America. *Univ. Kansas Sci. Bull.* **52**(6): 59-195.

PTILODACTYLA SERRICOLLIS (COLEOPTERA: PTILODACTYLIDAE) IN BRITISH COLUMBIA

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The Ptilodactylidae (Toed-winged Beetles) contains about 35 genera and 300 species according to recent definitions of the family (Lawrence 1982). Such definitions are much broader than those published by Arnett (1968, 1983). It is primarily a tropical family.

Adults of the Ptilodactylidae are "2-16 mm (usually 4-12 mm) in length, oblong to elongate, and glabrous or clothed with fine hairs. The antennae range from serrate to pectinate, and are usually more highly modified in males..." (Lawrence 1982). In *Ptilodactyla* the antennae are 11-segmented, serrate in the female, pectinate in the male; in the latter, segments 4-10 each bear a long, narrow basal process (Arnett 1968).

Adults are found on vegetation, often in marshy areas, and frequently are attracted to lights at night. The larvae live in leaf litter, rotting logs, damp soil and debris at the edge of streams (Arnett 1968, Lawrence 1982).

On 20 July 1979 one of us (JGF) collected a male and female *Ptilodactyla serricollis* (Say) on the garden patio of an apartment building adjacent to Beacon Hill Park, Victoria, B.C.

P. serricollis is one of the more common species of the family in North America. It is recorded from the eastern United States (Arnett 1983) and from Québec (Chagnon and Robert 1962) and Ontario (Evans 1904). All specimens in the Canadian National Collection (Agriculture Canada, Ottawa) are from Québec and Ontario (LeSage, *in litt.*).

Since specimens of *Ptilodactyla* are "rather commonly transported as larvae in greenhouse potting soils" (J. B. Stribling, *in litt.*), it is probable that the two specimens were merely adventives from eastern North America. Potted plants and nursery stock were abundant around the collection site. Nevertheless, the possibility of small populations of *P. serricollis* becoming established on the Pacific coast should not be discounted.

Acknowledgements

Walter Lazorko (Vancouver) first identified the specimens; James Stribling (Department of Entomology, Ohio State University) confirmed the identification. Syd Cannings (Department of Zoology, University of British Columbia) and Laurent LeSage (Biosystematics Research Institute, Agriculture Canada) commented on the manuscript.

References

Arnett, R. H., Jr. 1968. The Beetles of the United States. The American Entomological Institute, Ann Arbor.

Arnett, R. H., Jr. 1983. Checklist of the Beetles of North and Central America and the West Indies. Vol. 3. The Scarab Beetles, Buprestid Beetles and related groups. Flora and Fauna Publications, Gainesville.

Chagnon, G. and A. Robert. 1962. P. 195 *in* Principaux Coléoptères de la Province de Québec (2ème édition). Les Presses de l'Université de Montréal.

Evans, J. D. 1904. Insects collected at light during the season of 1904. Entomological Society of Ontario Annual Report No. **35**: 82-85.

Lawrence, J. F. 1982. Coleoptera. Pp. 482-553 *in* Synopsis and Classification of Living Organisms. Vol. 2. (Sybil P. Parker, ed.). McGraw-Hill Inc., Toronto.

FIELD TECHNIQUES FOR REARING AND MARKING MOUNTAIN PINE BEETLE FOR USE IN DISPERSAL STUDIES

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Abstract

Mountain pine beetles, *Dendroctonus ponderosae,* were marked with fluorescent (Day-Glo) powders in vacuum chambers and on powder-covered brood trees in the field for use in release-recapture studies of dispersal behavior. A large wall tent was used as a field insectary to accelerate late stages of development of large numbers of beetles in naturally infested bolts of lodgepole pine. Up to 28% of the marked beetles which flew were recovered from lethal trap trees. Beetles self-marked on powdered brood trees were captured in barrier traps in predicted proportions.

Résumé

Des dendroctones du pin ponderosa ont été marqués à l'aide de poudres fluorescentes (Day-Glo) dans des chambres à dépression ainsi que sur des arbres foyers couverts de poudre sur le terrain pour des études par libération-recapture du comportement de dispersion. Une grande tente canadienne a été employée comme insectarium sur le terrain pour accélérer les derniers stades de développement des grands nombres de dendroctones se trouvant dans des billons de pins tordus infestés naturellement. Jusqu'à 28% des dendroctones marqués qui s'étaient envolés ont été retrouvés dans des arbres pièges létaux. Les dendroctones qui s'étaient marqués eux-mêmes sur les arbres foyers couverts de poudre ont été capturés dans des pièges dans les proportions prévues.

Introduction

A series of release-recapture field experiments to study the dispersal of mountain pine beetles, *Dendroctonus ponderosae* Hopk., (mpb) required development of techniques for rearing, marking, releasing, and subsequently recapturing large numbers of these insects. The experiments were carried out from 1982 to 1985 in the Cariboo Forest Region of B.C. near Riske Creek.

Fluorescent powders have been used extensively as markers on insects and are usually non toxic, readily available, and inexpensive (Gangwere *et al.* 1964; Gara 1967; Moffitt and Albano 1972; Schmitz 1980). Techniques have been described for applying powders to large numbers of moths or flies quickly and reliably using a vacuum dusting chamber (Dunn and Mechalas 1963; Moffitt and Albano 1972). We used similar chambers made from 6-mm-thick plexiglass (Fig. 1) to dust up to 250 adult mpb placed on the bottom of the chamber at one time using 0.5 g of dust.

In the absence of a permanent insectary, mpb were partially force-reared in a large wall tent which incorporated a specially constructed door consisting of a large window above a cold trap for capturing live beetles soon after emergence. Storage, handling, and release and recapture methods used in 1982 and 1983 are described. Also presented is a new and simple method of marking beetles (tested in 1983 and used in experiments in 1984 and 1985) by applying fluorescent powder to brood trees before emergence. The powders are shown to have no apparent effect on dispersal behavior or longevity of mpb up to the time of release and they persist through pre-flight handling, dispersal flight, and handling subsequent to recapture. Full results of the dispersal experiments will be reported elsewhere.

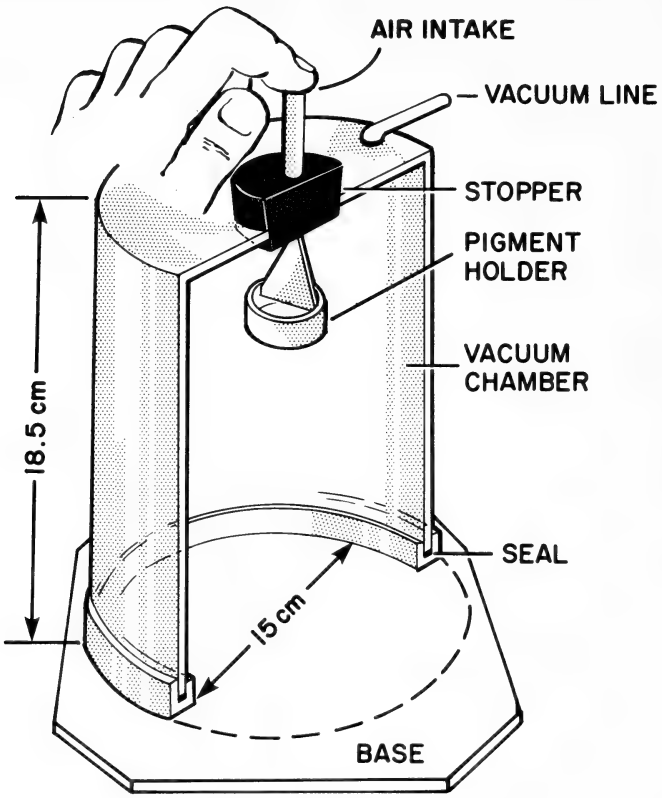

FIG. 1. Vacuum dusting chamber (Dunn & Mechalas 1963: Moffitt & Albano 1973).

Rearing

In early June, 1982 and 1983, 15-20 infested lodgepole pine, *Pinus contorta* var. *latifolia* Dougl., were felled, and the lower 2-7 m were sawn into 1 m lengths. All logs were examined for density of live mpb brood, and the most heavily infested logs (93 in 1982, 90 in 1983) were piled between heavy posts driven into the ground within a 3 m x 4 m area which had been cleared of debris and vegetation. The log pile was made up to fit within a 3 m x 4 m x 2 m canvas wall tent having 1-m-high walls, leaving at least 25 cm of clearance on all sides. The tent was erected over the log pile and was covered by an opaque plastic tarpaulin fly suspended about 25 cm above the roof.

The tent was left closed on all but the hottest days, when end flaps were opened to prevent possible lethally high temperatures. A 3000-btu catalytic propane heater (Coleman model # 9446-510) was used during cool weather and at night. A thermograph in the tent recorded temperatures (Fig. 2).

Brood development in the logs was monitored every few days by removing small areas of bark. In late June tenerals were found and a sloped clear plastic window with a rectangular sheet metal funnel at the bottom was installed on a plywood frame in the west-facing tent door. The funnel fed into a portable 12 V refrigerator (Koolatron mod. 10) which was operated on the "max cold" setting 24 hours a day using an AC adapter and line (110 V) current. The original lid of the refrigerator was removed and replaced with an insulated plywood lid having a 7.5 cm square center hole which fitted tightly around the funnel tube. The temperature inside the refrigerator remained between 1 and 5 °C, which was cool enough to rapidly immobilize the trapped beetles. The metal heat exchanger portion of the bottom of the refrigerator

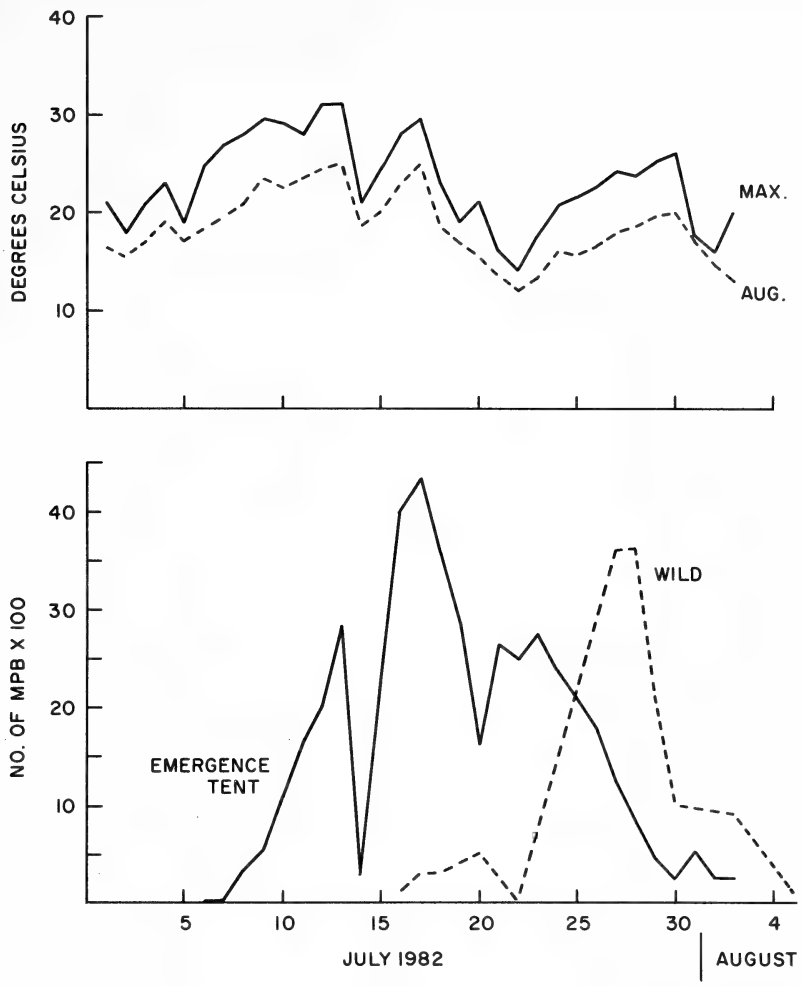

Fig. 2. ABOVE. Solid line = maximum temperatures attained inside the rearing tent. Dotted line = average ambient temperatures. BELOW. Solid line = emergence of mpb from rearing tent. Dotted line = total catches of wild mpb at trap trees. All data recorded Jul-Aug, 1982.

compartment was lined with tightly fitted cardboard to prevent insects from freezing from direct contact; crumpled paper towel was also placed in the bottom to provide climbing surfaces, thus minimizing crowding which results in insects injuring one another. When newly emerged photopositive beetles attempted to fly out of the tent they struck the plastic barrier, and fell into the cold trap. In 1982, 45,415 beetles were collected between July 8 and August 4. In 1983, approximately 25,000 beetles were collected between June 14 and July 24.

The cold trap was cleared of insects daily (more often during peak emergence). Beetles were kept cool until counted by hand into lots of 250 in preparation for vacuum dusting. Beetles having obvious injuries or malformations were discarded.

Vacuum Dusting

To distinguish beetles released on different days or plots, we used four colors: corona magenta, Saturn yellow, arc yellow, and horizon blue (Day-Glo Corp, Cleveland, Ohio). These colors were chosen for ease of separation under UV light. After dusting, the beetles in lots of up to 1000 were stored for periods of up to 10 days in 1 L of fresh lodgepole pine sawdust (from a chainsaw operated with no chain oil) in plastic 4-L ice cream pails in a refrigerator

(4°C). After storage, the fluorescent dust was no longer visible to the naked eye, but was easily recognized under a dissecting microscope (16x) in a darkened room using long-wave UV illumination provided by a fluorescent tube (Sylvania F15T8-BLB) held 5-10 cm from the insects. To prevent loss of night vision due to glare, and to maximize the intensity of light on the microscope stage, it was necessary to shade the fluorescent tube.

Release – Recapture Studies, 1982

On July 15, 1982 at 14:15 Pacific Daylight Time, 2750 each of marked and unmarked mpb were released from two sites in a lodgepole pine forest near Riske Creek, B.C. The peak flight of wild beetles in the area occurred July 26-28. The pails containing beetles were removed from the refrigerator at 08:30 and transported to the release site where they were kept shaded until needed. At the time of release at each site, the beetles and their storage sawdust were spread evenly on the upper surfaces of two release platforms (one for marked beetles, the other for unmarked). A layer of fresh pine excelsior 5-10 cm thick (made by chain-saw ripping a log with an unoiled chain) was sprinkled over the top of the sawdust to provide many locations for takeoffs. The release platforms consisted of three concentric squares of 6-mm plywood, one above the other separated by 1.5-cm spacers. The largest (bottom) square was 120 cm, the smallest (top) 60 cm. The top surface had a rim 7.5 cm high and 1.5 cm wide set back 1 cm from the edge. The rim prevented sawdust from blowing off, and the multiple steps provided many edges for takeoffs. The platforms were supported 1 m above the ground on a pole structure. Insect screen was suspended below the platforms to catch nonflying beetles which fell. Another screen was suspended 1.5 m above the platforms to provide partial shade to prevent overheating.

At each site, four trap lines were established, one in each cardinal direction radiating from the plot center. The traps were approximately 10, 29, 85 and 250 m from the center. The traps consisted of two trees sprayed to a height of 4 m with 2% Sevin (prepared from Sevin SL in water) and basketed at the base with wire screening to trap poisoned beetles. Each tree was baited with (a) 0.5 ml of both transverbenol and mycrene in separate size 00 polyethylene Been capsules (J.B. EM Services Inc., Dorval, Quebec) and (b) four virgin females caged on 600-cm^2 slabs of fresh lodgepole pine. In addition, a 30-cm^2 window trap (Chapman and Kinghorn 1958) was hung 1.5 m high facing the plot center, 45 cm from each tree bole. Traps were checked and cleared every 3 h during the day for several days after a release. Trapped mpb were placed in 70% alcohol in vials and examined in the lab as described above.

On the two sites, 24.3% and 28.0% of the marked beetles that flew were recaptured during the first 3 days after release. Comparable figures for the unmarked beetles were 34.5% and 47.6%. The relatively larger proportion of unmarked beetles trapped possibly indicates that even though most of the wild beetles were not ready to fly, some flight of wild beetles occurred, more on one of the plots, during the trapping period (Fig. 2). Alternatively, differences in the detectability under blacklight or washing in alcohol of different colored fluorescent powders could also explain this result. These factors need further investigation.

During cloudy periods, the beetles tended to drop from the excelsior and conceal themselves in the sawdust on the platform surface. If the platforms were left unattended, the beetles remaining on the platform were subject to predation by birds (species unknown). Dragonflies were observed capturing and eating mpb as they flew from the platforms.

Five and seven percent of the marked released beetles failed to fly on the two plots and the corresponding figures for unmarked beetles were 6% and 7%. On average, 1% of the marked beetles and 2% of the unmarked beetles were dead on the flight platform. Thus, marking did not increase mortality or physical injury over that resulting from normal handling of emerged beetles.

These results indicate that marked and unmarked beetles behaved similarly under our experimental conditions; marking did not have a significant effect on mortality up to release or ability to take flight. More marked beetles than unmarked beetles may have been lost during dispersal flight. The vacuum method is well suited to quick marking of large numbers of

beetles. The marking is not lost when the beetles are stored in sawdust but there was some transfer of powder onto unmarked individuals when trapped beetles were collected in alcohol and the vials were agitated. However, this problem does not appear to introduce a serious bias into identification of tagged beetles and can be minimized by reducing the volume of alcohol in the collecting vials.

Self-Dusting

Gara (1967) marked *Dendroctonus frontalis* and Schmitz (1980) marked *Ips pini* in the field by forcing the insects to walk across tables or platforms coated with fluorescent powders.

Laboratory trials had shown us that mpb emerging from logs heavily dusted with fluorescent powders became marked similarly to those treated in vacuum dusters. In the field shortly before mpb emerged, we applied the powders to brood trees using a gasoline-powered backpack sprayer (Holder, Supra-Neu 40) equipped with a dusting adapter (Marino Inc.) instead of the normal spray wand. Approximately 250 g of dust was used to treat a 30-cm-dbh pine to a height of 2.0 m. Care was taken to blow the dust into bark crevices, and to uniformly cover the boles.

Clear plastic barrier traps were used to capture beetles as they dispersed into the surrounding forest. Collections were made daily throughout the flight period and were handled as described above. Sampling of brood trees in plot areas in 1985 revealed a total population of approximately 56,000 mpb expected to emerge from 639 attacked trees in an isolated 5.86-ha stand of lodgepole pine. Based on the same sampling, approximately 4800 mpb were expected to emerge from 47 dusted trees. Based on the above figures, 8.6% of the beetles captured should have been marked. The total trap catch in 1985 was 162 mpb, 15 of which (9.3%) were marked. The extra marked beetles are probably a result of having the dusted trees close to the trap locations, and the percentage of beetles recovered indicates that performance of the marking system was excellent.

Summary

The marking and handling techniques described have proven valuable tools for the study of mountain pine beetle dispersal. The low toxicity, ease of application, and ease of examination using common equipment make fluorescent powders attractive for field use. The mass rearing of mpb in a tent provided up to 50,000 mpb with a total loss from handling or other factors of only 7% up to the time of release. Marking beetles with fluorescent dust using either technique did not apparently alter their dispersal behavior or increase mortality prior to flight.

References

Chapman, J.A., and J. Kinghorn. 1958. Studies of flight and attack activity of the ambrosia beetle, *Trypodendron lineatum* (Oliv.), and other scolytids. *Can. Ent.* **90**: 362-372.

Dunn, Paul H., and Byron J. Mechalas. 1963. An easily constructed vacuum duster. *J. Econ. Ent.* **56(6)**: 899.

Gangwere, S.K., W. Chavin, and F.C. Evans. 1964. Methods of marking insects, with special regard to Orthoptera (Sens. Lat.). *Ann. Ent. Soc. Amer.* **57**: 662-669.

Gara, R.I., 1967. Studies on the attack behavior of the southern pine beetle. I. The spreading and collapse of outbreaks. *Contrib. Boyce Thompson Inst.* **23(10)**: 349-354.

Moffitt, H.R. and D.J. Albano. 1972. Vacuum application of fluorescent powders as markers for adult codling moths. *Econ. Ent.* **65**: 882-884.

Schmitz, R.F. 1980. Dispersal of pine engraver beetles in second growth ponderosa pine forests. *In* Proceedings of the Second IUFRO Conference on Dispersal of Forest Insects: Evaluation, Theory and Management Implications. Edited by A.A. Berryman and L. Safranyik. Sandpoint, Idaho August 27-31, 1979.

MANIPULATIONS OF EGG-GALLERY LENGTH TO VARY BROOD DENSITY IN SPRUCE BEETLE *DENDROCTONUS RUFIPENNIS* (COLEOPTERA: SCOLYTIDAE): EFFECTS ON BROOD SURVIVAL AND QUALITY

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Abstract

Different brood densities were produced under a constant bark surface area of the spruce host, by excising egg-producing female *Dendroctonus rufipennis* from the host material after they had excavated galleries of specified lengths. This procedure allowed a constant attack density. The numbers of adult progeny produced/cm of egg-gallery were significantly greater from bark slabs with short galleries and low densities: the sizes (pronotal widths) of adult progeny of both sexes were also significantly greater from low than from high densities; and the distribution patterns of chromatin differed significantly among high, medium and low densities.

Résumé

Les auteurs ont obtenu différentes densités d'oeufs sous une section constante d'écorce de l'épinette hôte en retirant des femelles ovipares de *Dendroctonus rufipennis* du tissu hôte après qu'elles aient creusé des galeries de longueur déterminée. Cette méthode permet d'obtenir une densité d'invasion constante. Le nombre de descendants adultes produit par centimètre de galerie de ponte était beaucoup plus élevae dans les sections d'écorce à galeries courtes et à densité d'oeufs faible; la taille (largeur du pronotum) des descendants adultes des deux sexes étaient également beaucoup plus élevée lorsque la densité des oeufs était faible. De plus, les modes de répartition de la chromatine différaient énormément selon qu'elle provenait d'oeufs à forte, moyenne ou faible densité.

Introduction

In population dynamics studies of bark beetles, the effect of density on brood production has been studied mostly in relation to the attack density of the parent beetles (McMullen and Atkins 1961; Cole 1962; Reid 1963; Berryman and pienaar 1973). Studying this relationship carries practical advantages in that the attack density can be readily determined in natural stands without destroying the sample and variations in attack density can be easily created in controlled experiments. Such experiments, however, do not discriminate between reduced brood production due to fewer parent beetles (McMullen and Atkins 1961; Thomson and Sahota 1981) and that due to brood density and competition among the progeny. Some experiments, using this approach, have related brood quality, such as adult size in the brood, to the density of parental attack (Reid 1962; McGhehey 1971; Safranyik and Linton 1985). Possibly, the effect of attack density on brood is indirect, emanating through changes in brood density.

Cole (1973) isolated the effects of brood density on the quality of the brood as shown by their reproductive capacity when mature. Varying the density of *Dendroctonus ponderosae* larvae on a phloem diet showed that increased density and competition among larvae led to reduced reproductive capacity in the resulting adult females. In the present paper, we have isolated the effects of brood density from those of parental attack density among progeny raised on the natural host diet. Survival and individual size of the brood adults are reported. Also reported are cytological differences among the brood from the various density classes as indicators of differences in population quality.

Materials and Methods

The spruce beetles, *Dendroctonus rufipennis* (Kirby) used in this study were collected from a natural endemic field population near Hixon, British Columbia as well as the laboratory-reared progeny of these beetles. The bolts of host trees containing adult beetles were collected from the field and stored in the laboratory at O°C (±1°C) from October to April.

In May the bolts were transferred to cages at room temperature leading to emergence of the beetles. Fresh host material was obtained from the beetle collection site by cutting a spruce tree (*Picea engelmannii* Parry) of 34-cm-dbh. Bark-bearing slabs measuring 30 cm x 20 cm x 5 cm thick were cut out of the bole. Surfaces without bark were coated with molten paraffin wax to avoid excessive moisture loss.

Each female beetle was introduced 5 cm from one end of each slab by making a small hole in the bark and confined there with a gelatin capsule. The male followed the female one day later. Infested slabs were maintained at 18.3 ± 1°C, each standing on its beetle-containing end to encourage directional gallery production by the beetles. This arrangement was used to produce three sets of slabs (9-10 slabs/set) containing parental galleries of 6.8 cm, 9.8 cm and 12.8 cm while the bark surface areas of all the slabs remained identical. The required gallery length was achieved by X-raying the slabs and excising the female at the proper point. Beetle excision was carried out by cutting about 1 cm x 1 cm piece of the bark. This opening was sealed with molten paraffin after removal of the female. It was not possible, however, to excise each beetle at precisely the specified gallery length. Eighteen slabs were started for each density level; 9-10 of these were successfully colonized for each level. The three brood densities resulting from these galleries were designated as low, medium and high respectively. The slabs containing the parental galleries and eggs were kept at 18.3°C. In September, when the progeny had reached the adult stage, the slabs were placed at 0°C for over-wintering. The slabs were peeled to remove the adult progeny in May of the following year. The total parental gallery length, the egg-gallery length (total parental gallery - initial egg free gallery) and the number of adults produced in each slab were recorded. The pronotal widths of all progeny were measured and their sexes determined.

Cytological investigations relating to quality differences among progeny from different densities were carried out by analysing digitized images of fat body nuclei (Sahota *et al.* 1984). Ten to 15 females from each density group were fixed in 3 parts ethanol: 1 part acetic acid for 2h. Their abdomens were slit open to facilitate penetration of fixative. The fat body was stained in situ with Fuelgen stain after a 20 min hydrolysis with 3.5N HC1 at 37°C. The fat body cells were spread on microscopic slides as described by Farris *et al.* (1982).

Digitized images of fat body nuclei were created by scanning the samples at 570 nm using a Zeiss SMP5 microphotometer system on line to a PDP 11/34 minicomputer. This process measures the light transmitted through every 0.25 μm square of the scanned area producing a matrix of numbers or the digitized image. Materials other than nuclei in the digitized images were removed by editing. Seventy-five variables were mathematically derived from each of the edited images. Derivation of these variables or features along with the scanning and editing procedures are described in Peet and Sahota (1984, 1985) and Sahota *et al.* (1986).

For analysis of data dealing with gallery lengths, progeny produced, and average individual size of the progeny at various densities, we used ANOVA followed by Newman-Keul's multiple range test. The relationship between the adult progeny per unit of egg-gallery length at various densities was examined by regression analysis.

To investigate cytological differences among progeny groups from different densities, the three features with the highest merit value for discriminating among the three density classes were selected by the computer. These included a histogram feature (HIST04) and two transition probability features (TRPR23 and TRPR61). Histogram features examine the probability of the pixels of a nucleus belonging to a given optical density bin of a 20-bin histogram generated from the optical densities of all the pixels comprising the nucleus. HIST04 refers to the fourth bin of such a histogram. Transition probabilities relate to the degree of change of optical density between a pixel and its eight immediate neighbours. A detailed description of these and other features is given in Peet and Sahota (1984). We applied discriminant analysis (Cooley and Lohnes 1971; Duda and Hart 1973) to the above three features of the three cell populations. These methods generated a set of axes that maximized the distances between the distributions representing various populations and minimized the distances within each distribution. The 99% confidence ellipses were drawn with respect to the first two of these new variables as the two axes. A more detailed description of this application

of discriminant analysis is given in Sahota *et al.* (1986).

Results and Discussion

Changes in brood density per 20 cm x 30 cm bark surface created by the variations in the length of egg-gallery resulted in changes in the pronotal widths of brood members as well as their survival to the adult stage. There was a significant decrease ($p < 0.01$) in the pronotal widths with increasing brood density in both sexes (Table 1). This is similar to the results obtained by varying the attack density (Safranyik and Linton 1985). The three groups of egg-gallery lengths created for producing the three brood density classes were significantly different from each other ($P < 0.05$). However, the number of adult progeny per slab or per cm of the egg-gallery differed significantly between high and low densities but neither differed from the medium density ($P > 0.05$) (Table 1).

When adult progeny per unit length of the egg-gallery was plotted against the length of such galleries (Fig. 1), it was shown that increased egg-gallery length and competition led to a decrease of adult progeny produced per cm of this gallery. The relationship depicted in this figure was significant at the 95% confidence level. Thus it appears that the range of brood densities created in the experiment produced biological effects of competition on brood survival. Safranyik and Linton (1985) concluded that fewer adults produced per unit length of the egg-gallery with increasing density was due to brood mortality. In their experiments, however, differences in brood density were created by varying the attack density of parent beetles per unit area of bark surface. Their argument that the decrease in adult progeny per unit gallery length was not due to a decrease in egg production, was based on the demonstration by Thomson and Sahota (1981) that competition among parent beetles does not alter the number of eggs deposited per unit egg-gallery length. The present results are in agreement with those of Sefranyik and Linton (1985) but provide more direct evidence to show that the decrease in adult progeny produced per unit length of the egg-gallery was solely due to brood competition as parental attack density was constant in these experiments. It may be pointed out that in most of the slabs less than 70% of the phloem was used by the brood. In two of the slabs nearly 90% of the phloem had been used.

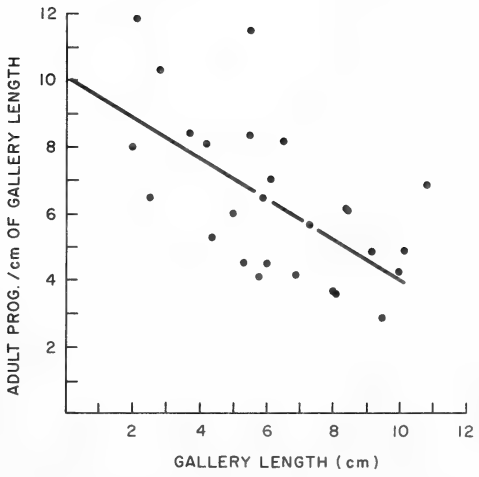

Fig. 1. Influence of egg-gallery length (brood density) on the survival per cm of egg gallery of *Dendroctonus rufipennis* brood in 30 cm x 20 cm of bark surface area.

Table 1. Egg-gallery lengths of the parent adults and some characteristics of their adult progeny raised at three brood density levels on 30cm x 20cm slabs of *Picea engelmanni*.

		Brood Density Level		
		High	Medium	Low
No. of parental egg-galleries		9	9	10
Egg-gallery Lengths (cm)		8.81 a (0.40)	6.01 b (0.02)	3.72 c (0.41)
Adult progeny per bark slab		42.8 ab (4.9)	38.7 bc (5.0)	23.8 c (2.4)
Brood adults produced per cm. of egg-gallery		4.81 ab (0.42)	6.15 bc (0.88)	7.09 c (0.91)
Pronotal widths of brood adults (mm)	Female	2.14 a (0.004)	2.29 b (0.005)	2.38 c (0.01)
	Male	2.09 a (0.003)	2.29 b (0.007)	2.34 c (0.01)

Note: Numbers within brackets show the standard error of the means they are associated with. Means followed by the same letters within each row are not significently different at 95% level (Newman-Keul's multiple range test).

Effects of the brood density on the "population quality" of the progeny were investigated by examining individual size (pronotal width) in the progeny and changes created in the distribution patterns of chromatin (DNA). Increase in brood density created by the increase in length of the egg-galleries resulted in a significant reduction of the individual size of the progeny of both sexes (Table 1). Brood density also produced cytological changes in the fat body nuclei which reveal significant differences among the progeny from the three brood density classes. Fig. 2 shows the 99% confidence ellipses of the means of the progeny from the three density classes. These ellipses are based on the three features with the highest merit value derived from the distribution pattern of chromatin. Chromatin distribution pattern have been used to demonstrate small differences among cell and insect populations (Bartels and Wied 1977; Bartels and Olson 1980; Sahota *et al.* 1984). Furthermore, Sahota *et al.* (1986) have shown that changes in the functions of the differentiating follicular epithelial cells are accompanied by changes in the chromatin distribution patterns and that the treatments leading to blockage of functional differentiation of these cells also block changes in chromatin distribution patterns, thus providing evidence for a relationship between chromatin distribution pattern and cell function.

The results presented in this paper show that the influences of brood density on the survival and quality of the progeny are similar to those created in response to attack density (See Safranyik and Linton 1985). It appears that attack density effects are produced indirectly through brood density as a result of competition. The results also show that analysis of chromatin distribution patterns can detect population quality differences created by brood density and competition. Sahota *et al.* (1984) have pointed out that population quality differences related to reproductive capacity may result from the influence of a variety of factors such as environment, genetics, competition, disease, etc. However, chromatin distribution patterns resulting from the influence of these factors may be different. Thus, density-related distribution patterns of chromatin in broods provide further information required to build a comprehensive picture of chromatin distribution patterns in relation to population quality and reproduction.

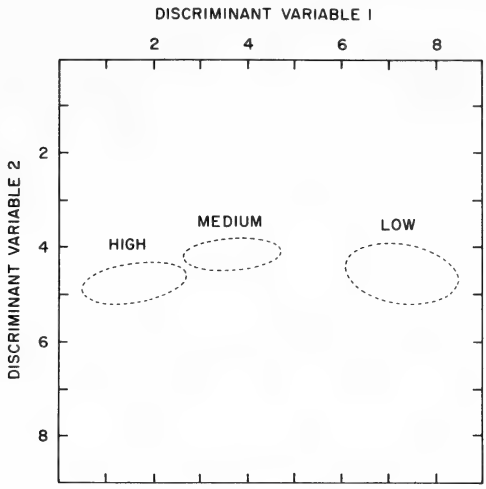

Fig. 2. Ninety-nine percent confidence ellipses of the means of distribution of the *Dendroctonus rufipennis* broods raised under three different densities. These distributions are based on patterns of chromatin distribution.

References

Bartels, P.H. and G.L. Wied. 1977. Computer analysis and biomedical interpretation of microscopic images; current problems and future directions. Proc. IEEE. **65**: 252-262.

Bartels, P.H. and G.B. Olson. 1980. Computer analysis of lymphocyte images. *in* Methods in Cell Separation. N. Catsimpoolas (ED.) **3**: pp. 1-67. Plenum Press, New York.

Berryman, A.A. and L.V. Pienaar. 1973. Simulation of intraspecific competition and survival of *Scolytus ventralis* broods (Coleoptera: Scolytidae). *Environ. Ent.* **2**: 447-459.

Cole, W.E. 1962. The effects of intraspecific competition within mountain pine beetle broods under laboratory conditions. Intermountain Forest Range Exp. Stn., Res. Note No. 97. 4 pp.

Cole, W.E. 1973. Crowding effects among single-age larvae of mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae). *Environ. Ent.* **2**: 185-293.

Cooley, W.W. and P.R. Lohnes. 1971. Multivariate Data Analysis. pp. 1-364. John Wiley and Sons, New York.

Duda, R.O. and P.E. Hart. 1973. Pattern Classification and Scene Analysis. pp. 114-228. John Wiley and Sons, New York.

Farris, S.H., T.S. Sahota, A. Ibaraki and A.J. Thomson. 1982. Use of pectinase to dissociate plant nuclei for squash preparation. Effect of hydration procedures. *Stain Technol.* **57**: 283-288.

McGhehey, J.H. 1971. Female size and egg production of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins. Northern Forest Research Centre, Edmonton, Alberta. Information Rep. NOR-X-9, 18 pp,

McMullen, L.H. and M.D. Atkins. 1961. Intraspecific competition as a factor in the natural control of the Douglas-fir beetle. *For. Sci.* **7**: 197-203.

Peet, F.G. and T.S. Sahota. 1984. A computer assisted cell identification system. *Anal. Quantit. Cytol.* **6**: 59-70.

Peet, F.G. and T.S. Sahota. 1985. Surface curvature as a measure of image texture. IEEE. Trans. Pattern Anal. Machine Intell. PAMI. **7**: 734-738.

Reid, R.W. 1962. Biology of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, in the East Kootenay region of British Columbia. II. Behaviour in the host, fecundity and internal changes in the female. *Can. Ent.* **94**: 605-613.

Reid, R.W. 1963. Biology of the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, in the East Kootenay region of British Columbia. III. Interaction between the beetle and its host, with emphasis on brood mortality and survival. *Can. Ent.* **95**: 225-238.

Safranyik, L. and D.A. Linton. 1985. Influence of competition on size, brood production and sex ratio in spruce beetles (Coleoptera: Scolytidae). *J. Ent. Soc. B.C.* **82**: 52-56.

Sahota, T.S., F.G. Peet and P.H. Bartels. 1984. Progress towards early detection of population quality differences in bark beetles (Coleoptera: Scolytidae). *Can. Ent.* **116**: 481-486.

Sahota, T.S., F.G. Peet, A. Ibaraki and S.H. Farris. 1986. Chromatin distribution pattern and cell functioning. *Can. J. Zool.* **64**: 1908-1913.

Thomson, A.J. and T.S. Sahota. 1981. Competition and population quality in *Dendroctonus rufipennis* (Coleoptera: Scolytidae). *Can. Ent.* **113**: 177-183.

THE GROUND MANTIS, *LITANEUTRIA MINOR* (DICTUOPTERA: MANTIDAE) IN BRITISH COLUMBIA

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Abstract

The status of the Ground Mantis, *Litaneutria minor* (Scudder), in British Columbia and Canada is discussed, and brief notes on its natural history are given. Characteristics for separating this species, the only native Canadian mantis, from the introduced and sympatric *Mantis religiosa* L., are tabulated.

Only three species of Mantidae (Dictuoptera) are known from Canada, representing two subfamilies. The Mantinae include the European Praying Mantis, *Mantis religiosa* L., and the Chinese Mantis, *Tenodera aridifolia sinensis* Saussure; the Amelinae are represented by the Ground Mantis, *Litaneutria minor* (Scudder). *M. religiosa* and *T. aridifolia sinensis* were introduced into the eastern United States in the 1890s and subsequently spread to southern Ontario and Quebec (Kevan 1979). The former was also introduced into the southern Okanagan Valley of British Columbia for biological control purposes in 1938 and 1939 (Buckell 1941). For many years it apparently was rather scarce, and few specimens were collected; since the 1970s, however, the population has been frequently observed between Okanagan Falls and Osoyoos. Both brown and green colour phases occur there.

Litaneutria minor is widespread in the drier regions of North America from Mexico, Texas and California north to North Dakota and British Columbia (Essig 1926, Vickery and Kevan 1983, 1986). It is the only mantid native to Canada, where it is rather rare and seldom collected, being known only from the southern Okanagan Valley in British Columbia. Vickery and Kevan (1983) note that although the species is not yet recorded from Manitoba, Saskatchewan, or Alberta, it may be expected to appear in the southernmost parts of these provinces.

Canadian Material Examined. BRITISH COLUMBIA: Oliver, 1000′, 12.viii.1953, 2 males (D.F. Hardwick) (CNC); *ibid.*, 18.viii,1953, 4 males (D.F. Hardwick) (CNC); *ibid.*, 30.viii.1953, 1 male (D.F. Hardwick) (CNC); Oliver, 9 mi S - Haynes Lease Ecological Reserve, 1.x.1963, 1 female in funnel trap (W.B. Preston) (specimen apparently donated to Spencer Entomological Museum U.B.C., but cannot now be located); Oliver, east bench 1100′, 29.viii.1920, 1 female - head,prothorax, one foreleg only (E. Hearle) (CNC); Osoyoos, Haynes Point Prov. Park, 24.viii.1986, 1 male at light inside changeroom (M. Sarell) (BCPM).

The above records represent all but two of the Canadian specimens known to me. Vickery and Kevan (1983) list two males collected at Oliver (1000′) on 17 and 18 July 1953 by J.E.H. Martin and D.F. Hardwick, respectively. The specimens were received by the Lyman Entomological Museum, McGill University on exchange from the Canadian National Collection; they are now in poor condition (D.. McE. Kevan, pers. comm.). Habitats, habitat and life history are summarized by Vickery and Kevan (1983, 1086). *Litaneutria* is a ground-dweller, but sometimes is found on low vegetation; Hearle's specimen (Osoyoos, 1920) was collected on a sage brush (Buckell 1922). In Texas, Roberts (1937) found the mantid mostly on low, rocky ridges sparsely clothed with bunchgrass. It can run with great agility and is often difficult to capture (Essig 1926), but pan traps are often effective (Barnum 1964, Vickery and Kevan 1983, 1986). The gravid female collected by W.B. Preston at Oliver in 1963 was captured in a funnel trap designed to collect rattlesnakes. Flying males are often attracted to lights; all of the 11 males collected in Canada were collected at or near lights in July and August.

Small egg masses, about 7 mm long and rather rectangular in shape are deposited on the stems of low shrubs. These eggs overwinter in our area, and hatch in 185 to 205 days after laying. Nymphs mature in about 13 weeks. Roberts (1937) recorded males living up to 47 days and females up to 156 days.

The two species of mantids in British Columbia's Okanagan Valley are sympatric at least from Oliver south to the International Boundary. They can be separated by the characteristics listed in Table 1.

Table 1. Some characteristics separating *Litaneutria minor* from *Mantis religiosa*

Species	Length of adult	Colour	Setae on antennae and anterior margin of tegmina of male	Wing development
Litaneutria minor	less than 35 mm	buff to dark brown	present	females brachypterous (tegimina equal to, or less than, 1.3 length of abdomen); males usually fully winged; male usually with dark spot on hindwing
Mantis religiosa	more than 35 mm	light brown or green	absent	both sexes fully winged

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References

Barnum, A.H. 1964. Orthoptera of the Nevada test site. *Brigham Young Univ. Sci. Bull. (Biol.)* **4**: 1-134.

Buckell, E.R. 1922. A list of the Orthoptera and Dermaptera recorded from British Columbia prior to the year 1922, with annotations. *Proc. ent. Soc. British Columbia* **20**: 3-41.

Buckell, E.R. 1941. Field crops and garden insects of the season 1940 in British Columbia. *Can. Insect Pest Rev.* **19**: 81-84.

Essig, E.O. 1926. Insects of western North America. Macmillan, New York. 1035 pp.

Kevan, D.K. McE. 1979. Dictuoptera. Pp. 314-316 *in* H.V. Danks (ed.) Canada and its insect fauna. *Mem. ent Soc. Canada* **108**: 1-573.

Roberts, R.A. 1937. Biology of the Minor Mantid, *Litaneutria minor* Scudder (Orthoptera: Mantidae). *Ann. ent. Soc. Amer.* **30**: 111-121.

Vickery, V.R. and D.K. McE. Kevan. 1983. A monograph of the Orthopteroid insects of Canada and adjacent regions. Vol. 1. *Mem. Lyman Ent. Mus. and Res. Lab.* **13**: xxii + iv + 657 p.

Vickery, V.R. and D.K. McE. Kevan. 1986. The Grasshoppers, Crickets, and Related Insects of Canada and Adjacent Regions. Ulonata: Dermaptera, Cheleutoptera, Notoptera, Dictuoptera, Grylloptera, and Orthoptera. The Insects and Arachnids of Canada. Part 14. Research Branch, Agriculture Canada Publication 1777. 981 pp.

ADDENDUM

As this paper was going to press, I captured a female *Litaneutria* at the Haynes Lease Ecological Reserve, located at the north end of Osoyoos Lake. It was sitting in the open on a dirt road at 16:00 h PDT on 24 August 1987. The specimen is in the collection of the B.C. Provincial Museum, Victoria.

THE APHIDS (HOMOPTERA: APHIDIDAE) OF BRITISH COLUMBIA 16. FURTHER ADDITIONS

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ABSTRACT

Six species of aphids and new host records are added to the taxonomic list of the aphids of British Columbia.

INTRODUCTION

Twelve previous lists of the aphids of British Columbia (Forbes, Frazer and MacCarthy 1973; Forbes, Frazer and Chan 1974; Forbes and Chan 1976, 1978, 1980, 1981, 1983, 1984, 1985, 1986a, 1986b; Forbes, Chan and Foottit 1982) recorded 386 species of aphids collected from 865 hosts or in traps and comprises 1660 aphid-host plant associations. The present list adds 6 aphid species (indicated with an asterisk in the list) and 104 aphid-host plant associations to the previous lists. Fifty-four of the new aphid-host plant associations are plant species not recorded before. The additions bring the number of known aphid species in British Columbia to 392. Aphids have now been collected from 919 different host plants and the total number of aphid-host plant associations is 1764.

The aphid names are listed alphabetically by species and are in conformity with Eastop and Hille Ris Lambers (1976). Seven new collection sites are tabulated in Table 1. The location of each collection site can be determined from Table 1 or from the tables of localities in the previous papers. The reference points are the same as those shown on the map which accompanies the basic list (Forbes, Frazer and MacCarthy 1973).

LIST OF SPECIES

ABIETINUM (Walker), ELATOBIUM
Picea pungens: Vancouver, Apr3/58.
*ABSINTHII (Linnaeus), MACROSIPHONIELLA
Artemisia arborescens 'Powis Castle': Vancouver (UBC), Aug29/86.
AEGOPODII (Scopoli), CAVARIELLA
Sium suave: Sea Island, Jul15/59.
AGATHONICA Hottes, AMPHOROPHORA
Rubus idaeus: Abbotsford, Jul23/74.
ALBIFRONS Essig, MACROSIPHUM
Lupinus arboreus: Vancouver (UBC), Feb9/87, Aug29/86.
ALNIFOLIAE (Williams), PROCIPHILUS
Amelanchier sp. : Soda Creek, Jun16/56.
ANNULATUS (Hartig), TUBERCULATUS
Quercus garryana: Vancouver (UBC), Jun19/59.
ARUNDINARIAE (Essig), TAKECALLIS
Pseudosasa japonica: Vancouver (UBC), Jan7/87, Dec20/86.
ASCALONICUS Doncaster, MYZUS
Baccharis magellanica: Vancouver (UBC), Feb19/87.
Crocus sp.: Vancouver, May23/59.
Dahlia sp.: Vancouver, Apr13/58.
Draba borealis: Vancouver (UBC), Apr3/86.
Draba ruaxes: Vancouver (UBC), Mar15/85.
Lilium x hollandicum: Vancouver (UBC), May1/58.
Phacelia heterophylla: Vancouver (UBC), Apr3/86.
Stellaria media: Lulu Island, Mar24/60; Vancouver, Dec30/59.
AVELLANAE (Schrank), CORYLOBIUM
Corylus cornuta var. *californica*: Vancouver, Apr16/85, Jun2/86.

AVENAE (Fabricius), SITOBION
Capsella bursa-pastoris: Vancouver (CDA), Jan20/87.
BAKERI (Cowen), NEARCTAPHIS
Malus sylvestris: Oliver, May1/40.
BRASSICAE (Linnaeus), BREVICORYNE
Brassica napobrassica group: Creston, Oct2/57.
Brassica oleracea botrytis group: Chilliwack, Sep4/57.
CAPILANOENSE Robinson, AULACORTHUM
Rubus spectabilis: Vancouver (UBC), May29/86.
CARNOSUM (Buckton), MICROLOPHIUM
Urtica dioica: Peace Arch Park, Aug4/86.
CERTUS (Walker), MYZUS
Capsella bursa-pastoris: Vancouver (CDA), Dec30/86.
Gomphrena globosa: Vancouver (CDA), Dec30/86.
*CHRYSANTHEMI (Theobald), PLEOTRICHOPHORUS
Chrysanthemum balsamita: Vancouver (UBC), Aug1/86.
CIRCUMFLEXUM (Buckton), AULACORTHUM
Apium graveolens: Vancouver (CDA), Jan20/87.
Atropa belladonna: Vancouver (CDA), Jan22/87.
Corydalis aurea ssp. *aurea*: Vancouver (CDA), Oct17/85.
Crocus sp.: Vancouver, May23/59.
Fuchsia x *hybrida 'Jack Shahan'*: Vancouver (UBC), Aug1/86.
Impatiens wallerana 'Futura Wildrose': Vancouver (UBC), Aug1/86.
Iris sp.: Vancouver, Jun29/58.
Linnaea borealis: Vancouver (CDA), Oct17/85.
Lonicera 'Dropmore Scarlet': Vancouver (CDA), Oct17/85.
Schizostylis coccinea: Vancouver (CDA), Oct17/85.
Vaccinium corymbosum: Vancouver (CDA), Oct17/85.

TABLE 1. Collection sites of aphids, with airline distances from reference points.

Locality	Reference Point	Dir	Distance km	mi
Bowen Island	Vancouver	NW	22	14
Chehalis River	Vancouver	NE	82	51
Choate	Vancouver	NE	146	91
Harrison Hot Springs	Vancouver	E	102	64
Peace Arch Park	Vancouver	S	53	33
Sasquatch Provincial Park	Vancouver	E	110	69
Smithers	Prince Rupert	NE	218	136

CORYLI (Goeze), MYZOCALLIS
Corylus sp.: Vancouver, Jun22/56, Oct13/57, Nov1/57.
COWENI (Cockerell), TAMALIA
Arctostaphylos uva-ursi: Vancouver (UBC), Jun13/85.
*CRATAEGI (Monell), UTAMPHOROPHORA
Crataegus x *lavallei*: Vancouver (UBC), Jun19/84.
CREELII Davis, MACROSIPHUM
Chenopodium murale: Vancouver (CDA), Jan30/87.
*CRYSTLEAE SSP BARTHOLOMEWI (Essig), ILLINOIA
Lonicera involucrata: Chehalis River, Jun30/86.
DAPHNIDIS Borner, MACROSIPHUM
Daphne laureola: Vancouver (UBC), Apr2/86.
DIRHODUM (Walker), METOPOLOPHIUM
Rosa rugosa 'Rubra': Vancouver (UBC), Apr2/86.
EQUISETI Holman, SITOBION
Equisetum arvense: Vancouver, Oct21/85.
EQUISETICOLA Ossiannilsson, APHIS
Equisetum arvense: Vancouver, Jun9/84.
EUPHORBIAE (Thomas), MACROSIPHUM
Chenopodium murale: Vancouver (CDA), Dec30/86.
Solanum tuberosum: Alexandria, Aug17/66; Quesnel, Aug17/66; Smithers, Jul22/57.
FABAE Scopoli, APHIS
Lilium philadelphicum var. *andinum*: Vancouver, Ju15/71.
Tripleurospermum maritimum: Vancouver (UBC), Jul11/84.
FAGI (Linnaeus), PHYLLAPHIS
Fagus sylvatica 'Atropunicea': Milner, Jun6/58.
Fagus sylvatica 'Pendula': Trout Creek, Sep3/65.
FIMBRIATA Richards, FIMBRIAPHIS
Fragaria x *ananassa 'Totem'*: Abbotsford, Aug7/86.
FOENICULI (Passerini), HYADAPHIS
Lonicera involucrata: Ladner, May25/66.
Lonicera pyrenaica: Vancouver (UBC), Oct20/86.
FRAGAEFOLII (Cockerell), CHAETOSIPHON
Fragaria sp.: Richmond, Apr14/65, Apr29/65, May31/65.
FRAGARIAE (Walker), SITOBION
Holcus lanatus: Richmond, Aug2/64.
GILLETTEI Davidson, EUCERAPHIS
Alnus rubra: Mount Seymour, May20/73.
*GNAPHALODES (Palmer), PLEOTRICHOPHORUS
Artemisia stelleriana: Vancouver (UBC), Aug29/86.
HELICHRYSI (Kaltenbach), BRACHYCAUDUS
Antirrhinum majus: Chilliwack, May4/58.
Salvia officinalis: Vancouver (UBC), Jun15/84.
HIPPOPHAES (Walker), CAPITOPHORUS
Polygonum persicaria: Vancouver (UBC), Aug13/86.
IDAEI van der Goot, APHIS
Rubus idaeus: Vancouver, Jun10/86.
KONOI Takahashi, CAVARIELLA
Apium graveolens: Cloverdale, Ju11/86.
LACTUCAE (Linnaeus), HYPEROMYZUS
Ribes magellanica: Vancouver (UBC), Oct1/85.
LANIGERUM (Hausmann), ERIOSOMA
Malus fusca: Ladner, May25/66.

LATYSIPHON (Davidson), RHOPALOSIPHONINUS
Gladiolus sp.: Vancouver, Mar22/60.
LONICERAE (Siebold), RHOPALOMYZUS
Lonicera pyrenaica: Vancouver (UBC), Oct20/86.
MAIDIS (Fitch), RHOPALOSIPHUM
Capsella bursa-pastoris: Vancouver (CDA), Dec20/86.
MANITOBENSE (Robinson), SITOBION
Cornus sericea: Vancouver (UBC), Sep4/86.
MILLEFOLII (de Geer), MACROSIPHONIELLA
Achillea millefolium: Bowen Island, Aug13/86; Vancouver (UBC), Sep23/75.
Achillea millefolium var. *borealis*: Vancouver (UBC), Oct20/86.
NYMPHAEAE (Linnaeus), RHOPALOSIPHUM
Capsella bursa-pastoris: Agassiz, Jul12/56.
ORNATUS Laing, MYZUS
Campsis x *tagliabuana 'Madame Galen'*: Vancouver (UBC), Aug14/85.
Ceratostigma willmottianum: Vancouver (UBC), Sep3/85.
Chamomilla suaveolens: Vancouver, Apr7/60.
Cirsium arvense: Vancouver (UBC), Jan7/87.
Coleus blumei: Vancouver, May1O/59.
Dahlia sp.: Vancouver, Apr13/58.
Lamium amplexicaule: Vancouver (UBC), Jan22/60.
PADI (Linnaeus), RHOPALOSIPHUM
Capsella bursa-pastoris: Vancouver (CDA), Dec20/86.
Stipa elegantissima: Vancouver (UBC), Feb19/87.
PARVIFOLII Richards, MACROSIPHUM
Vaccinium parvifolium: Vancouver (UBC), Apr8/86.
PATRICIAE (Robinson), ILLINOIA
Tsuga heterophylla: North Vancouver, Aug25/71.
*PENDERUM Robinson, UROLEUCON
Grindelia integrifolia: Pender Island, Ju19/85 (Robinson 1986); Vancouver (UBC), Oct25/85, Nov4/85.
PERSICAE (Sulzer), MYZUS
Amaranthus retroflexus: Chilliwack, Jun17/58.
Brassica napobrassica group: Chilliwack, Aug22/57; Creston, Oct2/57.
Brassica oleracea botrytis group: Agassiz, Jun9/58.
Brassica rapa: Agassiz, Jul12/56.
Capsella bursa-pastoris: Creston, May28/58; Pemberton, Sep2/86; Vancouver (UBC), Jan22/60; Westham Island, Sep10/86.
Cucurbita sp.: Vancouver, Jun20/58.
Dahlia sp.: Vancouver, Apr13/58.
Digitalis lanata: Saanich, Ju16/59.
Hibiscus sabdariffa: Vancouver (UBC), Jan5/59.
Nicotiana tabacum: Vancouver (UBC), Aug29/58.
Plantago major: Pemberton, Sep2/86.
Raphanus raphanistrum: Pemberton, Sep2/86.
Solanum tuberosum: Alexandria, Aug17/66; Chilliwack, May22/58; Kelowna, Aug18/54; Lulu Island, Sep18/56; Pemberton, Sep2/86.
Zinnia elegans: Vancouver, Jun3/56.
PISUM (Harris), ACYRTHOSIPHON
Cytisus scoparius: Vancouver, Jul21/58.
PLANTAGINEA (Passerini), DYSAPHIS
Malus sylvestris: Penticton, Ju127/57.
POMI de Geer, APHIS
Cotoneaster franchetii: Vancouver, Jul12/57.

PRUNI (Geoffroy), HYALOPTERUS
Prunus domestica: Chilliwack, Ju123/86.
PUNCTATUS (Monell), MYZOCALLIS
Quercus garryana: Vancouver (UBC), Jun19/59.
PUNCTIPENNIS (Zetterstedt), EUCERAPHIS
Alnus viridis ssp. *sinuata*: Vancouver (UBC), Sep3/86.
RHAMNI (Clarke), SITOBION
Rhamnus purshiana: Vancouver (UBC), May23/86.
RIBIS (Linnaeus), CRYPTOMYZUS
Ribes magellanica: Vancouver (UBC), Oct1/85.
RIEHMI (Borner), THERIOAPHIS
Medicago sativa: Lister, Aug25/58.
ROBINIAE (Gillette), APPENDISETA
Robinia pseudoacacia: Harrison Hot Springs, Aug13/86.
ROSAE (Linnaeus), MACROSIPHUM
Rosa 'White Dawn': Vancouver, Ju123/86.
ROSARUM (Kaltenbach), MYZAPHIS
Rosa rugosa: Vancouver (UBC), May23/86.
SANGUICEPS Richards, PTEROCOMMA
Salix scouleriana: Vancouver (UBC), Apr3/74.
SOLANI (Kaltenbach), AULACORTHUM
Alstroemeria chilensis: Vancouver (UBC), Feb19/87.
Amaranthus retroflexus: Chilliwack, Jun17/58.
Anagallis monelli: Vancouver (UBC), Feb18/87.
Antirrhinum majus: Chilliwack, May4/58.
Aguilegia caerulea var. *ochroleuca*: Vancouver (UBC), Feb19/87.
Artemisia absinthium: Vancouver (UBC), May23/86.
Baccharis magellanica: Vancouver (UBC), Feb19/87.
Citrullus lanatus: Vancouver, Sep26/86.
Conium maculatum: Vancouver (UBC), May23/86.
Dahlia sp.: Vancouver, Apr13/58.
Eucryphia lucida: Vancouver (UBC), Feb18/87.
Fragaria chiloensis: Vancouver (UBC), Feb19/87.
Grindelia integrifolia: Vancouver (UBC), Nov4/85.
Iris sp.: Vancouver, Jun29/58.
Iris tectorum: Vancouver (UBC), Feb19/87.
Lamium amplexicaule: Vancouver, Jan22/60.
Linnaea borealis: Vancouver (UBC), May6/86.
Lycium chinense: Vancouver (UBC), May23/86.
Lycopersicon lycopersicum: Vancouver, Jun22/61.
Nicandra physalodes: Vancouver (UBC), Feb28/58.
Papaver alpinum 'Plena': Vancouver (UBC), Feb18/87.
Parthenocissus quinquefolia: Vancouver, Jun22/84.
Plantago rubrifolia: Vancouver (UBC), May23/86.
Primula parryi: Vancouver (UBC), Feb19/87.
Senecio canus: Vancouver (UBC), May23/86.
Solanum tuberosum: Boundary Bay, Mar24/60; Chilliwack, May22/58.
Stellaria media: Vancouver, Dec30/59.
Tanacetum vulgare: Vancouver (UBC), May23/86.
Tripleurospermum maritimum: Vancouver (UBC), Ju111/84.
SPIRAEAE (MacGillivray), ILLINOIA
Spiraea douglasii: Abbotsford, Jun16/65.
SPIRAECOLA (Patch), ILLINOIA
Spiraea thunbergii: Vancouver (UBC), May6/86.

SPYROTHECAE Passerini, PEMPHIGUS
Populus nigra 'Italica': Sasquatch Provincial Park, Aug13/86.
STAPHYLEAE (Koch), RHOPALOSIPHONINUS
Astilbe microphylla: Vancouver (UBC), Apr18/86.
Cardiocrinum giganteum: Vancouver (UBC), Apr18/86.
Geranium 'Ballerina': Vancouver (UBC), Apr18/86.
Helleborus orientalis: Vancouver (UBC), Apr18/86.
Parthenocissus quinquefolia: Vancouver, Jun22/84.
Viburnum farreri 'Bowles': Vancouver (UBC), Apr18/86.
STELLARIAE Theobald, MACROSIPHUM
Catharanthus roseus: Vancouver (CDA), Oct13/86.
Rheum rhabarbarum 'Victoria': Vancouver (CDA), Oct10/86.
TANACETARIA (Kaltenbach), MACROSIPHONIELLA
Chrysanthemum balsamita: Vancouver (UBC), Aug1/86.
Chrysanthemum parthenium: Vancouver (UBC), Aug1/86.
Matricaria perforata: Vancouver (UBC), Sep22/86.
Tanacetum vulgare: Choate, Ju124/67.
TESTUDINACEUS (Fernie), PERIPHYLLUS
Acer macrophyllum: Vancouver (UBC), May10/74.
TILIAE (Linnaeus), EUCALLIPTERUS
Tilia americana: Vancouver (UBC), Sep25/86.
VANCOUVERENSE Robinson, UROLEUCON
Solidago missouriensis var. *missouriensis*: Vancouver (UBC), 0ct20/86.
VARIABILIS Richards, BOERNERINA
Alnus viridis ssp. *sinuata*: Vancouver (UBC), Sep3/86.
VARIANS Patch, APHIS
Ribes magellanica: Vancouver (UBC), 0ct1/85.
WALSHII (Monell), MYZOCALLIS
Quercus sp.: Vancouver, Sep21/59.

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REFERENCES

Eastop, V.F., and D. Hille Ris Lambers. 1976. Survey of the world's aphids. Dr. W. Junk b.v., Publisher, The Hague.

Forbes, A.R., and C.K. Chan. 1986a. The aphids (Homoptera: Aphididae) of British Columbia. 15. Further additions. *J. ent. Soc. Brit. Columbia* **83**: 70-73.

Forbes, A.R., and C.K. Chan. 1986b. The aphids (Homoptera: Aphididae) of British Columbia. 14. Further additions. J. ent. Soc. Brit. Columbia **83** : 66-69.

Forbes, A.R., and C.K. Chan. 1985. The aphids (Homoptera: Aphididae) of British Columbia. 13. Further additions. *J. ent. Soc. Brit. Columbia* **82**: 56-58.

Forbes, A.R., and C.K. Chan. 1984. The aphids (Homoptera: Aphididae) of British Columbia. 12. Further additions. *J. ent. Soc. Brit. Columbia* **81**: 72-75.

Forbes, A.R., and C.K. Chan. 1983. The aphids (Homoptera: Aphididae) of British Columbia. 11. Further additions. *J. ent. Soc. Brit. Columbia* **80**: 51-53.

Forbes, A.R., and C.K. Chan. 1981. The aphids (Homoptera: Aphididae) of British Columbia. 9. Further additions. *J. ent. Soc. Brit. Columbia* **78**: 53-54.

Forbes, A.R., and C.K. Chan. 1980. The aphids (Homoptera: Aphididae) of British Columbia. 8. Further additions and corrections. *J. ent. Soc. Brit. Columbia* **77**: 38-42.

Forbes, A.R., and C.K. Chan. 1978. The aphids (Homoptera: Aphididae) of British Columbia. 6. Further additions. *J. ent. Soc. Brit. Columbia* **75**: 47-52.

Forbes, A.R., and C.K. Chan. 1976. The aphids (Homoptera: Aphididae) of British Columbia. 4. Further additions and corrections. *J. ent. Soc. Brit. Columbia* **73**: 57-63.
Forbes, A.R., C.K. Chan and R. Foottit. 1982. The aphids (Homoptera: Aphididae) of British Columbia. 10. Further additions. *J. ent. Soc. Brit. Columbia* **79**: 75-78.
Forbes, A.R., B.D. Frazer and C.K. Chan. 1974. The aphids (Homoptera: Aphididae) of British Columbia. 3. Additions and corrections. *J. ent. Soc. Brit. Columbia* **71**: 43-49.
Forbes, A.R., B.D. Frazer and H.R. MacCarthy. 1973. The aphids (Homoptera: Aphididae) of British Columbia. 1. A basic taxonomic list. *J. ent. Soc. Brit. Columbia* **70**: 43-57.
Robinson, A.G. 1986. Annotated list of *Uroleucon* (*Lambersius*) (Homoptera: Aphididae) of America north of Mexico, with a key and descriptions of new species. *Canad. Ent.* **118**: 559-570.

THE APHIDS (HOMOPTERA:APHIDIDAE) OF BRITISH COLUMBIA 17. A REVISED HOST PLANT CATALOGUE

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ABSTRACT

A host plant catalogue of 919 species and the associated aphids collected in British Columbia is presented.

INTRODUCTION

This host plant catalogue includes all of the aphids recorded in British Columbia (Forbes, Frazer and MacCarthy 1973; Forbes, Frazer and Chan 1974; Forbes and Chan 1976, 1978b, 1980, 1981, 1983, 1984, 1985, 1986a, 1986b, 1987; Forbes, Chan and Foottit 1982) that were actually colonizing hosts. It supercedes previous ones (Forbes and Chan 1978a; Forbes and Frazer 1973).

Names of native plants are based on Anonymous (1982); Crabbe, Jermy and Mikel (1975); Hitchcock and Cronquist (1973); Schofield (1969); and Taylor and MacBryde (1977). Names of cultivated plants are based on Anonymous (1976); and Fernald (1970). The plant hosts are listed alphabetically by genus, species and variety with a cross index of common names and family names. The aphids colonizing each host are given alphabetically by genus and species. Their names are in conformity with Eastop and Hille Ris Lambers (1976).

This catalogue was compiled by computer using a Fortran program (Raworth and Frazer 1976).

HOST PLANT CATALOGUE

Abelia x 'Edward Goucher'
Edward Goucher Abelia (F. Caprifoliaceae)
Myzus ornatus

Abies balsamea Balsam Fir (F. Pinaceae)
Cinara curvipes
Cinara occidentalis

Abies grandis Grand Fir (F. Pinaceae)
Cinara confinis
Cinara curvipes
Cinara occidentalis
Cinara sonata
Mindarus abietinus
Mindarus victoria

Abies lasiocarpa Alpine Fir (F. Pinaceae)
Cinara confinis
Cinara curvipes

Abies sibirica Siberian Fir (F. Pinaceae)
Cinara occidentalis

Abies sp. Fir (F. Pinaceae)
Cinara confinis
Cinara sonata

Acer cappadocicum
Cappadocian Maple (F. Aceraceae)
Periphyllus testudinaceus

Acer circinatum Vine Maple (F. Aceraceae)
Periphyllus californiensis
Periphyllus lyropictus
Periphyllus testudinaceus

Acer ginnala Amur Maple (F. Aceraceae)
Periphyllus testudinaceus

Acer glabrum
Rocky Mountain Maple (F. Aceraceae)
Drepanosiphum platanoidis
Periphyllus brevispinosus

Acer glabrum var. douglasii
Douglas Maple (F. Aceraceae)

Periphyllus testudinaceus
Acer macrophyllum
Broadleaf Maple (F. Aceraceae)
Drepanosiphum platanoidis
Periphyllus californiensis
Periphyllus lyropictus
Periphyllus testudinaceus
Acer negundo Box-Elder (F. Aceraceae)
Drepanosiphum platanoidis
Periphyllus californiensis
Periphyllus negundinis
Periphyllus testudinaceus

Acer palmatum
Japanese Maple (F. Aceraceae)
Periphyllus testudinaceus
Acer platanoides
Norway Maple (F. Aceraceae)
Drepanosiphum platanoidis
Periphyllus lyropictus
Periphyllus testudinaceus
Acer rubrum Red Maple (F. Aceraceae
Periphyllus testudinaceus
Acer saccharinum
Silver Maple (F. Aceraceae
Periphyllus testudinaceus
Acer sp. Maple (F. Aceraceae
Drepanosiphum platanoidis
Periphyllus aceris
Periphyllus californiensis
Periphyllus lyropictus
Periphyllus testudinaceus
Achillea 'Coronation Gold'
Coronation Gold Yarrow (F. Compositae)
Macrosiphoniella millefolii
Achillea millefolium
Common Yarrow (F. Compositae)
Macrosiphoniella millefolii
Uroleucon achilleae
Achillea millefolium var. borealis
Northern Yarrow (F. Compositae)
Macrosiphoniella millefolii
Achillea millefolium 'Cerise Queen'
Cerise Queen Yarrow (F. Compositae)
Macrosiphoniella millefolii
Achillea millefolium var. lanulosa
Western Yarrow (F. Compositae)
Macrosiphoniella millefolii
Aegopodium podograria
Goutweed (F. Umbelliferae)
Cavariella aegopodii
Hyadaphis foeniculi
Aeschynanthus radicans
Lipstick Plant (F. Gesneriaceae)
Aulacorthum solani
Aesculus hippocastanum
Horse Chestnut (F. Hippocastanaceae)
Periphyllus testudinaceus
Aethionema schistosum
Turkey Stone Cress (F. Cruciferae)
Myzus persicae
Agropyron repens
Couch Grass (F. Gramineae)
Sipha elegans
Tetraneura ulmi
Utamphorophora humboldti
Agropyron sp. Wheat Grass (F. Gramineae)
Sipha elegans
Sitobion avenae
Agrostis stolonifera var. palustris
Creeping Bent Grass (F. Gramineae)
Sipha glyceriae
Alcea rosea Hollyhock (F. Malvaceae)
Myzus persicae
Alchemilla mollis
Soft Lady's Mantle (F. Rosaceae)
Aulacorthum solani
Brachycaudus helichrysi
Myzus ascalonicus
Alchemilla vulgaris
Common Lady's Mantle (F. Rosaceae)
Aulacorthum circumflexum
Aulacorthum solani
Myzus ornatus
Alisma plantago-aquatica
American Waterplantain (F. Alismataceae)
Rhopalosiphum nymphaeae
Allium cepa Onion (F. Liliaceae)
Myzus ascalonicus
Allium schoenoprasum Chive (F. Liliaceae)
Myzus ascalonicus
Allium tuberosum
Chinese Chive (F. Liliaceae)
Myzus persicae
Alnus incana ssp. tenuifolia
Thin-Leaved Mountain Alder (F. Betulaceae)
Oestlundiella flava
Pterocallis alnifoliae
Alnus rubra Red Alder (F. Betulaceae)
Euceraphis gillettei
Euceraphis punctipennis
Pterocallis alni
Alnus sp. Alder (F. Betulaceae)
Boernerina variabilis
Euceraphis gillettei
Oestlundiella flava
Pterocallis alni
Alnus viridis ssp. sinuata
Sitka Mountain Alder (F. Betulaceae)
Boernerina variabilis
Euceraphis punctipennis
Euceraphis sitchensis
Aloe barbadensis Barbados Aloe (F. Liliaceae)
Aulacorthum solani
Aloysia triphylla
Lemon Verbena (F. Verbenaceae)
Aulacorthum solani
Myzus persicae
Alstroemeria aurantiaca
Yellow Alstroemeria (F. Amaryllidaceae)
Aulacorthum solani
Myzus ornatus
Alstroemeria chilensis
Chilean Alstroemeria (F. Amaryllidaceae)
Aulacorthum solani

Althaea sp. Althaea (F. Malvaceae)
Uroleucon eoessigi
Alyogyne huegelii
Huegel's Hibiscus (F. Malvaceae)
Myzus persicae
Alyssum montanum
Mountain Alyssum (F. Cruciferae)
Myzus ascalonicus
Alyssum murale Yellow-Tuft (F. Cruciferae)
Myzus ornatus
Amaranthus retroflexus
Redroot Pigweed (F. Amaranthaceae)
Aulacorthum solani
Myzus persicae
Amelanchier alnifolia
Western Serviceberry (F. Rosaceae)
Acyrthosiphon macrosiphum
Prociphilus alnifoliae
Amelanchier canadensis
Shadblow Serviceberry (F. Rosaceae)
Acyrthosiphon macrosiphum
Aphis fabae
Aphis pomi
Prociphilus alnifoliae
Amelanchier laevis
Allegheny Serviceberry (F. Rosaceae)
Acyrthosiphon macrosiphum
Fimbriaphis gentneri
Amelanchier ovalis
European Serviceberry (F. Rosaceae)
Fimbriaphis gentneri
Amelanchier sp. Serviceberry (F. Rosaceae)
Nearctaphis sensoriata
Prociphilus alnifoliae
Prociphilus corrugatans
Amsinckia intermedia
Fiddle-Neck (F. Boraginaceae)
Pleotrichophorus amsinckii
Anagallis monelli
Monell Pimpernel (F. Primulaceae)
Aulacorthum solani
Anaphalis margaritacea
Pearly Everlasting (F. Compositae)
Brachycaudus helichrysi
Illinoia richardsi
Uroleucon russellae
Androsace sarmentosa
Rock-Jasmine (F. Primulaceae)
Aulacorthum solani
Anemone halleri
Haller Anemone (F. Ranunculaceae)
Aulacorthum solani
Myzus ascalonicus
Anemone pulsatilla
European Pasqueflower (F. Ranunculaceae)
Myzus ascalonicus
Anethum graveolens Dill (F. Umbelliferae)
Cavariella aegopodii
Angelica genuflexa
Kneeling Angelica (F. Umbelliferae)
Cavariella aegopodii
Antennaria neglecta var. attenuata
Field Pussytoes (F. Compositae)
Brachycaudus helichrysi
Antennaria umbrinella
Dusky Brown Pussytoes (F. Compositae)
Brachycaudus helichrysi
Anthericum liliago
St-Bernard's Lily (F. Liliaceae)
Myzus persicae
Anthoxanthum odoratum
Sweet Vernal Grass (F. Gramineae)
Sitobion fragariae
Antirrhinum majus
Common Snapdragon (F. Scrophulariaceae)
Aulacorthum solani
Brachycaudus helichrysi
Aphelandra squarrosa
Zebra Plant (F. Acanthaceae)
Macrosiphum euphorbiae
Apium graveolens Celery (F. Umbelliferae)
Aulacorthum circumflexum
Aulacorthum solani
Cavariella konoi
Hyadaphis foeniculi
Macrosiphum stellariae
Myzus persicae
Apocynum androsaemifolium
Common Dogbane (F. Apocynaceae)
Aphis fabae
Aulacorthum solani
Macrosiphum euphorbiae
Myzus ornatus
Myzus persicae
Rhopalosiphoninus staphyleae
Aquilegia alpina
Alpine Columbine (F. Ranunculaceae)
Kakimia aquilegiae
Aquilegia caerulea var. ochroleuca
White-Sepal Colorado Columbine
(F. Ranunculaceae)
Aulacorthum solani
Aquilegia chrysantha
Golden Columbine (F. Ranunculaceae)
Kakimia aquilegiae
Aquilegia formosa
Sitka Columbine (F. Ranunculaceae)
Kakimia aquilegiae
Aquilegia olympica
Caucasus Columbine (F. Ranunculaceae)
Myzus ornatus
Aquilegia sp. Columbine (F. Ranunculaceae)
Aulacorthum solani
Kakimia aquilegiae
Longicaudus trirhodus
Aquilegia vulgaris
Garden Columbine (F. Ranunculaceae)
Aphis fabae
Aulacorthum circumflexum
Aulacorthum solani
Kakimia aquilegiae
Longicaudus trirhodus
Macrosiphum euphorbiae
Myzus ascalonicus

Arabis caucasica Wall Rockcress (F. Cruciferae)
Myzus ascalonicus
Myzus ornatus
Aralia elata
Japanese Angelica-Tree (F. Araliaceae)
Aphis fabae
Myzus persicae
Rhopalosiphoninus staphyleae
Arbutus menziesii
Pacific Madrone (F. Ericaceae)
Wahlgreniella nervata
Wahlgreniella nervata arbuti
Arbutus unedo Strawberry Tree (F. Ericaceae)
Wahlgreniella nervata
Arctostaphylos uva-ursi
Bearberry (F. Ericaceae)
Aphis fabae
Aulacorthum circumflexum
Aulacorthum solani
Brachycaudus helichrysi
Ericaphis scammelli
Fimbriaphis fimbriata
Myzus ascalonicus
Myzus ornatus
Rhopalosiphoninus staphyleae
Tamalia coweni
Wahlgreniella vaccinii
Arctostaphylos uva-ursi 'Point Reyes'
'Point Reyes' Bearberry (F. Ericaceae)
Wahlgreniella nervata
Arnica amplexicaulis
Clasping Arnica (F. Compositae)
Illinoia davidsoni
Arnica chamissonis
Chamisso's Arnica (F. Compositae)
Myzus ornatus
Arnica latifolia var. gracilis
Broad-Leaved Arnica (F. Compositae)
Myzus ascalonicus
Arrhenatherum elatius 'Variegatum'
Variegated Oat Grass (F. Gramineae)
Metopolophium dirhodum
Sipha glyceriae
Sitobion avenae
Artemisia absinthium Absinthe (F. Compositae)
Aulacorthum solani
Artemisia arborescens 'Powis Castle'
Powis Castle Shrubby Sagebrush (F. Compositae)
Macrosiphoniella absinthii
Artemisia ludoviciana
Western Mugwort (F. Compositae)
Macrosiphoniella ludovicianae
Artemisia sp. Sagebrush (F. Compositae)
Obtusicauda frigidae
Artemisia stelleriana
Hoary Mugwort (F. Compositae)
Pleotrichophorus gnaphalodes
Artemisia tridentata
Common Sagebrush (F. Compositae)
Aphis canae
Microsiphoniella oregonensis
Obtusicauda artemisiae
Asclepias speciosa
Showy Milkweed (F. Asclepiadaceae)
Aphis asclepiadis
Myzus persicae
Asclepias tuberosa
Butterfly Weed (F. Asclepiadaceae)
Aulacorthum solani
Asparagus densiflorus 'Sprengeri'
Sprenger Asparagus (F. Liliaceae)
Aulacorthum circumflexum
Brachycolus asparagi
Macrosiphum euphorbiae
Myzus persicae
Asparagus officinalis
Garden Asparagus (F. Liliaceae)
Aphis fabae
Aphis helianthi
Brachycolus asparagi
Macrosiphum euphorbiae
Macrosiphum stellariae
Myzus persicae
Sitobion avenae
Aster alpinus Alpine Aster (F. Compositae)
Macrosiphum subviride
Aster foliaceus var. cusickii
Leafy-Bracted Aster (F. Compositae)
Aulacorthum solani
Aster sp. Aster (F. Compositae)
Brachycaudus helichrysi
Macrosiphum pallidum
Myzus persicae
Uroleucon ambrosiae
Uroleucon breviscriptum
Uroleucon paucosensoriatum
Astilbe microphylla
Small-Leaved False Goat's Beard (F. Saxifragaceae)
Rhopalosiphoninus staphyleae
Athyrium distentifolium var. americanum
Alpine Lady Fern (F. Aspleniaceae)
Sitobion adianti
Athyrium filix-femina
Lady Fern (F. Aspleniaceae)
Sitobion adianti
Athyrium filix-femina ssp. cyclosorum
Common Lady Fern (F. Aspleniaceae)
Sitobion adianti
Atropa belladonna Belladonna (F. Solanaceae)
Aulacorthum circumflexum
Aubrieta deltoidea
Purple Rock-Cress (F. Cruciferae)
Myzus ascalonicus
Myzus ornatus
Myzus persicae
Aucuba japonica
Japanese Aucuba (F. Cornaceae)
Aulacorthum solani
Myzus ascalonicus
Aucuba japonica 'Variegata'
Gold-Dust Tree (F. Cornaceae)
Aulacorthum solani
Avena sativa Oat (F. Gramineae)

Metopolophium dirhodum
Rhopalosiphum padi
Sitobion avenae
Baccharis magellanica
Magellan Baccharis (F. Compositae)
Aulacorthum solani
Myzus ascalonicus
Balsamorhiza sagittata
Arrowleaf Balsamroot (F. Compositae)
Macrosiphum euphorbiae
Barbarea orthoceras
American Winter Cress (F. Cruciferae)
Myzus ornatus
Barbarea verna
Early Winter Cress (F. Cruciferae)
Myzus ornatus
Begonia cucullata var. hookeri
Wax Begonia (F. Begoniaceae)
Aphis gossypii
Myzus ornatus
Bellis perennis English Daisy (F. Compositae)
Aulacorthum solani
Myzus ascalonicus
Myzus ornatus
Berberidopsis corallina
Coral Berberidopsis (F. Flacourtiaceae)
Aulacorthum circumflexum
Berberis buxifolia
Magellan Barberry (F. Berberidaceae)
Liosomaphis berberidis
Berberis x hybrido-gagnepainii
False Black Barberry (F. Berberidaceae)
Liosomaphis berberidis
Berberis thunbergii
Japanese Barberry (F. Berberidaceae)
Liosomaphis berberidis
Berberis verruculosa
Warty Barberry (F. Berberidaceae)
Liosomaphis berberidis
Beta vulgaris Sugar Beet (F. Chenopodiaceae)
Aphis fabae
Macrosiphum euphorbiae
Macrosiphum stellariae
Myzus persicae
Pemphigus betae
Betula occidentalis
Western Birch (F. Betulaceae)
Calaphis betulaefoliae
Euceraphis punctipennis
Symydobius intermedius
Betula papyrifera Paper Birch (F. Betulaceae)
Asiphum tremulae
Calaphis betulicola
Callipterinella callipterus
Callipterinella minutissima
Euceraphis punctipennis
Betula papyrifera var. papyrifera
Common Paper Birch (F. Betulaceae)
Euceraphis punctipennis
Betula pendula Weeping Birch (F. Betulaceae)
Betulaphis quadrituberculata
Calaphis betulicola
Euceraphis punctipennis
Betula pendula 'Dalecarlica'
Dalecarlica Weeping Birch (F. Betulaceae)
Callipterinella callipterus
Euceraphis punctipennis
Betula sp. Birch (F. Betulaceae)
Betulaphis aurea
Betulaphis brevipilosa
Betulaphis helvetica
Betulaphis quadrituberculata
Calaphis betulaecolens
Calaphis betulicola
Calaphis flava
Euceraphis gillettei
Euceraphis punctipennis
Hamamelistes spinosus
Bidens cernua
Smooth Beggartick (F. Compositae)
Aphis fabae
Myzus persicae
Bletia sp. Bletia (F. Orchidaceae)
Myzus ascalonicus
Myzus persicae
Brassica juncea 'Florida Broadleaf'
Florida Broadleaf Mustard (F. Cruciferae)
Brevicoryne brassicae
Rhopalosiphoninus staphyleae
Brassica napobrassica group
Rutabaga (F. Cruciferae)
Brevicoryne brassicae
Myzus persicae
Brassica oleracea acephala group
Kale (F. Cruciferae)
Brevicoryne brassicae
Macrosiphum euphorbiae
Brassica oleracea botrytis group
Broccoli (F. Cruciferae)
Brevicoryne brassicae
Myzus persicae
Brassica oleracea var. capitata
Cabbage (F. Cruciferae)
Brevicoryne brassicae
Myzus persicae
Brassica oleracea var. gemmifera
Brussels Sprouts (F. Cruciferae)
Brevicoryne brassicae
Lipaphis erysimi
Macrosiphum euphorbiae
Myzus persicae
Brassica oleracea 'Waltham 29'
Waltham 29 Broccoli (F. Cruciferae)
Brevicoryne brassicae
Myzus persicae
Brassica 'Osaka Red'
Ornamental Kale (F. Cruciferae)
Brevicoryne brassicae
Brassica pekinensis Pe-Tsai (F. Cruciferae)
Brevicoryne brassicae
Rhopalosiphoninus staphyleae
Brassica rapa Field Mustard (F. Cruciferae)
Myzus persicae
Brassica rapa ssp. campestris
Bird Rape (F. Cruciferae)

Lipaphis erysimi
Macrosiphum euphorbiae
Myzus persicae
Brassica rapa var. lorifolia
Turnip (F. Cruciferae)
Brevicoryne brassicae
Brassica sp. Mustard (F. Cruciferae)
Myzus persicae
Bromus ciliatus
Fringed Brome Grass (F. Gramineae)
Sitobion fragariae
Buddleja davidii
Orange-Eye Butterflybush (F. Buddlejaceae)
Myzus ornatus
Myzus persicae
Calamagrostis sp. Reed Grass (F. Gramineae)
Sitobion fragariae
Calceolaria crenatiflora
Slipperwort (F. Scrophulariaceae)
Myzus persicae
Calendula officinalis
Pot-Marigold (F. Compositae)
Aphis fabae
Myzus persicae
Callistephus chinensis
China Aster (F. Compositae)
Aphis fabae
Macrosiphum euphorbiae
Myzus persicae
Callitriche stagnalis
Pond Water-Starwort (F. Callitrichaceae)
Myzodium knowltoni
Rhopalosiphum nymphaeae
Calluna vulgaris Scotch Heather (F. Ericaceae)
Aphis callunae
Caltha sp. Marsh Marigold (F. Ranunculaceae)
Rhopalosiphum nymphaeae
Calycanthus fertilis
Pale Sweetshrub (F. Calycanthaceae)
Aphis citricola
Calystegia sepium
Hedge Bindweed (F. Convolvulaceae)
Myzus persicae
Campanula persicifolia
Peachleaf Bellflower (F. Campanulaceae)
Aulacorthum circumflexum
Myzus ornatus
Campanula portenschlagiana
Dalmatian Bellflower (F. Campanulaceae)
Myzus ascalonicus
Campsis x tagliabuana 'Madame Galen'
Clinging Vine (F. Bignoniaceae)
Myzus ornatus
Cannabis sativa True Hemp (F. Cannabaceae)
Myzus persicae
Capsella bursa-pastoris
Shepherd's Purse (F. Cruciferae)
Aphis fabae
Aulacorthum solani
Brachycaudus helichrysi
Macrosiphum euphorbiae
Macrosiphum pyrifoliae
Macrosiphum stellariae
Myzus ascalonicus
Myzus certus
Myzus persicae
Nasonovia ribisnigri
Rhopalosiphoninus staphyleae
Rhopalosiphum maidis
Rhopalosiphum nymphaeae
Rhopalosiphum padi
Sitobion avenae
Capsicum frutescens
Tabasco Pepper (F. Solanaceae)
Macrosiphum euphorbiae
Capsicum sp. Pepper (F. Solanaceae)
Myzus persicae
Caragana arborescens
Siberian Peashrub (F. Leguminosae)
Acyrthosiphon caraganae
Caragana pygmaea
Pygmy Peashrub (F. Leguminosae)
Acyrthosiphon caraganae
Cardamine oligosperma
Little Western Bitter Cress (F. Cruciferae)
Myzus ascalonicus
Cardiocrinum giganteum
Giant-Lily (F. Liliaceae)
Rhopalosiphoninus staphyleae
Carduus sp. Plumeless Thistle (F. Compositae)
Brachycaudus cardui
Carex capitata ssp. capitata
Capitate Sedge (F. Cyperaceae)
Glabromyzus schlingeri
Sitobion fragariae
Carex concinnoides
Northwestern Sedge (F. Cyperaceae)
Rhopalosiphum padi
Carex flava var. flava
Yellow-Fruited Sedge (F. Cyperaceae)
Sitobion fragariae
Carex geyeri Elk Sedge (F. Cyperaceae)
Ceruraphis eriophori
Carex glareosa ssp. glareosa
Clustered Sedge (F. Cyperaceae)
Ceruraphis eriophori
Thripsaphis verrucosa
Carex leporina Harefoot Sedge (F. Cyperaceae)
Ceruraphis eriophori
Glabromyzus schlingeri
Carex limosa Shore Sedge (F. Cyperaceae)
Ceruraphis eriophori
Glabromyzus schlingeri
Carex mertensii Mertens' Sedge (F. Cyperaceae)
Byrsocryptoides polunini
Carex pendula Sedge Grass (F. Cyperaceae)
Ceruraphis eriophori
Rhopalosiphum padi
Thripsaphis verrucosa
Carex sitchensis Sitka Sedge (F. Cyperaceae)
Ceruraphis eriophori
Thripsaphis cyperi
Carex sp. Sedge (F. Cyperaceae)

Ceruraphis eriophori
Iziphya umbella
Sitobion caricis
Thripsaphis cyperi
Thripsaphis verrucosa

Carpinus betulus
European Hornbeam (F. Betulaceae)
Myzocallis carpini

Carpinus betulus 'Fastigiata'
Pyramidal European Hornbean (F. Betulaceae)
Myzocallis carpini

Castanea dentata American Chestnut (F. Fagaceae)
Myzocallis castanicola

Castanea sp. Chestnut (F. Fagaceae)
Myzocallis castanicola

Castilleja miniata
Common Red Indian Paintbrush (F. Scrophulariaceae)
Kakimia castilleiae

Castilleja sp
Indian Paintbrush (F. Scrophulariaceae)
Kakimia castilleiae

Catalpa sp. Indian Bean (F. Bignoniaceae)
Aulacorthum solani

Catalpa speciosa
Western Catalpa (F. Bignoniaceae)
Aphis fabae
Aulacorthum solani
Ceruraphis eriophori
Macrosiphum euphorbiae
Myzus ornatus
Nasonovia ribisnigri
Rhopalosiphum padi

Catharanthus roseus
Rose Periwinkle (F. Apocynaceae)
Aphis fabae
Macrosiphum euphorbiae
Macrosiphum stellariae
Myzus certus
Nasonovia ribisnigri
Rhopalosiphoninus staphyleae
Rhopalosiphum nymphaeae

Ceanothus sanguineus
Wild Lilac (F. Rhamnaceae)
Aphis ceanothi

Ceanothus velutinus
Sticky Laurel (F. Rhamnaceae)
Aphis ceanothi

Centaurea diffusa
Diffuse Knapweed (F. Compositae)
Aphis armoraciae

Centranthus ruber
Red Valerian (F. Valerianaceae)
Macrosiphum euphorbiae

Cerastium fontanum ssp. triviale
Mouse-Ear Chickweed (F. Caryophyllaceae)
Myzus ascalonicus

Cerastium tomentosum
Snow-In-Summer (F. Caryophyllaceae)
Aulacorthum solani

Ceratostigma willmottianum
Chinese Plumbago (F. Plumbaginaceae)
Myzus ornatus

Chaenomeles japonica
Lesser Flowering Quince (F. Rosaceae)
Aphis pomi
Brachycaudus helichrysi
Illinoia macgillivrayae
Macrosiphum euphorbiae
Rhopalosiphum insertum
Rhopalosiphum nymphaeae

Chaenomeles speciosa
Japanese Quince (F. Rosaceae)
Aulacorthum solani
Myzus ornatus

Chamaecyparis lawsoniana
Lawson Falsecypress (F. Cupressaceae)
Illinoia morrisoni

Chamaecyparis pisifera
Sawara Falsecypress (F. Cupressaceae)
Illinoia morrisoni

Chamaecyparis pisifera 'Boulevard'
Boulevard Sawara Falsecypress (F. Cupressaceae)
Illinoia morrisoni

Chamaecyparis pisifera 'Filifera'
Thread Sawara Falsecypress (F. Cupressaceae)
Illinoia morrisoni

Chamaecyparis pisifera 'Plumosa'
Plume Sawara Falsecypress (F. Cupressaceae)
Illinoia morrisoni

Chamaecyparis pisifera 'Squarrosa'
Moss Sawara Falsecypress (F. Cupressaceae)
Illinoia morrisoni

Chamomilla suaveolens
Pineapple Weed (F. Compositae)
Aphis fabae
Aulacorthum solani
Brachycaudus helichrysi
Macrosiphum euphorbiae
Myzus ornatus
Myzus persicae

Chenopodium album
Lamb's Quarters (F. Chenopodiaceae)
Aphis fabae
Hayhurstia atriplicis
Macrosiphum euphorbiae
Myzus persicae
Pemphigus populivenae

Chenopodium capitatum
Strawberry-Blite Goosefoot (F. Chenopodiaceae)
Aphis fabae
Macrosiphum euphorbiae

Chenopodium glaucum
Oak-Leaved Goosefoot (F. Chenopodiaceae)
Aphis fabae
Hayhurstia atriplicis

Chenopodium murale
Nettle-Leaved Goosefoot (F. Chenopodiaceae)
Macrosiphum creelii
Macrosiphum euphorbiae

Chenopodium quinoa

Quinoa (F. Chenopodiaceae)
Aphis fabae
Macrosiphum euphorbiae
Chrysanthemum balsamita
Costmary (F. Compositae)
Macrosiphoniella tanacetaria
Pleotrichophorus chrysanthemi
Chrysanthemum frutescens
Marguerite (F. Compositae)
Brachycaudus helichrysi
Chrysanthemum leucanthemum
Ox-Eye Daisy (F. Compositae)
Macrosiphoniella millefolii
Myzus ornatus
Chrysanthemum x morifolium
Florist's Chrysanthemum (F. Compositae)
Aulacorthum circumflexum
Aulacorthum solani
Brachycaudus helichrysi
Macrosiphoniella sanborni
Macrosiphum euphorbiae
Myzus ornatus
Myzus persicae
Chrysanthemum parthenium
Feverfew (F. Compositae)
Brachycaudus helichrysi
Macrosiphoniella tanacetaria
Chrysothamnus nauseosus
Rabbit Bush (F. Compositae)
Aphis chrysothamni
Cichorium intybus
Common Chichory (F. Compositae)
Nasonovia ribisnigri
Cinna latifolia Woodreed Grass (F. Gramineae)
Rhopalosiphum padi
Sitobion fragariae
Cirsium arvense Canada Thistle (F. Compositae)
Aphis fabae
Brachycaudus cardui
Macrosiphum euphorbiae
Myzus ornatus
Uroleucon cirsii
Cirsium brevistylum
Indian Thistle (F. Compositae)
Capitophorus elaeagni
Uroleucon cirsii
Cirsium sp. Thistle (F. Compositae)
Bipersona ochrocentri
Uroleucon cirsii
Cirsium undulatum
Wavy-Leaved Thistle (F. Compositae)
Brachycaudus cardui
Cirsium vulgare Bull Thistle (F. Compositae)
Bipersona ochrocentri
Brachycaudus cardui
Brachycaudus helichrysi
Cistus ladanifer Gum Rock-Rose (F. Cistaceae)
Myzus ornatus
Myzus persicae
Cistus laurifolius
Laurel Rock-Rose (F. Cistaceae)
Myzus persicae
Citrullus lanatus Watermelon (F. Cucurbitaceae)
Aulacorthum solani
Citrus maxima Shaddock (F. Rutaceae)
Macrosiphum euphorbiae
Citrus sp. Citrus (F. Rutaceae)
Aulacorthum circumflexum
Clarkia pulchella Pinkfairies (F. Onagraceae)
Myzus ornatus
Claytonia sibirica var. sibirica
Siberian Spring-Beauty (F. Portulacaceae)
Macrosiphum euphorbiae
Myzus ascalonicus
Myzus persicae
Clematis 'Nelly Moser'
Nelly Moser Clematis (F. Ranunculaceae)
Aulacorthum solani
Coleus blumei Painted Nettle (F. Labiatae)
Myzus ornatus
Collinsia grandiflora
Bluelips (F. Scrophulariaceae)
Myzus ornatus
Myzus persicae
Colutea arborescens
Bladder-Senna (F. Leguminosae)
Acyrthosiphon caraganae
Myzus ascalonicus
Colutea melanocalyx
Black Bladder-Senna (F. Leguminosae)
Acyrthosiphon caraganae
Conium maculatum
Poison Hemlock (F. Umbelliferae)
Aulacorthum solani
Convolvulus arvensis
Dwarf Bindweed (F. Convolvulaceae)
Myzus persicae
Conyza canadensis var. canadensis
Canadian Fleabane (F. Compositae)
Aphis lugentis
Corallorhiza striata
Striped Coralroot (F. Orchidaceae)
Macrosiphum corallorhizae
Cordyline terminalis 'Hybrida'
Hybrid Ti (F. Agavaceae)
Aulacorthum circumflexum
Coriandrum sativum
Chinese Parsley (F. Umbelliferae)
Brachycaudus helichrysi
Myzus persicae
Coriandrum sativum 'Dark Green Italian'
Dark Green Italian Parsley (F. Umbelliferae)
Hyadaphis foeniculi
Cornus alba 'Argenteo-marginata'
Creamedge Tatarian Dogwood (F. Cornaceae)
Aphis salicariae
Cornus alba 'Sibirica'
Siberian Dogwood (F. Cornaceae)
Anoecia corni
Sitobion manitobense
Cornus 'Eddie's White Wonder'
Eddie White Wonder Dogwood (F. Cornaceae)
Aphis salicariae
Cornus florida

Flowering Dogwood (F. Cornaceae)
Aphis salicariae
Cornus florida 'Pluribracteata'
Double Flowering Dogwood (F. Cornaceae)
Aphis salicariae
Cornus kousa Japanese Dogwood (F. Cornaceae)
Aphis salicariae
Cornus mas
Cornelian-Cherry Dogwood (F. Cornaceae)
Aphis salicariae
Cornus nuttallii
Western Flowering Dogwood (F. Cornaceae)
Anoecia corni
Aphis salicariae
Macrosiphum euphorbiae
Cornus purpusii Silky Dogwood (F. Cornaceae)
Anoecia corni
Aphis salicariae
Cornus racemosa Gray Dogwood (F. Cornaceae)
Aphis salicariae
Cornus sanguinea
Bloodtwig Dogwood (F. Cornaceae)
Anoecia corni
Aphis salicariae
Cornus sericea
Red-Osier Dogwood (F. Cornaceae)
Anoecia corni
Aphis helianthi
Macrosiphum euphorbiae
Sitobion manitobense
Coronilla valentina ssp. glauca
Gray Valentine Crown-Vetch (F. Leguminosae)
Myzus ornatus
Cortaderia selloana
Pampas Grass (F. Gramineae)
Hyalopterus pruni
Sitobion fragariae
Corydalis aurea ssp. aurea
Golden Corydalis (F. Fumariaceae)
Aulacorthum circumflexum
Aulacorthum solani
Corylus avellana Hazelnut (F. Betulaceae)
Myzocallis coryli
Corylus cornuta
Beaked Hazelnut (F. Betulaceae)
Illinoia spiraeae
Myzocallis coryli
Corylus cornuta var. californica
California Filbert (F. Betulaceae)
Corylobium avellanae
Macrosiphum coryli
Macrosiphum pseudocoryli
Myzocallis coryli
Corylus maxima 'Purpurea'
Purple Filbert (F. Betulaceae)
Corylobium avellanae
Myzocallis coryli
Corylus sp. Filbert (F. Betulaceae)
Corylobium avellanae
Myzocallis coryli
Cotoneaster bullatus
Hollyberry Cotoneaster (F. Rosaceae)
Aphis pomi
Cotoneaster dammeri
Bearberry Cotoneaster (F. Rosaceae)
Aphis pomi
Cotoneaster franchetii
Franchet's Cotoneaster (F. Rosaceae)
Aphis pomi
Cotoneaster henryanus
Henry's Cotoneaster (F. Rosaceae)
Aphis pomi
Cotoneaster horizontalis
Rock Cotoneaster (F. Rosaceae)
Aphis pomi
Cotoneaster salicifolius 'Repens'
Creeping Willowleaf Cotoneaster (F. Rosaceae)
Aphis pomi
Cotoneaster sp. Cotoneaster (F. Rosaceae)
Aphis pomi
Eriosoma lanigerum
Cotula australis
Australian Cotula (F. Compositae)
Brachycaudus helichrysi
Myzus ascalonicus
Crataegus douglasii
Douglas Hawthorn (F. Rosaceae)
Aphis pomi
Fimbriaphis gentneri
Nearctaphis bakeri
Nearctaphis sclerosa
Crataegus laevigata 'Paul's Scarlet'
Paul's Scarlet Hawthorn (F. Rosaceae)
Aphis pomi
Fimbriaphis gentneri
Metopolophium dirhodum
Crataegus x lavallei
Lavalle Hawthorn (F. Rosaceae)
Fimbriaphis gentneri
Utamphorophora crataegi
Crataegus monogyna
Singleseed Hawthorn (F. Rosaceae)
Aphis pomi
Fimbriaphis gentneri
Crataegus monogyna 'Alba'
White Singleseed Hawthorn (F. Rosaceae)
Aphis pomi
Fimbriaphis gentneri
Macrosiphum euphorbiae
Crataegus sp. Hawthorn (F. Rosaceae)
Aphis pomi
Metopolophium dirhodum
Nearctaphis crataegifoliae
Nearctaphis sclerosa
Rhopalosiphum insertum
Crepis sp. Hawk's-Beard (F. Compositae)
Hyperomyzus sandilandicus
Crinodendron patagua
White Lily Tree (F. Elaeocarpaceae)
Aulacorthum circumflexum
Myzus ornatus
Crocosmia x crocosmiiflora

Montbretia (F. Iridaceae)
Aphis fabae
Crocus sp. Crocus (F. Iridaceae)
Aulacorthum circumflexum
Myzus ascalonicus
Crossandra infundibuliformis
Funnel-Form Firecracker Flower (F. Acanthaceae)
Aulacorthum circumflexum
Myzus persicae
Cryptogramma crispa
Parsley Fern (F. Adiantaceae)
Sitobion woodsiae
Cucumis sativus Cucumber (F. Cucurbitaceae)
Macrosiphum euphorbiae
Cucurbita sp. Squash (F. Cucurbitaceae)
Myzus persicae
Cupressocyparis leylandii
Leyland Cypress (F. Cupressaceae)
Illinoia morrisoni
Cuscuta sp. Dodder (F. Cuscutaceae)
Myzus persicae
Cuscuta subinclusa
Long-Flowered Dodder (F. Cuscutaceae)
Aphis fabae
Cyclamen persicum
Florist's Cyclamen (F. Primulaceae)
Aphis gossypii
Aulacorthum circumflexum
Cymbidium sp. Boat Orchid (F. Orchidaceae)
Myzus ornatus
Cynara scolymus Artichoke (F. Compositae)
Myzus persicae
Cyperus alternifolius
Umbrella Plant (F. Cyperaceae)
Rhopalosiphum padi
Cytisus austriacus
Southern Broom (F. Leguminosae)
Acyrthosiphon pisum
Aphis cytisorum
Cytisus hirsutus var. demissus
Dwarf Broom (F. Leguminosae)
Aphis cytisorum
Cytisus scoparius
Scotch Broom (F. Leguminosae)
Acyrthosiphon pisum
Ctenocallis setosus
Daboecia cantabrica Irish-Heath (F. Ericaceae)
Illinoia lambersi
Daboecia cantabrica 'Alba'
White Irish-Heath (F. Ericaceae)
Illinoia lambersi
Daboecia cantabrica 'Atropurpurea'
Purple Irish-Heath (F. Ericaceae)
Illinoia lambersi
Daboecia cantabrica 'Praegerae'
Rosy Irish-Heath (F. Ericaceae)
Illinoia lambersi
Dactylis glomerata
Orchard Grass (F. Gramineae)
Hyalopteroides humilis
Rhopalomyzus lonicerae
Rhopalosiphum musae
Sitobion avenae
Dahlia sp. Dahlia (F. Compositae)
Aulacorthum solani
Macrosiphum euphorbiae
Myzus ascalonicus
Myzus ornatus
Myzus persicae
Daphne x burkwoodii 'Somerset'
Burkwood Daphne (F. Thymelaeaceae)
Macrosiphum daphnidis
Daphne cneorum
Garland Flower (F. Thymelaeaceae)
Macrosiphum euphorbiae
Daphne laureola
Spurge-Laurel (F. Thymelaeaceae)
Aulacorthum solani
Macrosiphum daphnidis
Macrosiphum euphorbiae
Datura inoxia
Downy Thorn Apple (F. Solanaceae)
Myzus persicae
Datura stramonium
Common Thorn Apple (F. Solanaceae)
Macrosiphum euphorbiae
Myzus persicae
Nasonovia ribisnigri
Rhopalosiphoninus staphyleae
Daucus carota Carrot (F. Umbelliferae)
Aulacorthum solani
Cavariella aegopodii
Macrosiphum stellariae
Myzus persicae
Delphinium x cultorum
Perennial Delphinium (F. Ranunculaceae)
Kakimia wahinkae
Deutzia gracilis
Slender Deutzia (F. Hydrangeaceae)
Aphis fabae
Aulacorthum solani
Macrosiphum euphorbiae
Rhopalosiphoninus hydrangeae
Deutzia x rosea 'Carminea'
Rosepanicle Deutzia (F. Hydrangeaceae)
Macrosiphum euphorbiae
Myzus ornatus
Deutzia scabra 'Candidissima'
Candidissima Deutzia (F. Hydrangeaceae)
Myzus ornatus
Dianthus alpinus
Alpine Pink (F. Caryophyllaceae)
Macrosiphum stellariae
Dianthus barbatus
Sweet William (F. Caryophyllaceae)
Macrosiphum euphorbiae
Macrosiphum stellariae
Myzus certus
Dianthus caryophyllus
Carnation (F. Caryophyllaceae)
Myzus persicae
Dianthus deltoides

Maiden Pink (F. Caryophyllaceae)
Macrosiphum euphorbiae
Myzus ascalonicus
Dianthus graniticus
Granite Pink (F. Caryophyllaceae)
Aulacorthum solani
Myzus ascalonicus
Dianthus microlepis
Microlepis Pink (F. Caryophyllaceae)
Myzus ascalonicus
Dianthus 'Scarlet Luminette'
Scarlet Luminette Pink (F. Caryophyllaceae)
Macrosiphum stellariae
Myzus certus
Dianthus sp. Pink (F. Caryophyllaceae)
Macrosiphum stellariae
Dicentra formosa ssp. formosa
Pacific Bleedingheart (F. Fumariaceae)
Macrosiphum euphorbiae
Dicentra formosa ssp. oregana
Oregon Bleedingheart (F. Fumariaceae)
Macrosiphum euphorbiae
Dieffenbachia maculata
Spotted Dumb Cane (F. Araceae)
Aphis gossypii
Aulacorthum circumflexum
Myzus ornatus
Digitalis lanata
Grecian Foxglove (F. Scrophulariaceae)
Myzus persicae
Digitalis purpurea
Common Foxglove (F. Scrophulariaceae)
Aulacorthum solani
Dipsacus fullonum ssp. fullonum
Fuller's Teasel (F. Dipsacaceae)
Macrosiphum rosae
Draba borealis
Northern Whitlow-Grass (F. Cruciferae)
Myzus ascalonicus
Draba ruaxes
Wind-River Whitlow-Grass (F. Cruciferae)
Myzus ascalonicus
Elodea canadensis
Canadian Waterweed (F. Hydrocharitaceae)
Rhopalosiphum nymphaeae
Elymus mollis var. mollis
Dune Wild Rye Grass (F. Gramineae)
Sitobion avenae
Enkianthus campanulatus
Redvein Enkianthus (F. Ericaceae)
Macrosiphum euphorbiae
Epidendrum ibaguense
Buttonhole Orchid (F. Orchidaceae)
Myzus persicae
Epilobium alpinum
Alpine Willow-Herb (F. Onagraceae)
Aphis varians
Epilobium angustifolium
Fireweed (F. Onagraceae)
Aphis praeterita
Aphis salicariae
Aphis varians
Macrosiphum fuscicornis
Epilobium ciliatum
Purple-Leaved Willow-Herb (F. Onagraceae)
Aphis epilobii
Myzus persicae
Epilobium sp. Willow-Herb (F. Onagraceae)
Aphis salicariae
Macrosiphum euphorbiae
Epiphyllum sp. Orchid Cactus (F. Cactaceae)
Aulacorthum circumflexum
Myzus ornatus
Equisetum arvense
Common Horsetail (F. Equisetaceae)
Aphis equiseticola
Aulacorthum circumflexum
Sitobion avenae
Sitobion equiseti
Erigeron speciosus
Showy Fleabane (F. Compositae)
Brachycaudus helichrysi
Myzus ascalonicus
Erigeron speciosus var. macranthus
Large-Flower Showy Fleabane (F. Compositae)
Brachycaudus helichrysi
Eriogonum compositum
Northern Buckwheat (F. Polygonaceae)
Macrosiphum euphorbiae
Erodium cicutarium ssp. cicutarium
Common Stork's-Bill (F. Geraniaceae)
Aulacorthum solani
Macrosiphum pallidum
Myzus ascalonicus
Eryngium maritimum
Sea Holly (F. Umbelliferae)
Aulacorthum solani
Myzus ascalonicus
Escallonia x langleyensis
Hybrid Escallonia (F. Grossulariaceae)
Macrosiphum euphorbiae
Eucryphia lucida
Shining Eucryphia (F. Eucryphiaceae)
Aulacorthum solani
Euonymus alata
Winged Spindle Tree (F. Celastraceae)
Aphis fabae
Euonymus europaea
European Spindle Tree (F. Celastraceae)
Aphis fabae
Euonymus fortunei 'Kewensis'
Kewensis Clinging Vine (F. Celastraceae)
Myzus ascalonicus
Euonymus japonica 'Albo-marginata'
Pearl Edge Euonymus (F. Celastraceae)
Myzus persicae
Euonymus latifolia
Broadleaf Spindle Tree (F. Celastraceae)
Aphis fabae
Euphorbia lathyris
Caper Spurge (F. Euphorbiaceae)
Macrosiphum euphorbiae
Euphorbia pelpus

Petty Spurge (F. Euphorbiaceae)
Aulacorthum solani
Myzus ornatus
Fagus grandifolia American Beech (F. Fagaceae)
Phyllaphis fagi
Fagus sp. Beech (F. Fagaceae)
Phyllaphis fagi
Fagus sylvatica European Beech (F. Fagaceae)
Phyllaphis fagi
Fagus sylvatica 'Atropunicea'
Copper Beech (F. Fagaceae)
Phyllaphis fagi
Fagus sylvatica 'Borneyensis'
Fountainlike European Beech (F. Fagaceae)
Phyllaphis fagi
Fagus sylvatica 'Pendula'
Weeping Beech (F. Fagaceae)
Phyllaphis fagi
Fallopia convolvulus
Black Bindweed (F. Polygonaceae)
Myzus persicae
Fatsia japonica Japan Fatsia (F. Araliaceae)
Aphis fabae
Festuca brachyphylla
Alpine Fescue (F. Gramineae)
Rhopalosiphum padi
Sipha glyceriae
Sitobion fragariae
Ficus carica Common Fig (F. Moraceae)
Aphis fabae
Foeniculum vulgare var. dulce
Florence Fennel (F. Umbelliferae)
Cavariella aegopodii
Forsythia x intermedia
Border Forsythia (F. Oleaceae)
Myzus ornatus
Forsythia sp. Forsythia (F. Oleaceae)
Macrosiphum euphorbiae
Fragaria x ananassa
Pineapple Strawberry (F. Rosaceae)
Aphis forbesi
Aulacorthum solani
Chaetosiphon fragaefolii
Macrosiphum euphorbiae
Myzus ascalonicus
Fragaria x ananassa 'Fort Laramie'
Fort Laramie Strawberry (F. Rosaceae)
Chaetosiphon fragaefolii
Fimbriaphis fimbriata
Sitobion fragariae
Fragaria x ananassa 'Hecker'
Hecker Strawberry (F. Rosaceae)
Fimbriaphis fimbriata
Fragaria x ananassa 'Olympus'
Olympus Strawberry (F. Rosaceae)
Fimbriaphis fimbriata
Sitobion fragariae
Fragaria x ananassa 'Ozark Beauty'
Ozark Beauty Strawberry (F. Rosaceae)
Fimbriaphis fimbriata
Sitobion fragariae
Fragaria x ananassa 'Quinalt'
Quinalt Strawberry (F. Rosaceae)
Chaetosiphon fragaefolii
Fimbriaphis fimbriata
Sitobion fragariae
Fragaria x ananassa 'Shuksan'
Shuksan Strawberry (F. Rosaceae)
Fimbriaphis fimbriata
Fragaria x ananassa 'Sweetheart'
Sweetheart Strawberry (F. Rosaceae)
Chaetosiphon fragaefolii
Fimbriaphis fimbriata
Myzus ornatus
Sitobion fragariae
Fragaria x ananassa 'Totem'
Totem Strawberry (F. Rosaceae)
Fimbriaphis fimbriata
Myzus ornatus
Sitobion fragariae
Fragaria chiloensis
Beach Strawberry (F. Rosaceae)
Aulacorthum solani
Fragaria sp. Strawberry (F. Rosaceae)
Acyrthosiphon malvae rogersii
Acyrthosiphon pisum
Chaetosiphon fragaefolii
Fimbriaphis fimbriata
Macrosiphum euphorbiae
Myzus ascalonicus
Myzus ornatus
Myzus persicae
Fragaria vesca Woods Strawberry (F. Rosaceae)
Aulacorthum solani
Myzus ornatus
Myzus persicae
Fragaria vesca 'Alpine'
Alpine Woods Strawberry (F. Rosaceae)
Myzus ornatus
Fragaria vesca 'Alpine Alexandria'
Alpine Alexandria Strawberry (F. Rosaceae)
Chaetosiphon fragaefolii
Fimbriaphis fimbriata
Myzus ornatus
Sitobion fragariae
Fragaria vesca ssp. bracteata
Wild Strawberry (F. Rosaceae)
Aphis forbesi
Fragaria vesca 'Semperflorens'
Always-Flowered Woods Strawberry (F. Rosaceae)
Macrosiphum euphorbiae
Fragaria vesca 'Yellow Alpine'
Yellow Alpine Strawberry (F. Rosaceae)
Chaetosiphon fragaefolii
Myzus ornatus
Fragaria virginiana
Virginia Strawberry (F. Rosaceae)
Chaetosiphon fragaefolii
Fragaria virginiana ssp. glauca
Blueleaf Strawberry (F. Rosaceae)
Chaetosiphon fragaefolii
Fimbriaphis fimbriata

Fraxinus excelsior European Ash (F. Oleaceae)
Prociphilus fraxinifolii
Fraxinus nigra Black Ash (F. Oleaceae)
Prociphilus fraxinifolii
Fraxinus ornus Flowering Ash (F. Oleaceae)
Prociphilus fraxinifolii
Fuchsia x hybrida
Common Fuchsia (F. Onagraceae)
Macrosiphum euphorbiae
Fuchsia x hybrida 'Jack Shahan'
Jack Shahan Common Fuchsia (F. Onagraceae)
Aulacorthum circumflexum
Fuchsia magellanica
Hardy Fuchsia (F. Onagraceae)
Myzus ornatus
Fuchsia sp. Fuchsia (F. Onagraceae)
Aulacorthum solani
Myzus ornatus
Fumaria officinalis
Common Fumitory (F. Fumariaceae)
Aulacorthum circumflexum
Macrosiphum euphorbiae
Galega officinalis Goat's Rue
(F. Leguminosae)
Aulacorthum solani
Galeopsis tetrahit Hemp Nettle (F. Labiatae)
Cryptomyzus ribis
Galium aparine Cleavers (F. Rubiaceae)
Macrosiphum euphorbiae
Myzus cerasi
Myzus ornatus
Myzus persicae
Galium mollugo White Bedstraw (F. Rubiaceae)
Aphis fabae
Myzus cerasi
Myzus ornatus
Gardenia jasminoides
Common Gardenia (F. Rubiaceae)
Aphis gossypii
Aulacorthum circumflexum
Myzus ornatus
Gaultheria shallon Salal (F. Ericaceae)
Illinoia lambersi
Sitobion dorsatum
Geranium 'Ballerina'
Ballerina Crane's-Bill (F. Geraniaceae)
Rhopalosiphoninus staphyleae
Geranium dalmaticum
Dalmatia Crane's-Bill (F. Geraniaceae)
Acyrthosiphon malvae
Geranium molle
Dove's-Foot Crane's-Bill (F. Geraniaceae)
Myzus ascalonicus
Geranium renardii
Caucasus Crane's-Bill (F. Geraniaceae)
Myzus ornatus
Geranium sp. Crane's-Bill (F. Geraniaceae)
Aulacorthum solani
Geranium viscosissimum var. viscosissimum
Sticky Purple Crane's-Bill (F. Geraniaceae)
Amphorophora geranii
Brachycaudus helichrysi
Macrosiphum aetheocornum
Geum aleppicum Yellow Avens (F. Rosaceae)
Myzus ornatus
Geum macrophyllum
Large-Leaved Avens (F. Rosaceae)
Amphorophora rossi
Aulacorthum solani
Macrosiphum euphorbiae
Myzus ascalonicus
Geum schofieldii
Queen Charlotte Avens (F. Rosaceae)
Macrosiphum euphorbiae
Myzus ornatus
Ginkgo biloba
Maidenhair Tree (F. Ginkgoaceae)
Rhopalosiphum padi
Gladiolus x hortulanus
Garden Gladiolus (F. Iridaceae)
Aphis fabae
Macrosiphum euphorbiae
Gladiolus sp. Gladiolus (F. Iridaceae)
Myzus ornatus
Rhopalosiphoninus latysiphon
Gnaphalium uliginosum
Cudweed (F. Compositae)
Brachycaudus helichrysi
Gomphrena globosa
Globe Amaranth (F. Amaranthaceae)
Macrosiphum euphorbiae
Myzus certus
Myzus persicae
Rhopalosiphoninus staphyleae
Grindelia integrifolia
Entire-Leaved Gumweed (F. Compositae)
Aulacorthum solani
Uroleucon erigeronensis
Uroleucon penderum
Grindelia nana Low Gumweed (F. Compositae)
Brachycaudus helichrysi
Uroleucon chani
Gynura aurantiaca Velvet-Plant (F. Compositae)
Macrosiphum euphorbiae
Myzus ornatus
Halesia carolina
Carolina Silverbell (F. Styracaceae)
Macrosiphum euphorbiae
Myzus ornatus
Hebe sp. Hebe (F. Scrophulariaceae)
Myzus persicae
Hedera canariensis 'Canary Cream'
Canary Cream Algerian Ivy (F. Araliaceae)
Aulacorthum circumflexum
Macrosiphum euphorbiae
Hedera helix
Aphis fabae
Aphis hederae
Aulacorthum circumflexum
Hedera sp. Ivy (F. Araliaceae)
Aphis nasturtii
Helianthemum nummularium
Rock Rose (F. Cistaceae)

Myzus ornatus
Helianthus annuus
Common Sunflower (F. Compositae)
Aphis helianthi
Helianthus sp. Sunflower (F. Compositae)
Aphis helianthi
Helichrysum virgineum
Virgin Everlasting (F. Compositae)
Uroleucon russellae
Helleborus niger
Christmas Rose (F. Ranunculaceae)
Aulacorthum solani
Helleborus orientalis
Lenten Rose (F. Ranunculaceae)
Rhopalosiphoninus staphyleae
Heracleum sphondylium ssp. montanum
Cow Parsnip (F. Umbelliferae)
Aphis heraclella
Aulacorthum solani
Cavariella pastinacae
Macrosiphum euphorbiae
Myzus ascalonicus
Hesperis matronalis
Sweet Rocket (F. Cruciferae)
Myzus ascalonicus
Heterotheca villosa var. villosa
Hairy Golden-Aster (F. Compositae)
Brachycaudus helichrysi
Heuchera micrantha var. diversifolia
Small-Flowered Alumroot (F. Saxifragaceae)
Kakimia heucherae
Hibiscus calyphyllus
Lemon-Yellow Hibiscus (F. Malvaceae)
Aulacorthum solani
Hibiscus rosa-sinensis
Chinese Hibiscus (F. Malvaceae)
Macrosiphum euphorbiae
Myzus persicae
Hibiscus sabdariffa Roselle (F. Malvaceae)
Myzus persicae
Hibiscus sp. Hibiscus (F. Malvaceae)
Myzus persicae
Hieracium aurantiacum
Orange Hawkweed (F. Compositae)
Macrosiphum euphorbiae
Hieracium murorum
Wall Hawkweed (F. Compositae)
Nasonovia ribisnigri
Hieracium scouleri var. scouleri
Scouler's Hawkweed (F. Compositae)
Brachycaudus helichrysi
Nasonovia ribisnigri
Hierochloe odorata ssp. hirta
Common Sweet Grass (F. Gramineae)
Sitobion fragariae
Hippophae rhamnoides
Sallow Thorn (F. Elaeagnaceae)
Capitophorus hippophaes
Holcus lanatus Velvet Grass (F. Gramineae)
Hyalopteroides humilis
Sitobion fragariae
Holodiscus discolor Ocean-Spray (F. Rosaceae)
Aphis craccivora
Aphis fabae
Aphis holodisci
Macrosiphum euphorbiae
Hordeum brachyantherum
Meadow Barley (F. Gramineae)
Sipha glyceriae
Sitobion fragariae
Hordeum jubatum Foxtail Barley (F. Gramineae)
Sitobion avenae
Sitobion fragariae
Hordeum vulgare Barley (F. Gramineae)
Macrosiphum euphorbiae
Metopolophium dirhodum
Rhopalosiphum maidis
Rhopalosiphum padi
Sitobion avenae
Sitobion fragariae
Hosta sieboldiana
Siebold Plantainlily (F. Liliaceae)
Aulacorthum solani
Macrosiphum euphorbiae
Hosta undulata
Wavy-Leaved Plantainlily (F. Liliaceae)
Aphis fabae
Humulus lupulus Common Hop (F. Moraceae)
Phorodon humuli
Hypericum patulum 'Hidcote'
Hidcote St-John's-Wort (F. Guttiferae)
Myzus ornatus
Wahlgreniella nervata
Hypericum perforatum
Common St-John's-Wort (F. Guttiferae)
Aulacorthum solani
Hypochoeris radicata
Spotted Cat's Ear (F. Compositae)
Macrosiphum euphorbiae
Myzus ascalonicus
Myzus ornatus
Uroleucon ambrosiae
Hypoestes phyllostachya
Polka-Dot-Plant (F. Acanthaceae)
Macrosiphum euphorbiae
Ilex x altaclarensis
Altaclara Holly (F. Aquifoliaceae)
Illinoia lambersi
Macrosiphum rosae
Ilex aquifolium English Holly (F. Aquifoliaceae)
Aphis fabae
Aulacorthum solani
Illinoia lambersi
Macrosiphum euphorbiae
Macrosiphum rosae
Ilex aquifolium 'Aureo-marginata'
Yellowedge English Holly (F. Aquifoliaceae)
Illinoia lambersi
Macrosiphum euphorbiae
Ilex glabra Inkberry (F. Aquifoliaceae)
Macrosiphum rosae
Ilex integra Mochi Tree (F. Aquifoliaceae)

Macrosiphum rosae
Impatiens glandulifera
Indian Balsam (F. Balsaminaceae)
Aphis fabae
Impatiens sp. Snapweed (F. Balsaminaceae)
Aphis gossypii
Myzus ornatus
Impatiens wallerana Zanzibar Balsam
(F. Balsaminaceae)
Myzus persicae
Impatiens wallerana 'Futura Wildrose'
Futura Wildrose Zanzibar Balsam
(F. Balsaminaceae)
Aulacorthum circumflexum
Incarvillea mairei var. grandiflora
Bigflower Incarvillea (F. Bignoniaceae)
Aulacorthum solani
Macrosiphum euphorbiae
Iris gatesii Gatesii Iris (F. Iridaceae)
Myrus persicae
Iris kaempferi Japanese Iris (F. Iridaceae)
Macrosiphum euphorbiae
Iris setosa Arctic Iris (F. Iridaceae)
Macrosiphum euphorbiae
Myzus ornatus
Iris sp. Iris (F. Iridaceae)
Aulacorthum circumflexum
Aulacorthum solani
Dysaphis tulipae
Rhopalosiphoninus staphyleae
Iris tectorum Wall Iris (F. Iridaceae)
Aulacorthum solani
Jacaranda acutifolia
Sharpleaf Jacaranda (F. Bignoniaceae)
Macrosiphum euphorbiae
Jasione montana
Mountain Jasione (F. Campanulaceae)
Myzus ascalonicus
Juglans regia English Walnut (F. Juglandaceae)
Callaphis juglandis
Juglans sp. Walnut (F. Juglandaceae)
Chromaphis juglandicola
Juncus articulatus Jointed Rush (F. Juncaceae)
Schizaphis palustris
Sitobion avenae
Sitobion fragariae
Juncus bufonius Toad Rush (F. Juncaceae)
Sitobion avenae
Sitobion fragariae
Juncus effusus var. pacificus
Pacific Common Rush (F. Juncaceae)
Glabromyzus schlingeri
Juncus tenuis Slender Rush (F. Juncaceae)
Schizaphis palustris
Juniperus chinensis 'Pfitzeriana'
Pyramid Chinese Juniper (F. Cupressaceae)
Cinara juniperi
Illinoia morrisoni
Juniperus sabina Savin Juniper (F. Cupressaceae)
Illinoia morrisoni
Juniperus scopulorum
Rocky Mountain Juniper (F. Cupressaceae)
Cinara sabinae
Juniperus squamata 'Meyeri'
Meyer Singleseed Juniper (F. Cupressaceae)
Cinara juniperi
Illinoia morrisoni
Juniperus virginiana
Red Cedar (F. Cupressaceae)
Illinoia morrisoni
Kalmia latifolia 'Alba'
White Mountain Laurel (F. Ericaceae)
Fimbriaphis wakibae
Kolkwitzia amabilis
Beautybush (F. Caprifoliaceae)
Aulacorthum solani
Macrosiphum euphorbiae
Laburnum anagyroides
Golden Chain (F. Leguminosae)
Aphis craccivora
Laburnum x watereri
Waterer Laburnum (F. Leguminosae)
Aphis cytisorum
Lactuca biennis
Tall Blue Lettuce (F. Compositae)
Uroleucon pseudambrosiae
Lactuca sativa Garden Lettuce (F. Compositae)
Aphis fabae
Aulacorthum solani
Macrosiphum euphorbiae
Myzus ascalonicus
Myzus persicae
Nasonovia ribisnigri
Pemphigus betae
Pemphigus populivenae
Uroleucon sonchi
Lactuca serriola Prickly Lettuce (F. Compositae)
Acyrthosiphon lactucae
Lactuca sp. Lettuce (F. Compositae)
Acyrthosiphon lactucae
Myzus ascalonicus
Myzus ornatus
Nasonovia ribisnigri
Lactuca tatarica ssp. pulchella
Blue-Flowered Lettuce (F. Compositae)
Hyperomyzus lactucae
Macrosiphum euphorbiae
Lamium amplexicaule
Henbit Dead-Nettle (F. Labiatae)
Aulacorthum solani
Myzus ornatus
Lantana camara Yellow Sage (F. Verbenaceae)
Macrosiphum euphorbiae
Lapsana communis Nipplewort (F. Compositae)
Aulacorthum solani
Macrosiphum euphorbiae
Myzus ornatus
Nasonovia ribisnigri
Larix occidentalis Western Larch (F. Pinaceae)
Cinara laricifoliae
Lathyrus japonicus var. glaber
Beach Pea (F. Leguminosae)
Acyrthosiphon pisum
Macrosiphum creelii

Lathyrus nevadensis ssp. lanceolatus
Nuttall's Peavine (F. Leguminosae)
Nearctaphis sclerosa
Lembotropis nigricans
Black Broom (F. Leguminosae)
Acyrthosiphon pisum
Leontopodium alpinum
Edelweiss (F. Compositae)
Brachycaudus helichrysi
Leonurus cardiaca
Common Motherwort (F. Labiatae)
Myzus ornatus
Leucothoe fontanesiana
Doghobble (F. Ericaceae)
Illinoia rhokalaza
Lewisia cantelowii
Cantelowii Lewisia (F. Portulacaceae)
Macrosiphum euphorbiae
Ligustrum vulgare Common Privet (F. Oleaceae)
Myzus ligustri
Lilium auratum Gold-Banded Lily (F. Liliaceae)
Aulacorthum solani
Lilium 'Cinnabar' Cinnabar Lily (F. Liliaceae)
Aulacorthum circumflexum
Myzus ascalonicus
Lilium x hollandicum
Candlestick Lily (F. Liliaceae)
Aulacorthum solani
Myzus ascalonicus
Lilium longiflorum Trumpet Lily (F. Liliaceae)
Aulacorthum circumflexum
Lilium mackliniae Mackline Lily (F. Liliaceae)
Aulacorthum solani
Lilium philadelphicum var. andinum
Wood Lily (F. Liliaceae)
Aphis fabae
Lilium speciosum Showy Lily (F. Liliaceae)
Myzus ascalonicus
Lilium szovitsianum Szovitz Lily (F. Liliaceae)
Aulacorthum solani
Linnaea borealis Twinflower (F. Caprifoliaceae)
Aulacorthum circumflexum
Aulacorthum solani
Liquidambar styraciflua
Sweetgum (F. Hamamelidaceae)
Aulacorthum solani
Myzus ornatus
Liriodendron tulipifera
Tulip Tree (F. Magnoliaceae)
Aphis fabae
Fimbriaphis fimbriata
Hyalopterus pruni
Illinoia liriodendri
Macrosiphum euphorbiae
Myzus cerasi
Rhopalosiphum insertum
Lolium perenne
Perennial Rye Grass (F. Gramineae)
Sitobion fragariae
Lomatium dissectum var. multifidum
Fern-Leaved Lomatium (F. Umbelliferae)
Cavariella aegopodii
Lomatium nudicaule
Barestem Lomatium (F. Umbelliferae)
Aphis fabae
Cavariella aegopodii
Hyadaphis foeniculi
Lonicera ciliosa
Orange Honeysuckle (F. Caprifoliaceae)
Hyadaphis foeniculi
Lonicera 'Dropmore Scarlet'
Dropmore Scarlet Honeysuckle
(F. Caprifoliaceae)
Aulacorthum circumflexum
Hyadaphis foeniculi
Rhopalomyzus lonicerae
Lonicera etrusca
Etruscan Honeysuckle (F. Caprifoliaceae)
Hyadaphis foeniculi
Lonicera involucrata
Black Twin-Berry (F. Caprifoliaceae)
Delphiniobium canadense
Hyadaphis foeniculi
Illinoia crystleae
Illinoia crystleae ssp. bartholomewi
Lonicera pyrenaica
Pyrenean Honeysuckle (F. Caprifoliaceae)
Hyadaphis foeniculi
Rhopalomyzus lonicerae
Lunaria annua Money Plant (F. Cruciferae)
Aphis fabae
Lupinus arboreus Bush Lupine (F. Leguminosae)
Macrosiphum albifrons
Lupinus arcticus
Arctic Lupine (F. Leguminosae)
Macrosiphum albifrons
Lupinus argenteus var. argenteus
Silvery Lupine (F. Leguminosae)
Macrosiphum albifrons
Lupinus nootkatensis var. nootkatensis
Nootka Lupine (F. Leguminosae)
Macrosiphum albifrons
Lupinus polyphyllus
Big-Leaved Lupine (F. Leguminosae)
Macrosiphum albifrons
Lupinus rivularis
Streambank Lupine (F. Leguminosae)
Macrosiphum albifrons
Lupinus sericeus Silky Lupine (F. Leguminosae)
Macrosiphum albifrons
Lupinus sp. Perennial Lupine (F. Leguminosae)
Acyrthosiphon pisum
Aphis lupini
Macrosiphum albifrons
Luzula arctica ssp. latifolia
Arctic Wood-Rush (F. Juncaceae)
Glabromyzus schlingeri
Luzula nivea Snowy Wood-Rush (F. Juncaceae)
Glabromyzus schlingeri
Sitobion avenae
Lycium chinense
Chinese Matrimony Vine (F. Solanaceae)
Aulacorthum solani

Lycopersicon lycopersicum
Tomato (F. Solanaceae)
Aphis fabae
Aulacorthum solani
Macrosiphum euphorbiae
Lysichiton camtschatcense
Kamchatka Skunk Cabbage (F. Araceae)
Aulacorthum solani
Lysimachia punctata
Yellow Loosestrife (F. Primulaceae)
Aphis fabae
Aulacorthum solani
Magnolia sieboldii
Oyama Magnolia (F. Magnoliaceae)
Aulacorthum solani
Mahonia aquifolium
Tall Oregon-Grape (F. Berberidaceae)
Liosomaphis berberidis
Mahonia repens
Creeping Oregon-Grape (F. Berberidaceae)
Liosomaphis berberidis
Maianthemum kamtschaticum
Wild Lily-Of-The-Valley (F. Liliaceae)
Macrosiphum euphorbiae
Malus coronaria
Wild Sweet Crabapple (F. Rosaceae)
Aphis pomi
Malus fusca Western Crabapple (F. Rosaceae)
Eriosoma lanigerum
Malus ioensis Prairie Crabapple (F. Rosaceae)
Aphis pomi
Dysaphis plantaginea
Rhopalosiphum insertum
Malus pumila Common Apple (F. Rosaceae)
Dysaphis plantaginea
Dysaphis sorbi
Eriosoma lanigerum
Macrosiphum euphorbiae
Rhopalosiphum insertum
Sitobion avenae
Malus sp
Ornamental & Table Crabapple (F. Rosaceae)
Aphis pomi
Dysaphis plantaginea
Rhopalosiphum insertum
Malus sylvestris Apple (F. Rosaceae)
Aphis pomi
Dysaphis plantaginea
Nearctaphis bakeri
Marsilea vestita
Hairy Pepperwort (F. Marsileaceae)
Myzus persicae
Matricaria perforata
Scentless Mayweed (F. Compositae)
Macrosiphoniella tanacetaria
Matteuccia struthiopteris
Ostrich Fern (F. Aspleniaceae)
Aulacorthum circumflexum
Sitobion adianti
Meconopsis betonicifolia
Blue Poppy (F. Papaveraceae)
Aulacorthum solani
Myzus ascalonicus
Meconopsis cambrica
Welsh Poppy (F. Papaveraceae)
Aphis fabae
Meconopsis paniculata
Nepal Poppy (F. Papaveraceae)
Aulacorthum solani
Myzus persicae
Medicago sativa Alfalfa (F. Leguminosae)
Acyrthosiphon pisum
Macrosiphum creelii
Macrosiphum euphorbiae
Myzus persicae
Therioaphis riehmi
Melilotus alba
White Sweet Clover (F. Leguminosae)
Acyrthosiphon pisum
Macrosiphum euphorbiae
Therioaphis riehmi
Melilotus officinalis
Yellow Sweet Clover (F. Leguminosae)
Acyrthosiphon pisum
Melilotus sp. Sweet Clover (F. Leguminosae)
Acyrthosiphon pisum
Mentha arvensis ssp. borealis
Field Mint (F. Labiatae)
Aulacorthum solani
Capitophorus elaeagni
Ovatus crataegarius
Mentha spicata Spearmint (F. Labiatae)
Myzus ornatus
Mentzelia sp. Blazing-Star (F. Loasaceae)
Macrosiphum mentzeliae
Menziesia ferruginea ssp. glabella
Smooth Pacific Menziesia (F. Ericaceae)
Illinoia menziesiae
Mertensia paniculata var. borealis
Smooth-Panicled Mertensia (F. Boraginaceae)
Brachycaudus helichrysi
Mespilus germanica Medlar (F. Rosaceae)
Fimbriaphis gentneri
Rhopalosiphum insertum
Mikania scandens
Climbing Hempweed (F. Compositae)
Myzus persicae
Mimulus cardinalis
Scarlet Monkey Flower (F. Scrophulariaceae)
Kakimia alpina
Morus alba White Mulberry (F. Moraceae)
Aphis citricola
Myosotis arvensis
Field Forget-Me-Not (F. Boraginaceae)
Aphis fabae
Aulacorthum solani
Macrosiphum euphorbiae
Myzus ascalonicus
Myzus ornatus

Myrica californica
California Bayberry (F. Myricaceae)
Aphis fabae
Myrica gale Sweet Gale (F. Myricaceae)
Macrosiphum euphorbiae
Nasturtium officinale
Common Water Cress (F. Cruciferae)
Myzus cerasi
Nemophila menziesii var. discoidalis
Baby Blue-Eyes (F. Hydrophyllaceae)
Myzus persicae
Nepeta cataria Catnip (F. Labiatae)
Aulacorthum solani
Myzus ornatus
Nephrolepis exaltata 'Bostoniensis'
Boston Fern (F. Davalliaceae)
Aulacorthum solani
Nicandra physalodes
Apple-Of-Peru (F. Solanaceae)
Aulacorthum solani
Nicotiana sp. Tobacco (F. Solanaceae)
Aphis nasturtii
Nicotiana tabacum Tobacco (F. Solanaceae)
Myzus persicae
Nothofagus antarctica
Antarctic Falsebeech (F. Fagaceae)
Macrosiphum euphorbiae
Nuphar lutea ssp. polysepala
Indian Pond Lily (F. Nymphaeaceae)
Macrosiphum audeni
Nuphar sp. Cow Lily (F. Nymphaeaceae)
Rhopalosiphum nymphaeae
Nymphaea sp. Water Lily (F. Nymphaeaceae)
Rhopalosiphum nymphaeae
Oemleria cerasiformis
Indian-Plum (F. Rosaceae)
Macrosiphum euphorbiae
Macrosiphum osmaroniae
Oenanthe sarmentosa
Water Parsley (F. Umbelliferae)
Cavariella aegopodii
Hyadaphis foeniculi
Oenothera erythrosepala
Red-Sepaled Evening Primrose (F. Onagraceae)
Myzus ornatus
Origanum vulgare Marjoram (F. Labiatae)
Myzus ornatus
Ovatus crataegarius
Osmorhiza chilensis
Sweet Cicely (F. Umbelliferae)
Myzus ascalonicus
Osmunda regalis Royal Fern (F. Osmundaceae)
Aulacorthum circumflexum
Aulacorthum solani
Oxalis corniculata
Creeping Yellow Wood-Sorrel (F. Oxalidaceae)
Aulacorthum circumflexum
Myzus ornatus
Oxalis deppei Good-Luck Leaf (F. Oxalidaceae)
Aphis fabae
Papaver alpinum 'Plena'
Plena Alpine Poppy (F. Papaveraceae)
Aulacorthum solani
Papaver orientale
Oriental Poppy (F. Papaveraceae)
Aulacorthum circumflexum
Aulacorthum solani
Papaver rhoeas Corn Poppy (F. Papaveraceae)
Aphis fabae
Parahebe catarractae
Parahebe (F. Scrophulariaceae)
Myzus ornatus
Parthenium hysterophorus
Santa Maria Feverfew (F. Compositae)
Brachycaudus helichrysi
Parthenocissus quinquefolia
Virginia Creeper (F. Vitaceae)
Aulacorthum solani
Rhopalosiphoninus staphyleae
Pastinaca sativa Parsnip (F. Umbelliferae)
Aphis heraclella
Cavariella aegopodii
Paulownia tomentosa
Royal Paulownia (F. Scrophulariaceae)
Aulacorthum solani
Paxistima myrsinites
Oregon Boxwood (F. Celastraceae)
Wahlgreniella nervata arbuti
Pelargonium x hortorum
Fish Geranium (F. Geraniaceae)
Aulacorthum circumflexum
Pellaea glabella var. simplex
Smooth Cliff-Brake (F. Adiantaceae)
Aulacorthum circumflexum
Sitobion adianti
Penstemon 'Evelyn'
Evelyn Beard-Tongue (F. Scrophulariaceae)
Rhopalosiphoninus staphyleae
Pereskia aculeata
Barbados Gooseberry (F. Cactaceae)
Myzus ornatus
Petroselinum crispum Parsley (F. Umbelliferae)
Cavariella aegopodii
Myzus ornatus
Petunia 'Coral Satin'
Coral Satin Petunia (F. Solanaceae)
Macrosiphum euphorbiae
Phacelia heterophylla
Diverse-Leaved Phacelia (F. Hydrophyllaceae)
Myzus ascalonicus
Phacelia sericea ssp. sericea
Silky Phacelia (F. Hydrophyllaceae)
Brachycaudus helichrysi
Phalaris arundinacea
Reed Canary Grass (F. Gramineae)
Sitobion fragariae
Phaseolus vulgaris
Kidney Bean (F. Leguminosae)
Acyrthosiphon pisum
Aphis fabae
Capitophorus elaeagni
Myzus persicae

Philadelphus lewisii
Lewis' Mock Orange (F. Hydrangeaceae)
Aphis fabae
Aulacorthum solani
Brachycaudus helichrysi
Glendenningia philadelphi
Illinoia spiraeae
Macrosiphum euphorbiae
Myzus ornatus
Myzus persicae
Philadelphus sp
Mock Orange (F. Hydrangeaceae)
Aphis fabae
Brachycaudus helichrysi
Philadelphus x virginalis
Virginalis Mock Orange (F. Hydrangeaceae)
Aphis fabae
Brachycaudus helichrysi
Macrosiphum euphorbiae
Myzus ornatus
Myzus persicae
Philodendron hastatum
Spadeleaf Philodendron (F. Araceae)
Myzus ornatus
Phlox paniculata
Perennial Phlox (F. Polemoniaceae)
Aphis fabae
Myzus ascalonicus
Phlox subulata Moss Phlox (F. Polemoniaceae)
Myzus ascalonicus
Photinia x fraseri
Fraser Photinia (F. Rosaceae)
Aphis pomi
Brachycaudus helichrysi
Macrosiphum euphorbiae
Phorodon humuli
Phragmites australis ssp. australis
Common Reed (F. Gramineae)
Hyalopterus pruni
Physalis alkekengi
Chinese Lantern (F. Solanaceae)
Aphis fabae
Myzus persicae
Physocarpus capitatus
Pacific Ninebark (F. Rosaceae)
Utamphorophora humboldti
Physocarpus malvaceus
Mallow Ninebark (F. Rosaceae)
Utamphorophora humboldti
Picea abies Norway Spruce (F. Pinaceae)
Cinara braggii
Picea engelmannii
Engelmann Spruce (F. Pinaceae)
Cinara obscura
Cinara saskensis
Elatobium abietinum
Picea glauca White Spruce (F. Pinaceae)
Cinara costata
Cinara hottesi
Picea pungens Blue Spruce (F. Pinaceae)
Cinara braggii
Cinara coloradensis
Cinara costata
Elatobium abietinum
Picea sitchensis Sitka Spruce (F. Pinaceae)
Cinara braggii
Cinara coloradensis
Cinara fornacula
Cinara nigripes
Cinara vandykei
Elatobium abietinum
Mindarus obliquus
Picea sp. Spruce (F. Pinaceae)
Aphis craccivora
Cinara caudelli
Cinara fornacula
Elatobium abietinum
Mindarus obliquus
Pieris japonica
Japanese Andromeda (F. Ericaceae)
Aulacorthum pterinigrum
Macrosiphum parvifolii
Wahlgreniella nervata
Pilularia globulifera Pillwort (F. Marsileaceae)
Aulacorthum circumflexum
Pinus albicaulis Whitebark Pine (F. Pinaceae)
Cinara inscripta
Cinara medispinosa
Cinara oregoni
Pinus contorta var. contorta
Shore Pine (F. Pinaceae)
Aphis pomi
Cinara brevispinosa
Cinara ferrisi
Cinara medispinosa
Cinara murrayanae
Mindarus abietinus
Pinus contorta var. latifolia
Lodgepole Pine (F. Pinaceae)
Cinara braggii
Cinara brevispinosa
Cinara medispinosa
Cinara murrayanae
Cinara pergandei
Mindarus abietinus
Pinus monticola
Western White Pine (F. Pinaceae)
Cinara ferrisi
Cinara kuchea
Cinara murrayanae
Pinus nigra Austrian Pine (F. Pinaceae)
Cinara pinea
Pinus ponderosa Ponderosa Pine (F. Pinaceae)
Cinara arizonica
Cinara medispinosa
Cinara ponderosae
Cinara thatcheri
Essigella gillettei
Euceraphis gillettei
Schizolachnus curvispinosus
Schizolachnus piniradiatae
Pinus sylvestris Scots Pine (F. Pinaceae)
Cinara pinea
Schizolachnus pineti

Pisum sativum Garden Pea (F. Leguminosae)
Myzus persicae
Pisum sativum var. arvense
Field Pea (F. Leguminosae)
Acyrthosiphon pisum
Plantago lanceolata Ribgrass (F. Plantaginaceae)
Macrosiphum euphorbiae
Myzus ascalonicus
Plantago major
Common Plantain (F. Plantaginaceae)
Macrosiphum euphorbiae
Myzus persicae
Plantago rubrifolia
Red-Leaved Plantain (F. Plantaginaceae)
Aulacorthum solani
Platycodon grandiflorus 'Apoyama'
Apoyama Balloon Flower (F. Campanulaceae)
Rhopalosiphoninus staphyleae
Pleione formosana
Formosa Pleione (F. Orchidaceae)
Aulacorthum solani
Pleione sp. Pleione (F. Orchidaceae)
Myzus ascalonicus
Myzus persicae
Poa annua Low Spear Grass (F. Gramineae)
Rhopalomyzus poae
Poa glauca Glaucous Blue Grass (F. Gramineae)
Rhopalosiphum padi
Sipha glyceriae
Sitobion avenae
Sitobion fragariae
Utamphorophora humboldti
Poa pratensis
Kentucky Blue Grass (F. Gramineae)
Sipha glyceriae
Sitobion fragariae
Poa pratensis ssp. agassizensis
Agassiz Blue Grass (F. Gramineae)
Sitobion fragariae
Poa sp. Meadow Grass (F. Gramineae)
Rhopalosiphum padiformis
Pogonatum urnigerum
Urn Bearded Moss (F. Polytrichaceae)
Myzodium modestum
Polemonium carneum
Salmon Polemonium (F. Polemoniaceae)
Macrosiphum euphorbiae
Polemonium nellitum
Nellitum Polemonium (F. Polemoniaceae)
Macrosiphum euphorbiae
Myzus persicae
Polygonum lapathifolium
Curltop Lady's Thumb (F. Polygonaceae)
Capitophorus hippophaes
Polygonum persicaria
Lady's Thumb (F. Polygonaceae)
Aphis fabae
Capitophorus hippophaes
Polypodium glycyrrhiza
Licorice Fern (F. Polypodiaceae)
Sitobion adianti
Polypogon monspeliensis
Rabbitfoot Polypogon (F. Gramineae)
Metopolophium dirhodum
Sitobion avenae
Polystichum lonchitis
Mountain Holly Fern (F. Aspleniaceae)
Aulacorthum circumflexum
Polystichum munitum
Sword Fern (F. Aspleniaceae)
Aulacorthum capilanoense
Aulacorthum solani
Sitobion adianti
Sitobion ptericolens
Polytrichum commune
Common Haircap Moss (F. Polytrichaceae)
Myzodium modestum
Polytrichum juniperinum
Juniper Haircap Moss (F. Polytrichaceae)
Myzodium modestum
Populus balsamifera
Balsam Poplar (F. Salicaceae)
Pterocomma bicolor
Populus grandidentata
Large-Toothed Aspen (F. Salicaceae)
Chaitophorus populifolii neglectus
Populus nigra 'Italica'
Lombardy Poplar (F. Salicaceae)
Chaitophorus populifolii neglectus
Pemphigus bursarius
Pemphigus spyrothecae
Pterocomma bicolor
Populus sp. Poplar (F. Salicaceae)
Chaitophorus populicola
Chaitophorus populifolii
Chaitophorus stevensis
Mordwilkoja vagabunda
Pemphigus monophagus
Pemphigus populivenae
Pterocomma bicolor
Pterocomma populeum
Pterocomma salicis
Pterocomma smithiae
Thecabius populiconduplifolius
Populus tremuloides
Trembling Aspen (F. Salicaceae)
Aphis maculatae
Chaitophorus populicola
Chaitophorus populifolii
Chaitophorus populifolii neglectus
Pachypappa sacculi
Populus trichocarpa
Black Cottonwood (F. Salicaceae)
Chaitophorus populicola
Chaitophorus populifolii
Pemphigus populicaulis
Pemphigus populivenae
Pterocomma bicolor
Pterocomma smithiae
Thecabius gravicornis
Thecabius populimonilis
Portulaca oleracea

Common Purslane (F. Portulacaceae)
Myzus persicae
Potentilla anserina Silver Weed (F. Rosaceae)
Chaetosiphon fragaefolii
Chaetosiphon potentillae
Potentilla argyrophylla 'Leucochroa'
Silverleaved Cinquefoil (F. Rosaceae)
Metopolophium dirhodum
Potentilla atrosanguinea
Himalayan Cinquefoil (F. Rosaceae)
Aulacorthum solani
Brachycaudus helichrysi
Macrosiphum euphorbiae
Potentilla fruticosa
Shrubby Cinquefoil (F. Rosaceae)
Macrosiphum euphorbiae
Myzaphis rosarum
Potentilla fruticosa ssp. floribunda
Full-Of-Flower Shrubby Cinquefoil (F. Rosaceae)
Myzaphis rosarum
Potentilla fruticosa 'Red Ace'
Red Ace Shrubby Cinquefoil (F. Rosaceae)
Myzaphis rosarum
Potentilla 'Gibson's Scarlet'
Gibson's Scarlet Cinquefoil (F. Rosaceae)
Myzus ascalonicus
Potentilla gracilis var. glabrata
Smooth Graceful Cinquefoil (F. Rosaceae)
Myzus ascalonicus
Potentilla gracilis var. gracilis
Graceful Cinquefoil (F. Rosaceae)
Aulacorthum solani
Potentilla pensylvanica
Pennsylvania Cinquefoil (F. Rosaceae)
Aulacorthum solani
Myzus ascalonicus
Primula alpicola ssp. luna
Moonlight Primrose (F. Primulaceae)
Myzus ornatus
Primula auricula
Auricula Primrose (F. Primulaceae)
Aulacorthum solani
Primula denticulata
Himalayan Primrose (F. Primulaceae)
Aulacorthum solani
Primula juliae 'Wanda'
Wanda Primrose (F. Primulaceae)
Aulacorthum solani
Primula parryi Parry Primrose (F. Primulaceae)
Aulacorthum solani
Primula sp. Primrose (F. Primulaceae)
Aulacorthum circumflexum
Aulacorthum solani
Myzus ornatus
Primula veris Cowslip Primrose (F. Primulaceae)
Aulacorthum solani
Primula vialii Littons Primrose (F. Primulaceae)
Aulacorthum solani
Prunus avium Sweet Cherry (F. Rosaceae)
Hyalopterus pruni
Myzus cerasi
Nearctaphis bakeri
Rhopalosiphum nymphaeae
Prunus cerasifera Cherry Plum (F. Rosaceae)
Myzus cerasi
Prunus cerasifera 'Atropurpurea'
Pissard Plum (F. Rosaceae)
Brachycaudus helichrysi
Phorodon humuli
Prunus cerasus Sour Cherry (F. Rosaceae)
Myzus cerasi
Prunus domestica Garden Plum (F. Rosaceae)
Brachycaudus cardui
Brachycaudus helichrysi
Hyalopterus pruni
Myzus lythri
Myzus persicae
Nearctaphis bakeri
Phorodon humuli
Rhopalosiphum nymphaeae
Rhopalosiphum padi
Prunus emarginata Bitter Cherry (F. Rosaceae)
Myzus cerasi
Myzus lythri
Prunus japonica
Japanese Bush Cherry (F. Rosaceae)
Phorodon humuli
Prunus persica Peach (F. Rosaceae)
Aphis pomi
Myzus persicae
Rhopalosiphum nymphaeae
Prunus 'Royal Anne'
Royal Anne Flowering Cherry (F. Rosaceae)
Myzus cerasi
Prunus serrulata 'Kwanzan'
Kwanzan Japanese Flowering Cherry (F. Rosaceae)
Myzus cerasi
Prunus serrulata 'Shiro-fugen'
Victoria Japanese Flowering Cherry (F. Rosaceae)
Myzus cerasi
Prunus sp. Cherry (F. Rosaceae)
Brachycaudus helichrysi
Hyalopterus pruni
Myzus cerasi
Rhopalosiphum cerasifoliae
Rhopalosiphum nymphaeae
Prunus virginiana
Common Chokecherry (F. Rosaceae)
Asiphonaphis pruni
Rhopalosiphum cerasifoliae
Rhopalosiphum padi
Prunus virginiana ssp. demissa
Western Chokecherry (F. Rosaceae)
Rhopalosiphum cerasifoliae
Pseudosasa japonica
Arrow Bamboo (F. Gramineae)
Takecallis arundinariae
Pseudotsuga menziesii Douglas Fir (F. Pinaceae)
Aphis fabae mordvilkoi
Cinara pseudotaxifoliae
Cinara pseudotsugae

Cinara splendens
Essigella wilsoni
Pteridium aquilinum
Bracken Fern (F. Dennstaedtiaceae)
Sitobion ptericolens
Sitobion pteridis
Pterocarya stenoptera
Chinese Wingnut (F. Juglandaceae)
Aphis fabae
Brachycaudus cardui
Pulmonaria officinalis
Jerusalem Sage (F. Boraginaceae)
Myzus ascalonicus
Pyracantha crenulata 'Flava'
Yellow Nepal Firethorn (F. Rosaceae)
Aphis pomi
Pyrus communis Pear (F. Rosaceae)
Aphis pomi
Aulacorthum solani
Quercus coccinea Scarlet Oak (F. Fagaceae)
Myzocallis multisetis
Quercus garryana Garry Oak (F. Fagaceae)
Myzocallis punctatus
Thelaxes californica
Tuberculatus annulatus
Tuberculatus columbiae
Quercus macrocarpa Bur Oak (F. Fagaceae)
Myzocallis punctatus
Quercus prinus Chestnut Oak (F. Fagaceae)
Myzocallis punctatus
Thelaxes californica
Quercus robur English Oak (F. Fagaceae)
Tuberculatus annulatus
Quercus robur 'Fastigiata'
Upright English Oak (F. Fagaceae)
Tuberculatus annulatus
Quercus rubra Red Oak (F. Fagaceae)
Myzocallis occultus
Myzocallis walshii
Quercus sp. Oak (F. Fagaceae)
Myzocallis walshii
Thelaxes californica
Tuberculatus annulatus
Ranunculus acris
Tall Buttercup (F. Ranunculaceae)
Aulacorthum solani
Myzus persicae
Ranunculus occidentalis
Western Buttercup (F. Ranunculaceae)
Myzus ascalonicus
Myzus ornatus
Rhopalosiphum padi
Thecabius affinis
Ranunculus sp. Buttercup (F. Ranunculaceae)
Aphis fabae
Myzus ornatus
Myzus persicae
Raphanus raphanistrum Charlock (F. Cruciferae)
Myzus persicae
Raphanus sativus Radish (F. Cruciferae)
Brevicoryne brassicae
Ratibida columnifera
Prairie Coneflower (F. Compositae)
Myzus ornatus
Reynoutria japonica
Japanese Knotweed (F. Polygonaceae)
Aulacorthum solani
Rhamnus purshiana Cascara (F. Rhamnaceae)
Sitobion rhamni
Rheum palmatum
Palmate-Leaved Rhubarb (F. Polygonaceae)
Myzus ornatus
Rheum rhabarbarum Rhubarb (F. Polygonaceae)
Aphis fabae
Macrosiphum euphorbiae
Myzus ascalonicus
Myzus ornatus
Myzus persicae
Rheum rhabarbarum 'Victoria'
Victoria Rhubarb (F. Polygonaceae)
Macrosiphum stellariae
Rhododendron 'Directeur Moerlands'
Directeur Moerlands Azalea
(F. Ericaceae)
Illinoia lambersi
Rhododendron 'Elizabeth'
Elizabeth Rhododendron (F. Ericaceae)
Illinoia lambersi
Rhododendron 'Glacier'
Glacier Azalea (F. Ericaceae)
Illinoia lambersi
Rhododendron luteum
Pontic Azalea (F. Ericaceae)
Illinoia lambersi
Rhododendron molle
Chinese Azalea (F. Ericaceae)
Illinoia lambersi
Rhododendron 'Princess Elizabeth'
Princess Elizabeth Rhododendron (F. Ericaceae)
Illinoia lambersi
Rhododendron sp. Rhododendron (F. Ericaceae)
Brachycaudus cardui
Illinoia lambersi
Macrosiphum euphorbiae
Ribes divaricatum
Coastal Black Gooseberry (F. Grossulariaceae)
Kakimia cynosbati
Ribes lacustre
Swamp Gooseberry (F. Grossulariaceae)
Aphis neomexicana
Kakimia cynosbati
Macrosiphum bisensoriatum
Ribes laxiflorum
Trailing Black Currant (F. Grossulariaceae)
Aphis neomexicana
Cryptomyzus galeopsidis
Hyperomyzus lactucae
Ribes magellanica

Magellan Currant (F. Grossulariaceae)
Aphis varians
Cryptomyzus ribis
Hyperomyzus lactucae
Ribes nigrum
European Black Currant (F. Grossulariaceae)
Cryptomyzus galeopsidis
Hyperomyzus lactucae
Nasonovia ribisnigri
Ribes nigrum 'Wellington XXX'
Wellington XXX European Black Currant (F. Grossulariaceae)
Aphis varians
Hyperomyzus lactucae
Ribes sanguineum
Red Flowering Currant (F. Grossulariaceae)
Aphis neomexicana
Kakimia muesebecki
Ribes sativum Red Currant (F. Grossulariaceae)
Cryptomyzus galeopsidis
Cryptomyzus ribis
Ribes sp. Currant (F. Grossulariaceae)
Cryptomyzus ribis
Ribes uva-crispa
English Gooseberry (F. Grossulariaceae)
Cryptomyzus ribis
Robinia pseudoacacia
Black Locust (F. Leguminosae)
Acyrthosiphon pisum
Appendiseta robiniae
Robinia pseudoacacia 'Inermis'
Mop-Head Acacia (F. Leguminosae)
Appendiseta robiniae
Robinia sp. False Acacia (F. Leguminosae)
Appendiseta robiniae
Rosa 'Agnes' Agnes Rose (F. Rosaceae)
Fimbriaphis wakibae
Myzaphis rosarum
Rosa 'Beauty Secret'
Beauty Secret Miniature Rose (F. Rosaceae)
Macrosiphum euphorbiae
Macrosiphum pyrifoliae
Rosa centifolia 'Cristata'
Mossy Cabbage Rose (F. Rosaceae)
Macrosiphum rosae
Rosa centifolia 'Muscosa'
Moss Rose (F. Rosaceae)
Macrosiphum rosae
Rosa 'Coral Dawn'
Coral Dawn Rose (F. Rosaceae)
Macrosiphum rosae
Metopolophium dirhodum
Rosa eglanteria Eglantine (F. Rosaceae)
Macrosiphum rosae
Rosa 'Golden Showers'
Golden Showers Rose (F. Rosaceae)
Macrosiphum rosae
Rosa gymnocarpa Baldhip Rose (F. Rosaceae)
Macrosiphum euphorbiae
Rosa 'Handel' Handel Rose (F. Rosaceae)
Macrosiphum rosae
Rosa 'Lichtkonigin Lucia'
Lichtkonigin Lucia Rose (F. Rosaceae)
Macrosiphum rosae
Rosa 'Mimi' Mimi Rose (F. Rosaceae)
Macrosiphum rosae
Rosa 'Nozomi' Nozomi Rose (F. Rosaceae)
Macrosiphum rosae
Rosa nutkana Nootka Rose (F. Rosaceae)
Eomacrosiphon nigromaculosum
Fimbriaphis fimbriata
Metopolophium dirhodum
Placoaphis siphunculata
Rosa nutkana var. nutkana
Nootka Rose (F. Rosaceae)
Placoaphis siphunculata
Rosa rugosa Turkestan Rose (F. Rosaceae)
Chaetosiphon tetrarhodum
Macrosiphum euphorbiae
Macrosiphum rosae
Metopolophium dirhodum
Myzaphis rosarum
Rosa rugosa 'Alba'
White Turkestan Rose (F. Rosaceae)
Chaetosiphon fragaefolii
Fimbriaphis wakibae
Macrosiphum euphorbiae
Myzus ornatus
Placoaphis siphunculata
Rosa rugosa 'Hansa'
Hansa Turkestan Rose (F. Rosaceae)
Chaetosiphon thomasi
Macrosiphum rosae
Metopolophium dirhodum
Placoaphis siphunculata
Rosa rugosa 'Rubra'
Red Turkestan Rose (F. Rosaceae)
Metopolophium dirhodum
Placoaphis siphunculata
Rosa sp. Rose (F. Rosaceae)
Chaetosiphon fragaefolii
Chaetosiphon tetrarhodum
Fimbriaphis fimbriata
Macrosiphum euphorbiae
Macrosiphum rosae
Maculolachnus sijpkensi
Metopolophium dirhodum
Myzus persicae
Placoaphis siphunculata
Pseudocercidis rosae
Pterocallis alni
Wahlgreniella nervata
Rosa 'Westerland'
Westerland Rose (F. Rosaceae)
Metopolophium dirhodum
Rosa 'White Dawn'
White Dawn Rose (F. Rosaceae)
Macrosiphum rosae
Rosa woodsii ssp. woodsii
Woods' Rose (F. Rosaceae)
Fimbriaphis wakibae
Macrosiphum rosae

Rosa 'Zephirine Drouhin'
Zephirine Drouhin Rose (F. Rosaceae)
Fimbriaphis fimbriata
Rosmarinus officinalis
Rosemary (F. Labiatae)
Myzus ornatus
Rubus discolor
Himalaya Blackberry (F. Rosaceae)
Amphorophora parviflori
Sitobion fragariae
Rubus idaeus Red Raspberry (F. Rosaceae)
Amphorophora agathonica
Aphis idaei
Aulacorthum solani
Macrosiphum euphorbiae
Sitobion fragariae
Rubus idaeus ssp. melanolasius
American Red Raspberry (F. Rosaceae)
Amphorophora agathonica
Illinoia rubicola
Rubus laciniatus
Cut-Leaved Blackberry (F. Rosaceae)
Sitobion fragariae
Rubus x loganobaccus
Loganberry (F. Rosaceae)
Aphis idaei
Rubus occidentalis
Blackcap Raspberry (F. Rosaceae)
Amphorophora agathonica
Rubus parviflorus
Thimbleberry (F. Rosaceae)
Amphorophora parviflori
Illinoia davidsoni
Illinoia maxima
Myzus ornatus
Rubus sp. Bramble (F. Rosaceae)
Illinoia rubicola
Sitobion fragariae
Rubus spectabilis Salmonberry (F. Rosaceae)
Amphorophora forbesi
Aulacorthum capilanoense
Macrosiphum euphorbiae
Rubus ursinus ssp. macropetalus
Pacific Trailing Blackberry (F. Rosaceae)
Amphorophora parviflori
Amphorophora rubitoxica
Rudbeckia hirta
Black-Eyed Susan (F. Compositae)
Aphis fabae
Macrosiphum euphorbiae
Rumex acetosella
Sheep Sorrel (F. Polygonaceae)
Brachycaudus rumexicolens
Myzus ascalonicus
Pemphigus populivenae
Rumex crispus Curled Dock (F. Polygonaceae)
Aphis rumicis
Myzus ascalonicus
Rumex obtusifolius ssp. obtusifolius
Broad-Leaved Dock (F. Polygonaceae)
Brachycaudus rumexicolens
Myzus persicae
Saintpaulia ionantha
Common African Violet (F. Gesneriaceae)
Aulacorthum circumflexum
Idiopterus nephrelepidis
Saintpaulia sp. African Violet (F. Gesneriaceae)
Aulacorthum circumflexum
Salicornia europaea
Sand-Fire (F. Chenopodiaceae)
Sitobion salicicornii
Salix acutifolia 'Pendulifolia'
Weeping Sharp-Leaved Willow (F. Salicaceae)
Aphis farinosa
Cavariella konoi
Salix babylonica
Weeping Willow (F. Salicaceae)
Pterocomma sanguiceps
Pterocomma smithiae
Salix exigua
Silver-Leaved Willow (F. Salicaceae)
Chaitophorus macrostachyae
Pterocomma sanguiceps
Salix fragilis Brittle Willow (F. Salicaceae)
Pterocomma smithiae
Salix lanata Woolly Willow (F. Salicaceae)
Myzus ornatus
Salix lasiandra Pacific Willow (F. Salicaceae)
Cavariella konoi
Cavariella pastinacae
Macrosiphum californicum
Pterocomma smithiae
Salix scouleriana
Scouler's Willow (F. Salicaceae)
Aphis farinosa
Macrosiphum californicum
Pterocomma salicis
Pterocomma sanguiceps
Salix sitchensis Sitka Willow (F. Salicaceae)
Aphis farinosa
Salix sp. Willow (F. Salicaceae)
Aphis farinosa
Cavariella pastinacae
Chaitophorus macrostachyae
Chaitophorus monelli
Chaitophorus nigrae
Chaitophorus pustulatus
Chaitophorus viminalis
Fullawaya bulbosa
Macrosiphum californicum
Macrosiphum euphorbiae
Plocamaphis flocculosa
Pterocomma bicolor
Pterocomma pilosum
Pterocomma salicis
Pterocomma sanguiceps
Tuberolachnus salignus
Salix triandra Almond Willow (F. Salicaceae)
Brachycaudus helichrysi
Macrosiphum californicum

Salvia officinalis Common Sage (F. Labiatae)
Brachycaudus helichrysi
Sambucus cerulea Blue Elder (F. Caprifoliaceae)
Macrosiphum stanleyi
Sambucus racemosa ssp. pubens var. arborescens
Coastal American Red Elder (F. Caprifoliaceae)
Aphis sambuci
Macrosiphum stanleyi
Sambucus racemosa ssp. pubens var. leucocarpa
Eastern American Red Elder (F. Caprifoliaceae)
Aphis sambuci
Macrosiphum stanleyi
Sambucus racemosa ssp. pubens var. melanocarpa
American Black-Fruited Elder (F. Caprifoliaceae)
Macrosiphum stanleyi
Sanvitalia procumbens
Creeping Zinnia (F. Compositae)
Aphis fabae
Sassafras albidum Sassafras (F. Lauraceae)
Aphis fabae
Saururus cernuus
Common Lizardtail (F. Saururaceae)
Rhopalosiphum nymphaeae
Schefflera octophylla
Eight-Leaved Umbrella Tree (F. Araliaceae)
Aulacorthum circumflexum
Schizostylis coccinea
Crimson Flag (F. Iridaceae)
Aulacorthum circumflexum
Macrosiphum euphorbiae
Scirpus lacustris ssp. validus var. validus
Softstem Bulrush (F. Cyperaceae)
Sitobion avenae
Sitobion fragariae
Scirpus microcarpus
Small-Flowered Bulrush (F. Cyperaceae)
Ceruraphis eriophori
Scirpus sp. Bulrush (F. Cyperaceae)
Rhopalosiphum padi
Secale cereale Rye (F. Gramineae)
Rhopalosiphum padi
Sitobion avenae
Sedum anglicum
English Stonecrop (F. Crassulaceae)
Aphis sedi
Sedum lanceolatum var. nesioticum
Lance-Leaved Stonecrop (F. Crassulaceae)
Macrosiphum euphorbiae
Sedum sp. Stonecrop (F. Crassulaceae)
Aphis sedi
Senecio canus Woolly Ragwort (F. Compositae)
Aulacorthum solani
Senecio cineraria Dusty-Miller (F. Compositae)
Brachycaudus helichrysi
Senecio cruentus
Florist's Cineraria (F. Compositae)
Aulacorthum solani
Myzus ascalonicus
Senecio jacobaea
Tansy Ragwort (F. Compositae)
Aphis lugentis
Geoica utricularia
Senecio sp. Groundsel (F. Compositae)
Aphis fabae
Aphis lugentis
Senecio vulgaris
Common Groundsel (F. Compositae)
Brachycaudus cardui
Brachycaudus helichrysi
Macrosiphum euphorbiae
Myzus ornatus
Myzus persicae
Sequoiadendron giganteum
Giant Sequoia (F. Taxodiaceae)
Illinoia morrisoni
Silene alba ssp. alba
White Campion (F. Caryophyllaceae)
Aphis fabae
Myzus persicae
Silene noctiflora Night-Flowering Catchfly (F. Caryophyllaceae)
Macrosiphum euphorbiae
Sinningia speciosa Gloxinia (F. Gesneriaceae)
Aulacorthum solani
Sisymbrium officinale
Tall Hedge Mustard (F. Cruciferae)
Lipaphis erysimi
Myzus ascalonicus
Myzus persicae
Sitobion fragariae
Sisymbrium sp. Hedge Mustard (F. Cruciferae)
Myzus persicae
Sitanion hystrix var. hystrix
Bottlebrush Squirreltail Grass (F. Gramineae)
Sitobion fragariae
Sium suave Water Parsnip (F. Umbelliferae)
Aphis heraclella
Cavariella aegopodii
Smilacina stellata
Star-Flowered Solomon's Seal (F. Liliaceae)
Sitobion insulare yagasogae
Solanum nigrum Nightshade (F. Solanaceae)
Myzus persicae
Solanum tuberosum Potato (F. Solanaceae)
Aphis fabae
Aulacorthum circumflexum
Aulacorthum solani
Macrosiphum euphorbiae
Myzus persicae
Rhopalosiphoninus latysiphon
Solidago canadensis
Canadian Goldenrod (F. Compositae)
Uroleucon erigeronensis
Uroleucon nigrotuberculatum
Solidago canadensis var. salesbrosa
Creek Goldenrod (F. Compositae)
Uroleucon vancouverense
Solidago missouriensis var. missouriensis
Missouri Goldenrod (F. Compositae)
Uroleucon vancouverense

Solidago sp. Goldenrod (F. Compositae)
Uroleucon gigantiphagum
Uroleucon rudbeckiae
Uroleucon solidaginis
Sonchus arvensis
Perennial Sowthistle (F. Compositae)
Hyperomyzus lactucae
Hyperomyzus pallidus
Uroleucon sonchi
Sonchus asper Spiny Sowthistle (F. Compositae)
Aphis fabae
Hyperomyzus lactucae
Uroleucon sonchi
Sonchus oleraceus
Annual Sowthistle (F. Compositae)
Hyperomyzus lactucae
Sonchus sp. Sowthistle (F. Compositae)
Hyperomyzus lactucae
Myzus ascalonicus
Sophora japonica
Japanese Pagoda Tree (F. Leguminosae)
Appendiseta robiniae
Sorbus americana
American Mountain Ash (F. Rosaceae)
Fimbriaphis gentneri
Sorbus aucuparia Rowan Tree (F. Rosaceae)
Aphis pomi
Macrosiohum pyrifoliae
Myzus ornatus
Nearctaphis californica
Sorbus aucuparia 'Edulis'
Moravian Rowan Tree (F. Rosaceae)
Aphis pomi
Sorbus scopulina
Wild Mountain Ash (F. Rosaceae)
Nearctaphis yohoensis
Sorbus sitchensis
Sitka Mountain Ash (F. Rosaceae)
Toxopterella drepanosiphoides
Sorbus sitchensis ssp. grayi
Western Sitka Mountain Ash (F. Rosaceae)
Macrosiphum pyrifoliae
Spartium junceum
Spanish Broom (F. Leguminosae)
Aphis craccivora
Spergularia rubra
Red Sandwort (F. Caryophyllaceae)
Myzus certus
Myzus persicae
Spinacia oleracea Spinach (F. Chenopodiaceae)
Aphis fabae
Spiraea x arguta
Garland Spirea (F. Rosaceae)
Illinoia spiraeae
Spiraea x bumalda
Bumalda Spirea (F. Rosaceae)
Illinoia spiraeae
Spiraea douglasii Hardhack (F. Rosaceae)
Eoessigia longicauda
Illinoia spiraeae
Macrosiphum euphorbiae
Spiraea sp. Spirea (F. Rosaceae)
Eoessigia longicauda
Spiraea thunbergii
Thunberg Spirea (F. Rosaceae)
Illinoia spiraecola
Stellaria media
Common Chickweed (F. Caryophyllaceae)
Aulacorthum solani
Myzus ascalonicus
Myzus persicae
Stellaria sp. Chickweed (F. Caryophyllaceae)
Myzus ascalonicus
Stipa elegantissima
Australian Needle Grass (F. Gramineae)
Rhopalosiphum padi
Stranvaesia davidiana
Chinese Stranvaesia (F. Rosaceae)
Aphis citricola
Styrax obassia
Fragrant Snowbell (F. Styracaceae)
Aphis fabae
Symphoricarpos albus
Common Snowberry (F. Caprifoliaceae)
Aphthargelia symphoricarpi
Macrosiphum euphorbiae
Tagetes erecta African Marigold (F. Compositae)
Macrosiphum euphorbiae
Tagetes tenuifolia 'Pumila'
Dwarf Marigold (F. Compositae)
Brachycaudus helichrysi
Tanacetum bipinnatum ssp. huronense
Western Dune Tansy (F. Compositae)
Macrosiphoniella tanacetaria
Tanacetum vulgare Tansy (F. Compositae)
Aulacorthum solani
Macrosiphoniella tanacetaria
Taraxacum officinale
Common Dandelion (F. Compositae)
Macrosiphum euphorbiae
Myzus ascalonicus
Myzus ornatus
Trama rara
Uroleucon taraxaci
Tellima grandiflora
Tall Fringecup (F. Saxifragaceae)
Aulacorthum solani
Kakimia cynosbati
Teucrium canadense ssp. viscidum
American Germander (F. Labiatae)
Myzus persicae
Thuja plicata
Western Red Cedar (F. Cupressaceae)
Illinoia morrisoni
Thujopsis dolabrata
Hiba Arborvitae (F. Cupressaceae)
Illinoia patriciae
Thymus pseudolanuginosus
Woolly Mother-Of-Thyme (F. Labiatae)
Myzus ornatus
Tilia americana American Linden (F. Tiliaceae)

Aulacorthum solani
Eucallipterus tiliae
Tilia petiolaris
Weeping White Linden (F. Tiliaceae)
Eucallipterus tiliae
Tilia sp. Linden (F. Tiliaceae)
Eucallipterus tiliae
Tolmiea menziesii
Thousand-Mothers (F. Saxifragaceae)
Aulacorthum solani
Tricyrtis hirta Hairy Toad Lily (F. Liliaceae)
Aulacorthum solani
Trientalis latifolia
Broad-Leaved Starflower (F. Plumbaginaceae)
Aulacorthum solani
Myzus persicae
Trifolium dubium
Suckling Clover (F. Leguminosae)
Myzus ornatus
Trifolium pratense Red Clover (F. Leguminosae)
Acyrthosiphon pisum
Aulacorthum solani
Brachycaudus helichrysi
Myzus ornatus
Nearctaphis sensoriata
Trifolium sp. Clover (F. Leguminosae)
Acyrthosiphon pisum
Nearctaphis bakeri
Triglochin maritimum
Seaside Arrow-Grass (F. Juncaginaceae)
Sitobion avenae
Tripleurospermum maritimum
Seashore Schultz-Bip (F. Compositae)
Aphis fabae
Aulacorthum solani
Trisetum spicatum
Spike Trisetum (F. Gramineae)
Sitobion fragariae
Triteleia hyacinthina
Wild Hyacinth (F. Amaryllidaceae)
Aulacorthum solani
Triticum x aestivum
Cultivated Wheat (F. Gramineae)
Rhopalosiphum padi
Sitobion avenae
Tropaeolum majus
Common Nasturtium (F. Tropaeolaceae)
Aphis fabae
Aulacorthum solani
Tsuga heterophylla
Western Hemlock (F. Pinaceae)
Cinara pilicornis
Cinara tsugae
Illinoia patriciae
Tulipa gesneriana Tulip (F. Liliaceae)
Aulacorthum circumflexum
Aulacorthum solani
Dysaphis tulipae
Macrosiphum euphorbiae
Myzus persicae
Rhopalosiphoninus staphyleae
Typha latifolia Common Cattail (F. Typhaceae)
Hyalopterus pruni
Rhopalosiphum enigmae
Ulmus americana American Elm (F. Ulmaceae)
Eriosoma americanum
Eriosoma grossulariae
Eriosoma ulmi
Myzocallis walshii
Tinocallis platani
Ulmus glabra 'Camperdownii'
Camperdown Elm (F. Ulmaceae)
Aulacorthum solani
Ulmus sp. Elm (F. Ulmaceae)
Eriosoma americanum
Tinocallis ulmifolii
Unknown sp. (F. Compositae)
Illinoia magna
Unknown sp. (F. Gramineae)
Aulacorthum solani
Diuraphis nodulus
Forda marginata
Geoica utricularia
Jacksonia papillata
Rhopalomyzus poae
Rhopalosiphum padi
Sipha elegans
Sitobion avenae
Sitobion fragariae
Tetraneura ulmi
Uroleucon taraxaci
Utamphorophora humboldti
Unknown sp. (F. Leguminosae)
Nearctaphis crataegifoliae
Unknown sp. (F. Polypodiaceae)
Idiopterus nephrelepidis
Urtica dioica Stinging Nettle (F. Urticaceae)
Microlophium carnosum
Urtica dioica ssp. gracilis var. lyallii
Lyall's Nettle (F. Urticaceae)
Amphorophora urtica
Macrosiphum euphorbiae
Vaccinium corymbosum
Highbush Blueberry (F. Ericaceae)
Aulacorthum circumflexum
Brachycaudus helichrysi
Ericaphis scammelli
Fimbriaphis fimbriata
Macrosiphum euphorbiae
Vaccinium macrocarpon
Cranberry (F. Ericaceae)
Illinoia azaleae
Vaccinium macrocarpon 'McFarlin'
McFarlin Cranberry (F. Ericaceae)
Aulacorthum circumflexum
Vaccinium parvifolium
Red Huckleberry (F. Ericaceae)
Macrosiphum parvifolii
Vaccinium sp. Blueberry (F. Ericaceae)
Aulacorthum pterinigrum
Fimbriaphis fimbriata
Valeriana officinalis

Common Valerian (F. Valerianaceae)
Macrosiphum euphorbiae
Veratrum viride ssp. eschscholtzii
Green False Hellebore (F. Liliaceae)
Aphis coweni
Verbena 'Coral Reef'
Coral Reef Verbena (F. Verbenaceae)
Myzus ornatus
Myzus persicae
Verbena x hybrida
Garden Verbena (F. Verbenaceae)
Brachycaudus helichrysi
Macrosiphum euphorbiae
Verbena x hybrida 'Springtime'
Springtime Garden Verbena (F. Verbenaceae)
Macrosiphum euphorbiae
Verbena 'Ideal Florist'
Ideal Florist Verbena (F. Verbenaceae)
Macrosiphum euphorbiae
Verbena 'Sangria'
Sangria Verbena (F. Verbenaceae)
Ovatus crataegarius
Verbesina encelioides
Butter Daisy (F. Compositae)
Aulacorthum circumflexum
Macrosiphum euphorbiae
Viburnum x bodnantense
Bodnantense Viburnum (F. Caprifoliaceae)
Aulacorthum solani
Ceruraphis eriophori
Myzus ascalonicus
Myzus ornatus
Viburnum edule
High Bush Cranberry (F. Caprifoliaceae)
Acyrthosiphon macrosiphum
Aphis fabae
Prociphilus xylostei
Viburnum farreri 'Bowles'
Bowles Fragrant Viburnum (F. Caprifoliaceae)
Rhopalosiphoninus staphyleae
Viburnum opulus ssp. trilobum
American Bush Cranberry (F. Caprifoliaceae)
Aphis fabae
Ceruraphis eriophori
Ceruraphis viburnicola
Viburnum sargentii 'Flavum'
Yellow Sargent Cranberry (F. Caprifoliaceae)
Ceruraphis eriophori
Vicia faba Broad Bean (F. Leguminosae)
Acyrthosiphon pisum
Aphis fabae
Macrosiphum creelii
Myzus persicae
Vicia sativa var. angustifolia
Narrow-Leaved Vetch (F. Leguminosae)
Acyrthosiphon pisum
Aulacorthum solani
Vinca major Big Periwinkle (F. Apocynaceae)
Aulacorthum solani
Vinca minor
Common Periwinkle (F. Apocynaceae)
Macrosiphum euphorbiae
Rhopalosiphoninus staphyleae
Viola septentrionalis
Northern Blue Violet (F. Violaceae)
Myzus ascalonicus
Viola sp. Violet (F. Violaceae)
Myzus ascalonicus
Rhopalosiphoninus latysiphon
Viola tricolor
European Wild Pansy (F. Violaceae)
Aulacorthum circumflexum
Myzus ascalonicus
Myzus ornatus
Myzus persicae
Vulpia myuros var. hirsuta
Rattail Vulpia (F. Gramineae)
Sitobion avenae
Weigela 'Eva Rathke'
Eva Rathke Weigela (F. Caprifoliaceae)
Myzus ornatus
Woodsia scopulina var. scopulina
Rocky Mountain Woodsia (F. Aspleniaceae)
Sitobion woodsiae
Yucca filamentosa Adam's Needle (F. Liliaceae)
Aphis fabae
Aulacorthum circumflexum
Macrosiphum euphorbiae
Myzus persicae
Rhopalosiphoninus staphyleae
Yucca sp. Yucca (F. Liliaceae)
Macrosiphum euphorbiae
Rhopalosiphoninus staphyleae
Zea mays Corn (F. Gramineae)
Macrosiphum euphorbiae
Rhopalosiphum maidis
Rhopalosiphum padi
Sitobion avenae
Zigadenus sp. Deathcamus (F. Liliaceae)
Macrosiphum kiowanepus
Zigadenus venenosus var. gramineus
Grass-Leaved Deathcamas (F. Liliaceae)
Macrosiphum kiowanepus
Zinnia elegans Common Zinnia (F. Compositae)
Aphis fabae
Macrosiphum euphorbiae
Myzus persicae

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REFERENCES

Anonymous. 1982. National list of scientific plant names. Vol. 1. List of plant names. SCS-TP-159. U. S. D.A.

Anonymous. 1976. Hortus Third: A concise dictionary of plants cultivated in the United States and Canada. MacMillan Publishing Co., Inc. N.Y. Collier MacMillan Publishers, Lond.

Crabbe, J.A., A.C. Jermy and J.T. Mickel. 1975. A new generic sequence for the pteridophyte herbarium. *Fern Gaz.* **11 (2&3)**: 141-162.

Eastop, V.F., and D. Hille Ris Lambers. 1976. Survey of the world's aphids. Dr. W. Junk b.v., Publisher, The Hague.

Fernald, M.L. 1970. Gray's manual of botany, 8th. ed. Rev. R.C. Rollins. Van Nostrand Reinhold.

Forbes, A.R., and C.K. Chan. 1987. The aphids (Homoptera: Aphididae) of British Columbia. 16. Further additions. *J. ent. Soc. Brit. Columbia* **84** (in press).

Forbes, A.R., and C.K. Chan. 1986a. The aphids (Homoptera: Aphididae) of British Columbia. 15. Further additions. *J. ent. Soc. Brit. Columbia* **83**: 70-73.

Forbes, A.R., and C.K. Chan. 1986b. The aphids (Homoptera: Aphididae) of British Columbia. 14. Further additions. *J. ent. Soc. Brit. Columbia* **83**: 66-69.

Forbes, A.R., and C.K. Chan. 1985. The aphids (Homoptera: Aphididae) of British Columbia. 13. Further additions. *J. ent. Soc. Brit. Columbia* **82**: 56-58.

Forbes, A.R., and C.K. Chan. 1984. The aphids (Homoptera: Aphididae) of British Columbia. 12. Further additions. *J. ent. Soc. Brit. Columbia* **81**: 72-75.

Forbes, A.R., and C.K. Chan. 1983. The aphids (Homoptera: Aphididae) of British Columbia. 11. Further additions. *J. ent. Soc. Brit. Columbia* **80**: 51-53.

Forbes, A.R., and C.K. Chan. 1981. The aphids (Homoptera: Aphididae) of British Columbia. 9. Further additions. *J. ent. Soc. Brit. Columbia* **78**: 53-54.

Forbes, A.R., and C.K. Chan. 1980. The aphids (Homoptera: Aphididae) of British Columbia. 8. Further additions and corrections. *J. ent. Soc. Brit. Columbia* **77**: 38-42.

Forbes, A.R., and C.K. Chan. 1978a. The aphids (Homoptera: Aphididae) of British Columbia. 7. A revised host plant catalogue. *J. ent. Soc. Brit. Columbia* **75**: 53-67.

Forbes, A.R., and C.K. Chan. 1978b. The aphids (Homoptera: Aphididae) of British Columbia. 6. Further additions. *J. ent. Soc. Brit. Columbia* **75**: 47-52.

Forbes, A.R., and C.K. Chan. 1976. The aphids (Homoptera:Aphididae) of British Columbia. 4. Further additions and corrections. *J. ent. Soc. Brit. Columbia* **73**: 57-63.

Forbes, A.R., C.K. Chan and R. Foottit. 1982. The aphids (Homoptera: Aphididae) of British Columbia. 10. Further additions. *J. ent. Soc. Brit. Columbia* **79**: 75-78.

Forbes, A.R., and B.D. Frazer. 1973. The aphids (Homoptera:Aphididae) of British Columbia. 2. A host plant catalogue. *J. ent. Soc. Brit. Columbia* **70**: 58-68.

Forbes, A.R., B.D. Frazer and C.K. Chan. 1974. The aphids (Homoptera: Aphididae) of British Columbia. 3. Additions and corrections. *J. ent. Soc. Brit. Columbia* **71**: 43-49.

Forbes, A.R., B.D. Frazer and H.R. MacCarthy. 1973. The aphids (Homoptera: Aphididae) of British Columbia. 1. A basic taxonomic list. *J. ent. Soc. Brit. Columbia* **70**: 43-57.

Hitchcock, C.L., and A. Cronquist. 1973. Flora of the Pacific Northwest. Univ. of Washington Press, Seattle & London. 730 pp.

Raworth, D.A., and B.D. Frazer. 1976. Compilation of taxonomic catalogues by computer. *J. ent. Soc. Brit. Columbia* **73**: 63-67.

Schofield, W.B. 1969. Some common mosses of British Columbia. Handbook No. 28. Brit. Columbia Prov. Mus. 262 pp.

Taylor, R.L., and B. MacBryde. 1977. Vascular plants of British Columbia – A descriptive resource inventory. Tech. Bull. No. 4. The botanical garden. Univ. of B.C.

AN ILLUSTRATED GUIDE TO THE IDENTIFICATION AND DISTRIBUTION OF THE SPECIES OF *DENDROCTONUS* ERICHSON (COLEOPTERA: SCOLYTIDAE) IN BRITISH COLUMBIA

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Abstract

An illustrated key is presented separating adults of the eight species of *Dendroctonus* Erichson occurring in British Columbia. Punctation on the episternal area of the prothorax and crenulations on the discal area of the elytra are used to provide reliable diagnoses of five species *(D. murrayanae, D. rufipennis, D. punctatus, D. simplex, D. pseudotsugae)* which could previously be distinguished only with considerable difficulty. Scanning electron micrographs illustrate these characters and simplify interpretation of the key. Distribution maps are provided which show many previously unpublished range extensions.

Résumé

Cet ouvrage présente une clé illustrée permettant de distinguer les adultes de huit espèces de *Dendroctonus* Erichson se retrouvant en Colombie-Britannique. L'auteur se fonde sur les ponctuations de la partie épisternale du prothorax et sur les crénulations de la région discale de l'élytre pour identifier de façon fiable cinq espèes *(D. murrayanae, D. rufipennis, D. punctatus, D. simplex, D. pseudotsugae)* qui étaient auparavant très difficiles ga distinguer. Des photographies de microscope électronique à balayage illustrent ces caractéristiques et facilitent l'interprétation. Des cartes des aires de répartition ont été ajoutées et montrent des aires d'extension autrefois inconnues.

Introduction

Eight species of *Dendroctonus* Erichson occur in British Columbia: *D. brevicomis* LeConte, *D. ponderosae* Hopkins, *D. valens* LeConte, *D. punctatus* LeConte, *D. murrayanae* Hopkins, *D. rufipennis* (Kirby), *D. simplex* LeConte and *D. pseudotsugae* Hopkins. Identification of the last five of these species is somewhat daunting using available keys. Wood (1963, 1982) and Bright (1976) distinguish them on the basis of differences in the size, density and distinctness of the punctures and granules on the frons.

The use of these characters on the frons has resulted in considerable difficulty and confusion in providing reliable identifications because of the relatively minor differences between species and the considerable variation within species. In this paper, differences in punctation in the episternal area of the prothorax and in the crenulation on the discal area of the elytra are presented as alternative characters which reliably separate these species. To eliminate possible confusion and simplify use of the key, each critical character is illustrated with a scanning electron micrograph. Characters used in this guide are easily observed at 100X or less magnification.

Distribution maps of locality records within British Columbia, as determined from Forest Insect and Disease Survey records, are included for each species. Numerous range extensions are noted.

Methods and Materials

Several adult beetles of each species were prepared for scanning electron microscope study as follows: 1) dry specimens were mounted on stubs and oriented so that the features to be studied could be readily viewed: 2) each specimen was sputter coated with gold-palladium for 6 min using a Hummer V sputter coater; 3) specimens were viewed using a Jeol 35C SEM set at 15 KV and at magnifications ranging from 50X to 200X. Following a detailed examination of external morphological features, micrographs were taken to illustrate potential diagnostic characters. The search for useful characters included all areas of the external morphology but was concentrated primarily on the frons, pronotum and elytra. Constancy of

each character was confirmed by stereo microscopic viewing of an additional 40 specimens of each species under diffuse light at 100-200X magnification.

Beetles examined in this study were selected to include specimens collected throughout the known geographic distribution of each species and on all of the host tree species attacked in British Columbia. Specimens examined are deposited in the Forest Insect and Disease Survey collection, Pacific Forestry Centre, Canadian Forestry Service, Victoria, British Columbia.

Results and Discussion

The keys and descriptions provided by Wood (1963, 1982) and Bright (1976) provide distinctive, readily observable characters to reliably separate *D. brevicomis*, *D. ponderosae*, and *D. valens*. The remaining five species occurring in British Columbia are difficult to identify using their keys. The following key and diagnostic notes present alternative morphological features by which these five species can be reliably separated.

Glossary

Crenulate:	rounded surface projections rising to a ridge.
Declivity:	the steeply sloping posterior face of the elytra.
Discal area:	central area, on elytra refers to anterodorsal area of elytra.
Elytra:	chitinous forewings of beetles serve as coverings for hind wings.
Episternal area:	posteroventral area of prothorax.
Epistomal process:	flattened prominence at the base of the frons.
Frons:	front part of head extending from epistoma to the upper level of the eyes.
Granulate:	a surface bearing granules.
Granule:	acute or blunt prominence on a surface.
Interspace:	the area between two elytral striae.
Puncture:	small impression on the surface of a body.
Rugulose:	wrinkled, marked with coarse elevations.
Stria:	punctured, impressed line on the elytra.
Tubercle:	knoblike prominence or a course granule.
Vertex:	top of insect head, between the eyes.

Key to the Species of *Dendroctonus* in British Columbia

1. Frons with deep median groove extending from near epistomal process to vertex; lateral areas of frons somewhat protuberant and, in the male, armed with tubercles (fig. 1); length 2.5-5.0 mm; in *Pinus ponderosa* ..... *brevicomis* LeConte

   Frons without deep median groove or protuberant lateral areas; frons of male not armed with tubercles (fig. 2) 2

2. Interspaces on elytral declivity minutely rugulose (fig. 3) 3.7-6.5 mm; in *Pinus* (occasionally in *Picea* in epidemics) ..... *ponderosae* Hopkins

   Interspaces on elytral declivity not minutely rugulose (figs. 4,7,8) 3

3. Upper margin of all declivital interspace punctures granulate (fig. 4); episternal area of prothorax coarsely granulate (fig. 9); body uniformly reddish brown; 5.4 - 9.0 mm; in *Pinus*, *Picea* ..... *valens* LeConte

   Upper margin of many to most declivital interspace punctures not granulate (figs. 5,6,7,8), episternal area of prothorax not granulate to minutely so (figs. 10, 11, 12); body not uniformly reddish brown 4

4. Declivital striae weakly to moderately impressed, if at all; declivital interspace 1 weakly to moderately elevated, interspace 2 not impressed and nearly as wide or wider than

interspace 1 or 3 (fig. 5); lateral margins of epistomal process moderately oblique (less than 55 degrees from horizontal) (fig. 13) 5

Declivital striae strongly impressed; declivital interspace 1 strongly elevated, interspace 2 weakly impressed and much narrower than interspace 1 or 3 (fig. 6); lateral margins of epistomal process strongly oblique (about 80° from horizontal) (fig. 14) 7

5. Punctures in episternal area of prothorax, distinctly marginate (figs. 10, 11) 6

Punctures in episternal area of prothorax, lack a distinct margin anterodorsally (fig. 12). 4.4-7.1 mm; in *Picea* ..... *rufipennis* (Kirby)

6. Strial punctures on declivity small (average <.15X interspace width) (fig. 7) body black with reddish brown elytra; 5.0-7.3 mm; in *Pinus contorta* ..... *murrayanae* Hopkins

Strial punctures on declivity large (average ≥.25X interspace width) (fig. 8); body uniformly dark brown; 6.0-7.5 mm; in *Picea* ..... *punctatus* LeConte

7. A few transverse crenulations on sutural interspace of disc (average 5 crenulations/10 strial punctures) (fig. 15); diameter of strial punctures on disc average ≥.6X sutural interspace width; frons moderately protuberant; 3.4-5.0 mm; in *Larix laricina* .... *simplex* LeConte

Many transverse crenulations on sutural interspace of disc (average 10 crenulations/10 strial punctures) (fig. 16); diameter of strial punctures on disc average <.45 X sutural interspace width; frons strongly protuberant; 4.7-7.0 mm; in *Pseudotsuga menziesii* occasionally *Larix occidentalis* ..... *pseudotsugae* Hopkins

Diagnostic Notes

Dendroctonus punctatus (figs. 8,11): This species is closely related to *D. murrayanae* and *D. rufipennis* from which it is reliably distinguished by the very large strial punctures on the declivity. The diameter of the strial punctures in *punctatus* are on average ≥.25X the interspace width. By comparison, these punctures are on average <.20X the interspace width in *rufipennis* and <.15X in *murrayanae*. As well, *punctatus* can be distinguished from *rufipennis* by the size and margination of punctures in the episternal area of the prothorax. The episternal punctures in *punctatus* are large and clearly marginate whereas those of *rufipennis* are small and lack a distinct margin anterodorsally. Other less definitive diagnostic features include body color and granulation on the frons. Mature *punctatus* have a dark brown pronotum and elytra. By contrast, mature *rufipennis* are either uniformly black or have a black pronotum and reddish brown elytra (immature *rufipennis* are somewhat lighter and may resemble *punctatus*); mature *murrayanae* have a black pronotum and reddish brown elytra. The frons of *punctatus* is smooth and polished with relatively little granular development; the frons of rufipennis is typically strongly granulate, however, the frons of *murrayanae* often has reduced granulation and may closely resemble *punctatus*.

Dendroctonus murrayanae (figs 5,7,10,13): This species is distinguished from *punctatus* by the very small strial punctures on the declivity (average diameter <.15X the interspace width versus ≥.25X interspace width in *punctatus*) and by the black pronotum and reddish brown elytra compared to an almost uniformly dark brown body in *punctatus*. From *rufipennis* it differs by the size, shape and margination of punctures in the episternal area of the prothorax. The episternal punctures of *murrayanae* are large, shallow, flat bottomed and distinctly marginate around their entire perimeter whereas those of *rufipennis* are small, deep and the bottom slopes up anterodorsally from the base of the seta to form an indistinct to barely distinct anterodorsal margin.

Dendroctonus rufipennis (fig. 12): This species is distinguished from both *murrayanae* and *punctatus* by the much smaller indistinctly margined punctures in the episternal area of the prothorax. It also differs from *punctatus* by body color (uniformly black or black pronotum with reddish brown elytra of *rufipennis* versus uniformly dark brown body of *punctatus*) and by smaller strial punctures on the declivity (average diameter <.20X interspace width versus ≥.25X interspace width).

Dendroctonus simplex (figs. 6,15): This species is similar to *D. pseudotsugae* from which it is readily distinguished by a much reduced degree of crenulation on the discal area of the elytra (average 5 crenulations/10 strial punctures) and by the relatively large strial punctures on the disc (average diameter ≥.6 X sutural interspace width). It also differs by having much larger pronotal punctures. Other less reliable characters include a less protuberant frons and smaller body (3.4-5.5 mm).

Dendroctonus pseudotsugae (fig. 16): This species is closely allied to *D. simplex* from which it is distinguished by a much greater degree of crenulation on the discal area of the elytra (average 10 crenulations/10 strial punctures in discal area) and by the relatively small strial punctures on the disc (average diameter <.45 X sutural interspace width). The pronotal punctures of *pseudotsugae* are much smaller. Other less distinctive characters include a more protuberant frons and larger body size (4.4-7.0 mm).

Distribution

Locality records [plotted in Figs. 17-24] are based on Forest Insect and Disease Survey, Pacific Region collection records. Extensions to the known geographic distribution (Bright 1976; Wood 1982) within British Columbia are documented for several species. *D. punctatus* is now known to occur widely in the interior of British Columbia (Mackenzie, Likely, Howser). It was previously known in British Columbia from a single collection near the Yukon border. *D. murrayanae* previously recorded only from south central to south eastern British Columbia is now known to occur west to the coast range (Anahim Lake, Smithers, Atlin) and north into the Yukon. Other notable range extensions include *D. pseudotsugae* which occurs north of 54° (Fort St. James), D. valens whose range occurs north to 54° (Prince George) and *D. ponderosae* which occurs west to Terrace and north to 56° (Meziadin Lake).

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I am particularly indebted to L. Manning, scanning electron microscopist at PFC, Victoria for much advice and help in securing the micrographs used in this paper. I also wish to thank my colleague L. Humble for critical review of the manuscript.

References

Bright, D.E. 1976. The insects and arachnids of Canada. Part 2. The Bark Beetles of Canada and Alaska (Coleoptera; Scolytidae). Agric. Can. Publ. 1576. 241 pp.

Wood, S.L. 1963. A revision of the bark beetle genus *Dendroctonus* Erichson (Coleoptera: Scolytidae). *Illustrated. Great Basin Nat.* **23(1-2)**: 1-117.

Wood, S.L. 1982. The bark and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxomonic monograph, Great Basin Nat. Memoirs No. 1. 1359 pp.

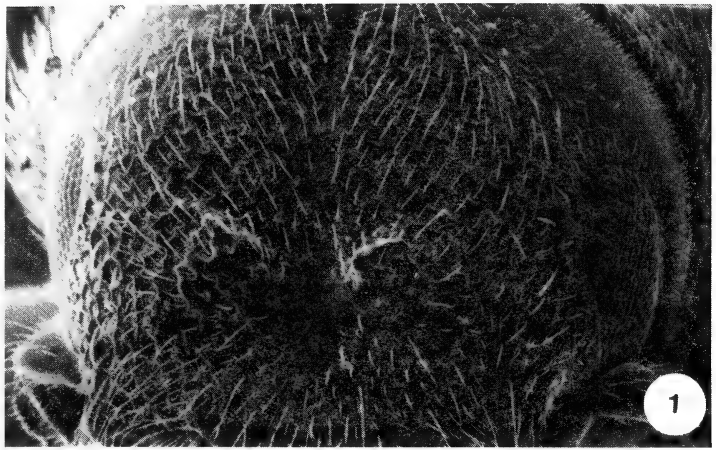

Fig. 1. *D. brevicomis*, deep median groove on frons

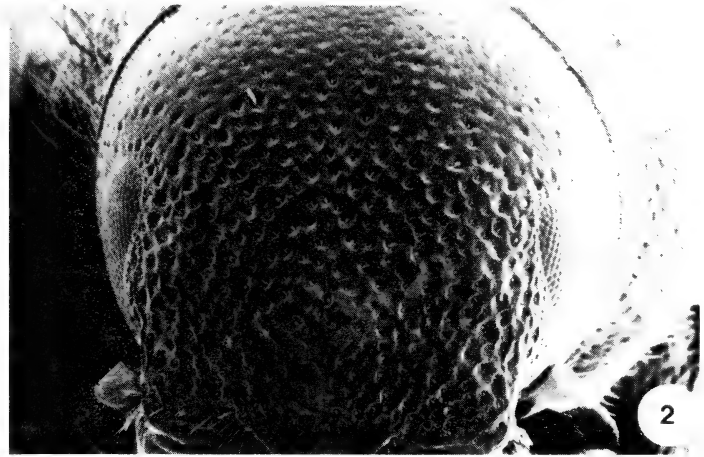

Fig. 2. *D. murrayanae*, lacks deep groove on frons

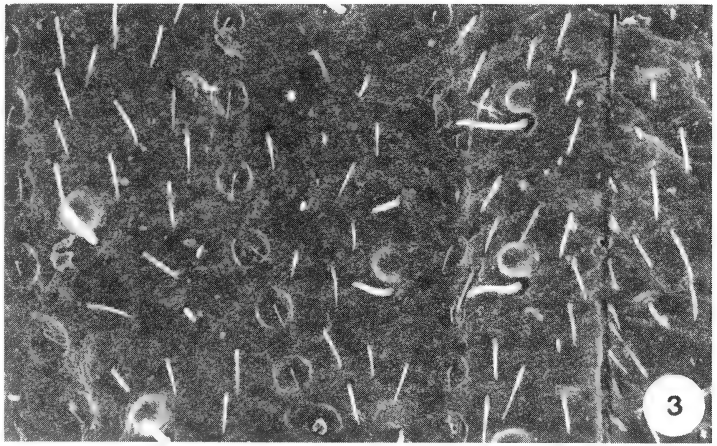

Fig. 3. *D. ponderosae*, minutely rugulose declivity

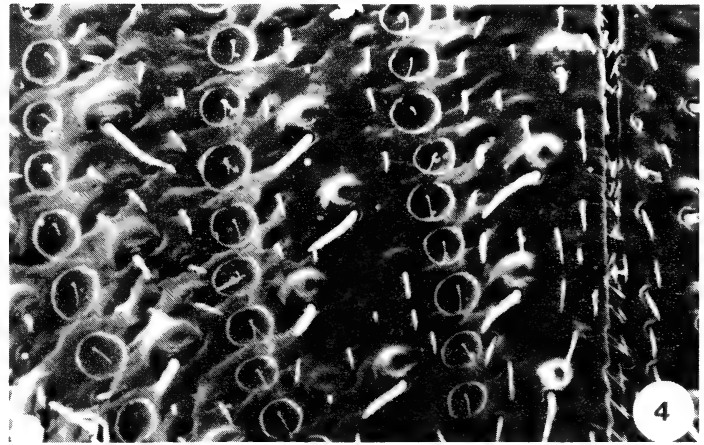

Fig. 4. *D. valens*, granulate punctures on declivity

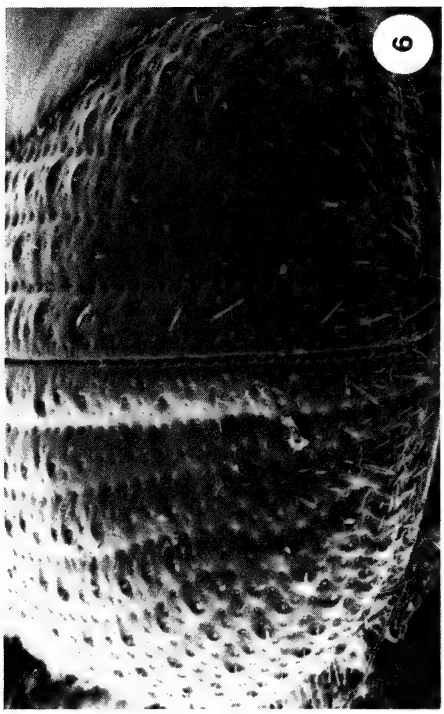

FIG. 6. *D. simplex*, declivity

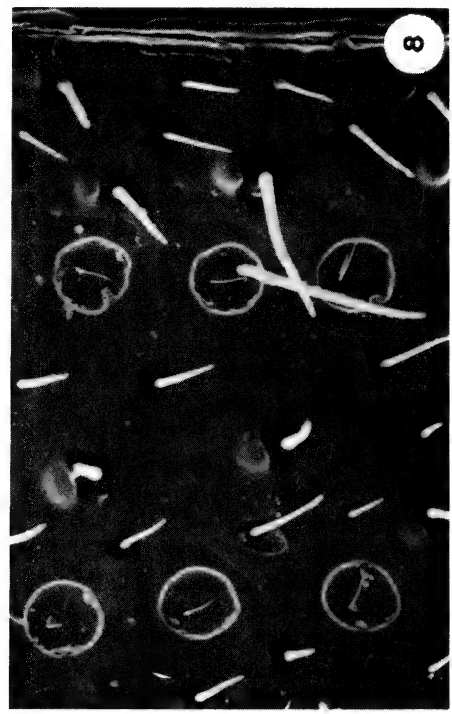

FIG. 8. *D. punctatus*, declivity

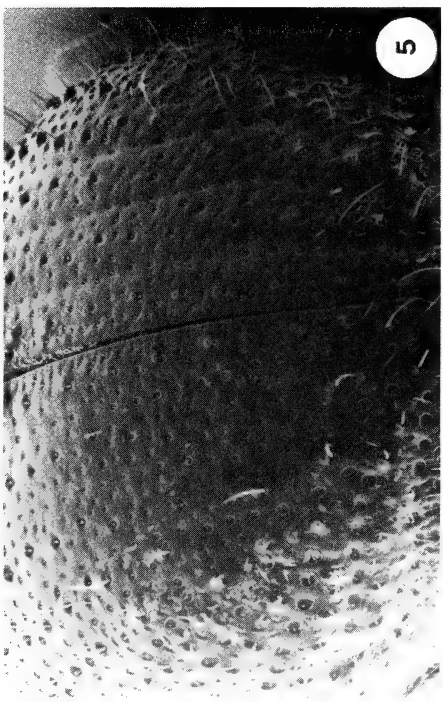

FIG. 5. *D. murrayanae*, declivity

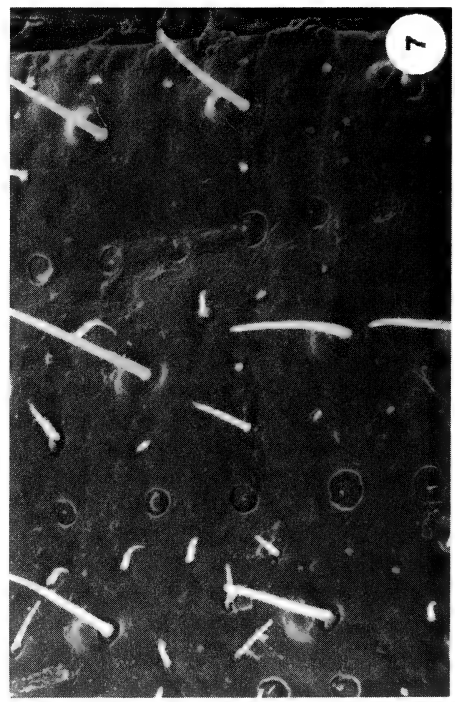

FIG. 7. *D. murrayanae*, declivity

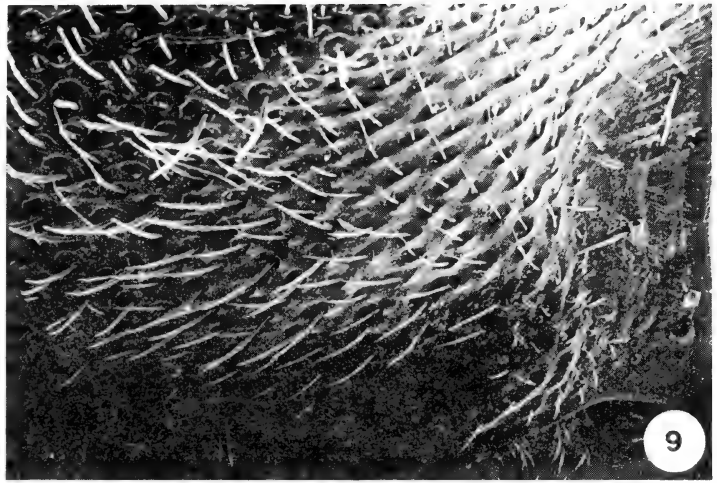

Fig. 9. *D. valens*, coarsely granulate episternal area of prothorax

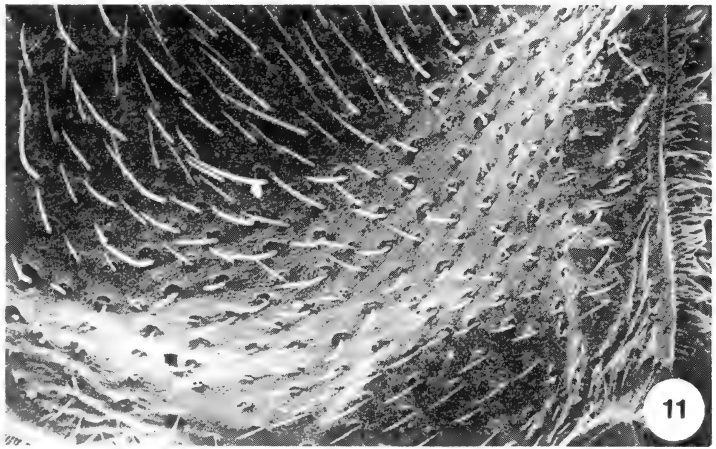

Fig. 11. *D. punctatus*,
non granulate episternal area bearing distinctly marginate punctures

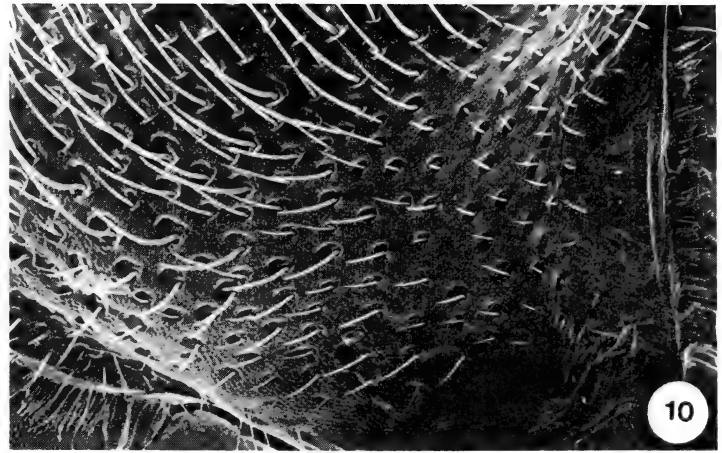

Fig. 10. *D. murrayanae*, non granulate episternal area bearing distinctly marginate punctures

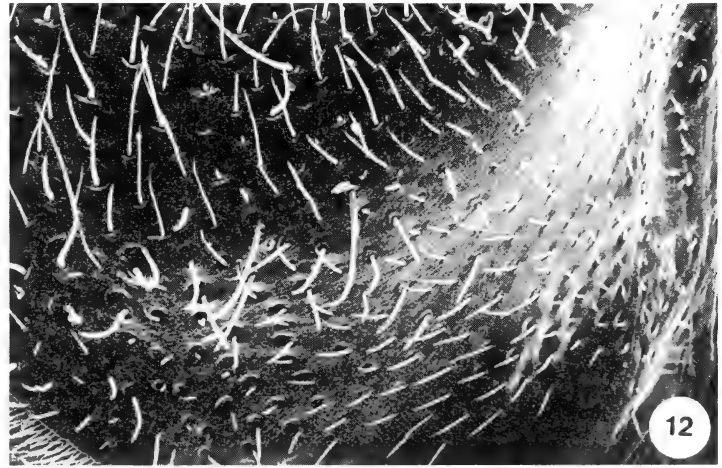

Fig. 12. *D. rufipennis*.
non granulate episternal area bearing indistinctly marginate punctures

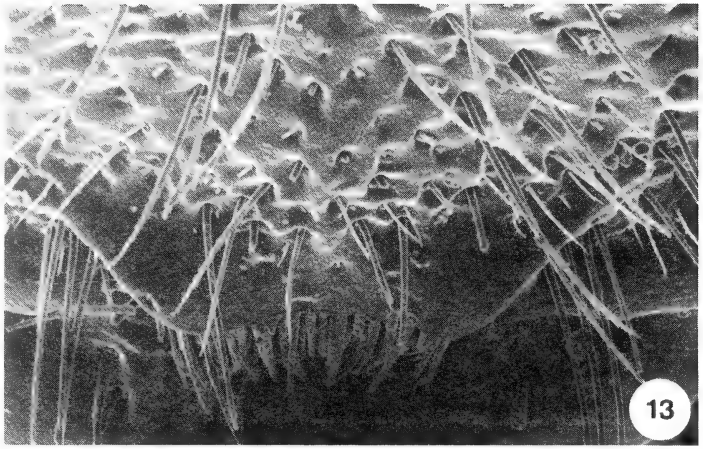

FIG. 13. *D. murrayanae*, moderately oblique margin of episternal process

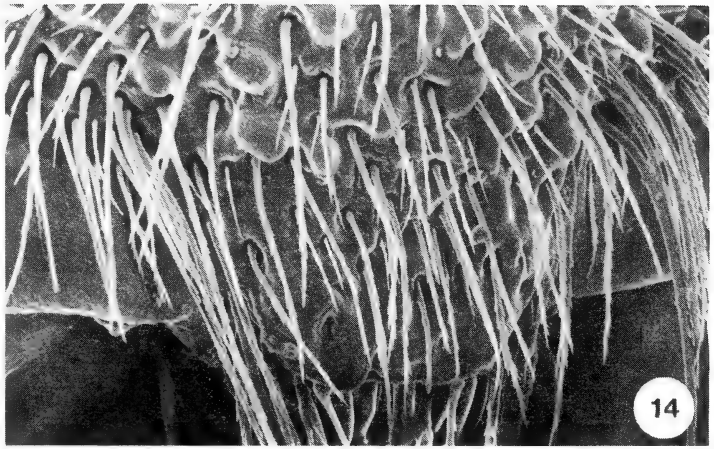

FIG. 14. *D. pseudotsugae*, strongly oblique margin of episternal process

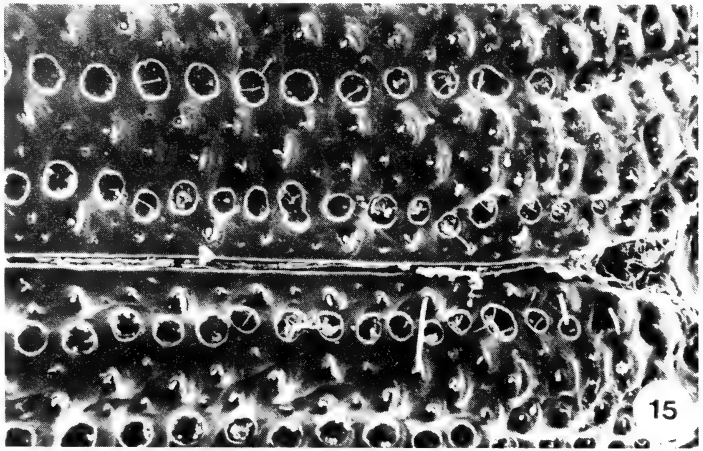

FIG. 15. *D. simplex*, moderately crenulate discal area

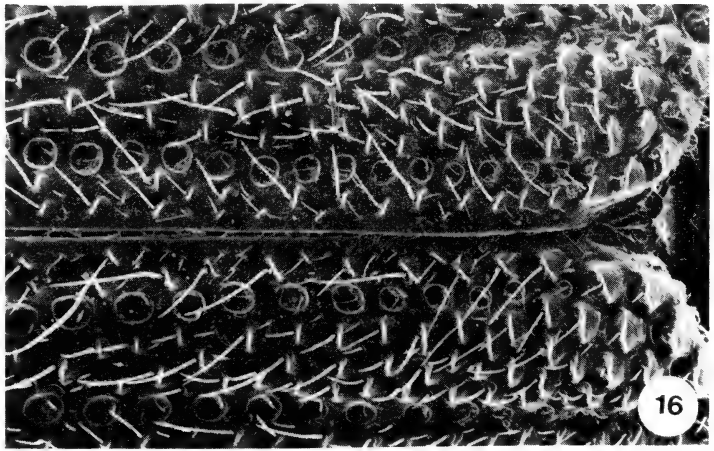

FIG. 16. *D. pseudotsugae*, strongly crenulate discal area

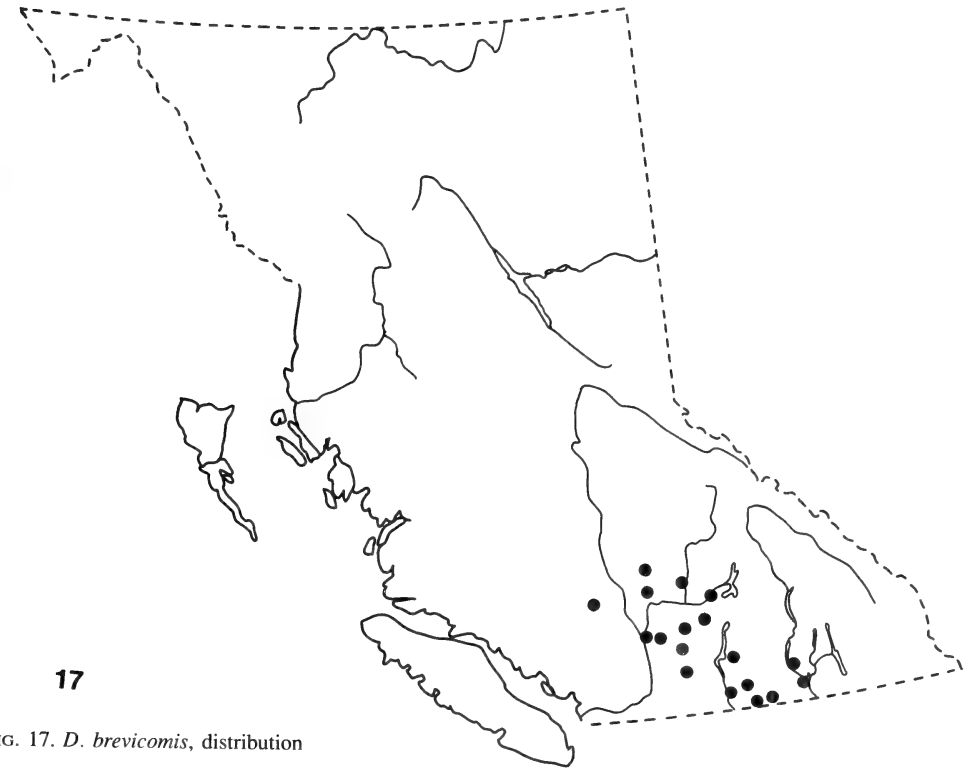

Fig. 17. *D. brevicomis*, distribution

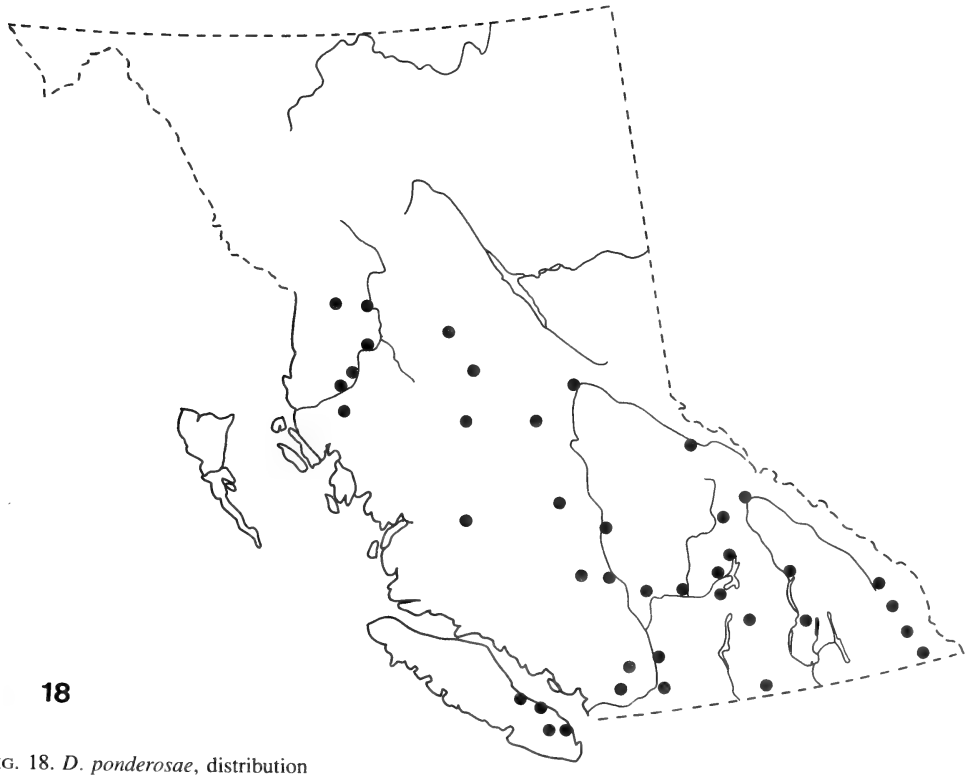

Fig. 18. *D. ponderosae*, distribution

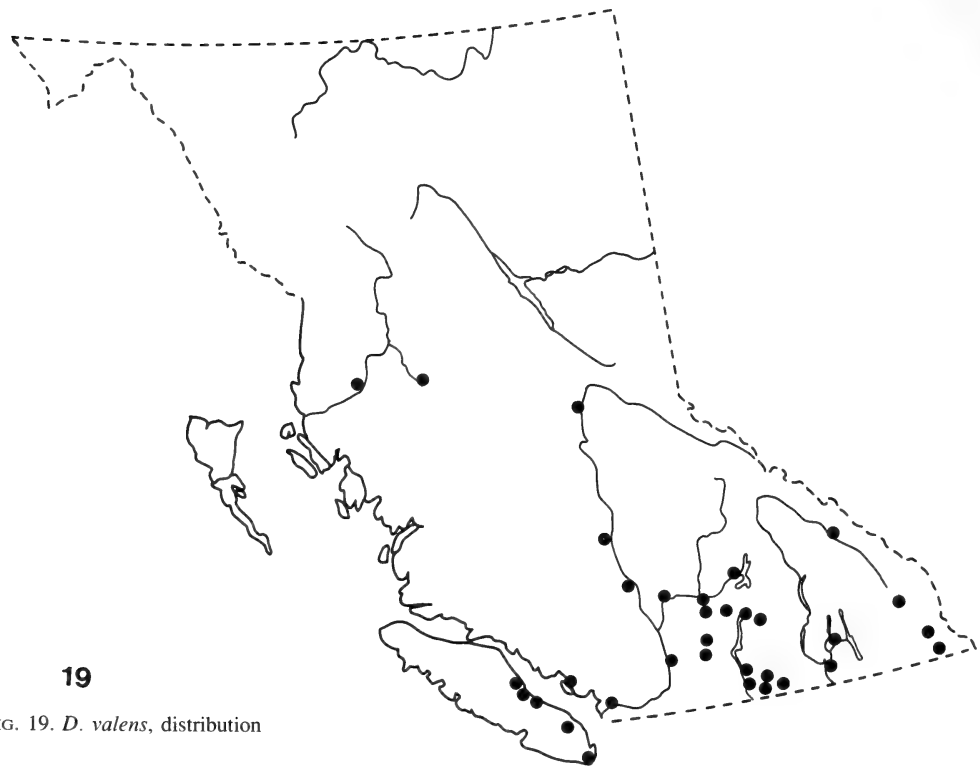

FIG. 19. *D. valens*, distribution

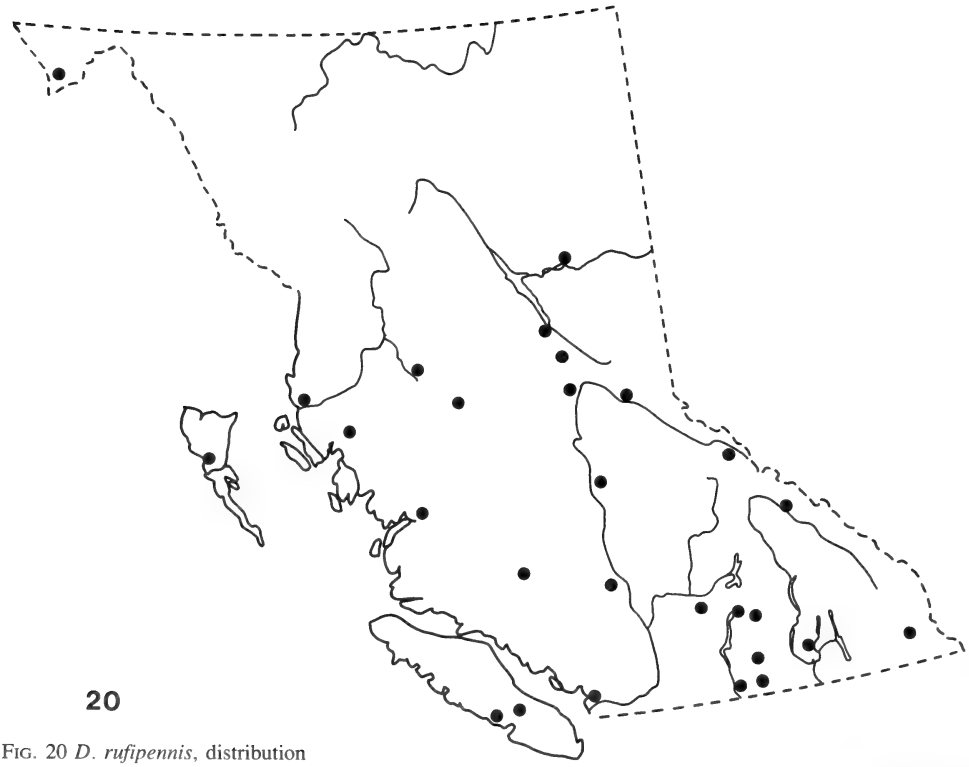

FIG. 20 *D. rufipennis*, distribution

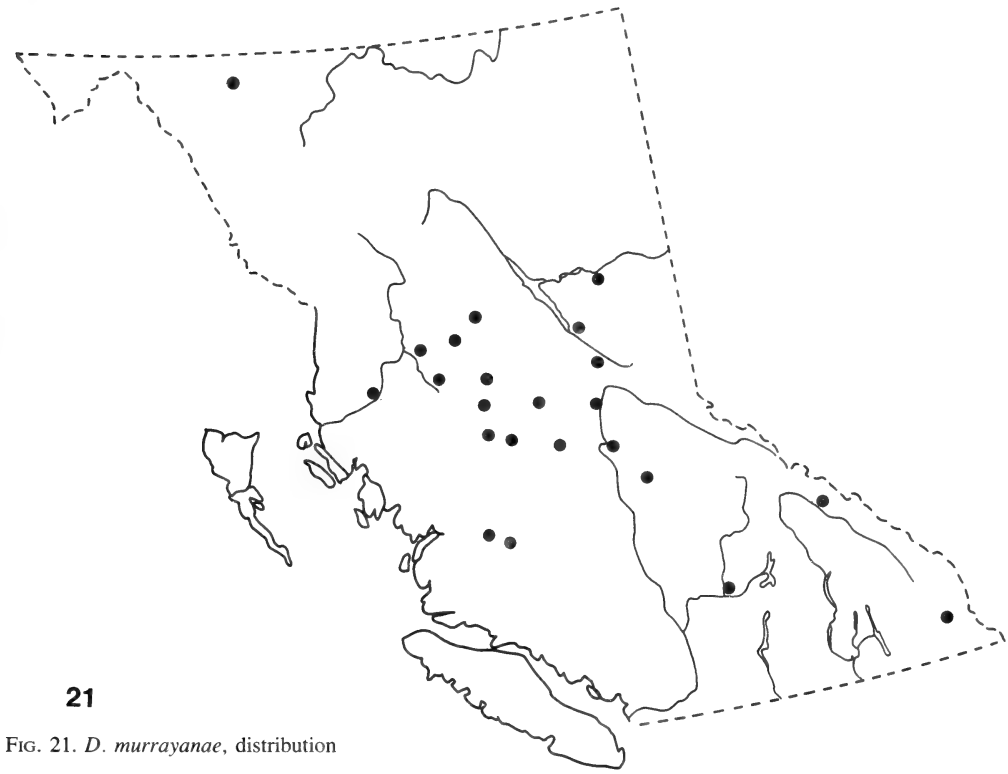

Fig. 21. *D. murrayanae*, distribution

Fig. 22. *D. punctatus*, distribution

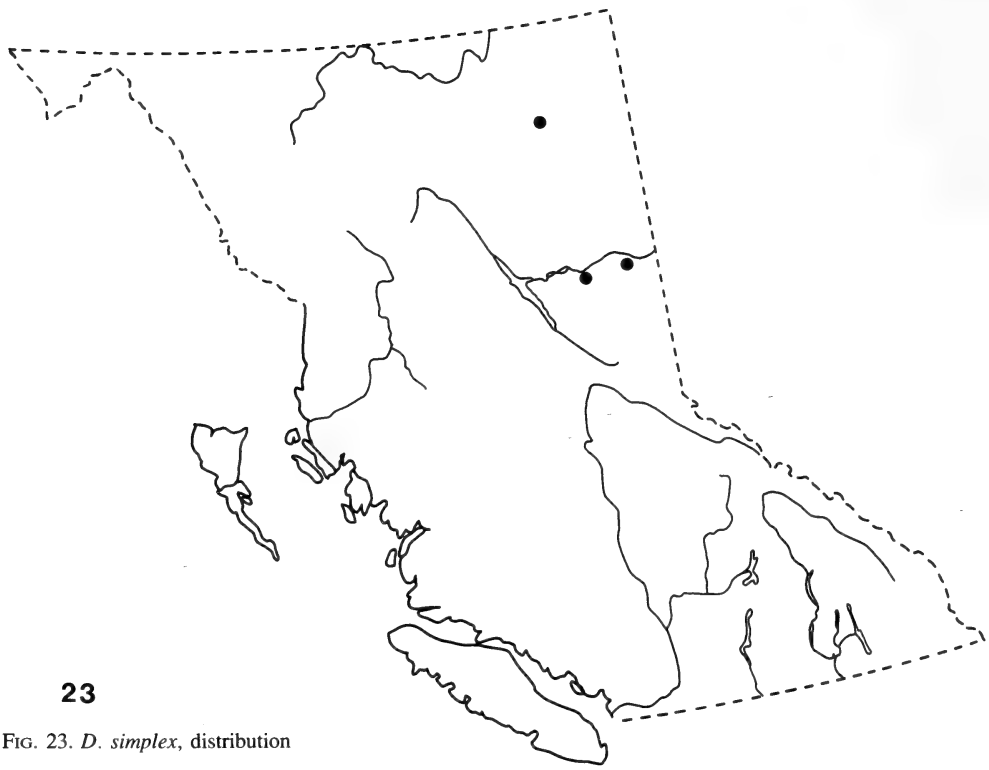

Fig. 23. *D. simplex*, distribution

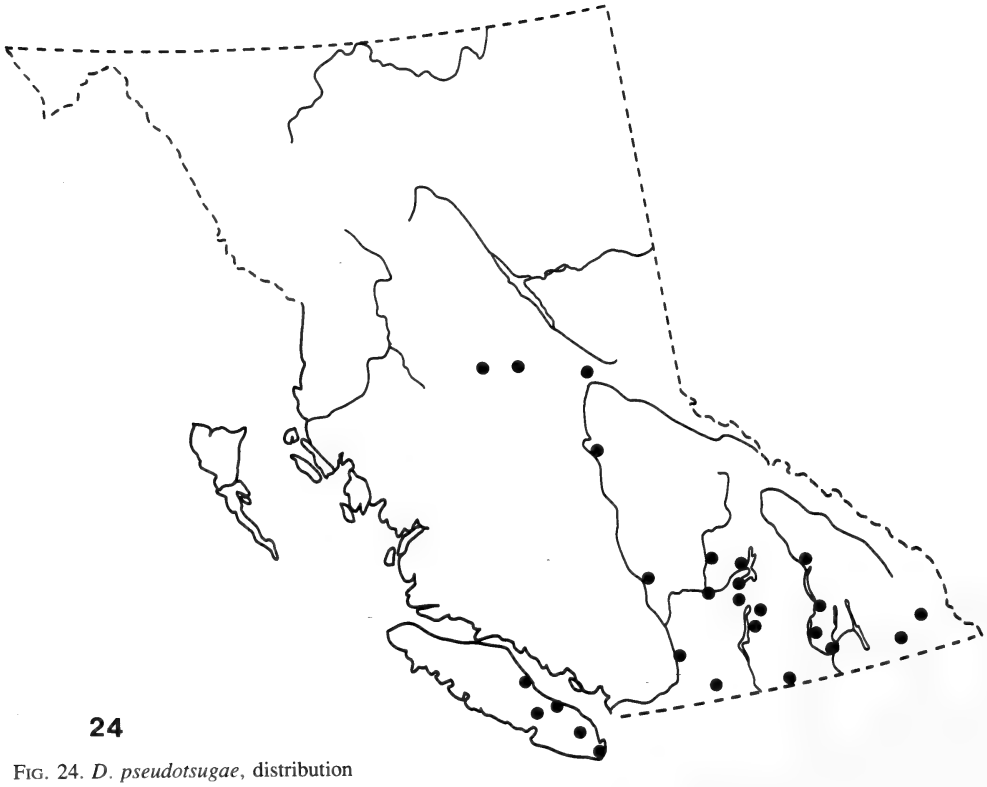

Fig. 24. *D. pseudotsugae*, distribution

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EFFICACY AND RESIDUES OF FOLIAR SPRAYS AGAINST THE LETTUCE APHID, *NASONOVIA RIBISNIGRI* (HOMOPTERA:APHIDIDAE), ON CRISPHEAD LETTUCE

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Agriculture Canada Research Station,
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ABSTRACT

The systemic insecticides disulfoton, oxydemeton-methyl and demeton, were highly effective in controlling the lettuce aphid, *Nasonovia ribisnigri* (Mosley) (Homoptera:Aphididae), when sprayed on crisphead lettuce at the early stage of heading. Total residues of disulfoton, applied at 1.12 kg AI/ha and oxydemeton-methyl at 0.56 kg AI/ha, diminished to less than 0.06 ppm 28 days after application, making these compounds strong candidates to replace the discontinued demeton. The local systemic compounds pirimicarb and methamidophos were intermediate in effectiveness between the systemics listed and contact insecticides such as endosulfan, mevinphos and parathion when applied to lettuce before the heading stage. Seven methods of applying methamidophos at 1.1 kg AI/ha all provided equally significant levels of lettuce aphid control.

INTRODUCTION

The lettuce aphid, *Nasonovia ribisnigri* (Mosley), has been a serious pest of crisphead lettuce in the lower Fraser Valley of B.C. since 1981 (Forbes and Mackenzie 1982). Unlike other lettuce infesting aphids, *N. ribisnigri* is particularly difficult to control at the heading stage with contact-action foliar sprays, since the preferred feeding niche of this pest is sheltered inside the head.

In 1982, several growers reported inadequate aphid control from certain insecticides registered for use against aphids on lettuce. Preliminary efficacy trials substantiated these reports (Mackenzie *et al.* 1982). These trials also showed that weekly applications of methamidophos alternately with pirimicarb, both local systemics, and interrupted at the start of heading by a single application of demeton, a systemic, would give excellent control of the lettuce aphid. This approach (B. C. Ministry of Agriculture and Food 1983) was adopted by growers following registration of pirimicarb in 1983. The demeton application was of key importance in that it provided systemic control of aphids protected within the newly-developing head. The overall effectiveness of this spray schedule, however, was threatened when demeton was withdrawn from the market in 1986.

In preliminary trials, disulfoton, a systemic, was highly efficacious when applied as a foliar spray to pre-heading lettuce. Total residues of disulfoton sprayed at a rate of 1.0 and 2.0 kg AI/ha just before the start of heading fell to less than the present tolerance level of 0.5 ppm in heads sampled 13 days later (Szeto *et al.* 1983). The primary objective of this study was to evaluate disulfoton as a suitable systemic replacement for demeton. Efficacy and residue studies were conducted for disulfoton, as well as for oxydemeton-methyl, a systemic compound structurally similar to demeton. These candidates were assessed for lettuce aphid control alongside a number of insecticides currently registered for use on lettuce.

A secondary objective of this study was to investigate the effect of different spray application techniques on aphid control. Several sprayer settings were compared for control efficacy using methamidophos at two stages of heading.

MATERIALS AND METHODS

Field trials were conducted at the Abbotsford Research Sub-station in 1985 and 1986. In all trials, crisphead lettuce, cv. Ithaca, was precision-seeded in beds, 1.75 m wide by 4 m long, with 4 rows per bed and 35 cm between rows. Adjacent and end-to-end beds were at least 1 m apart. Each bed was assigned a spray treatment, and each treatment was replicated four times, in a randomized complete block design.

Sprays were applied with a hand-pushed, CO_2-pressurized boom sprayer (R and D Sprayers Inc., Opelousas, La.). In the efficacy and residue trials, the spray boom was positioned 50 cm above ground and equipped with three, D4-25 hollow-cone nozzles (Spraying Systems Co., Wheaton, Ill.) spaced 60 cm apart. Treatments were delivered in 600 L of water/ha without spreader-sticker at a pressure of 690 kPa. Control plots were sprayed with water alone.

In all trials, treatments were assessed by examining four or six plants artificially infested with lab-reared *N. ribisnigri* (i.e. at least one infested plant/row in each bed). Plants of uniform size were arbitrarily selected for infestation within the centre 3 m of each bed. Treatments were assessed by cutting off marked plants at ground level and inspecting all leaves closely in the field for aphids.

TABLE 1. Efficacy of sprayed insecticides applied to lettuce on 29 July before the start of heading for control of *N. ribisnigri*, Abbotsford B.C., 1986.

		Number of Lettuce Aphids					
		Alatae		Apterae		Total	
Treatment	Rate (kg AI/ha)	1 Aug.[1]	5 Aug.	1 Aug.	5 Aug.	1 Aug.	5 Aug.
Demeton 240 EC	0.56	8	4	9	23	17 a[2]	27 ab
Disulfoton 720 EC	1.12	3	4	1	7	4 a	11 a
Endosulfan 4 EC	0.84	3	12	28	46	31 a	58 bcd
Methamidophos 480 EC	1.10	2	10	7	33	9 a	43 abcd
Mevinphos 6 EC	0.25	9	15	14	100	23 a	115 e
Parathion 800 EC	0.34	6	12	24	64	30 a	76 cd
Pirimicarb 50 WP	0.25	5	16	5	17	10 a	33 abc
Check	–	21	14	83	68	104 b	82 d

[1] Examination date.

[2] Numbers within a column followed by the same letter are not significantly different according to Duncan's multiple range test, $P < .05$.

Insecticide Efficacy: Pre-Heading Spray Trial

The efficacy of disulfoton was compared with that of demeton and other registered lettuce insecticides in a lettuce planting seeded 19 June, 1986. Just after thinning on 17 July, five lab-reared *N. ribisnigri* apterae were released onto each of four plants selected in each replicate. A subsequent release of 20 more aphids/plant was made on 24 July. Five days after the second release, spray treatments were applied on the early morning of 29 July before the plants had started heading (Table 1). Aphid mortality was assessed on two occasions. Two of the four infested plants/replicate were examined on 1 August ($\bar{X}$ = 10 leaves/plant), and again on 5 August ($\bar{X}$ = 12 leaves/plant) prior to the onset of heading.

Insecticide Efficacy: At-Heading Spray Trial

Two rates of disulfoton and one of oxydemeton-methyl were compared with the registered insecticides demeton and endosulfan in a lettuce planting seeded 2 July, 1985. On 13 and 16 August, just after the start of head formation ($\bar{X}$ = 15 leaves/plant), ten apterae were released onto each of six plants selected in each replicate. After the second release, the aphids were allowed four days to become established on the plants ($\bar{X}$ = 18 leaves/plant) before sprays were applied on the evening of 20 August (Table 2). Aphid mortality was assessed in the field on 22 and 23 August by close inspection of all 24 infested plants/treatment.

Residue Analyses: Disulfoton and Oxydemeton-methyl

The degradation of disulfoton and oxydemeton-methyl residues were monitored in lettuce plantings seeded on 10 and 20 June, and 2 July, 1985 (plantings 1, 2 and 3 respectively). Sprays were applied in the evening of 20 August, 1985 (Table 3) when planting 1 was approximately a week from maturity, planting 2 was in the early heading stage, and planting 3 was at a stage just before heading.

TABLE 2. Efficacy of sprayed insecticides applied to lettuce on 20 August at the start of head development for control of *N. ribisnigri*, Abbotsford B.C., 1985.

Treatment	Rate (kg AI/ha)	Total No. of Lettuce Aphids[1]			Percent Aphid Mortality
		Alive	Dead	Total	
Disulfoton 720 EC	0.56	13 a[2]	43 NS[3]	56 NS	76.8
Disulfoton 720 EC	1.12	4 a	71	75	95.0
Oxydemeton-methyl 240 EC	0.56	8 a	54	62	87.1
Demeton 240 EC	0.56	14 ab	35	48	72.9
Endosulfan 4 EC	0.84	22 ab	47	69	68.1
Check	–	65 b	8	73	11.0

[1] 2 Days after spray application.

[2] Numbers within a column followed by the same letter were not significantly different according to Duncan's multiple range test, $P < .05$.

[3] NS: none of the numbers within a column were significantly different according to analysis of variance (ANOVA), $P < .05$.

TABLE 3. Residues of disulfoton and oxydemeton-methyl after foliar spray in three lettuce plantings at different stages of growth, Abbotsford B.C., 1985.

Treatment and Rate (kg AI/ha)	Planting Number	Days From Spray Date to Sample Date	Residues in ppm (Fresh Weight)		
			DSO_2[1]	$DOASO_2$[1]	Total
A. Disulfoton					
1.12	1	6	1.69	0.83	2.52
1.12	2	15	0.13	0.27	0.40
1.12	3	28	TR[2]	0.01	0.01
Check	1	6	0.01	0.03	0.04
Check	2	15	ND[2]	TR	TR
Check	3	28	ND	ND	ND
B. Oxydemeton-methyl			–	$ODMSO_2$[3]	–
0.56	1	6	–	5.84	–
0.56	2	15	–	1.36	–
0.56	3	28	–	0.06	–
Check	1-3	as above	–	ND	–

[1] DSO_2: disulfoton sulfoxide; $DOASO_2$: disultoton oxygen analogue sulfone.

[2] TR: trace amount of residue detected; ND: no residue detected.

[3] $ODMSO_2$: oxydemeton-methyl sulfone. Residues of the parent compound *i.e.* oxydemeton-methyl, were oxidized to the sulfone which then represented the total amount of residue in the crop.

One plant was arbitrarily selected for residue analysis from the centre 3 m of each of the 4 rows/bed (n = 16 plants/treatment). Pooled samples from each replicate were separately analyzed. Planting 1 was sampled 6 days post-spray; planting 2, 15 days post-spray; and planting 3, 28 days post-spray. Only the three outermost wrapper leaves from the selected plants were analyzed. Total residues of disulfoton were determined by a modification of the method reported by Szeto and Brown (1982). In the modified method, all toxic oxidative metabolites were further oxidized with $KMnO_4$ to their sulfones, and recoveries were better than 90%.

Influence of Application Protocol on Insecticide Efficacy

The importance of seven different spray application protocols in controlling *N. ribisnigri* with methamidophos, a registered insecticide, were tested in trials seeded on 12 and 23 June, 1986 (trials 1 and 2 respectively). In the application protocol considered optimum for lettuce aphid control, the sprayer was configured to deliver 600 L of water/ha at a pressure of 690 kPa, using 4 hollow-cone nozzles (orifice size D4-25), each positioned 50 cm above each row. These were used as reference settings (RS) to each of the remaining six protocols tested in which we introduced a single variable from the reference settings. Specifically, the variables were: 1) RS with three nozzles per bed (45 cm apart); 2) RS with nozzles 100 cm above each row; 3) RS spraying at 345 kPa; 4) RS applying 1200 L of water/ha; 5) RS with four flat fan nozzles (size 8003); and 6) RS with spreader-sticker (Super Spread, Reichold-Niagara Chemical Co. Burlington, Ont.). Methamidophos was applied at a rate of 1.1 kg AI/ha in all treatments except the check plots which received water alone applied at the reference settings.

On 25 and 29-30 July, ten lab-reared apterae were released onto each of four arbitrarily selected plants in the centre 3 m of each bed. After the second release, aphids were allowed eight days to become established on the plants before sprays were applied on the early morning of 8 August. Trials 1 and 2 were both in the heading stage (i.e. $\bar{X}$ = 21 and 16 leaves/plant, respectively) when the plants were examined on 11 and 12 August.

RESULTS

Insecticide Efficacy: Pre-Heading Spray Trial

Although a total of 400 aphids were released in each treatment, only 104 were counted in check plots two days after spraying. The drop in aphid numbers could have been a result of a sudden change in environment between the rearing facility and the field, physical dislodging of aphids from plants by water applied to the check plots, natural predation, or a combination of these. Nevertheless, differences between the check plots and insecticide treatments were discernable (Table 1).

All treatments significantly ($P< 0.05$) reduced total aphid numbers compared with check plots when aphid mortality was assessed three days after application. Significant differences between insecticides did not occur at that time, although aphid numbers were higher in plots sprayed with the contact insecticides parathion or endosulfan. Disulfoton was providing significantly ($P < 0.05$) better control than the check, parathion, endosulfan or mevinphos treatments when they were assessed seven days post-spray. This indicates that disulfoton will provide better residual control of *N. ribisnigri* than the registered contact insecticides commonly used on lettuce. Methamidophos, pirimicarb and demeton were intermediate in control between disulfoton and the contact insecticides.

Insecticide Efficacy: At-Heading Spray Trial

Plots treated with disulfoton at 0.56 and 1.12 kg AI/ha and oxydemeton-methyl at 0.56 kg AI/ha, had significantly ($P < 0.05$) fewer surviving aphids than in the check plots (Table 2). Although there were no significant differences between insecticide treatments in numbers of surviving aphids, disulfoton and oxydemeton-methyl at the higher rates provided the highest percent mortality.

Residue Analyses

In a previous trial, head wrapper leaves and 2.5 cm thick vertical slices from the middle of lettuce heads were analyzed for disulfoton residues (Szeto *et al.* 1985a). Residue levels were lower in the head slice samples two days after treatment than in head wrapper leaves 14 days after treatment. The wrapper leaves likely contained higher residues since they were directly sprayed with disulfoton. Therefore, sampling of only head wrapper leaves in the present study provides an overestimation of residues in the total head, and thus is a more conservative approach to determining potential residue hazard in lettuce.

The degradation of residues after application of disulfoton and oxydemeton-methyl are shown in Table 3. Total residues detected in lettuce sprayed with disulfoton at 1.12 kg AI/ha were below 0.5 ppm 15 days post-spray and 0.01 ppm 28 days post-spray. Trace amounts of disulfoton residues found in check plots six days post spray are likely due to low level spray drift. Total oxydemeton-methyl residues were only 0.06 ppm 28 days post-spray.

Influence of Application Protocol on Insecticide Efficacy

The degree of aphid control achieved with methamidophos applied using seven application protocols did not significantly differ between protocols (Table 4) in either of the two plantings treated at heading. Significant ($P < 0.05$) differences, however, did occur between the seven protocols and the check plots. When counts of aphids from the two plantings were totalled, the highest numbers were found in plots sprayed with either four fan nozzles or three hollow cone nozzles. Nozzle style and number/bed, therefore, may be more important in achieving acceptable control than the other sprayer configurations tested. The fewest aphids were found in plots sprayed either at the reference settings or in plots which received twice the volume of water in the spray mix than the reference volume. These data also show a difference in aphid control between treatments applied at different stages of head development. In planting 1 (late heading), a total of 60 aphids were found in treated plots compared with only 29 in planting 2 (early heading).

TABLE 4. Comparison of several sprayer configurations for control of *N. ribisnigri* with methamidophos, Abbotsford B.C., 1986.

	Number of Lettuce Aphids						
	Alatae		Apterae		Total		
Treatment	1[1]	2	1	2	1	2	Total of 1 and 2
Reference Settings[2]	2	0	2	2	4 a[3]	2 a	6
3 Nozzles	8	6	5	2	13 a	8 a	21
High Boom	6	0	5	3	11 a	3 a	14
Low Pressure	2	2	2	2	4 a	4 a	8
High Volume	2	1	3	0	5 a	1 a	6
Fan Nozzles	8	1	4	9	12 a	10 a	22
Sticker Added	2	1	9	0	11 a	1 a	12
Check	3	9	99	141	102 b	150 b	252

[1] Planting number. Planting No. 1 was seeded on 12 June, Planting No. 2 on 23 June, 1986.

[2] See text for an elaboration on the sprayer settings.

[3] Numbers within a column followed by the same letter were not significantly different according to Duncan's multiple range test, $P < .05$.

DISCUSSION

Since a serious outbreak of lettuce aphids in 1982, the Lower Fraser Valley market has imposed a zero threshold for living or dead aphids on harvested head lettuce. Successful control of the lettuce aphid is dependent on routinely and accurately timing specific insecticide sprays with specific stages of crop growth (Mackenzie 1986). Prior to heading, when plants are small and aphids more exposed to insecticide sprays, local systemics such as methamidophos and pirimicarb can achieve almost complete aphid control (Mackenzie 1986). As shown in this study, the local systemics mentioned provided better control than did a number of commonly

used contact-action insecticides (Table 1). It is reasonable to assume that local systemics applied routinely and at optimal sprayer settings to lettuce in the pre-heading stage will provide the complete aphid control necessary up to the heading stage.

If aphids are present when the heads begin to form, they are protected within the enclosed leaves from foliar sprays and cannot be completely controlled thereafter. Incomplete aphid control at the heading stage has been observed when growers used non-prescribed insecticides, applied the insecticides incorrectly, or omitted key spray applications. The prescribed use of demeton at the early stage of heading (B. C. Ministry of Agriculture and Food 1983) was to provide systemic control of any aphids not controlled during the pre-heading stage of plant growth. The demeton application, followed by additional routine applications of methamidophos and pirimicarb has proven to be highly efficacious in keeping lettuce heads free from aphids until harvest. Since the manufacture of demeton was discontinued in 1986, the continuing success of the spray program now depends on replacing demeton with an equally efficacious systemic insecticide. The present study shows that disulfoton (Tables 1 and 2) and oxydemeton-methyl (Table 2) are equal to, or better than demeton in controlling lettuce aphids at the early stages of heading. In addition, data presented here, and other data (Szeto *et al.* 1985a and 1985b) indicate that residues of disulfoton fall below the maximum residue limit of 0.5 ppm in lettuce within 28 days of foliar application, and that total residues of oxydemeton-methyl fall to 0.13 ppm. Since heading usually begins about 35 days before harvest, a single application of either disulfoton or oxydemeton-methyl in place of demeton would allow sufficient time for total residues of either insecticide to decline well below allowable limits in harvested heads.

It appears from the spray application protocol study that differences in sprayer configuration may give rise to some variation in efficacy. Although differences in control levels between protocols were small (Table 4) even minor differences are important when virtually complete aphid control is needed. Therefore, in addition to the correct selection and timing of insecticide sprays, attention should be paid to selecting sprayer configurations that will provide the best control.

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REFERENCES

British Columbia Ministry of Agriculture and Food. 1983. Vegetable Production Guide for Commercial Growers. Victoria, B.C.

Forbes, A.R. and J.R. Mackenzie. 1982. The lettuce aphid, *Nasonovia ribisnigri* (Homoptera:Aphididae) damaging lettuce crops in British Columbia. J. Entomol. Soc. Brit. Columbia 79: 28-31.

Mackenzie, J.R., R.S. Vernon, S.Y. Szeto, and M.J. Brown. 1982. Lettuce aphid control with foliar sprays. Pesticide Research Report, Expert Committee for Pesticide Use in Agriculture.

Mackenzie, J.R. 1986. Improved insect pest management for crisphead lettuce grown in S.W. British Columbia. Master of Pest Management Professional Paper, Simon Fraser University, Burnaby, B.C.

Szeto, S.Y. and M.J. Brown. 1982. Gas-liquid chromatographic methods for the determination of disulfoton, phorate, oxydemeton-methyl, and their toxic metabolites in asparagus tissue and soil. J. Agric. Food Chem. 30(6):1082 -1086.

Szeto, S.Y., J.R. Mackenzie, M.J. Brown, and R.S. Vernon. 1983. The degradation of disulfoton in lettuce after applications for control of the lettuce aphid, *Nasonovia ribisnigri* (Mosley) J. environ. Sci. Health. B18(6): 725 - 734.

Szeto, S.Y., R.S Vernon, and J.R. Mackenzie. 1985a. Residues of disulfoton inlettuce after foliar application - Study I. Pesticide Research Report, Expert Committee for Pesticide Use in Agriculture.

Szeto, S.Y., R.S Vernon, and J.R. Mackenzie. 1985b. Residues of oxydemeton-methyl in lettuce after foliar application - Study I. Pesticide Research Report, Expert Committee for Pesticide Use in Agriculture.

SAMPLING FOR DISTRIBUTION OF THE LETTUCE APHID, *NASONOVIA RIBISNIGRI* (HOMOPTERA:APHIDIDAE), IN FIELDS AND WITHIN HEADS

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ABSTRACT

The lettuce aphid, *Nasonovia ribisnigri* (Mosley), is the most serious pest of crisphead lettuce in the lower Fraser Valley of British Columbia. To develop an efficient monitoring program, several fields of commercially grown head lettuce (cv. Ithaca) were inspected to determine the spatial distribution of the aphids. Infested plants were scattered in the fields but most often were near the margins. Therefore, to monitor for infestations, sampling should be confined to plants around the perimeters of commercial lettuce fields. Distribution within the heads was studied by infesting young plants and inspecting the leaves individually at harvest. Significantly more lettuce aphids were found on the wrapper leaves and just inside the lettuce heads than on the outer or the innermost leaves.

INTRODUCTION

The lettuce aphid, *Nasonovia ribisnigri* (Mosley), is at present the most serious insect pest of field-grown, crisphead lettuce in the lower Fraser Valley of British Columbia. The morphology and local life history of this aphid was described by Forbes and Mackenzie (1982). The aphid, which has not yet been documented as a pest elsewhere in North America, first appeared as a pest on lettuce in British Columbia late in the 1981 growing season, when the crop losses on three farms amounted to $20,000 (Cdn.). In 1982, all lower Fraser Valley growers were affected, and a $2,000,000 reduction in marketable heads occurred. Unlike other lettuce-infesting aphids such as the green peach aphid, *Myzus persicae* (Sulzer), and the potato aphid, *Macrosiphum euphorbiae* (Thomas), that prefer the older, outer leaves of head lettuce, *N. ribisnigri* colonizes leaves inside the developing heads. Once inside the heads, the aphids cannot be controlled with available aphicides, and their presence at harvest makes the lettuce unmarketable (Forbes and Mackenzie 1982). Since 1982, the market tolerance for aphids of any species on harvested lettuce heads in the lower Fraser Valley has been set at zero.

To ensure that commercial lettuce remained aphid-free until harvest, a stringent spray routine was undertaken by the affected growers in 1983. The program involved weekly applications of local systemic aphicides, pirimicarb and methamidophos, interrupted by a single pre-heading application of the fully systemic aphicide, demeton. This procedure, although intensive, has successfully prevented further crop losses.

For the spray program, monitoring was needed to give the growers current information on outbreaks and the efficacy of the control measures. With available manpower limited to one person, and a zero market tolerance for lettuce aphids, the monitoring program was designed to locate infested plants quickly and efficiently.

This paper examines the distribution of lettuce aphids in order to identify infested areas within the fields. The distribution of lettuce aphids within the plants was examined to identify their preferred niche. The method of sampling developed optimized efficiency of sampling and precision of results under the given constraints on manpower and the market tolerance for aphids.

MATERIALS AND METHODS

Field Distribution

Distribution of the aphid in the field was studied by intensively sampling 4 commercial-scale plantings of crisphead lettuce (cv. Ithaca) near Cloverdale, an agricultural region with highly organic soil in the lower Fraser Valley of B.C. Here lettuce is normally planted in raised beds, with four rows of lettuce in each bed. The rows are 35 cm apart, the bed centers 175 cm apart, and the plants within rows thinned to 30 cm spacings. When samples were taken all four

fields were at stages of growth between thinning (about five leaves per plant) and head initiation (about 15 leaves per plant).

Field 1 (31 beds by 120 m long; 0.65 ha) was seeded July 16, 1982 and was not sprayed before being sampled at the nine-leaf stage on 18 August. Every third bed was sampled (i.e. beds 1, 4, 7, ... 31), with one plant being removed from the center of each 20 m interval along each bed. Each plant was selected at random from among the four rows per bed, and destructively examined for aphids. Aphid counts were expressed as the number of living aphids/plant at each sample site.

Fields 2-4 were sampled during an outbreak of lettuce aphids in 1984. In these fields, four adjacent plants, one per row, were examined *in situ* midway along each 10 m of bed. Since Fields 2-4 were sprayed prior to sampling, both living and dead aphids were recorded. Field 2 (21 beds by 220 m long; 0.81 ha) was sampled at the 13 leaf stage on 17 July along five beds. Aphid counts were expressed as the number of living and dead aphids/plant on four plants at each sample site. In Field 3, (28 beds by 210 m long; 1.03 ha), four evenly spaced beds were sampled at the 11 and 13 leaf stage, respectively, on 12 July. In these fields, the number of infested plants of the four examined at each sample site were recorded. A total of 66 plants were examined in Field 1, 460 in Field 2, 384 in Field 3, and 272 in Field 4.

For Fields 1-4, the spatial distribution data were summed by columns (beds) and rows (intervals from which samples were taken along the bed), analyzed by ANOVA and compared by Duncan's multiple range test (Duncan, 1955) when appropriate. Fields 1-4 are equated with Figures 1-4.

Chi-square (Maxwell 1961) was used ($P = 0.05$) to determine differences between sites near the margins of Fields 1-4 (outer sites) and those located near the centres of the fields (inner sites). In Field 1, for example, the outer sites were those in the two outermost beds and the samples taken close to the ends of non-peripheral beds. Inner sites were all those remaining. In all four fields, data were subjected to log transformation before analysis.

In 1982, 26 commercial plantings were monitored for lettuce aphids. The plantings were about 200 m long and ranged from 13-20 beds in width. Within each planting, the two outermost beds and a bed mid-way between the other two were sampled. Within 50 m intervals along each sampled bed, a plant was arbitrarily chosen and destructively examined. The data from all the plantings were compiled and expressed as the mean number of infested plants/50 m interval/outside or inside sites.

Distribution Within Plants

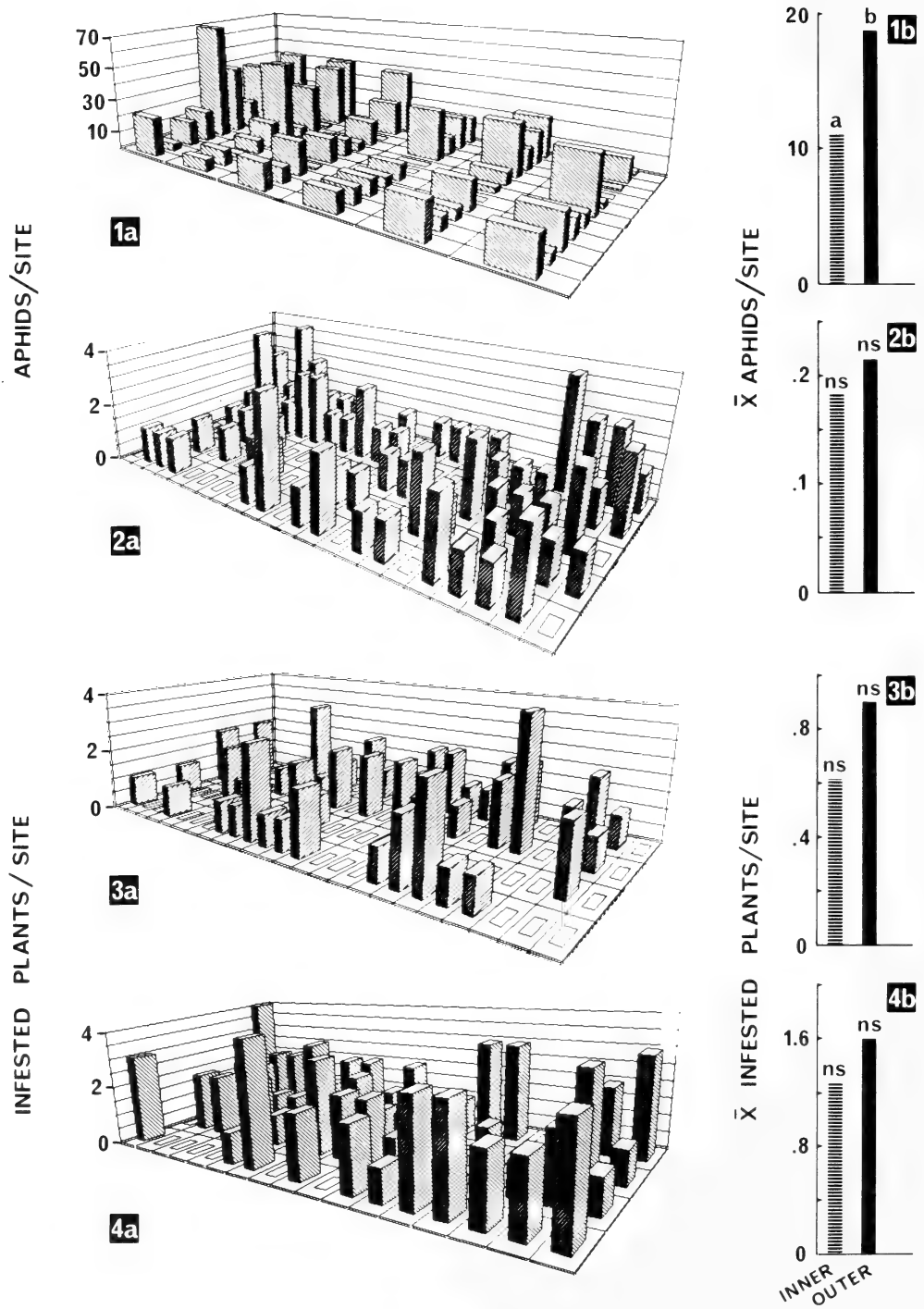
Crisphead lettuce, (*cv.* Ithaca), was seeded on 22 June, 1984 at Abbotsford, B.C. in a 0.12 ha field. The field was divided into four blocks, and within each block 26 plants were selected at random and marked; on 5, 9, 13, and 16 July five lettuce aphids were released on each of the marked plants to simulate an interval of recurring aphid migration and to ensure plants were colonized. Releases were made before the plants had produced five secondary leaves, well before the heading stage. At harvest (29 August), 6-7 plants from each block were examined by sequentially numbering and inspecting each plant leaf for lettuce aphids. The outermost leaf was leaf number 1, and the average number of leaves/plant was 32 (range 27-33). The cumulative number of aphids found alive on each leaf of the plants examined was averaged and expressed as the mean number of aphids/leaf number x, where x ranged from 1 to 33.

The aphid numbers within the plants were stratified according to the main leaf types comprising a lettuce plant at harvest: the loose outer leaves (1 to 12); the wrapper leaves (13 to 17); and the head leaves (18 to 33). Aphid counts were compiled by leaf type, analyzed by ANOVA, and compared by Duncan's multiple range test (Duncan 1955).

RESULTS AND DISCUSSION

Distribution Within Fields

In Fields 1-4, (Figs. 1a-4a, respectively), an analysis of variance between rows and columns was conducted and differences compared by Duncan's multiple range test. Either no significant differences were apparent (Field 4), or significantly ($P < 0.05$) greater numbers of aphids or infested plants were found in one or more outer rows or columns (Fields 1, 2 and 3).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Figs. 1-4. Infestation of fields of crisphead lettuce by *N. ribisnigri* in the lower Fraser Valley of British Columbia.

Fig. 1a) Counts of living aphids on four plants/sample site, using 66 plants in all from Field 1, at the 9-leaf stage, 18 Aug., 1982; 1b) Chi-square comparison of mean numbers of aphids/inner vs outer field sites; 2a) Counts of living and dead aphids on four plants/sample site, using 460 plants in all from Field 2, at the 13-leaf stage, 17 July, 1984;2b) As for Fig. 1b; 3a) Counts of infested plants out of four/sample site using 384 plants in all from Field 3, at the 11-leaf stage, 12 July, 1984; 3b) Chi-square comparison of mean numbers of infested plants/inner *vs* outer field sites; 4a) Counts of infested plants out of four/sample site using 272 plants in all from Field 4, at the 13-leaf stage, 12 July, 1984; 4b) As for Fig. 3b.

Overall, the number of instances in which an outer row or column had significantly more aphids or infested plants than an inner row or column was 14 in contrast to only 3 for the opposite case. When the data were examined on the average numbers of aphids or infested plants found near the outer as compared to the inner sites, more infested plants were found at the margins of all fields (Figs. 1b-4b). Only in Field 1, however, were there significantly more aphids at peripheral sites ($\chi^2 = 3.841$; df = 1, $P < 0.05$).

Records from 26 monitored commercial plantings in 1982 (unpublished data) confirmed that outer sites of plantings tended to be more heavily infested than inner sites. Overall, the average number of infested plants found at outer sites (0.35) was 25% greater than the number of infested plants found well inside the fields (0.26).

Distribution Within Plants

A total of 3,592 lettuce aphids were counted in the 26 infested plants examined at harvest. Of this total, 430 (12%) were found on the outer leaves, 2,111 (59%) on the wrapper leaves, and 1,051 (29%) were found within the heads (Fig. 5). Significantly more aphids were found on the five wrapper leaves and first five head leaves than on the outer leaves or innermost head leaves. Where the occasional plant was infested with both lettuce and green peach aphids, we observed a well defined transition from the latter on the outer leaves, to the former on the wrapper leaves, at about leaf 13. The preferred habitats of these 2 species in lettuce appear to be quite distinct. On lettuce inspected before the heading stage in several commercial

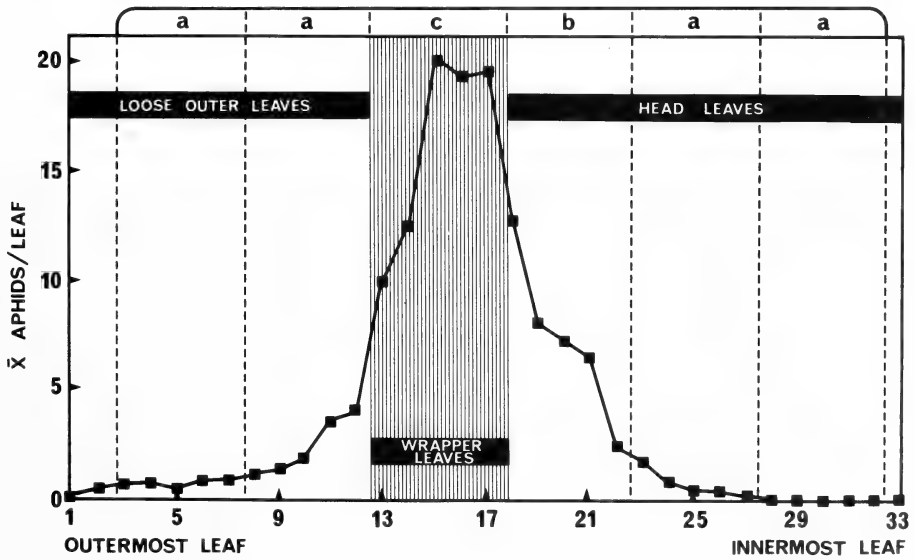

Fig. 5. Mean numbers of *N. ribisnigri* observed on leaves of 26 crisphead lettuce plants (*cv.* Ithaca) at harvest, 68 days after seeding. Groups of leaves marked with the same letter are not significantly different (Duncan's multiple range test: $P < 0.05$).

plantings, *N. ribisnigri* alates or apterae were most frequently observed on the youngest leaves near the middle of the plants.

Sampling Program for *N. ribisnigri*

The studies of field distribution reported here indicated that samples taken along the outermost beds on either side of a lettuce planting would be equal to, or better than, samples taken within a planting for detecting plants infested with *N. ribisnigri*. Since the market tolerance for all aphids is zero, and manpower for sampling is often severely limited, restricting monitoring to the perimeters of plantings would be efficient and overestimate the mean population of the entire planting.

The study of aphid distribution in plants showed that lettuce may be infested by *M. persicae* on the outer leaves and *N. ribisnigri* on the middle and inner leaves. Since the zero tolerance applies to all aphid species, lettuce plants must be completely inspected *in situ*, for all species living above-ground. A method of non-destructive sampling is required, since many samples may be taken between thinning and heading in commercial plantings (Dun 1984). This can be accomplished with moderate ease prior to the heading stage by gently prying apart the leaves for inspection. Once the head begins to form, however, plants can only be effectively examined destructively, requiring that sampling intensity be either reduced or stopped to avoid direct crop losses. The usefulness of monitoring after heading is questionable anyway, since *N. ribisnigri* infestations cannot be controlled once heads have formed.

In 1984, an industry-wide pilot monitoring program was implemented in the lower Fraser Valley, with about 127 lettuce plantings (a cumulative total of 560 ha) being examined for aphids over a 4-month period by a single person (Dun 1984). Four lettuce plants were examined *in situ* every 10 m along the outer perimeters of each planting from the thinning to the heading stage. This routine allowed the worker to visit each planting at least once a week, to inspect 100-150 plants/visit. This sample size was adequate, since the objective of monitoring was to ensure that pre-scheduled sprays (British Columbia Ministry of Agriculture and Food 1984) were being applied correctly and at the right time, rather than to determine if sprays were needed. In 1984, the sampling approach was very effective in locating aphids in lettuce in early stages of infestation, and unsatisfactory spray routines were identified and corrected. Since 1984, growers following the advice resulting from this sampling strategy have prevented crop loss attributed to aphids.

If the present level of aphid control on lettuce is maintained, it is likely that the strict intolerance for aphid infested lettuce at harvest will eventually be relaxed. Once this occurs, it will be possible to modify the existing monitoring program to assist growers in witholding insecticide sprays, and reducing the total number of sprays applied to a lettuce crop. A sequential sampling program based on more conservative action thresholds has been proposed by Mackenzie (1986). The proposed program reduces labour in years of high *N. ribisnigri* infestation, and reduces the number of sprays applied in years of low infestation.

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REFERENCES

British Columbia Ministry of Agriculture and Fisheries. 1984. Vegetable production guide for commercial growers. Victoria, B.C.

Dun, W. 1984. The application of IPM to lettuce production in B.C. Demonstration of Agricultural Technology and Economics Project No. 99, Unpub. report. B.C. Ministry of Agriculture and Fisheries, Surrey, B.C.

Duncan, D. B. 1955. Multiple range and multiple *F* tests. *Biometrics* 11: 1-42.

Forbes, A. R., and J. R. Mackenzie. 1982. The lettuce aphid, *N. ribisnigri* (Homoptera: Aphididae) damaging lettuce crops in British Columbia. *J. Entomol. Soc. Brit. Columbia* 79: 28-31.

Mackenzie, J. R. 1986. Improved insect pest management for crisphead lettuce grown in S. W. British Columbia. Master of Pest Management Professional Paper, Simon Fraser University, Burnaby, B.C.

Maxwell, A. E. 1961. Analysing quantitative data. John Wiley and Sons Inc., New York.

COMPARISON OF BINOCULAR AND CUT-BRANCH METHODS FOR ESTIMATING BUDWORM DEFOLIATION OF DOUGLAS-FIR

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Abstract

Defoliation caused by the western spruce budworm, *Choristoneura occidentalis* Freeman, was estimated on 91 Douglas-fir trees *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco, by both close examination of cut-branches and by observation with binoculars. For individual trees the accuracy attained with the binoculars was within 23% for current year's and 19% for foliage of all ages, with respect to the estimates made from cut branches. Inaccuracy was found to be mainly due to lack of precision as bias was minimal. When the trees were assigned, by each method, into the broad defoliation classes of light (1-25%), moderate (26-65%), and severe (66-100%), as used in forest insect surveys in British Columbia, the results agreed in 89% of the trees studied for defoliation estimates of current foliage and 68% of the trees for defoliation of total foliage. Classification of the location averages into severity classes agreed for all 5 locations studied for damage to current and total foliage. We concluded that the binocular method is a quick and useful means of classifying stands into broad defoliation severity classes, but is not suitable if a high degree of accuracy and precision is needed.

Résumé

Par l'examen physique de branches coupées et l'examen à la jumelle, on a évalué la défoliation causée par la tordeuse occidentale de l'épinette (*Choristoneura occidentalis* Freeman) à 91 douglas taxifoliés (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco). pour chaque arbre, la fidélité des évaluations à la jumelle ne s'écartait pas de plus de 23 %, pour le feuillage de l'année, et de 19 %, pour le feuillage total (feuillage de tous les âges), des évaluations sur les branches coupées. Il a été constaté que l'inexactitude est principalement liée au manque de précision, car l'erreur systématique est minime. Lorsqu'on on distribué les arbres dans les grandes classes de défoliation (légère [1-25 %], modérée [26-65 %] et grave [66-100] %), de l'inventaire des insectes forestiers en Colombie-Britannique, les résultats concordaient pour 89 % des arbres évalués pour la défoliation du feuillage total. En outre, le classement de cinq stations selon les mêmes critères a donné dans chaque cas un résultat identique, pour les deux types de feuillage. La jumelle est donc un moyen rapide et utile de classer les peuplements en grandes classes de défoliation, mais elle ne convient pas lorsqu'on recherche une fidélité et une précision élevées.

INTRODUCTION

Forest defoliator damage depends on the intensity and duration of the defoliation (Alfaro *et al.* 1982; Alfaro 1985). For this reason workers in forest pest management are often confronted with the need to measure the intensity of defoliation of individual trees or stands.

Several methods for individual trees have been developed and used to estimate defoliation by the eastern spruce budworm *Choristoneura fumiferana* (Clem.) in Canada (Sanders 1980; Dorais and Kettela 1982). The methods involving removal of branches and evaluation of defoliation by foliage age class (cut-branch method) (e.g. Fettes 1950) are considered to be the most accurate (MacLean and Lidstone 1982). These methods have the disadvantages of being slow, laborious and of needing cumbersome field equipment. They produce estimates that are unnecessarily precise for some survey purposes. More rapid estimates of percentage defoliation can be obtained by visual examination of the standing tree using the naked eye or binoculars. These estimates are relatively crude and subjective.

The purpose of this study was to examine how estimates of defoliation of Douglas-fir *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco caused by the western spruce budworm *C.*

occidentalis (Freeman), and made by a trained observer using binoculars, compared in accuracy and precision with estimates made by the cut-branch method.

METHODS

Both binocular and cut-branch estimates were made on a total of 91 Douglas-fir trees at five locations (Table 1), during late July and early August, 1980. The areas selected had a history of recent budworm damage and the trees sampled represented a wide range of defoliation intensities. These locations were located between the towns of Ashcroft and Clinton.

Binocular method

The upper crown half of each tree was scanned by an experienced observer using 7 X 50 binoculars. Separate estimates, to the nearest 5%, were made of the percentage defoliation of current year's (1980) and of older foliage (1979 and before).

Cut-branch method

Table 1. Number, mean diameter at breast height (DBH) and height of Douglas-fir trees sampled at five locations in British Columbia.

Location	No. of Trees	Mean (± s.e.)	
		D.B.H. (cm)	Height (m)
1. Veasy Lake	20	12.6 (0.5)	8.4 (0.2)
2. Hart Ridge	18	16.7 (0.6)	9.4 (0.3)
3. Loon Lake	19	15.0 (0.7)	9.0 (0.2)
4. Dude Ranch	10	14.8 (0.6)	10.1 (1.5)
5. Highland Valley	24	15.3 (0.9)	8.6 (0.4)
All Locations	91	14.9 (0.4)	9.0 (0.2)

Two 50 cm branches were cut from opposite aspects of the upper half of each tree crown. Defoliation was then separately estimated for each of the last three foliage age classes: current (grown in 1980), 1-year-old (grown in 1979), and 2-year-old (grown in 1978). All shoots in each of these age classes were counted and individually assigned to one of the following percentage defoliation classes (adapted from Fettes 1970), 0, 1-10, 11-20, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80, 81-90, 91-99, 100. The average defoliation for each of the 1978-1980 foliage age classes on each branch was calculated as the average of the defoliation classes of all shoots on the branch. For foliage grown in 1977 and before, shoots were not examined individually, but assigned as a whole to one of the 12 defoliation classes. Defoliation estimates of both branches were averaged to yield a single estimate for each foliage age class per tree.

Calculation of average tree defoliation

Average defoliation for each tree, by both binocular and branch methods, was calculated by weighting the defoliation measurement of each foliage age class by the proportion of the tree's foliage in that age class. We assumed that the amount of foliage in each age class was proportional to the number of shoots in that class. The number of shoots was counted on each branch sample for the last three foliage age classes (1978-1980). The number of shoots in the remaining foliage age classes in each branch were estimated by calculating, based on the available shoot counts, the average ratio of the number of shoots in one year to the number of shoots in the previous year. Separate ratios were developed for each locality; they varied from 1.2 to 1.6, and the average ratio for all localities combined was 1.4 (Table 2). Because of the branching pattern of Douglas-fir, the number of shoots in one age class is always greater than the number in the previous year's class. The method assumes that the ratios are constant from one year to the next.

Table 2. Average ratio of the number of shoots in one foliage age class to the number of shoots in the previous foliage age class, and percentage of all shoots in 50-cm branches by foliage age class in young interior Douglas-fir at five locations in British Columbia.

Location	Ratio	Percentage of shoots by foliage age class			
		Current	1-year-old	2-year-old	>2-year-old
1	1.3	25.4	24.2	16.6	33.8
2	1.3	23.0	23.4	16.0	37.6
3	1.4	30.2	23.3	16.1	30.4
4	1.2	24.4	21.0	16.1	38.5
5	1.6	37.5	25.5	15.9	21.4
All	1.4	29.0	23.8	16.1	31.1

For each branch, the number of shoots in the 1977 age class was calculated by dividing the shoot counts for 1978 by the average ratio for the locality where the branch was collected. The resulting number of shoots was again divided by the same ratio to obtain the 1976 shoot counts. This iterative process was repeated until the calculated shoot counts equaled 1 shoot, i.e. the initiation of the branch. This usually occurred after the calculation of the 6th or 7th foliage age class, which are the commonly observed number of age classes for Douglas-fir in interior British Columbia. Finally, shoot counts for all age classes in each branch were totaled and the percentages of this total that consisted of current shoots (1980), 1 year-old shoots, 2 year-old shoots and shoots older than two years were calculated (Table 2) and used as weighting factors in the tree defoliation calculations for both binocular and cut-branch estimates.

The binocular and cut-branch estimates of defoliation of both current year's and total foliage were compared using Freese's test of accuracy (Freese 1960) in which the accuracy of a new measuring technique is compared against an established or "true" method. In this study the binocular method was considered the new technique and the cut-branch the established method; cut-branch estimates are usually considered more accurate than binocular estimates (Fettes 1950; MacLean and Morgan 1981; MacLean and Lidstone 1982).

In the discussion that follows we use the terms "bias", "precision" and "accuracy" as defined in Freese (1962) where bias is a systematic distortion, accuracy refers to the success of estimating the true value of a quantity, and precision refers to the clustering of sample values around their own average. Accuracy, or closeness to the true value, may be absent because of bias, lack of precision or both.

As recommended by Freese (1960), the accuracy test was performed after removal of the bias. For this purpose, the linear regressions of the binocular estimates on the cut-branch estimates were calculated for both the current and total defoliation estimates. Then, the following χ^2 value was tested against the tabular $\chi^2(P = 0.05)$ (Freese (1960).

$$\chi^2_{(n-2)df} = \text{Residual SS}/\ \sigma^2$$

where:

Residual SS = the regression residual sum of squares
σ^2 = the hypothesized variance calculated as:

$$\sigma^2 = E^2 / t^2$$

where:

E = required accuracy (expressed in the same units as the mean)
t = standard normal deviate

In this study, the binocular method was considered accurate if it provided estimates that were within 10% of the cut-branch estimates (E = 10%).

After testing the accuracy using the 10% defoliation criterion selected (E), Freese's equation was rearranged, solving for E, to determine the accuracy achieved by the binocular estimates, as compared with the cut-branch estimates, for each location.

RESULTS

The average foliage distribution by age class for all locations (Table 2) agreed very closely with Silver's (1962) estimates for coastal Douglas-fir *P. menziesii* var. *meeenziesii* (Mirb.) Franco of 28, 23, 17, and 32% for current, 1 year-old, 2 year-old, and older foliage, respectively. Mitchell (1974) found a larger proportion of current and 1 year-old foliage than in Silver's or our study with his comparative values of 43, 28, 18, and 11%. Differences in branching pattern due to tree age, size or location may account for the variation in results.

The regression of the binocular estimates on the cut-branch estimates showed a strong relationship between the two variables for both current and total foliage (Fig.1). The binocular estimates showed a slightly negative bias with respect ot the cut-branch estimates indicating that 12% and 7.5%, respectively, of current year's and total foliage was defoliated as detected by the cut-branch method, before any defoliation was detected using binoculars (Fig.1).

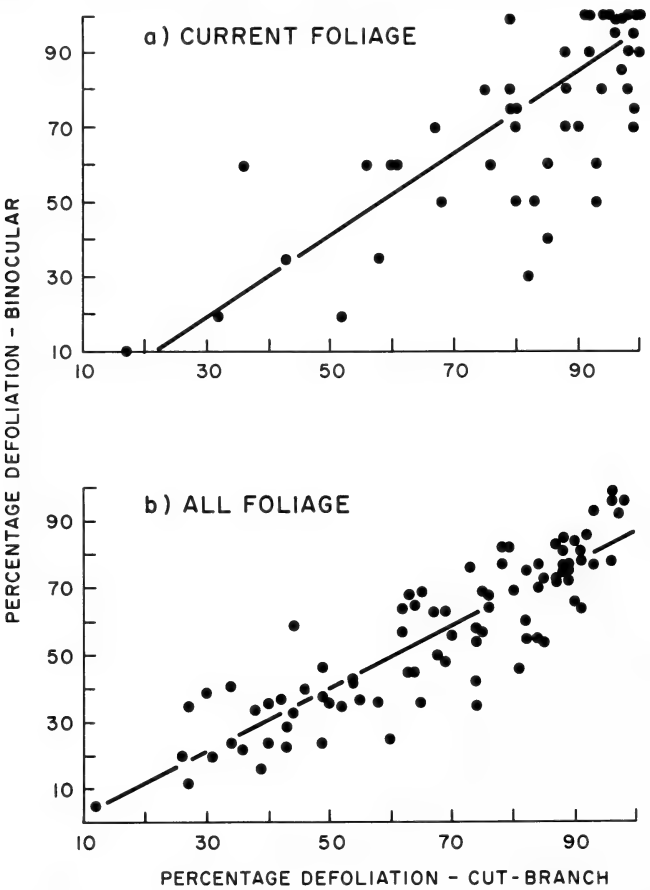

Figure 1. Regression of the estimates of western spruce budworm defoliation on 91 Douglas-fir trees, using the binocular method, on estimates made using the cut-branch method.
a. Current Year's Foliage: $y = -13.3 + 1.09x$; $R^2 = 0.67$
b. total foliage: $y = -7.1 + 0.942x$; $R^2 = 0.78$

The binocular method failed to meet our accuracy requirement of ± 10% of the defoliation as estimated by the cut-branch method, based on Freese's test. The accuracy obtained with the binocular method, after elimination of bias, was 23% for current year's and 19% for total foliage.

The difference between the two methods varied by location from 0.3 to 15.6% defoliation (average 4%) for current year's foliage, and from 4.5 to 15.9% (average 11%) for total foliage (Table 3). Estimates of mean defoliation for all locations were lower using the binocular method than the cut-branch method. Standard errors were consistently higher with the binocular than the cut-branch method (Table 3).

Table 3. Binocular and cut-branch estimates of interior Douglas-fir defoliation by the western spruce budworm at five locations in British Columbia.

Location	Estimated Mean Percentage Defoliation (s.e.)					
	Current Year's Foliage			Total Foliage		
	Cut-branch	Binocular	Diff.	Cut-branch	Binocular	Diff.
1	93.6 (1.6)	91.8 (3.6)	1.8	82.9 (2.1)	67.1 (4.2)	15.8
2	99.2 (0.4)	97.5 (1.5)	1.7	81.3 (2.7)	65.4 (3.8)	15.9
3	84.0 (3.1)	68.4 (4.8)	15.6	47.2 (3.4)	38.5 (3.2)	8.7
4	99.8 (0.1)	99.5 (0.5)	0.3	82.8 (4.6)	77.8 (5.7)	4.5
5	77.5 (5.2)	73.5 (5.8)	4.0	55.5 (4.3)	47.5 (4.9)	8.0
All	89.1 (1.8)	84.1 (2.4)	5.0	67.8 (2.3)	56.8 (2.40	11.0

The two methods were compared for estimation of defoliation in broad severity classes of light (1-25%), moderate (26-65%), and severe (66-100%), as used by the Forest Insect and Disease Survey of the Canadian Forestry Service in British Columbia. Eighty-one (89%) and 62 (68%) of the 91 trees for current year's and total foliage, respectively, were assigned to the same class using the two methods.

When classification was based on the average defoliation of the sampled trees for a location, as is the usual practice, there was complete agreement between the two methods as to the assigned defoliation class for all locations for both current and total foliage (Table 3).

DISCUSSION

The accuracy obtained with the binocular estimates of defoliation on individual trees, relative to the cut-branch method, was lower than the arbitrary 10% set as a threshold in this study. Bias in the relationship between the two estimates of defoliation was minimal (i.e. intercept not significantly different from zero, slope not significantly different from 1, t-ratio $p > 0.05$); therefore much of the lack of accuracy can be attributed to poor precision. In other words, on the average the binocular method will provide an unbiased estimate of mean defoliation as determined by the cut-branch method, but estimates for individual trees may fluctuate widely.

Our relative accuracy of 22.6% for defoliation of current year's Douglas-fir foliage by the western spruce budworm compares with 16.8% obtained in a comparison of mid-crown ocular estimates with cut-branch estimates for the eastern spruce budworm on balsam fir, *Abies balsamea* (L.) Mill. (MacLean and Lidstone 1982). In that study there was a bias towards overestimating defoliation on individual trees with the ocular method, especially at low levels of defoliation. The difference between the two studies in terms of bias may be due to the different tree and insect species involved, differences in individual observer bias or sample size. When mean current year's defoliation for a location was estimated using the two different methods the two studies produced similar results; MacLean and Lidstone (1982) found the cut-branch estimates averaged 8% higher than the ocular estimates whereas we found they averaged 5% higher (Table 3).

Bias and precision may vary with the observer. MacLean and Lidstone (1982) found that an experienced observer was generally 5 to 10% closer to the "true" value than an inexperienced observer. They also found consistent bias between the defoliation estimates made by three pairs of observers. Silver (1959) on the other hand, found that only one out of 5 observers was consistently biased while the estimates of the other 4 observers fluctuated around the average plot defoliation. We found that defoliation estimates made by our experienced observer were relatively unbiased with respect to the "true" mean, but we did not test differences between observers.

Our results indicate that the binocular method will not produce accurate or precise estimates of current or total defoliation for individual trees, as determined by the cut-branch method. However, mean defoliation estimates for a plot or location, based on a number of trees, showed fairly good agreement between the two methods. Similarly, the assignment into broad defoliation classes by the two methods did not result in close agreement for individual trees, especially for total foliage, but was acceptable for location averages. As most general surveys are based on the average defoliation of a number of trees, and because of the economy of time and labour, the binocular method is acceptable for this purpose.

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REFERENCES

Alfaro, R.I. 1985. Factors affecting loss in radial growth of Douglas-fir caused by western spruce budworm defoliation. *In* C.J. Sanders, R.W. Stark, E.J. Mullins, and J. Murphy (Eds.), Recent advances in spruce budworms research. Proc. of the CANUSA spruce budworms Research Symposium, Bangor, Maine, Sept. 16-20, 1984, pp. 251-252.

Alfaro, R.I., G.A. Van Sickle, A.J. Thomson and E. Wegwitz. 1982. Tree mortality and radial growth losses caused by the western spruce budworm in a Douglas-fir stand in British Columbia. Can. J. For. Res. 12: 780-787.

Dorais, L. and E.G. Kettela. 1982. A review of entomological survey and assessment techniques used in regional spruce budworm, *Choristoneura fumiferana* (Clem., surveys and in the assessment of operational spray programs. Eastern Spruce Budworm Council, Government of Quebec. 43 pp.

Fettes, J.H. 1950. Investigations of sampling techniques for population studies of the spruce budworm on balsam fir in Ontario. Forest Insect Laboratory, Sault Ste. Marie, Ontario. Annual Technical Report. 4 pp.

Freese, F. 1960. Testing accuracy. Forest Science 7: 139-145.

Freese, F. 1962. Elementary Forest Sampling. U.S.D.A. For. Serv. Handbook 232, 191 pp.

MacLean, D.A. and M.G. Morgan. 1981. The use of phyllotaxis in estimating defoliation of individual balsam fir shoots. Can. For. Serv. Res. Notes 1: 12-14.

MacLean, D.A. and R.G. Lidstone. 1982. Defoliation by spruce budworm: estimation by ocular and shoot-count methods and variability among branches, trees and stands. Can. J. For. Res. 12: 582-594.

Mitchell, R.G. 1974. Estimation of needle populations on young, open-grown Douglas-fir by regression and life table analysis. U.S.D.A. For. Serv. Res. Pap. PNW-181.

Sanders, C.J. 1980. A summary of current techniques used for sampling spruce budworm populations and estimating defoliation in eastern Canada. Environment Canada, Can. For. Serv., Great lakes Forest Research Centre, Report 0-X-306, 33 pp.

Silver, G.T. 1959. Indivudual differences in estimating defoliation. Can. Dep. Agric. Bi-monthly Prog. Rep. 15(3):3.

Silver, G.T. 1962. The distribution of Douglas-fir foliage by age. Forestry Chronicle 38: 433-438.

PREDICTING DOUGLAS-FIR DEFOLIATION FROM THE PERCENTAGE OF BUDS INFESTED BY THE WESTERN SPRUCE BUDWORM

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Abstract

Based on samples from 12 locations collected in British Columbia between 1977 and 1982, a regression model was developed for the relationship between percentage of buds of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, infested by western spruce budworm (WSB), *Choristoneura occidentalis* (Freeman), and the resulting stand defoliation. This relationship can be used to assess the budworm population in the early spring, either as a pre-treatment check or to predict damage.

Résumé

À partir d'échantillons prélevés dans 12 localités de la Colombie-Britannique entre 1977 et 1982, un modèle de régression a été construit pour corréler le pourcentage de bourgeons du douglas taxifolié (*Pseudotsuga menziesii* (Mirb.) Franco) infestés par la tordeuse occidentale de l'épinette (*Choristoneura occidentalis* [Freeman]), ainsi que la défoliation résultante des peuplements. Cette corrélation peut servir à évaluer les effectifs de la tordeuse au début du printemps, soit pour la vérification de prétraitement, soit pour la prévision des dégâts.

INTRODUCTION

The western spruce budworm (WSB), *Choristoneura occidentalis* (Freeman) (Lepidoptera:Tortricidae), is a chronic pest of Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, in British Columbia (Harris *et al.* 1985). The defoliation resulting from larval feeding can cause a serious loss of wood volume through growth reduction and mortality (Alfaro *et al.* 1982). There is a relationship between severity of defoliation and damage to the tree (Alfaro 1986).

The life cycle of the WSB in British Columbia is, briefly, as follows. Eggs, laid in early August, hatch within 12 days and the larvae seek shelter under lichen or bark scales. There they spin hibernaculae in which the overwinter as second instar larvae. In May they begin to mine needles or expanding flower and foliage buds. On completion of six instars they pupate in late June to mid-July; adults emerge 12-18 days later (Unger 1986).

In order to treat infestations of this insect with pesticides, infested areas must be ranked in terms of priority for treatment. Factors that are considered in assigning a priority ranking to a stand are the stand value and the expected losses: the latter being related to the severity of defoliation. Treatments are usually aimed at controlling the most destructive stages, larval instars 5 and 6.

Methods of predicting expected defoliation based on pheromone trap catches, samples of eggs masses, overwintering larvae or early spring larvae, have been investigated (Carolin and Coulter 1972; Twardus 1985) and some of these, especially egg mass counts, are used routinely as predictive indices (Shore 1985). However, pheromone trap catches have not yet been calibrated for predicting subsequent defoliation in British Columbia and, as with egg mass sampling, are so far removed in time from the damaging feeding state that various mortality factors may reduce budworm populations and seriously affect predictions. Sampling overwintering larvae is laborious because a chemical wash is required to extract the tiny larvae from their hibernaculae, and since this method has not been fully developed and calibrated for WSB it is seldom used (Twardus 1985).

Sampling larval instars 3 and 4, in the early spring, as they infest the opening buds, provides a pre-treatment estimate of the population density after fall and winter mortality. Larvae of WSB infest buds just prior to, or as, they are opening. This is a time of relative population stability for about 10 days (Carolin and Coulter 1972; Twardus 1985), when temperatures are cool at nights, development is slow and larval mortality is low. These make ideal conditions for sampling if carefully timed (Morris 1955; Carolin and Coulter 1972).

It is the purpose of this paper to present information on the relationship between the percentage of Douglas-fir buds infested by WSB and subsequent defoliation, and to show how the relationship can be used to improve the management of this serious forest pest.

METHODS AND MATERIALS

Douglas-fir trees were sampled repeatedly at 12 locations between 1977 and 1982. A total of 60 estimates of percentage of WSB-infested buds and resultant defoliation were obtained (all locations were not sampled every year). The estimates were made by removing mid-crown branch tips, using pole pruners, until 100 buds were examined on each of three dominant or codominant trees. The percentage of infested buds for the location was then calculated as the average of the three individual tree estimates. In late summer of the same year, after WSB larval feeding ended, defoliation was assessed for the location by examining 10 dominant or codominant trees selected at random. The percentage defoliation of current year's foliage was estimated separately for the upper-, mid-, and lower-crown levels using binoculars. The defoliation per tree was calculated as the average of the three crown level estimates, and the defoliation per stand as the average of the 10 single tree estimates.

The relationship between the percentage of infested buds and subsequent defoliation was examined using a number of linear and non-linear regression models. Prior to the regression analysis the data were tested for autocorrelation using the Durbin-Watson statistic which indicated no significant autocorrelation ($P>0.05$). The models that best fitted the data were selected based on comparisons of R^2 and F values, and on examination of plot residuals.

RESULTS AND DISCUSSION

Preliminary analysis indicated a statistically significant relationship between percent defoliation and the percentage of infested buds. However, it was observed that in the final year or two of an infestation there could be a high percentage of infested buds, but little or no defoliation. This was the result of high WSB mortality in the period following bud sampling. The relationship was re-examined omitting those cases where the population had collapsed following sampling, leaving 46 sample points.

After examination of many possible regression models the one that best fitted the data was:

$$\ln (\text{Defoliation} + 1) = A + B \ln (\text{Buds} + 1) \qquad [1]$$

where ln = natural logarithm
Defoliation = average tree defoliation (%) per location
Buds = % buds infested by WSB per location
A = -0.3491
B = 1.2053
$R^2 = 0.76$, F = 136.8, MSE = 0.667, $P < 0.01$, N = 46

However, the simple linear model (Fig. 1):

$$\text{Defoliation} = A + B (\text{Buds}) \qquad [2]$$

where A = -0.189
B = 1.835
Defoliation and buds are defined as above
$R^2 = 0.68$, F = 94.4, MSE = 0.319, $P < 0.01$, N = 46

also gave an acceptable fit.

Since we omitted the sample points from locations where the WSB population collapsed following sampling, our method will overestimate defoliation in such cases and therefore,

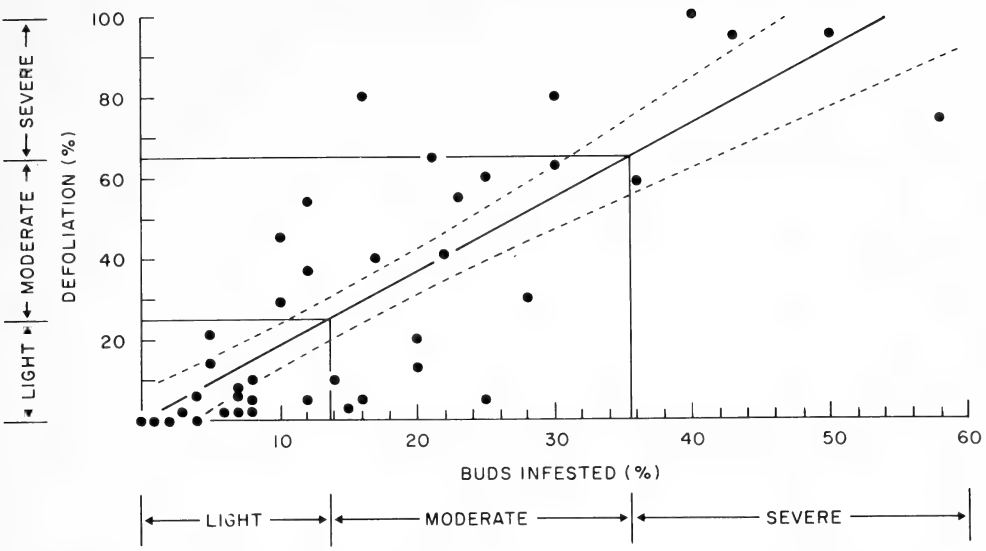

Figure 1. The relationship between the percentage of Douglas-fir buds infested by western spruce budworm and subsequent average tree defoliation; y = -0.189 + 1.835x, R^2 = 0.68 (---- = 95% confidence limits). Thresholds for light, moderate and severe defoliation are shown.

provides a worst case scenario. This does not decrease its usefulness for pre-treatment classification of potential stand defoliation.

Working in eastern Oregon, Carolin and Coulter (1972) developed a linear relationship to predict a current year's defoliation from the number of larvae per 1000 buds. For comparison, we transformed their data to percentage of infested buds by dividing the independent variable by 10. We assumed from their methods that they were sampling primarily larvae infested buds. Our linear model was remarkably similar to that found by Carolin and Coulter (1972) (Fig.2). For this reason and for simplicity of use and understanding we recommend the use of the linear model [2], even though the logarithmic model fitted the data slightly better.

These relationships can be used to develop broad defoliation severity classes corresponding to ranges of percentage of infested buds. Based on our models, we calculated the percentage of buds infested that result in the defoliation severity classes used in British Columbia by the Forest Insect and Disease Survey of the Canadian Forestry Service (Table 1).

We compared the defoliation severity predictions based on our models with data for 57 stands in British Columbia collected between 1984 and 1986, where average percentage of buds infested and subsequent estimates of stand defoliation severity from the air were available. Although our method was based on ground observations of defoliation, and the aerial estimates of defoliation use more subjective criteria (Shore 1985), a comparison is useful. Our linear model accurately predicted aerial defoliation severity class for 32 stands (56%), it overestimated in 22 stands (39%) and underestimated in 3 stands (5%). The corresponding predictions for the logarithmic model agreed in 65%, overestimated in 30%, and underestimated in 5% of the stands. This suggests that defoliation is rated lower by the

Table 1. Percentage of buds infested by western spruce budworm and expected defoliation of Douglas-fir

Buds infested (%)		Expected defoliation	
Linear	Logarithmic	Class	Percent
0	0	none	0
1-13	1-19	light	1-25
14-35	20-41	moderate	26-65
36-100	42-100	severe	66-100

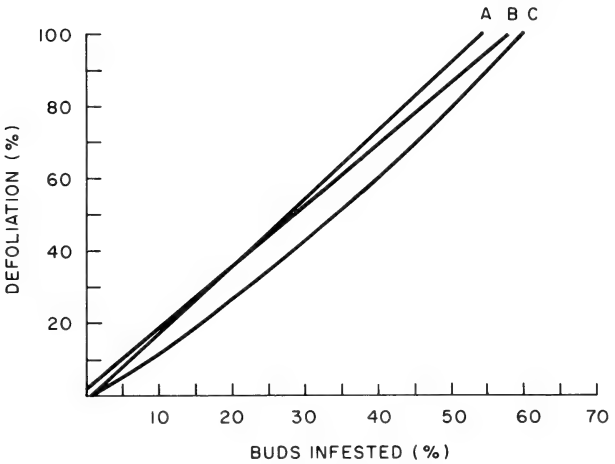

Figure 2. A comparison of three models to describe the relationship between the percentage of Douglas-fir buds infested by western spruce budworm and subsequent average tree defoliation. A = linear model in Fig. 1, B = Carolin and Coulter (1972), C = logarithmic model (see text).

aerial classification system than it is from the ground. The higher classification thresholds produced by the logarithmic model agree more closely with aerial defoliation estimates that do those of the linear model.

The timing of sampling for percentage of infested buds is critical. Shepherd (1983) described the relationship between temperature (in degree days), bud and WSB development for some interior locations in British Columbia. He found that larvae averaged instar 2.9 and were beginning to penetrate the buds at approximately 265 degree-days (over a 5° C threshold) and remain in their protective feeding sites, consuming the expanding foliage, until the buds reach stage 6 (372 degree-days). Sampling should be conducted when the buds are in stages 3 to 6, described by Shepherd (1983) (which includes photographs) as follows:

stage 3-white scale stage: bud all light brown or yellow, scales separated to reveal white layers underneath.

stage 4-columnar stage: bud columnar shape with a rounded tip, green needles visible beneath semi-transparent scales.

stage 5-split stage: bud split open to reveal green needles, bud cap may still be present, needles still tight together.

stage 6-brush stage: bud cap gone, needles flaring but little shoot growth so needles appear to arise from one location

Feeding in the buds occurs for a period of about 3-4 weeks (Shepherd 1983).

In the event of a budworm infestation, managers are faced with the task of preparing for a possible spray operation several months ahead of the damage. In order to provide enough time for this complex operation, preliminary spray plans should be based on egg mass surveys conducted in the fall (Shore 1985; Carolin and Coulter 1972; Twardus 1985). Sampling infested buds in the spring for predicting expected current foliage defoliation, should serve a useful purpose for refining the spray plans by, for example, avoiding the treatment of areas where the population has collapsed through winter mortality.

ACKNOWLEDGEMENTS

We thank the Forest Insect and Disease Survey of the Canadian Forestry Service at Pacific Forestry Centre for making these data available to us.

REFERENCES

Alfaro, R.I. 1986. Douglas-fir mortality and top-kill caused by the western spruce budworm in British Columbia. J. Ent. Soc. B.C. 83:19-26.

Alfaro, R.I., G.A. Van Sickle, A.J. Thomson and E. Wegwitz. 1982. Tree mortality and radial growth losses caused

by the western spruce budworm in a Douglas-fir stand in British Columbia. Can. J. For. Res. 12: 780-787.
Carolin V.M. and W.K. Coulter. 1972. Sampling populations of western spruce budworm and predicting defoliation on Douglas-fir in eastern Oregon. U.S.D.A. for. Serv. Res. Pap. PNW-149. 38 pp.
Harris J.W.E., R.I. Alfaro, A.F. Dawson and R.G. Brown. 1985. The western spruce budworm in British Columbia 1909-1983. Can. for. Serv. Pac. For. Cent. Inf. Rep. BC-X-257. 32 pp.
Morris R.F. 1955. Development of sampling techniques for forest insect defoliators, with special reference to the spruce budworm. Can. J. Zool. 33: 225-294.
Shepherd R.F. 1983. A technique to study phenological interactions between douglas-fir buds and emerging second instar western spruce budworm. *In* R.L. Talerico and M. Montgomery (Editors). Forest defoliator-host interactions: A comparison between gypsy moth and spruce budworms. Conference Proceedings. U.S.D.A. For. Serv. Gen. Tech. Rept. NE-85. 141 pp.
Shore T.L. 1985. General Instructions Manual: Forest Insect and Disease Survey, Canadian Forestry Service, Pacific and Yukon Region. Unpublished report. 125 pp.
Twardus D.B. 1985. Surveys and sampling methods for population and damage assesment. *In* Brooks M.H., J.J. Colbert, R.G. Mitchell and R.W. Stark (Technical coordinators). U.S.D.A. for. Serv. Cooperative State Research Service, Tech. Bull. No. 1695. 111 pp.
Unger L.S. 1986. Spruce budworms in British Columbia. Can. For. Serv., Pac. For. Cent., For. Pest Leafl. 31, 4 pp.

SURVIVAL OF SELF-MARKED MOUNTAIN PINE BEETLES EMERGED FORM LOGS DUSTED WITH FLUORESCENT POWDER

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Abstract

Mountain pine beetles, *Dendroctonus ponderosae* Hopk. (Coleoptera: Scolytidae), were allowed to emerge in the laboratory from naturally infested lodgepole pine bolts, which had been heavily dusted with dry fluorescent (Day-Glo) powder. Emergent beetles were collected daily and stored at 5°C. Mortality was assessed daily for 21 days, after which the insects were killed. All dead beetles were examined under UV light for the presence and degree of marking. The survival of marked beetles was compared to that of unmarked beetles from control bolts. Analysis of variance showed no difference in mortality rate due to the treatment.

Résumé

On a épandu abondamment une poudre fluorescente sàche (Day-Glo) sur des billes de pin tordu infestés naturellement par des dendroctones du pin ponderosa (*Dendroctonus ponderosae* Hopk.) Coleoptera: Scolytidae). On a recueilli chaque jour les ensectes émergents et on les a placés dans une enceinte réfrigérée à 5°C. On a contrôlé la mortalité chaque jour pendant 21 jours, puis on a tué les insectes. On a examiné tous les insectes morts sous un éclairage UV pour connaître le degré de marquage. On a comparé la survie des insectes marqués à celle d'insectes non marqués ayant émergé des billes témoins. D'après l'analyse de la variance, le tratiement n'a eu aucun effet sur le taux de mortalité.

INTRODUCTION

An ongoing series of field experiments to study the dispersal behavior of mountain pine beetles (mpb), *Dendroctonus ponderosae* Hopk., was begun in 1982 near Riske Creek, in the Cariboo Forest Region of B.C. These experiments required the development of techniques suitable for field-marking large numbers of emergent mpb used in release-recapture experiments.

Fluorescent powders have been used extensively as markers on insects and are usually non-toxic, readily available and inexpensive (Gangwere *et al* 1964; Gara 1967; Moffitt and Albano 1972; Schmitz 1980). Powders have been applied to insects using vacuum chambers (Dunn and Michalas 1963; Moffitt and Albano 1972; Linton *et al* 1987), or the insects have

been allowed to dust themselves on release platforms (Gara 1976; Schmitz 1980). An alternative method for applying the powder was sought which did not involve handling the insects. The method proposed and used in 1984 and 1985 (Linton *et al* 1987) was to apply a heavy coating of fluorescent powder to the lower boles of infested lodgepole pine trees, *Pinus contorta* Dougl. var *latifolia* Englm. when the brood adults were ready to emerge and begin their dispersal flight. It was thought that the beetles would become coated with the dust while they moved around on the bark surface prior to taking flight. This experiment was carried out to determine whether or not emergent mpb would pick up enough fluorescent powder to become reliably marked, and how the survival of the self- marked beetles compared to unmarked beetles.

METHODS AND MATERIALS

Six infested lodgepole pine bolts (24-30 cm in diameter and 15-22 cm in length) were collected in fall, 1982 near Riske Creek. The bolts were transported to outdoor storage in Victoria and waxed on both ends to prevent desiccation. In January, 1983, the bolts were brought into the laboratory. The insects were in the late larval stages and in winter dormancy. The bolts were kept at 20 ± 2 °C until most of the brood had developed to the adult stage and were ready to emerge. Three of the bolts were selected randomly for treatment, the remainder were controls. Treatment consisted fo uniformly coating the entire bark surface of each bolt with fluorescent powder (Day-Glo Corp., Cleveland, Ohio 44103, #A-21 Corona Magenta) by blowing the dust from an aspirator made from a 250-ml vacuum flask connected to the lab air supply at 100 kPa. Approximately 50g of powder were applied to each bolt. All six bolts were then placed separately in darkened cages with light traps for emergents, and were held at room temperature. Emergent mpb were collected from the light traps daily and placed in vials in a refrigerator (5°C). Each day's collection was examined for mortality every day for 21 days, which was considered adequate for the purpose of the experiment, as under natural conditions flight, attack and brood establishment are normally completed within 3 weeks of emergence. At the end of the 21 day experimental period, the remaining live beetles were killed.

After death, each beetle from the treated bolts was examined for the presence and degree of marking using the naked eye or a dissecting microscope (16X) in a darkened room with short-wave ultra violet (UV) lamp (Pin-Ray Quartz Lamp, Ultra Violet Porducts Inc., San Gabriel, Calif. 91778) held 5-10 cm from the insects. (It is necessary to protect the eyes with effective filter goggles when using these lamps.) The degree of marking on each insect was classified into one of the following categories: none, light, medium, or heavy. Heavily marked insects were easily seen by the naked eye in normal daylight or using the UV lamp. Medium marking was visible only with the UV, but magnification was not always necessary. color was easily seen on most of the insects' dorsal or ventral surfaces using the microscope. Light marking was not visible to the naked eye, and only seen with difficulty using the microscope; often only a few grains of powder were present, usually on the ventral surfaces concentrated in sutures and declivities. Beetles from dusted bolts having no visible marking were classified as having "none." Emergents from the unmarked bolts formed the control group.

Mortality was analysed by ANOVA in a split-plot design with two treatments (dusted vs undusted) and three time durations (1-7 days, 8-14 days, 15-21 days). Differences in mortality among groups of beetles with different degrees of self-marking, and variation in the relative proportions of beetles with different degrees of self-marking among the replicates were examined by χ^2 analysis.

RESULTS AND DISCUSSION

On average, of the 765 and 683 beetles that emerged from treated and control bolts, respectively, 0.7% and 1%, 2.5% and 1.3%, 5.5% and 5.7% died within the 1st, 2nd, and 3rd week after emergence. Of the beetles that emerged from the treated bolts, 758 (99.1%) were marked. Of the marked beetles, 43 (5.6%) were heavily marked, 204 (26.7%) were medium, and 511 (66.8%) were light. The relative proportions of beetles in the four marking degree categories were not significantly different among the three replicates (bolts) ($\chi^2$6df=10.43,

p=0.11). Analysis of variance indicated that the mortality of emerged beetles increased significantly with time, but there was no significant difference between the controls and treatments, or in the interaction of treatment x time (Table 1).

In mortality among beetles that emerged from treated bolts, there was no interaction between storage duration and degree or marking (χ^2_{6df}=4.41, p=0.63); mortality, however, did increase with the degree of marking ($\chi^2 2_{df}$=116.37, p<0.001). Average mortality in the light, medium and heavy marking classes was 2.7%, 15.7% and 51.2%. As average mortality was not statistically significant between treatment and control (Table 1), the finding above appears to indicate that beetles of reduced viability may have spent more time on the treated bark than did more active beetles and thus become more heavily marked, or were less able to cleanse themselves of the powder. We have observed that beetles which do not readily fly, tend to spend considerably more time on the bark following emergence than beetles which are good fliers. Furthermore, we have found in several experiments using marked and unmarked beetles, that there are usually between 1 and 8% which will not fly (Linton *et al.* 1987, and unpublished data). The apparent association between the degree of self-marking and viability requires further investigation.

These results indicate that there was no statistically significant difference in survival in the laboratory between self-marked or control beetles for the first three weeks after emergence.

Table 1. Analysis of variance of percent mortality by treatment and storage interval following emergence of mountain pine beetles from bolts of lodgepole pine dusted with fluorescent powder and from undusted bolts.

Source	df	Sum squares	Mean squares	F-value[a]
Replication (bolts)	2	9.1892	4.5936	<1 n.s.
Treatments (dusted vs undusted)(D)	1	1.7422	1.7422	<1 n.s.
Error I	2	40.6834	20.3417	
Major plots	5	51.6148		
Time intervals (T)	2	282.5391	141.2695	35.08**
DxT	2	18.2290	9.1145	2.26 n.s.
Error II	8	32.2184	4.0273	
Total	17	384.6013		

a. Percentages were transformed to arcsine sqrt x prior to analysis. n.s. = not significant; ** = significant at p<0.01.

REFERENCES

Dunn, Paul H., and Byron J. Machalas. 1963. An easily constructed vacuum duster. J. Econ. Ent. 56: 899.

Gangwere, S.K., W. Chavin, and F.C. Evans. 1964. Methods of marking insects, with special regard to Orthoptera (*Sens. Lat.*) Ann. Ent. Soc. Am. 57: 662-669.

Gara, R.I. 1976. Studies on the attack behavior of the southern pine beetle. I. The spreading and collapse of outbreaks. Contrib. Boyce Thompson Inst. 23: 349-354.

Linton, D.A., L. Safranyik, L.H. McMullen and R. Betts. 1987. Field Techniques for rearing and marking mountain pine beetle for use in dispersal studies. J. Ent. Soc. B.C. 84: 53-57.

Moffitt, H.R. and D.J. Albano. 1972. Vacuum application of fluorescent powders as markers for adult codling moths. J. Econ. Ent. 65: 882-884.

Schmitz, R.F. 1980. Dispersal of pine engraver beetles in second growth ponderosa pine forests. *In* Proceedings of the second IUFRO conference on dispersal of forest insects: evaluation, theory and management implications. A.A. Berrymand and L. Safranyik, eds. Sandpoint, Idaho, August 27-31, 1979.

ASSESSMENT OF TWO PINE OIL TREATMENTS TO PROTECT STANDS OF LODGEPOLE PINE FROM ATTACK BY THE MOUNTAIN PINE BEETLE

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Abstract

Pine oil (Norpine-65) was evaluated as an infestation deterrent for the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, in a high hazard forest of lodgepole pine, *Pinus contorta* var. *latifolia* Engelmann. Two experimental treatments were tested, each in four, 9 ha, square blocks (replicates): 1) spraying trees in a grid at 50 m centres with 1.8 L of pine oil/tree, and 2) creating a "barrier" consisting of a double line of pine oil-sprayed trees, 25 m apart, 25 m within the block boundary. There were significantly-reduced ratios of newly-infested (green) trees to the previous year's infested (red) trees in both treatments compared to control blocks. However, neither treatment prevented beetles from attacking semiochemical-baited trees 75 m inside the block boundaries, and neither treatment is recommended for operational use. At maximum costs/ha of $22.04 and $43.39 (Can.) for grid and barrier treatments, respectively, the operational use of a repellent, or an insecticide would approach cost effectiveness if it reduced new infestations of *D. ponderosae* by 1 or 2 trees/ha, respectively.

INTRODUCTION

Pine oil is a commercially-available by-product of the pulp and paper industry. When sprayed on the boles of trees or on logs, it has repeatedly been shown completely or partially to deter attack by scolytid beetles (Nijholt 1980; Nijholt and McMullen 1980; Nijholt *et al.* 1981; Richmond 1985; McMullan and Safranyik 1985; Berisford *et al.* 1986; O'Donnell *et al.* 1986; Werner et al. 1986). Nijholt et al. (1981) reported that attack by the mountain pine beetle, *Dendroctonus ponderosae* Hopkins, was deterred up to 10 m from pine oil-treated lodgepole pines, *Pinus contorta* var. *latifolia* Engelmann. This result suggested that pine oil might have potential in protecting large blocks of forest from attack by the beetles. However, McMullen and Safranyik (1985) did not induce such protection by affixing pine oil-impregnated fibre boards on trees or distributing them on the forest floor.[1]

Our objective was to test pine oil on an operational basis to determine if it could be used to protect high hazard stands from attack by the mountain pine beetle. Several criteria had to be met in such a program: 1) the stands had to have minimal infestations; 2) there had to be sufficient mountain pine beetle infestation in the adjacent forest to threaten each treated block; 3) the pine oil treatment had to be simple enough for regular forestry crews to carry out; 4) the pattern of treated trees had to be set up so that large blocks could be treated in a reasonably short time; and 5) the treatments had to be cost-effective.

[1] McMullen, L.H. and L. Safranyik. 1983. Effect of pine oil distributed in fibre board on the ground for protecting lodgepole pine from mountain pine beetle attack. Can. For. Serv., Pac. For. Res. Cen., Victoria, B.C.

METHODS AND MATERIALS

Twelve, 9 ha blocks, 300 x 300 m, were selected along the Ketchan Road, west of Summers Creek, approximately 25 - 35 km southeast of Merritt, B.C. in the Merritt Timber Supply Area. The stands were chosen on the basis of predominance of pine, age class 5 (81-100 years-old) or higher, and site quality (predominately medium to good). There was minimal infestation recorded in the area occupied by the blocks by B.C. Forest Service surveys, but the blocks were threatened by invasion of mountain pine beetles from a large infestation in the Summers Creek Valley and vigorous small infestations on the plateau where the blocks were situated.

Three treatments were selected (Fig. 1): 1) an untreated control; 2) a grid treatment, in which 36 lodgepole pines at 50 m centres within the block (4 trees per ha) were treated with pine oil; and 3) a "barrier" treatment in which there were 72 pine oil-treated trees in two lines, 25 m apart, with the outer line 25 m inside the block boundary.

From 9-17 May, 1984, the blocks were laid out and randomly assigned to treatment, all treatment trees were marked, their diameters at breast height (dbh) taken, and lines between trees marked with plastic flagging. (None of these procedures would be required in an operational program). The mean dbh ± S.E. of the trees marked for pine oil treatment in the grid blocks was 27.5 ± 0.5 cm, and in the barrier blocks 27.7 ± 0.4 cm.

Pine oil treatments were applied from 23 - 25 June, 1984. Marked trees were sprayed to run-off up to a height of 4.5 m with Norpine 65 (Northwest Petrochemical, Anacortes, Washington). Spraying was done with a hand-pressurized, backpack sprayer (Solo Kleinmotoren GMbH, Sindelfingen, West Germany) fitted with a 1.2 m extension wand and a flat fan nozzle oriented vertically. A mean ± S.E. of 1.80 ± 0.03 L of pine oil was used/tree in the 8 treated blocks.

At a distance of 75 m from the boundaries of each block, 12 trees, 50 m apart (Fig. 1), were baited with mountain pine beetle tree baits (Phero Tech Inc., Vancouver, B.C.) comprised of myrcene, *trans*-verbenol and *exo*-brevicomin released at 17.6, 1.0 and 0.2 mg/24 h, respectively. A baited tree has a maximum range of approximately 50 m within a well-stocked stand[2] (personal observation).

Therefore, it was unlikely that these trees would attract beetles into the blocks, but rather that they would arrest beetles that flew through the pine oil barrier or grid, i.e., they measured the efficacy of the treatments. The mean dbh ± S.E. of baited trees in the control, grid and barrier blocks were 27.5 ± 0.8, 27.7 ± 1.0 and 28.8 ± 0.9 cm, respectively.

The efficacy of the treatments was assessed from 15 - 19 October, 1984. Every lodgepole pine tree in each 9 ha block was examined for attack by *D. ponderosae*. If a tree was attacked, the attack density was counted in two, 20 x 40 cm frames on opposite sides of the tree at eye level. The location of each attacked tree was plotted on a grid map.

RESULTS AND DISCUSSION

Efficacy

The pine oil applications, particularly the grid treatment, created a distinct odor throughout the treated blocks. This odor was still apparent to the human nose in temperatures <0° C in October, 1984, 4 mo after treatment. However, neither the barrier, nor the grid treatment deterred *D. ponderosae* from attacking many of the baited trees and those adjacent to them

[2] Heath, D. 1986. Assessment of operational pheromone-based containment programs for mountain pine beetle control in the Cariboo Forest Region. B.C. For. Serv. Int. Rept. PM-C-1.

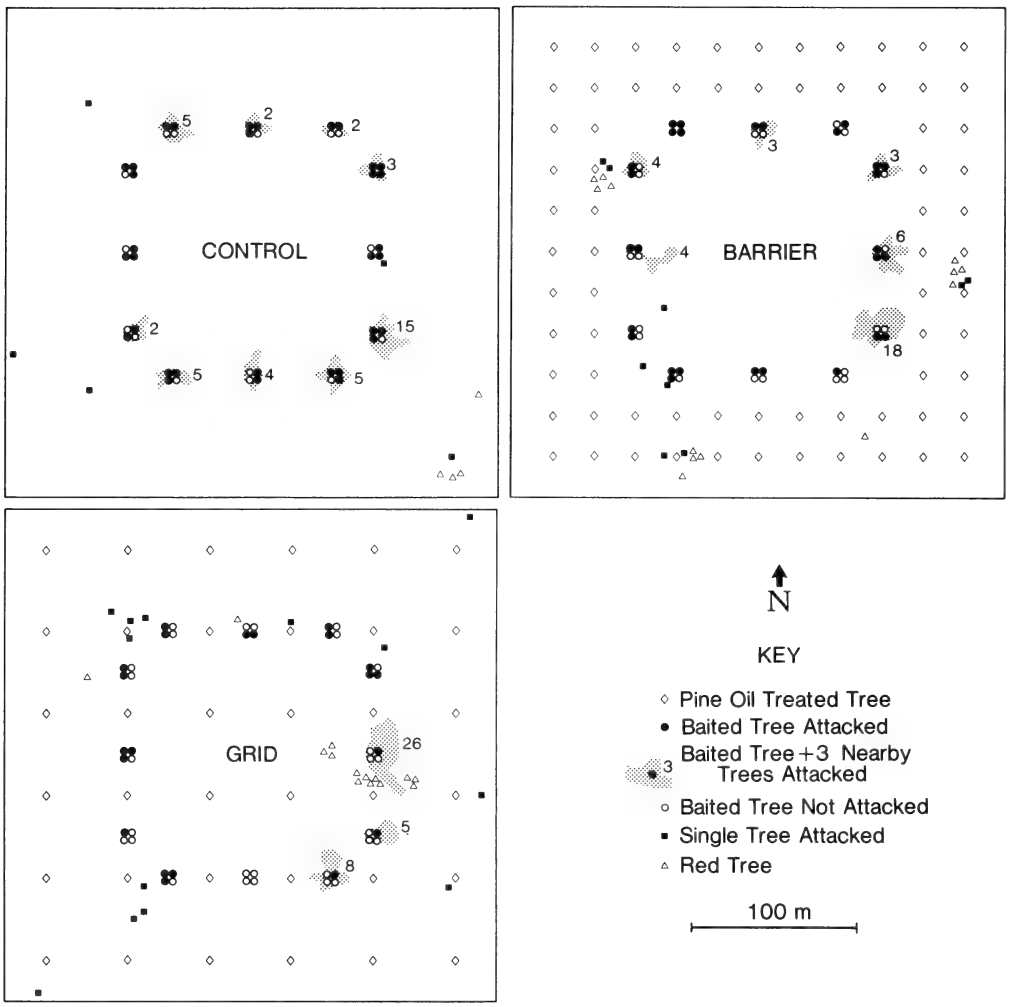

Fig. 1 Layout of 9 ha control blocks and barrier and grid pine oil treatment blocks, showing placement of pine oil-treated trees, semiochemical-baited trees, and attack by the mountain pine beetle (4 replicates superimposed for each treatment).

(Fig. 1), an attack pattern commonly observed in tree-baiting programs (Borden *et al.* 1986).

Although newly-attacked trees occurred as close as 4-5 m to trees treated with pine oil (Fig. 1) not one of the 432 pine oil-treated trees sustained a single attack by *D. ponderosae*. Thus, the treated trees were probably protected from the beetle, a result in keeping with those of other investigations with Norpine-65 (Nijholt *et al.* 1981; Richmond 1985; McMullen and Safranyik 1985).

There were no significant differences between treatments in the numbers of trees attacked or in attack densities on newly-infested, green trees (Table 1). However, in both the barrier and grid treatments, there were reduced green:red ratios, i.e., there were fewer newly-attacked, green trees for each tree with red-colored foliage attacked in the previous year (Table 1).

Thus the treatments did appear to reduce the intensity of the infestation, compared to what it might have been. The supposition is that some of the beetles emerging from the few red trees were induced to leave the treated blocks, and that dispersing beetles either entered the treated blocks at a lesser rate than the control blocks, or were deterred from remaining within them.

Table 1 Numbers of trees attacked by *D. ponderosae*, attack density and ratios of newly-attacked (green) trees to previous year's (red) trees in 9 ha blocks untreated or subjected to one of two pine oil treatments. N=4 replicates per treatment.

Treatment	No. of trees attacked (all blocks combined)[a]		Attack density on green trees	Green: red ratios (all) blocks combined)[c]
	Red	Green	(x ± S.E.)[b]	
Control	4	81	58.9 ± 5.2	20.3 a
Barrier	13	76	58.2 ± 4.9	4.8 b
Grid	13	72	44.7 ± 4.9	5.5 b

[a]ANOVA P between treatment means >0.5 in both cases.

[b]ANOVA P = 0.15.

[c]Ratios followed by the same letter are not significantly different, Newman Keuls test modified for proportional data (Zar 1984), P < 0.05.

Operational Feasibility

The pine oil treatments and semiochemical baiting took three full days with a 5-person crew: two sprayers, two packers to replenish the spray tanks, and one person to bait trees and tag pine oil-treated trees as "pesticide treated" in accordance with B.C. Ministry of the Environment requirements. In an operational program, the latter person would be used in advance of the sprayers to compass, chain and flag the lines, to mark treatment trees and to pre-tag them as "pesticide treated."

Approximately 144 trees were treated/8 h day, not including travel to the area, but including travel between sites. On the actual blocks, a 36-tree grid required a mean of 95 min, i.e. 2.6 min/tree. The corresponding treatment time for a 72-tree barrier block was 145 min or 2.0 min/tree, somewhat less/tree than required for a grid block because of the shorter walking distances.

Table 2 Costs in Canadian dollars at 1987 rates for grid and barrier pine oil treatments on a per tree and per ha basis.

Units and items evaluated	Costs[a] Grid Treatment	Barrier Treatment
EXPENDITURES PER TREE		
Labor, incl. 35% benefits[b]		
Crew Chief	$ .77	$ .59
Crew Members	2.48	1.92
Subtotal	$3.25	$2.51
Pine Oil, 1.8 L per tree	1.38	1.38
Other materials, incl. flagging, tree-marking, paint and labels	.88	.63
Total cost per tree	$5.51	$4.52
EXPENDITURES PER HA		
5 ha	$22.04	$43.39
10 ha	$22.04	$36.16
20 ha	$22.04	$27.12

[a]Costs do not include capital outlay for such items as spray equipment and packing tanks. Costs for grid treatment on a per ha basis are constant because of a fixed density of 4 trees/ha. Costs for barrier treatment decline as area increases because there are 24, 40 and 60 trees for areas of 5, 10 and 20 ha, respectively.

[b]Based on B.C. Forest Service 1987 rates for Forestry Technician (FT)-3 (crew chief) and FT-1 (crew members).

At the above labor requirements and treatment times/tree, the cost of a grid treatment would be $5.51/tree or $22.04/ ha (Table 2). The barrier treatment would cost $4.52/tree; costs/ha would be higher, but decreasing as the size of the block increased (Table 2).

The lack of complete exclusion of attack with these pine oil treatments suggests that they will not be operationally implemented. However, the cost figures would apply equally well to a similar program which used a more effective repellent, or employed semiochemical-baited trees surface-treated with a toxic insecticide (Smith 1986). If implemented on a grid basis, the latter treatment might have considerable potential in reducing infestation levels within moderately-attacked stands. In either case as it costs a minimum of $20.00 to dispose of an attacked tree by felling and burning (P.M. Hall,[3] pers. comm.) prices of approximately $20.00 and $40.00 per ha would be cost effective if the treatment reduced the incidence of newly attacked, green trees by 1 or 2 trees per ha, respectively.

CONCLUSION

Although potentially cost-effective and operationally feasible, neither the grid nor the barrier treatments with pine oil met the objective of reducing *D. ponderosae* attacks below the critical level of 2.2 mass-attacked trees/ha which would require remedial treatment (Safranyik *et al.* 1974). Therefore, we conclude that pine oil as formulated and deployed by us should not be recommended for operational use in protecting high hazard stands of lodgepole pine. This limitation, however, does not preclude its use in protecting individual trees.

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REFERENCES

Berisford, C.W., U.E. Brady, C.W. Fatzinger and B.H. Ebel. 1986. Evaluation of a repellent for prevention of attacks by three species of southern pine bark beetles. J. Entomol. Sci. 21:316-318.

Borden, J.H., L.J. Chong and T.E. Lacey. 1986. Pre-logging baiting with semiochemicals for the mountain pine beetle, *Dendroctonus ponderosae*, in high hazard stands of lodgepole pine. For. Chron. 62:20-23.

McMullen, L.H. and L. Safranyik. 1985. Some effects of pine oil on mountain pine beetle (Coleoptera:Scolytidae) at different population levels. J. Entomol. Soc. B.C. 82:29-30.

Nijholt, W.W. 1980. Pine oil and oleic acid delay and reduce attacks on logs by ambrosia beetles (Coleoptera:Scolytidae). Can. Entomol. 112:199-204.

Nijholt, W.W. and L.H. McMullen. 1980. Pine oil prevents mountain pine beetle attack on living lodgepole pine trees. Can. Dept. Env., Can. For. Serv. Bi-Mon. Res. Notes 36:1-2.

Nijholt, W.W., L.H. McMullen and L. Safranyik. 1981. Pine oil protects living trees from attack by three bark beetle species, *Dendroctonus* spp. (Coleoptera:Scolytidae). Can. Entomol. 113:337-340.

O'Donnell, B.P., T.L. Payne and K.D. Walsh. 1986. Effect of pine oil on landing and attack by the southern pine beetle (Coleoptera:Scolytidae). J. Entomol. Sci. 21:319-321.

Richmond, C.E. 1985. Effectiveness of two pine oils for protecting lodgepole pine from attack by mountain pine beetle (Coleoptera:Scolytidae). Can. Entomol. 117:1445-1446.

Safranyik, L. 1974. Management of lodgepole pine to reduce losses from the mountain pine beetle. Env. Can., For. Serv. Pac. For. Res. Cen. For. Tech. Rept. No. 1.

Smith, R.H. 1986. Trapping western pine beetles with baited toxic trees. USDA, For. Ser. Res. Note PSW-382.

Werner, R.A., E.H. Holsten and F.L. Hastings. 1986. Evaluation of pine oil for protecting white spruce from spruce beetle (Coleoptera:Scolytidae) attack. J. Entomol. Soc. B.C. 83:3-5.

Zar, J.H. 1984. Biostatistical analysis, 2nd ed. Prentice-Hall, Englewood Cliffs, New Jersey.

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SEMIOCHEMICALS FOR CAPTURING THE AMBROSIA BEETLE, *TRYPODENDRON LINEATUM*, IN MULTIPLE-FUNNEL TRAPS IN BRITISH COLUMBIA

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Abstract

The host attractants, ethanol and alpha-pinene, and the aggregation pheromone, lineatin, were tested alone and in all combinations for attracting the ambrosia beetle, *Trypodendron lineatum* (Olivier), to Lindgren multiple-funnel traps in a forest setting. A laboratory study examined the flight responses of *T. lineatum* to various release rates of ethanol and lineatin, alone and in combination, in a wind tunnel. Lineatin was the only effective chemical in attracting the beetles to the traps in both studies. There were no synergistic effects from adding ethanol or α-pinene, alone or together, to lineatin-baited traps in the field. The responses of both sexes in the wind tunnel were highest at lineatin release rates of 8 and 64 ug/24 h. A decrease in response occurred at 512 ug/24 h.

INTRODUCTION

The ambrosia beetle, *Trypodendron lineatum* (Olivier), like most species of the family Scolytidae, relies on its olfactory perception of chemicals for host attraction and mating (Borden 1985). Because this insect is a major pest of logged timber on the Pacific coast of British Columbia, a substantial effort has been put into identifying and quantifying the chemicals and the combinations to which the beetle responds. This has resulted in improved methodology in surveying and managing the pest (Borden and McLean 1981; Lindgren *et al.* 1983).

Three chemicals have been identified as attractants for *T. lineatum* in North America; ethanol (Moeck 1970, 1971) and α-pinene (Nijholt and Schonerr 1976) as host attractants, and lineatin, a tri-cyclic ketal (MacConnell *et al.* 1977; Borden *et al.* 1979) as the aggregation pheromone. Combinations of these chemicals, for use in trapping programs, have been investigated in Europe and western North America where *T. lineatum* occurs. Borden *et al.* (1982) confirmed reports from Europe that ethanol, α-pinene, and lineatin acted synergistically in attracting *T. lineatum*. However, they found that ethanol and α-pinene did not enhance the attraction of *T. lineatum* to sticky wire mesh or drainpipe traps in British Columbia. In contrast, Shore and McLean (1983) found that ethanol and α-pinene together did act synergistically with lineatin in attracting *T. lineatum* adults to drainpipe traps.

The different results may be attributed to several factors. Firstly, Borden *et al.* (1982) used release rates of ethanol and α-pinene 3-6 and 2-3 times greater, respectively, than did Shore and McLean (1983). Secondly, Shore and McLean (1983) actually tested for interactions between the semiochemicals of *Gnathotrichus sulcatus* (LeConte) and *T. lineatum*. These interactions may have influenced beetle response to traps baited only with *T. lineatum* semiochemicals. In addition, the latter authors did not differentiate the effects of ethanol and α-pinene in their treatments.

The conflicting results of these studies, along with the development and widespread use of the multiple-funnel trap (Lindgren 1983), prompted us to investigate the importance of these semiochemicals in attracting *T. lineatum* to the efficient new traps. We set out to determine: 1) the optimal combination of semiochemicals needed for attraction (Bedard and Wood 1981; Pearce *et al.* 1975; Renwick 1970) and 2) their optimal release rates (Baker and Linn 1984; Schlyter *et al.* 1987). We designed a field experiment to see which combination of semiochemicals resulted in the highest number of beetles caught, and a wind tunnel study to compare the number of *T. lineatum* caught in traps baited with the pheromone and a host attractant, using various combinations and release rates.

MATERIALS AND METHODS

Experiment 1

An 8 X 8 Latin square design (Steel and Torrie 1960) was used to test the attraction of *T. lineatum* to Lindgren multiple-funnel traps, unbaited and baited with ethanol, α-pinene, and lineatin, alone and in combinations. For each trapping period, which averaged 4 days, traps were assigned new positions randomly so that after eight trapping intervals, all the treatments had been in each of the eight positions once. This was used to control any possible effects of time and position on the trap catches.

The semiochemical release devices used and their placement in the funnel traps were consistent with the procedures used in commercial mass-trapping programs along the B.C. coast at the time of the study[1]. Ethanol (95%) was released from a 40 mL plastic container with a 1 mm-diam-aperture (release rate = 75mg/24 h), placed in the middle funnel of the traps. Alpha-pinene was released from a 4.5 mL glass bottle with a 4 mm-diam-aperture (release rate = 30 mg/24 h), also placed in the middle funnel. A slow-release lineatin lure[2] (release rate = 100 ug/24 h) was set in both the top and bottom funnels of the traps.

The traps were placed about 25 m apart in a forested site near a large log boom storage area, on the North Arm of the Fraser River in Vancouver, B.C. The experiment was run from May 12 - June 12, 1985. The traps were checked daily and every time any of the traps caught about 100 beetles, all the traps were emptied and moved to a new, randomly assigned position. The beetles were counted and sexed for each trapping period of the test.

The data were transformed by $x' = \log_{10}(x+1)$ and analyzed by analysis of variance (ANOVA) and the Student-Newman-Keuls test (SNK)($P \leq 0.05$) using U.B.C. ANOVAR (Greig and Osterlin 1978).

Experiment 2

The attraction of beetles to funnel traps baited with various release rates of ethanol and lineatin, was studied in 1987 in a wind tunnel described by Angerilli and McLean (1984), but since shortened to 3.6 m in length, while the width and height remained at 1.2 m each. The tunnel was fitted with activated charcoal and dust filters. Cool white fluorescent lights (660 W each), situated 2 m above the tunnel, were turned on because *T. lineatum* normally flies during the daylight. The acrylic plastic ceiling of the tunnel was covered with cellulose acetate to minimize glare and diffuse the illumination. Windspeed in the tunnel was maintained at 15 cm/sec, and the temperature averaged 23 ± 2° C.

Three 8-funnel traps were placed in the upwind section of the tunnel, 0.5 m from the screen. The three traps provided a larger plume of semiochemicals within the tunnel than could be achieved with a single trap.

Treatments for testing the reponse of *T. lineatum* in the wind tunnel included 4 lineatin release rates (0, 8, 64, and 512 ug/24 h), each tested in all combinations with 3 release rates of 95% ethanol (0, 75, and 150 mg/24 h). This resulted in 12 combinations of lineatin and ethanol treatments. The 0,0 release rate was the control treatment.

Slow-release lineatin lures were used, in the form of Hercon controlled release dispensers (Kydonieus and Beroza 1981), with release rates based on lure size (7.0 ug/24 h/cm^2)[1]. The lures were aged for one week at ambient temperatures to allow the release rates to stabilize. Six lures were used in each lineatin treatment. A lure was placed in the top and bottom of each trap. The size of each lure used for release rates of 8, 64, and 512 ug/24 h, were 0.19, 1.51, and 12.2 cm^2, respectively.

Ethanol was released from the same device described in experiment 1. For release rate treatments of 75 mg/24h, one lure was placed in the central trap, and for treatments of 150 mg/24 h, one lure was placed in each of the outer traps.

Traps used for the control treatments were not the same as those used for the baited treatments. To see if baited traps carried residue, a comparative test was run to compare beetle response to these traps following bait removal, with the response to the control traps.

The beetles used in this study had been collected during the spring of 1987 with lineatin-baited multiple-funnel traps at the same field site used in experiment 1. Beetles were collected daily and placed in 1 L plastic containers with moistened cloth towels. The containers were stored in a walk-in cooler at 4° C under a 14:10 h (L:D) photoperiod. The containers were checked twice weekly to monitor moisture levels. These beetles survived for more than 100 days.

1 Phero Tech. Inc., 1140 Clark Dr., Vancouver, B.C. V5L 3K3.

2 Biolure Reg. TM Consep Membranes of Bend, Oregon.

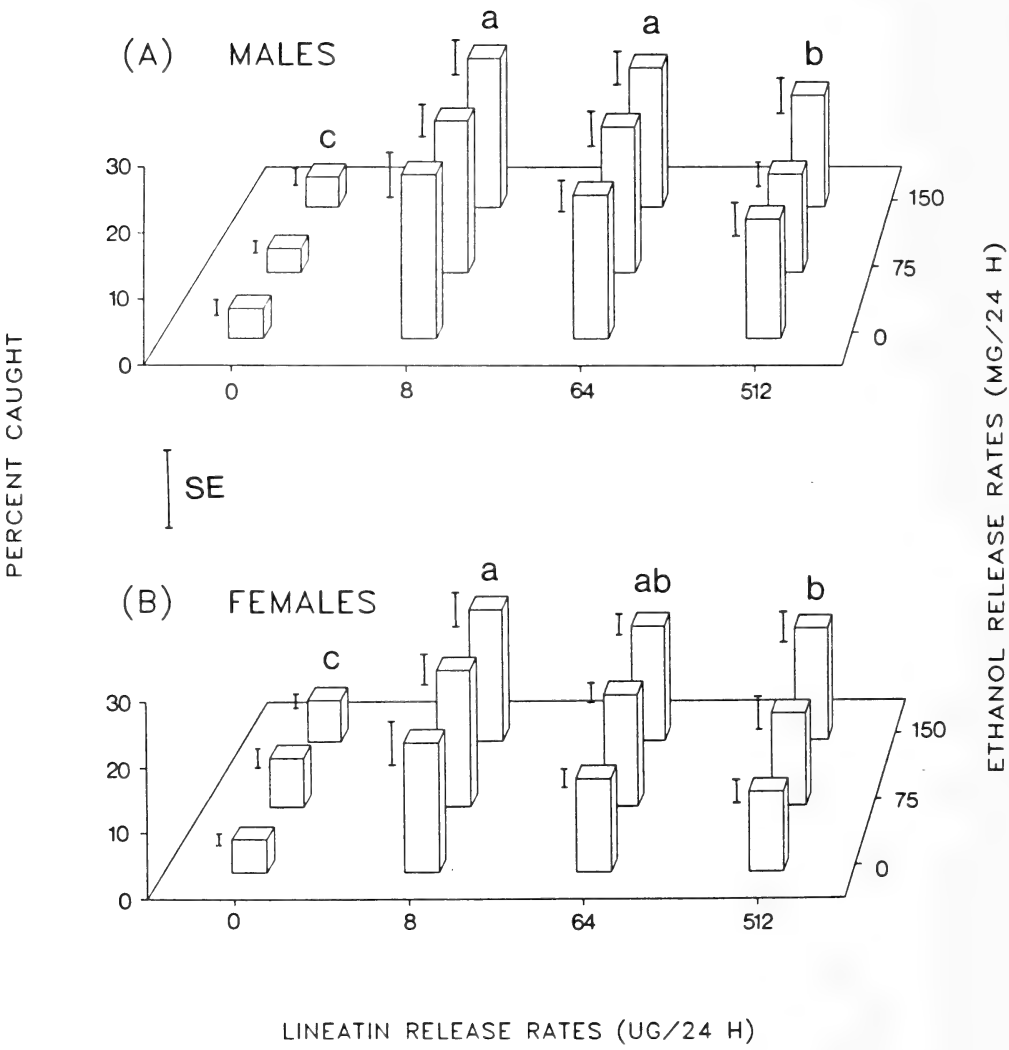

Figure 1. Mean percent (±) SE of *T. lineatum* caught in traps in response to combinations of varied release rates of lineatin and ethanol in a wind tunnel: A) Males and B) Females. Lineatin release rate columns, pooled across ethanol treatments, with the same letter are not significantly different (SNK; $P \leq 0.05$).

Prior to testing, the beetles were removed from the plastic containers and selected for testing based on their healthy appearance (i.e. presence of all body parts) and their ability to walk normally. The selected beetles were then placed in petri dishes with cloth towels and stored at 4° C until needed for the test, always on the same day. The beetles were given a warm-up period of 15 min at room temperature prior to release. The beetles were released from a horizontal tray, 35 cm above the tunnel floor, 1.5 m downwind from the traps.

A 4 X 3 factorial experiment was set up as a randomized complete block design with days serving as blocks. Males and females were tested separately. Because of the large number of treatments, one replication was tested per day for each of 15 experimental days. For each replication, 25 beetles were released and allowed 10 min to respond. The percentage of beetles caught in the traps was used as the dependent variable. The arc sine transformed data were analyzed by ANOVA and mean separation between treatments was carried out with the SNK test ($P \leq 0.05$) (SAS 1985).

RESULTS

Experiment 1

The number of *T. lineatum* caught differed significantly with trapping period ($F_{7,42}$ = 13.3; P kw 0.01), but not with trap position ($F_{7,42} = 0.8$; P 0.05), demonstrating the importance of the Latin square design in providing confidence that position was not a significant source of variation. Traps baited with lineatin caught significantly more beetles than traps not baited with this chemical (Table 1). Traps baited with ethanol and α-pinene showed no significant differences in catch when compared with the unbaited trap. Ethanol and α-pinene combined with lineatin did not enhance the catch of beetles, and in fact, resulted in a slightly lower catch than the treatment with lineatin alone.

Experiment 2

The number of *T. lineatum* caught in funnel traps in the wind tunnel was not significantly affected by the presence of ethanol either for males ($F_{2,154} = 0.4$; P 0.05) or females ($F_{2,154}$ = 1.4; P 0.05). In contrast, a significant increase in the number of beetles caught did occur with the presence of lineatin for both males ($F_{3,154} = 61.9$; $P < 0.01$) and females ($F_{3,154} = 32.0$; $P < 0.01$).

Males responded best at the lowest release rates of lineatin with an average trap catch of 23.5 and 21.6% for the 8 and 64 ug/24 h release rates, respectively (Figure 1A). A significant reduction in response occurred at 512 ug/24 h with a mean catch of 16.6% of the beetles tested. Despite somewhat lower catches, similar responses were found for females (Figure 1B), in which the highest catches, 20.0 and 16.1%, were obtained at 8 and 64 ug/24 h, respectively. Mean catch at 512 ug/24 h was 14.3 %, a significantly lower response than for the 8 ug treatment.

Table 1. Response by *Trypodendron lineatum* to semiochemical-baited funnel traps set in a forest from May - June, 1985.

	Mean Catch/Trap/ Sampling Period		
Bait	Males	Females	Total
Control (unbaited)	0.3 b[1]	0.1 b	0.4 b
Ethanol (E)	2.3 b	3.4 b	5.7 b
Alpha-pinene (P)	0.8 b	0.5 b	1.3 b
E + P	0.4 b	0.6 b	1.0 b
Lineatin (L)	735.0 a	616.0 a	1351.0 a
L + E	415.9 a	438.5 a	854.4 a
L + P	590.1 a	328.6 a	918.7 a
L + E + P	510.9 a	466.8 a	977.7 a

1 Means followed by the same letter not significantly different (SNK; $P \leq 0.05$).

No significant differences in response by *T. lineatum* were observed between the control traps and unbaited traps that had previously held ethanol and lineatin during the experiment ($F_{5,72}$ = 0.9; P 0.05). Thus, there was no evidence for contamination of the traps.

DISCUSSION

The hypothesis supporting the use of ethanol in trapping ambrosia beetles is that it acts as an arrestant/boring stimulant for beetles in close proximity to a suitable host (McLean and Borden 1977). Drainpipe traps require that beetles land on the trap and crawl through small diam holes in order to enter the trap (Bakke 1983). This contrasts with the immediate knockdown capture of beetles in funnel traps (Lindgren 1983). Our data suggest that there is no gain in adding ethanol and/or α-pinene baits to funnel traps, as the lineatin alone is sufficient to attract *T. lineatum* close enough to the trap for capture.

It is possible that ethanol and α-pinene may be important in attracting *T. lineatum* to funnel traps, but that the dispensers normally used for releasing them may account for our results. This is being investigated (Cushon unpublished)[3]. Nevertheless, the same dispensers were shown to be effective in enhancing the attraction of *T. lineatum* in Europe as well as another ambrosia beetle species, *Gnathotrichus sulcatus* (LeConte) to sticky wire mesh traps (Borden *et al.* 1982).

Response of *T. lineatum* to various release rates of lineatin has been previously examined in a field setting in British Columbia by Lindgren *et al.* (1983). They found that the number of beetles caught on cylindrical traps baited with lineatin, increased as release rates increased, from 10-40 ug/24h, and remained the same between 40 and 800 ug/24h. In a later experiment from the same paper, release rates of 40 ug/24h were found to be optimal for funnel traps, yet a release rate of only 10 ug/24 h of lineatin was adequate as long as the remaining lineatin (30 ug/24 h) was placed within 1.5 - 2 m of the trap. Our results in the wind tunnel with low release rates correspond well with those from Lindgren *et al.* (1983). However, a decrease in response was observed in the wind tunnel at the higher release rates. The differences in sensitivity of the beetles at the higher rates may have resulted from artificial factors imposed by the wind tunnel, such as an enclosed environment and a constant, unidirectional air flow. Both factors resulted in continuous exposure of the beetles to the pheromone, whereas in the field, pheromone plumes are often broken up by turbulence and wind shifts (Fares *et al.* 1980), resulting in non-continuous exposure. For these reasons and because the lures weaken with age, it is probably best for mass-trapping in the field to keep the release rates of lineatin higher than for studying beetle flight behavior in the wind tunnel.

Host volatiles may well be important in initial host recognition by *T. lineatum* in a natural forest situation. However, from our results, lineatin baits alone appear to be sufficient for running an effective mass-trapping program with Lindgren funnel traps around log booms and dryland sorts, where host volatiles are likely to be present anyway. The expense and extra labor involved in maintaining the ethanol and α-pinene baits would not seem to be necessary for maintaining effective mass-trapping programs for *T. lineatum* in British Columbia.

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REFERENCES

Angerilli, N. and J.A. McLean. 1984. Windtunnel and field observations of western spruce budworm responses to pheromone-baited traps. J. Entomol. Soc. Brit. Columbia. 81:10-16.

Baker, T.C. and C.E. Linn, Jr. 1984. Wind tunnels in pheromone research. *In* Hummel, H.E. and T.A. Miller. (Eds.). Techniques in Pheromone research. Springer-Verlag, New York. pp. 75-110.

Bakke, A. 1983. Dosage response of the ambrosia beetle *Trypodendron lineatum* (Olivier) (Coleoptera:Scolytidae) to semiochemicals. Z. ang. Ent. 95:158-161.

Bedard, W.D. and D.L. Wood. 1981. Suppression of *Dendroctonus brevicomis* by using a mass-trapping tactic. *In* Mitchell, E.R. (Ed.). Management of Insect Pests With Semiochemicals: Concepts and Practice. Plenum Press, New York. pp. 103-114.

Borden, J.H. 1985. Aggregation pheromones. *In* Behavior. Kerkut, G.A. (Ed.). Vol 9. *In* Comprehensive Insect Physiology, Biochemistry and Pharmacology. Kerkut, G.A. and LI. Gilbert (Eds.). Pergamon Press, Oxford. pp. 257-285.

Borden, J.H. and J.A. McLean. 1981. Pheromone-based suppression of ambrosia beetles in industrial timber processing area. *In* Mitchell, E.R. (Ed.). Management of Insect Pests With Semiochemicals: Concepts and Practice. Plenum Press, New York. pp. 133-154.

Borden, J.H., J.R. Handley, B.D. Johnston, J.G. Macconnell, R.M. Silverstein, K.N. Slessor, A.A. Swigar, and D.T.W. Wong. 1979. Synthesis and field testing of 4,6,6-lineatin, the aggregation pheromone of *Trypodendron lineatum* (Coleoptera, Scolytidae). J. Chem. Ecol. 5:681-689.

Borden, J.H., C.J. King, S. Lindgren, L. Chong, D.R. Gray, A.C. Oehlschlager, K.N. Slessor, and H.D. Pierce, Jr. 1982. Variation in response of *Trypodendron lineatum* from two continents to semiochemicals and trap form. Environ. Entomol. 11:403-408.

Fares, Y., P.J.H. Sharpe, and C.E. Magnuson. 1980. Pheromone dispersion in forests. J. Theor. Biol. 84:335-359.

Greig, M. and D. Osterlin. 1978. U.B.C. ANOVAR: Analysis of Variance and Covariance. Adapted from Brigham Young University Documentation. 69 pp.

Kydonieus, A.F. and M. Beroza. 1981. The hercon dispenser formulation and recent test results. *In* Mitchell, E.R. (Ed.). Management of Insect Pests With Semiochemicals: Concepts and Practice. Plenum Press, New York. pp. 445-454.

Lindgren, B.S. 1983. A multiple funnel trap for scolytid beetles (Coleoptera). Can. Ent. 115:299-302.

Lindgren, B.S., J.H. Borden, L. Chong, L.M. Friskie, and B.B. Orr. 1983. Factors influencing the efficiency of pheromone-baited traps for three species of ambrosia beetles (Coleoptera: Scolytidae). Can. Ent. 115:303-313.

MacConnell, J.G., J.H. Borden, R.M. Silverstein, and E. Stokkink. 1977. Isolation and tentative identification of lineatin, a pheromone from the frass of *Trypodendron lineatum* (Coleoptera: SColytidae). J. Chem. Ecol. 5:549-561.

McLean, J.A. and J.H. Borden. 1977. Attack by *Gnathotrichus sulcatus* (Coleoptera:Scolytidae) on stumps and felled trees baited with sulcatol and ethanol. Can. Ent. 109:675-686.

Moeck, H.A. 1970. Ethanol as the primary attractant for the ambrosia beetle *Trypodendron lineatum* (Coleoptera: Scolytidae). Can. Ent. 102:985-995.

Moeck, H.A. 1971. Field test of ethanol as a scolytid attractant. Can. Dept. Fish. and For. Bi-Mon. Res. Notes. 27(2):11-12.

Nijholt, W.W. and J. Schonherr. 1976. Chemical response behavior of scolytids in West Germany and western Canada. Environ. Canada, Bi-mon. Res. Notes. 32:31-32.

Pearce, G.T., W.E. Gore, R.M. Silverstein, J.W. Peacock, R.A. Cuthbert, G.N. Lanier, and J.B. Simeone. 1975. Chemical attractants for the smaller European elm bark beetle *Scolytus multistriatus* (Coleoptera:Scolytidae). J. Chem. Ecol. 1:115-124.

Renwick, J.A.A. 1970. Chemical aspects of bark beetle aggregation. Symp. on population Attractants. Contrib. Boyce Thompson Inst. 24:337-341.

SAS Institute. 1985. SAS user's guide: Statistics. SAS Institute, Cary, N.C.

Schlyter, F., J.A. Byers, and J. Lofqvist. 1987. Attraction to pheromone sources of different quantity, quality, and spacing: Density-regulation mechanisms in bark beetle *Ips typographus*. J. Chem. Ecol. 13: 1503-1523.

Shore, T.L. and J.A. McLean. 1983. A further evaluation of the interactions between the pheromones and two host kairomones of the ambrosia beetles *Trypodendron lineatum* and *Gnathotrichus sulcatus* (Coleoptera:Scolytidae). Can. Ent. 115:1-5.

Steel, R.G.D. and J.H. Torrie. 1960. Principles and Procedures in Statistics. McGraw-Hill, New York. 481 pp.

FIELD TRIALS OF FENVALERATE AND ACEPHATE TO CONTROL SPRUCE BUD MIDGE, *DASYNEURA SWAINEI* (DIPTERA: CECIDOMYIIDAE)

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ABSTRACT

Three concentrations each of fenvalerate and acephate were tested for efficacy against the spruce bud midge on black and white spruce in southcentral Alaska in 1985. Only the highest concentration of fenvalerate (0.025 percent), which is currently registered with the United States Environmental Protection Agency for forest use, provided significant protection.

INTRODUCTION

The spruce bud midge, *Dasyneura (Rhabdophaga) swainei* Felt, kills terminal and lateral vegetative buds of white spruce, *Picea glauca* (Moench) Voss, and black spruce, *P. mariana* (Mill.) B.S.P. (Furniss and Carolin 1977). Larvae emerge from eggs deposited on newly developing shoots, crawl to the shoot tips, and enter the host through the bases of new needles (Cerezke 1972, Clark 1952). Successful larvae migrate through shoot tissue to newly formed buds, feed on and kill the bud apical meristem, and overwinter usually singly in the still living, galled buds. Adults emerge in the spring from pupae in the galled buds and lay eggs as new shoots begin to elongate. The buds soon die, but they persist as gray, weathered, swollen galls.

Loss of terminal buds may result in reduced height growth (Cerezke 1972) and stem deformity because multiple leaders develop from lateral buds. Such effects are undesirable in trees grown for timber because reduced height growth in seedlings and saplings can delay height dominance over competing vegetation, and repeated stem deformities cause defects in harvested posts, poles, and logs.

This experiment was intended to determine whether registered concentrations (or formulations) of fenvalerate and acephate for control of seed, cone, and needlemining insects would effectively reduce damage by spruce bud midges. Fenvalerate, a synthetic pyrethroid, was chosen because of its low toxicity to vertebrates, except fish and amphibians, and its high toxicity to insects. It is rainfast on host foliage if applied as Pydrin® Emulsible Concentrate[1] diluted in water. Acephate was chosen because it is partially systemic (Lyon 1973), has low vertebrate toxicity, and is highly toxic to insects. If applied as Orthene® Tree and Ornamental Spray dissolved in water, some of the active ingredient is presumably absorbed within several hours by the host foliage and translocated to internal feeding sites of insects (Crisp *et al.* 1978), such as new needles.

MATERIALS AND METHODS

The area selected for the test was denuded by fire in 1959 but had revegetated naturally with black spruce and white spruce seedlings.

A total of 105 spruce seedlings ranging from 0.7 to 2.0 m in height and infested by spruce bud midge were examined, selected and labeled with numbered tags. Eleven trees were white spruce and 94 were black spruce. All were formerly infested and most had multiple leaders.

The trial was completely randomized. Fifteen trees, selected by numbers using a calculator programmed to generate random numbers, were assigned to each of 7 treatments.

Treatments were: a) 0.025%[2], b) 0.0125%, and c) 0.00625% fenvalerate aqueous dilutions; d) 1.0%[3], e)0.5%, and f)0.25% acephate aqueous solutions; and g) controls, without treatment. Insecticide formulations were mixed with water at ratios shown in Table 1.

The trees were treated after shoot elongation had begun, and formulations were applied by backpack hydraulic sprayer until runoff. Spray treatments were applied on 26 June, 1985 during still, clear weather in this order: f), e), d), c), b), and a). The sprayer was rinsed with water between treatments and with water and Nutrasol® between the acephate and fenvalerate treatments.

The trees were re-examined after bud flush on 17 June, 1986 to assess the efficacy of the insecticide treatments. The terminal bud formed in 1986 on the dominant leader of each tree was classified as infested or uninfested. Buds that were swollen and rosetted in a manner characteristic of bud midge damage (Clark 1952) and that did not form shoots in 1986, were considered infested. For comparison, the terminus of each leader dominant at the end of the 1984 growing season was examined. If a new leader had grown from the terminal bud in 1985, it was classified as uninfested. If the terminal bud formed in 1984 was dead and galled in a manner typical of bud midge infested buds, it was classified as infested. Furthermore, the upper 25 terminal buds combined on primary, secondary, and tertiary shoots of each test tree were classified as uninfested, currently infested, or formerly infested.

Numbers of infested terminal buds on the upper 25 primary, secondary, and tertiary shoots before and after treatment were analyzed by analysis of variance (ANOV). Post-treatment results were compared by Bonferroni's multiple pairwise comparison t-test with *Alpha* = 0.05. Data were also analyzed through analysis of covariance (ANCOV) using numbers of buds infested in 1984 or earlier as the covariate. Proportions of trees with an infested leader terminal bud were analyzed by paired treatments for significant differences by computing a critical Z statistic[4] with *Alpha* = 0.05. In the analysis of proportions, the condition of only one bud per tree, the terminal bud on the dominant leader, was considered.

Table 1. Insecticide concentrations and formulations in water, Alaska, 1985.

Insecticide	Treatment	Concentration	Formulation in water	
		percent	fl oz/gal	ml/l
Fenvalerate[1]	a)	0.025	0.110	0.860
	b)	0.125	0.055	0.430
	c)	0.0625	0.028	0.215
		percent	oz/gal	g/l
Acephate[2]	d)	1.00	0.107	0.799
	e)	0.50	0.053	0.400
	f)	0.25	0.027	0.200

[1] Pydrin® 2.4 Emulsible Concentrate
[2] Orthene® Tree and Ornamental Spray

[1] Trade names of commercial products are mentioned solely for information. No endorsement by the U.S. Department of Agriculture is implied.
[2] Highest concentration has U.S. Environmental Protection Agency Registration No 201-401 for forest use.
[3] Highest concentration has U.S. Environmental Protection Agency Registration No. 239-2427-AA for general use.
[4] $$Z = \frac{\hat{P}_1 - \hat{P}_2}{\left(\frac{\hat{P}_1(1-\hat{P}_1)}{n_1} + \frac{\hat{P}_2(1-\hat{P}_2)}{n_2}\right)^{1/2}}$$
Where P_i is the proportion of trees with their leader terminal bud attacked in treatment i, and n_i is the number of tree replicates for treatment i.

Table 2. Effect of fenvalerate and acephate treatments on incidence of spruce bud midge in terminal buds, Alaska, 1985.

Treatment	Insecticide concentration	Infested terminal buds			
		Mean number ± SE on upper 25 shoots		Proportion on leaders only	
	percent	pre-1985	1985[1]	1984	1985
Fenvalerate	0.025	3.93 ± 0.69 a[2]	1.53 ± 0.41 a	0.73	0.13 c[3]
	0.0125	3.40 ± 0.49 a	1.80 ± 0.49 ab	0.67	0.27 cd
	0.00625	3.67 ± 0.58 a	2.80 ± 0.63 ab	0.67	0.53 cd
Control	0.00000	3.47 ± 0.61 a	4.13 ± 0.84 b	0.73	0.60 d
Acephate	1.00	2.60 ± 0.65 a	3.53 ± 0.65 b	0.93	0.47 cd
	0.50	4.00 ± 0.32 a	3.27 ± 0.59 b	0.67	0.27 c
	0.25	4.33 ± 0.60 a	2.93 ± 0.63 b	0.80	0.47 cd
Control	0.00	3.47 ± 0.61 a	4.13 ± 0.84 b	0.73	0.60 d

[1] For fenvalerate, ANOV F = 3.64, P = 0.01; ANCOV F = 3.67, P = 0.01. For acephate, ANOV F = 0.55, P = 0.65; ANCOV F = 0.70, P = 0.59.

[2] Means followed by the same letter in the same subcolumn were not significantly different at *Alpha* = 0.05.

[3] Proportions followed by the same letter were not significantly different at a confidence coefficient of 0.95.

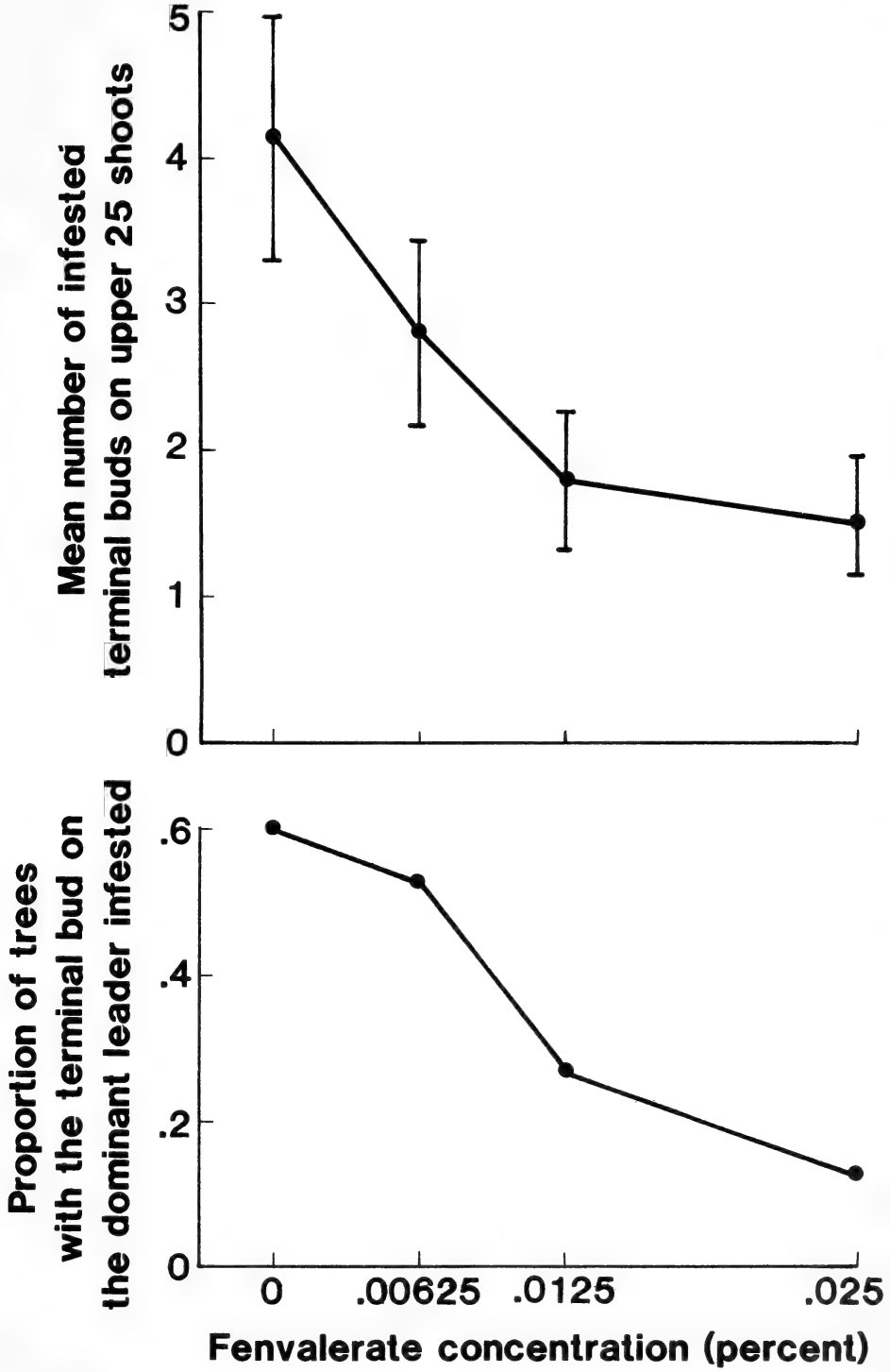

Figure 1. *Upper:* Mean number of posttreatment infested terminal buds on the upper 25 primary, secondary, and tertiary shoots combined, for fenvalerate treated and control trees. Vertical bars span ± 1 standard error.
Lower: Proportion of fenvalerate treated and control trees that had the terminal bud on the dominant leader infested in 1985.

RESULTS AND RECOMMENDATIONS

Only one white spruce received acephate treatment and one received the most concentrated fenvalerate treatment. The remaining nine white spruce were divided equally among the two less-concentrated fenvalerate treatments and the controls. Pretreatment mean number of infested buds was not significantly different for white and black spruce (for acephate and controls, $F = 0.01$, $P > 0.75$; for fenvalerate-treated trees and controls, $F = 0.41$, $p > 0.50$). Posttreatment mean number of infested buds, which were analyzed only for the three treatments that had more than one white spruce per treatment, were not significantly different for white and black spruce (for the 0.0125% fenvalerate treatment, $F = 1.37$, $P > 0.25$; for the 0.00625% fenvalerate treatment, $F = 0.79$, $P > 0.25$; and for the controls, $F = 0.14$, $P > 0.50$).

Analysis of Variance of data pooled for both species indicated no significant differences in prespray numbers of infested buds among treatments (Table 2). Furthermore, use of prespray numbers of infested buds as the covariate had essentially no effect on results of posttreatment analysis. The only treatment that provided significant protection from the spruce bud midge was 0.025% fenvalerate. Acephate could have washed off because of its solubility in water and poor rainfastness (Robertson and Boelter 1979, Haverty and Robertson 1982). But acephate's reputed systemic insecticidal activity may also be inoperative when sprayed on spruce, evidenced by Sundaram and Hopewell (1976) who failed to recover significant amounts of acephate or its systemic metabolite from spruce foliage after simulated aerial spray application.

We recommend that future insecticide trials for control of spruce bud midge include proven systemic insecticides, such as dimethoate and metasystox, and additional rainfast compounds, such as carbaryl and permethrin, that are a ready registered for use against other forest pests. We do not recommend testing higher concentrations of fenvalerate because results of this trial suggest that the maximum-effect dose has been closely approached at the 0.025% concentration (Fig. 1. Upper and lower).

REFERENCES

Cerezke, H. F. 1972. Observations on the distribution of the spruce bud midge (*Rhabdophaga swainei* Felt) in black and white spruce crowns and its effect on height growth. Can. J. For. Res. 2: 69-72.

Clark, J. 1952. The spruce bud midge, *Rhabdophaga swainei* Felt (Cecidomy iidae: Diptera) Can. Entomol. 84: 87-89.

Crisp, C.E., T.W. Koerber, C.E. Richmond, and B.H. Roettgering. 1978. Acropetal translocation of acephate into terminal shoots of Jeffrey pine for control of western pine shoot borer. In: Proc. Symp. on Systemic Chem. Treatments in Tree Culture. Oct. 9-11, 1978, East Lansing, MI. p. 307-324.

Furniss, R.L., and V.M. Carolin. 1977. Western Forest Insects. USDA For. Serv. Misc. Pub. No. 1339. Sup. Doc. Washington, D.C., 654 p.

Haverty, M.I., and J.L. Robertson. 1982. Laboratory bioassays for selecting candidate insecticides and application rates for field tests on the western spruce budworm. J. Econ. Entomol. 17: 179-182.

Lyon, R.L. 1973. Reports from the Insecticide Evaluation Project. PSW-2203. USDA For. Serv., Pacific Southwest Forest and Range Exp. Stn., Berkeley, CA 5 p.

Robertson, J.L., and L.H. Boelter. 1979. Toxicity of insecticides to Douglas-fir tussock moth, *Orgyia pseudotsugata* (Lepidoptera: Lymantriidae). II. Residual toxicity and rainfastness. Can. Entomol. 111: 1161-1175.

Sundaram, K.MS., and W.W. Hopewell. 1976. Distribution, persistence and translocation of Orthene in spruce trees after simulated aerial spray application. Environment Canada, Chem. Control Res. Inst. Rep. CC-X-121.

CHEMICAL AND BIOLOGICAL CONTROL OF ERYTHRONEURA LEAFHOPPERS ON *VITIS VINIFERA* IN SOUTHCENTRAL WASHINGTON

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ABSTRACT

Fenpropathrin (56 g [AI]/ha) and dimethoate (1681 g [AI]/ha) controlled the western grape leafhopper, *Erythroneura elegantula* Osborn. Arthropod predators were collected on wine grapes, *Vitis vinifera* (L.). Most were of uncertain importance in the regulation of *Erythroneura* spp. populations. The greatest source of leafhopper egg mortality is parasitization by the mymarid wasp, *Anagrus epos* Girault. Vineyards grown in isolated areas (10-20 Km from other irrigated areas) are subject to leafhopper injury in the absence of the parasitoid which requires a continuous supply of leafhopper eggs. The concept of infesting French prune, *Prunus domestica* L., with non-pestiferous *Erythroneura prunicola* as a winter refugium for *A. epos* is advanced as an approach to biological control of *Erythroneura* spp. in isolated areas.

KEY WORDS: *Erythroneura elegantula, Erythroneura ziczac, Vitis vinifera, Anagrus epos,* parasitoid, leafhopper control, wine grape pest management

INTRODUCTION

Control of the western grape leafhopper (WGLH), *Erythroneura elegantula* Osborn, has been investigated extensively for many years, particularly in California. Excessive application of pesticides to control WGLH in California led to both insecticide resistance in the leafhopper (Doutt and Smith 1971) and tetranychid mite outbreaks (Flaherty and Huffaker 1970). Problems from unnecessary sprays were avoided after it was established that Thompson seedless vines grown for wine production suffered no economic loss from a mean of 20 first generation nymphs per leaf and 10-15 second and third generation nymphs per leaf (Jensen *et al.* 1969). Most Washington wine grape growers use these threshold levels. Pacific Northwest Extension recommends parathion, demeton, azinphosmethyl, oxydemetonmethyl, or phosdrin for control of "leafhoppers" on Vitis spp. (Capizzi *et al.* 1987). In addition, dimethoate is registered for leafhopper control in Washington. The British Columbia Ministry of Agriculture recommends carbaryl, azinphosmethyl, or endosulfan for control of Virginia creeper leafhopper (VCLH), *Erythroneura ziczac* Walsh, on Vitis spp. (J. Vielvoye 1985 pers. comm.).

Jensen and Flaherty (1981) listed several WGLH predators and parasitoids. Although many predators and parasitoids are known in the Pacific Northwest, the association of these beneficial arthropods with young wine grape vineyards in isolated areas of the region has not been determined. Since 1982, Washington wine grape pest management specialists have found parasitized WGLH eggs and suspected the mymarid wasp *Anagrus epos* Girault. This species attacks a variety of typhlocybine leafhoppers including *Typhlocyba pomaria* McAtee, *T. quercus* (F.), *Edwardsiana prunicola* (Edwards), *E. rosae* (L.), *Erythroneura plena* Beamer (Mulla, 1956); *Dikrella cruentata* (Gillette), *E. elegantula* (Doutt and Nakata 1973); *Dikrella californica* Lawson (Williams 1984); and *E. ziczac* (McKenzie and Beirne 1972).

Girault (1911) described *A. epos* from a specimen collected on a windowpane in Illinois. Mulla (1956) illustrated the immature forms. *A. epos* completes about three generations for every one of the WGLH (Doutt and Nakata 1973) and had an intrinsic rate of increase about twice that of the leafhopper (Williams 1984). *A. epos* parasitism reached 70% in samples of VCLH eggs in British Columbia (McKenzie and Beirne 1972). Cate (1975) observed that parasitism in two California vineyards increased from 7.5 and 23.4% of first generation WGLH eggs, to 70 and 88% in late season.

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Doutt and Nakata (1973) first considered using *A. epos* regulation of WGLH to reduce pesticide applications that were triggering pesticide resistance and spider mite outbreaks.

The purpose of this study was: 1) to evaluate insecticides for control of *Erythroneura* leafhoppers on *Vitis vinifera* (L.), 2) to determine the presence of predators or parasitoids and their influence on leafhopper density, and 3) to determine if economic leafhopper injury is associated with isolation from *A. epos*.

MATERIALS AND METHODS

Pesticide evaluation. In 1984, a commercial Riesling vineyard was used to test the effect of dimethoate on a mixed population of WGLH and VCLH. The vineyard rows ran north-south. The 10 rows on the west edge were left unsprayed. Two unsprayed plots of 25 and 29 vines were established at the northwest and southwest corners of the vineyard, respectively. Five unsprayed rows were left between the control plots and the sprayed vines. Two sprayed plots of 30 vines were established, one at the north and one at the south edge of the sprayed vines. Dimethoate 25% wettable powder (WP) was applied on 30 June using a Degania^{R} sprayer operating at 23,000 g/cm^2 at a rate of 1702.5 g (AI) in 470 liters H_2O/ha. Four rows were treated with each pass.

Erythroneura spp. population density was sampled without replacement by counting the number of nymphs on the underside of one shaded leaf picked from each of 30 vines.

Table 1. Mean number of *Erythroneura* spp. nymphs underside of *V. vinifera* var. Riesling leaf treated with dimethoate 25% WP[a], Cold Creek, Washington, 1984

Days post-application	untreated (n=54)	treated (n=60)
- 1	22.3	28.7
7	5.8	0.1
19	0.9	0.1
26	0.9	0.0
33	0.3	0.0
40	0.1	0.0
47	0.8	0.0
57	0.8	0.1
61	1.4	0.0
69	0.6	0.8
75	0.2	0.2
82	0.2	0.2
89	0.1	0.1
96	0.0	0.1

[a] 1702 g (AI) applied in 470 liters H_2O/ha.

In 1985 and 1986, plots were established in a block of Chenin Blanc grapes located at Washington State University, Irrigated Agriculture Research and Extension Center (WSU-IAREC), Prosser, WA. Plots consisted of six vines and were replicated four times in a randomized complete block design. In 1985, dimethoate, fenpropathrin and cloethocarb were evaluated. Rates are listed in Table 2. Treatments in 1986 included dimethoate and fenpropathrin (rates listed in Table 3). Pretreatment counts were made 1 August (1985) and 8 July (1986). Applications were made 5 August (1985), 15 July and 22 August (1986) using an air blast sprayer operated at 21,000 gm/cm^2. Plot rows were sprayed from both sides using a total volume of 1870 l H_2O/ha. Cross row contamination was avoided by using only the nozzles on one side of the sprayer with the spray directed against a canvas shield, 2.6 m high and 3.7 m long, pulled by a tractor in the adjacent row (Grimes and Cone 1985).

WGLH population density was sampled with replacement by counting the number of nymphs on the underside of 10 leaves, approximately breast height, from each of six vines per plot 1985 and 1986. Data were subjected to analysis of variance and means were compared using Duncan's multiple range test (Duncan 1955).

Table 2. Effect of pesticides on WGLH on *V. vinifera* var. Chenin blanc, IAREC, Prosser, WA 1985. Mean number nymphs/underside of 60 leaves

Treatment	Rate (g AI/ha)[a]	Mean number nymphs 4 days post-application[b]	Mean number nymphs 24 days post-application
Unsprayed	----	16.0 a	11.0 a
Cloethocarb 50% WP	141.9	4.5b	9.8ab
"	233.8	1.3b	5.3ab
"	567.5	0.0b	3.3b
Dimethoate 25% WP	2270.0	0.8 b	5.0ab
Fenpropathrin 2.4% EC	227.0	0.0b	3.3b

[a] All materials were applied in 1870 liters H_2O/ha.
[b] Column means followed by the same letter are not significantly different DMRT, $P < .01$.

Survey for arthropod predators and parasitoids. Leaf and sweep net samples were collected from *V. vinifera* grapes during the 1983 and 1984 growing seasons at WSU-IAREC and Cold Creek, WA. Leaf and sweep net samples were taken in September and October 1984 from 12 vineyards throughout southcentral Washington. At least 50 m of each vineyard margin was sampled with a sweep net and a minimum of 200 leaves sampled from each location at each sampling date. Leaves were examined for the presence of *Erythroneura* immatures and evidence (see methods under *Anagrus parasitism*) of *A. epos*. The sweep net samples were sorted for predators or parasitoids which were pinned, labeled and prepared for identification. Cicadellidae species were determined using the keys of Oman (1949) and Beirne (1956). Other specimens were sent to appropriate authorities for identification (see acknowledgment). Voucher specimens were placed in the M. T. James Insect Museum at Washington State University, Pullman.

Anagrus parasitism. Two vineyards observed to have high numbers of *A. epos* were sampled for their incidence of egg parasitism. One hundred shaded leaves were picked from WGLH infested vines 3.2 km north of Grandview, WA on 4 October 1984, and from caged and uncaged Grenache vines with both WGLH and VCLH at IAREC on 27 September 1984. The cages had been installed in July using saran screen of 12.5 X 12.5 strands/cm^2 (Bioquip Corp. El Segundo, CA). The effect of the cages on *A. epos* movement was unknown. The sampled leaves were examined under a dissecting microscope (20X). To determine the incidence of parasitism, eggs containing visible *Anagrus* larvae were counted as parasitized. Young *A. epos* larvae just beginning develpment in its *Erythroneura* host cannot be recognized so those eggs were not counted as parasitized. In addition, emergence holes in leaf tissue were counted. Wasp emergence holes were circular whereas normal leafhopper emergence left a narrow slit in the leaf tissue (Fig.1). The difference between the circular holes and the narrow slits provided a clear postemergence method for distinguishing between normal and parasitized eggs. Since only *Anagrus epos* were recovered from reared material, we assumed the emergence holes to be produced by that species.

RESULTS AND DISCUSSION

Pesticide evaluation. The mean number of *Erythroneura* spp. nymphs per leaf on vines treated with dimethoate in 1984 are compared with untreated vines (Table 1). *Erythroneura* nymph density dropped dramatically and remained low in both the sprayed and unsprayed plots. Pesticide drift into the control plots was observed at the time of application and may have caused the drop in nymphal density observed in all experimental plots. Although nymph density was low in both treated and untreated areas, numbers were slightly higher in the untreated area after 7 days and remained slightly higher throughout the test period. Nymphal density on nearby untreated Grenache vines increased during the same period until the vines were defoliated.

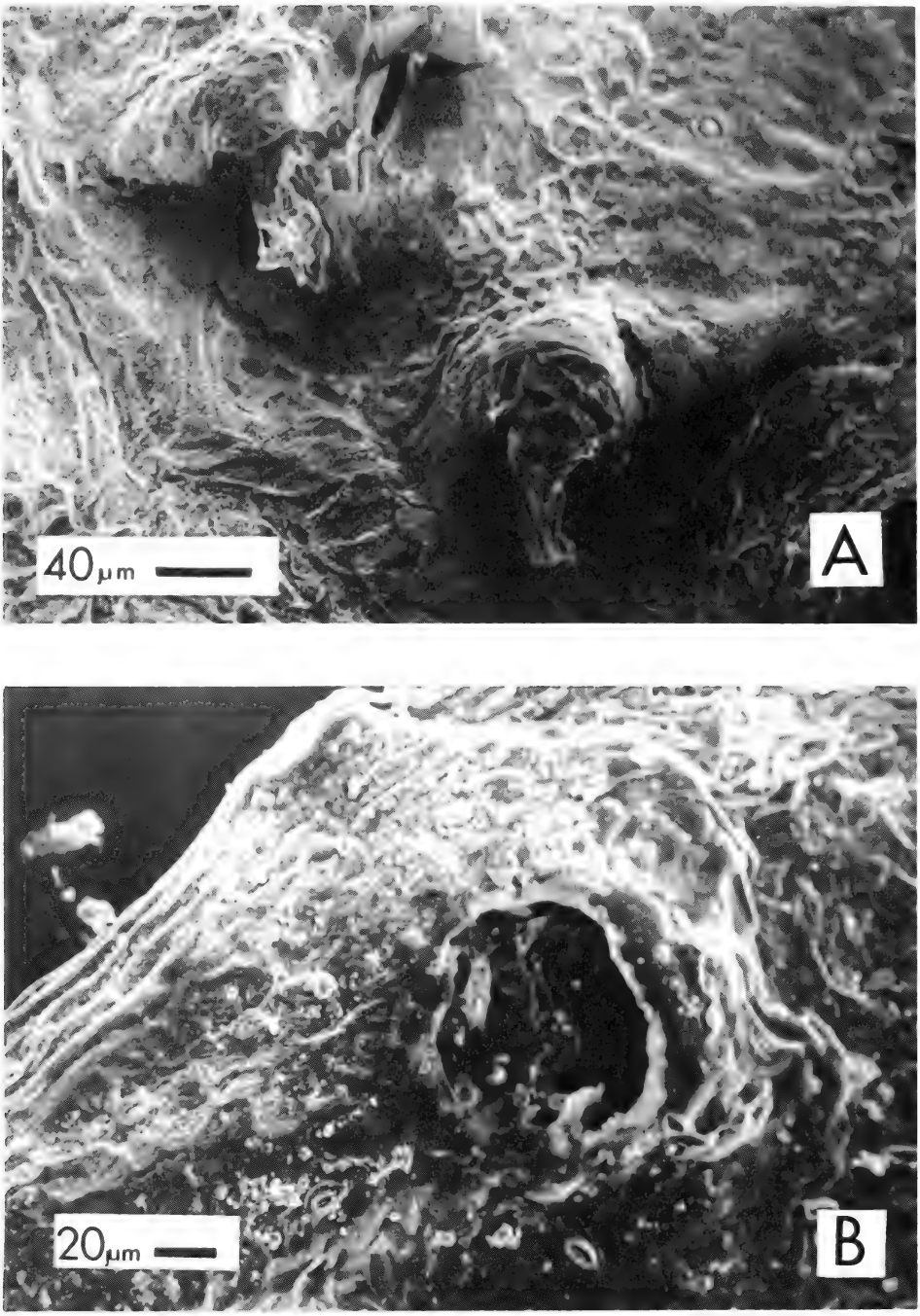

Figure 1. SEM of *Vitis vinifera* leaves comparing the slit-like, normal emergence hole of western grape leafhoppers (A) and the circular hole of its parasitoid *Anagrus epos* (B).

The mean number of WGLH nymphs per 60 leaves in each treatment in 1985 is given in Table 2. Four days post-treatment, nymphal density was significantly lower in all pesticide treated plots compared with unsprayed plots. Twenty-four days post-treatment, only vines sprayed with fenpropathrin and the highest concentration of cloethocarb (560.7 g [AI]/ha) had nymphal densities significantly lower than the unsprayed vines.

In 1986, three rates of fenpropathrin were compared with dimethoate and an untreated check. Leafhopper nymphs were counted weekly from early July until harvest in September (Table 3). The number of leafhopper nymphs were about equal in all plots on July 8 before the first application was made. Fenpropathrin at 56, 112, and 224 g (AI)/ha provided excellent control of western grape leafhopper. A few nymphs appeared in the plots treated with 56 g (AI)/ha after one month. Plots treated with dimethoate at 1681 g (AI)/ha had reduced numbers of nymphs two days after treatment but they were not significantly different from the untreated check. Nymphs appeared in dimethoate treated plots after one month. A second application was made to treatment plots on August 22 in anticipation of a fall increase and based on increasing numbers in the untreated plots. The fall population increase did not develop.

Survey for predators and parasitoids. Many arthropod predators were found on *V. vinifera* in southcentral Washington (Table 4). An unidentified salticid spider was the only species observed to prey on *Erythroneura nymphs*. Many of the predators found, however, prey on *Erythroneura* spp. elsewhere (Knowlton, 1946; McKenzie and Beirne, 1972; Jensen and Flaherty, 1981) and probably do so in Washington. Hemerobiid adults were found on *V. vinifera* at the end of the growing season, but were not collected in this survey. The mite fauna on *V. vinifera* were not considered, but *Anystis agilis* (Banks), known to prey on WGLH (Jensen and Flaherty 1981), is found on several Washington crops (W. W. Cone, unpublished data). It appears that predation on either WGLH or VCLH is isolated and sporadic with no consistent predator-prey relationships.

Anagrus parasitism. The greatest source of egg mortality for WGLH or VCLH seemed to be parasitization by *Anagrus epos*. No adult or nymphal parasitoids of *Erythroneura* spp. were found in this study. The incidence of *A. epos* parasitism (12 Sept 1984) on uncaged vines at an IAREC vineyard was 83.2% (322 of 387 eggs) and 74% (276 of 373 eggs) at a vineyard 3.2 km north of Grandview, WA. Parasitism of eggs laid in clusters by VCLH or those laid singly by either VCLH or WGLH appeared equal.

Although some vineyards in the study area developed high numbers of *A. epos* late in the season, early season *A. epos* activity is important in regulating WGLH populations (Doutt and Nakata, 1973) and should be investigated more closely in the Pacific Northwest. Since the wasp requires a continuous supply of host eggs, it cannot overwinter in Washington vineyards. Doutt and Nakata (1973) found that vineyards within 3.2 km of natural *Rubus* spp. stands, with their year-round supply of *Dikrella cruentata* eggs, typically did not need chemical control measures. In Washington, vineyards established in desert locations, far from *A. epos*, displayed the worst WGLH problems. Growers close to *A. epos* overwintering sites needed only to recognize that fact and avoid the calendar-dictated spray schedule. In British Columbia, VCLH in vineyards near overwintering refuges such as wild *Rosa* sp. or apple, experienced *A. epos* parasitism one month earlier than vineyards surrounded by desert (McKenzie and Beirne, 1972).

Early efforts to bring wasps to isolated vineyards by planting *Rubus* spp. failed when the interior of the blackberry stands became too dry to support *Dikrella* sp. (Jensen and Flaherty, 1981). This problem may be resolved as horticultural practices are refined (Williams, 1984). Kido *et al.* (1984) found that orchards of French prune, *Prunus domestica* L., orchards with the non-pestiferous *E. prunicola* can supply sufficient *A. epos* to control WGLH in adjacent vineyards.

The concept of establishing winter refuges for *A. epos* may be very useful for biological control of *Erythroneura* spp., particularly where vineyards are isolated from other irrigated areas. Varieties of *Prunus domestica* might be investigated for production of *Erythroneura* spp. and *A. epos* and then planted near isolated *V. vinifera* vineyards where they would serve as an early season source of *A. epos*. Surveys of several Italian prune orchards in the vicinity of IAREC indicated high populations of *E. prunicola*.

Table 3. Mean number of western grape leafhopper nymphs per 10 leaves in plots of Chenin blanc grapes treated with insecticides.[a] WSU-IAREC, Prosser, WA. 1986

Treatment	Rate (g [AI]/ha)	$\bar{x}$ WGLH nymphs/10 leaves[b] 7/8	7/17	7/24	7/30	8/7	8/15	8/20	8/27	9/4	9/10
Fenpropathrin	56	7.8 a	0 a	0 a	0 a	0 a	0.1 a	0.5 a	0 a	0 a	0 a
	112	6.5 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a
	224	7.2 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a	0 a
Dimethoate	1681	6.3 a	1.3 b	0.1 a	0 a	0 a	0.2 a	0.3 a	0 a	0 a	0 a
Untreated	--	7.6 a	3.3 b	2.2 a	0.9 a	4.1 b	8.1 b	13.4 b	7.9 b	2.1 b	0.3 a

[a]Treated July 15 and Aug 22, plots replicated four times.

[b]Column means followed by the same letter are not significantly different (DMRT, $P \leq 0.01$).

Table 4. Arthropod predators collected on *V. vinifera* in southcentral Washington, 1984

ARACHNIDA

Thomisidae

Xysticus sp.[a]

Salticidae[a]

Oxyopidae

Oxyopes sp.[a]

Tetragnathidae[a]

Anyphaenidae[a]

Araneidae

Argiope trifaseiuta (Forskal)

COLEOPTERA

Coccinellidae

Hippodamia convergens Guérin-Méneville

Coccinella transversoguttata Falderman

Stethorus punctum picipes Casey

Hyperaspis dissoluta nevadica Casey

NEUROPTERA

Chrysopidae

Chrysopa nigricornis Burmeister

HEMIPTERA

Anthocoridae

Orius tristicolor (White)

Reduviidae

Sinea diadema (F.)

Lygaeidae

Geocoris pallens Stal

Nabidae

Nabis alternatus Parshley

[a] Specimens were immature and could not be identified further.

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REFERENCES

Beirne, B. P. 1956. Leafhoppers (Homoptera: Cicadellidae) of Canada and Alaska. Can. Entomol. Suppl. 2. 180 p.

Cate, J. R. 1975. Ecology of *Erythroneura elegantula* Osborn in grape ecosystems in California. Unpubl. Ph.D. Thesis, Univ. Calif. Berkeley. 349 p.

Capizzi, J., G. Fisher, H. Homan, C. Baird, A. Antonelli, and D. Mayer. 1987. Pacific Northwest Insect Control Handbook. Cooperative Extension of Oregon, Idaho, and Washington. 316 p.

Doutt, R. L. and R. F. Smith. 1971. The pesticide syndrome-diagnosis and suggested prophylaxis, pp. 3-15. *In* C. B. Huffaker (ed.), Biological Control. Plenum, New York. 511 p.

Doutt, R. L. and J. Nakata. 1973. The *Rubus* leafhopper and its egg parasitoid: an endemic biotic system useful in grape-pest management. Environ. Entomol. 2: 381-386.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1-42.

Flaherty, D. L. and C. B. Huffaker. 1970. Biological control of Pacific mites and Willamette mites in San Joaquin vineyards. I. Role of *Metaseiulus occidentalis*. Hilgardia 40: 267-308.

Girault, A. A. 1911. Description of North American Mymaridae with synonymic and other notes on described genera and species. Am. Entomol. Soc. Trans. 37: 253-324.

Grimes, E. W. and W. W. Cone. 1985. Control of the grape mealybug, *Pseudococcus maritimus* (Ehrhorn), (Homoptera: Pseudococcidae) on Concord grape in Washington. J. Entomol. Soc. Brit. Columbia 82:3-6.

Jensen, F. L., D. L. Flaherty, and L. Chiarappa. 1969. Population densities and economic injury levels of grape leafhopper. Calif. Agric. 23(4): 9-10.

Jensen, F. L. and D. L. Flaherty. 1981. Grape leafhopper, pp. 98-110. *In* D. L. Flaherty, F. L. Jensen, A. N. Kasimatis, H. Kido, and W. J. Moller (eds.). Grape Pest Management. Div. Agric. Sci. Univ. Calif. Pub. 4105. 312 p.

Kido, H., D. L. Flaherty, D. F. Bosch and K. A. Valero. 1984. French prune trees as overwintering sites for the grape leafhopper egg parasite. Am. J. Enol. Vit. 35: 156-160.

Knowlton, G. F. 1946. *Deraeocoris brevis* feeding observations. Bull. Brooklyn Entomol. Soc. 41: 100-101.

McKenzie, L. M. and B. P. Beirne. 1972. A grape leafhopper, *Erythroneura ziczac* (Homoptera: Cicadellidae), and its mymarid (Hymenoptera) egg-parasite in the Okanagan Valley, British Columbia. Can. Entomol. 104: 1229-1233.

Mulla, M. S. 1956. Two mymarid parasites attacking *Typhlocyba* species in California. J. Econ. Entomol. 49: 438-441.

Oman, P. W. 1949. The nearctic leafhoppers (Homoptera: Cicadellidae), a generic classification and checklist. Entomol. Soc. Wash. Mem. 3. 253 p.

Williams, D. W. 1984. Ecology of a blackberry-leafhopper-parasite system and its relevance to California grape agroecosystems. Hilgardia 52: 1-33.

WESTERN CHERRY FRUIT FLY (DIPTERA: TEPHRITIDAE): EFFICACY OF HOMEMADE AND COMMERCIAL TRAPS

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Abstract

Populations of western cherry fruit flies (WCFF), *Rhagoletis indifferens* Curran, were monitored at weekly intervals during the flight periods from 1982 through 1985 in an unsprayed experimental orchard planting near Moxee, Washington. Yellow Pherocon AM (apple maggot) traps usually caught more WCFF than McPhail, Rebell and other traps tested. Most of the traps also caught large numbers of other species of flies, which obscured the presence of WCFF. A bell-shaped trap constructed from the top of a plastic soft drink bottle, painted saturn yellow and baited with the Pherocon AM bait caught the largest numbers of WCFF but very few other species of flies.

Key words: *Rhagoletis indifferens,* attractants, baits, flies, McPhail traps, Diptera.

INTRODUCTION

Traps have been used to monitor fruit fly populations for many years. Frick (1952) reported that an inverted waxed food carton containing ammonium carbonate as a bait and coated on the inside surface with a sticky material was effective in catching cherry fruit flies in Washington. Banham (1973) compared the effectiveness of yellow sticky boards, bait pans containing glycine-lye and cartons containing ammonium carbonate and found that double faced sticky boards with Staley bait mixed in the Stikem were more attractive to western cherry fruit fly (WCFF), *Rhagoletis indifferens* Curran, than other combinations tested. AliNiazee (1978, 1981) showed that in the Pacific Northwest various kinds of traps could be used to time management programs for the WCFF. Monitoring fly populations has resulted in control with fewer sprays. Yellow sticky board traps, such as the Pherocon® AM (apple maggot) trap (Zoecon Corp., Palo Alto, CA), have been used to monitor WCFF populations in cherry orchards and to determine when to apply sprays based on first fly catch and seasonal distribution of fly catch (AliNaizee 1978).

The yellow sticky board trap is not specific for fruit flies. It attracts numerous other species of flies that clutter the trap and may obscure any fruit flies present (Howitt & Connor 1965, Moore 1969). This can be a serious problem for detection of the first fruit flies present in an orchard. Prokopy (1975) found that a cone-shaped yellow sticky trap attracted as many of the eastern cherry fruit fly, *Rhagoletis cingulata* (Loew), and did not attract as many other large insects as did the yellow rectangular traps.

This paper reports results of research to evaluate the effectiveness of commercial and experimental trap designs for attracting WCFF but not other non-economic species of Diptera.

METHODS

WCFF populations in an isolated stone fruit orchard at the Plant Quarantine Station, Moxee, WA, were monitored from 1982 through 1985, using Pherocon AM traps as well as experimental traps of various designs. Ammonium carbonate was applied as a bait and Tanglefoot spray as a sticky material to some of the traps and AM bait and sticky material supplied by Zoecon Corp. to other traps. Usually the experimental traps were painted saturn yellow (Day Glo Color Corp., Cleveland, Ohio).

The orchard consisted of a mixed planting, including 24 seedling cherry trees and 38 bearing cherry trees of different cultivars, as well as numerous plum, peach and apricot trees. The eastern edge of the orchard was bordered by pear and apple trees; the other borders were open sagebrush rangeland. Traps were randomized in blocks and usually placed approximately 2 m high on the south side of the cherry trees. At weekly intervals the traps were moved to the next cherry tree in the row or succession. Traps were rebaited and Tanglefoot added weekly or as needed. The number of WCFF per trap was determined weekly.

Trap catches were transformed to log (x+1) for analysis of variance and significant differences ($P \leq 0.05$) among treatment means were determined using Duncan's (1955) new multiple range test.

In 1982 traps of 23 experimental or commercial designs were tested, mostly one trap per tree, replicated at least two times. These included Pherocon AM, Rebell® (Swiss Federal Research Station, Wadenswil, Switzerland) and McPhail (Steyskal 1977) traps for comparison of efficacy. Twelve of the homemade traps were sprayed with Tanglefoot and sprinkled with ammonium carbonate as bait. Six of the homemade traps were funnels (7 to 15 cm diameter) fitted with plastic vials containing ammonium carbonate on the funnel stem. These 18 traps were painted saturn yellow. Two of the Tanglefoot sprayed traps were painted arc yellow (Day Glo Color Corp.). At least two traps of each type were placed in the orchard. Most of the traps were in the orchard from May 26 until Oct. 6, 1982.

In 1983 four experiments were conducted in which two different traps were placed in each tree. At weekly intervals, traps on the west side of each tree were moved to the adjacent tree on the south, and those on the east side were moved to the tree on the north. A total of 116 traps of various designs were placed in 58 trees from May 12 until Oct. 6, 1983. Most of the homemade traps were similar to those tested in 1982. However, in some experiments bait and/or sticker supplied by Zoecon Corp. was substituted for ammonium carbonate and/or Tanglefoot. Also, two of the experiments were replicated four times and two were replicated twice.

In 1984 eight of the more promising trap designs, based on observations made in previous years, were selected for further tests. One trap was placed in each tree, replicated five times in a split plot design. Each week the traps were removed and returned to the laboratory where the number of WCFF were counted. A duplicate set of traps was used to replace the traps as they were removed. The replacements were placed in the next succeeding tree, moving south in a row and from west to east in adjacent rows.

In 1985 only the Pherocon AM and the trap made from the bell-shaped section of a soft drink bottle (bell trap) were tested (Fig. 1). The latter traps were baited with Zoecon AM bait and sticker. Eight Pherocon and 16 bell traps were tested individually in 24 trees. Traps were moved to the next succeeding tree at weekly intervals.

RESULTS

During the period from 1982 to 1985 over 30,000 WCFF were removed from the orchard as shown in Table 1. In each year, more than 50% of the WCFF were trapped during a two-week period: the first two weeks of July in 1982, the last week of June and the first week of July in 1983 and 1984, and the last two weeks of June in 1985 (Table 1).

Each year the number of WCFF trapped declined rapidly in July and August. However, a few flies continued to be caught each week up to the end of September. The WCFF usually has a single generation each year, overwintering as pupae. Other research on WCFF from the Yakima area (Burditt unpublished data) has demonstrated that each year a few pupae do not enter diapause, resulting in emergence of second generation adults in August and September.

Response of WCFF to six types of traps in 1982 and 1983 (Table 2) showed that the Pherocon AM trap caught the most flies each year. However, the differences between responses generally were not statistically significant. In 1982 the Rebell trap and in 1983 the McPhail and bell traps caught significantly fewer WCFF than did the Pherocon AM trap. All but the Pherocon AM trap were baited with ammonium carbonate. In 1983 paired Pherocon and homemade traps baited with ammonium carbonate caught significantly fewer WCFF (40.3 flies per trap per season) than similar traps baited with the Zeocon AM bait (219.3). Most of the homemade traps caught very few WCFF and were discarded from future tests.

In 1984 the bell and Rebell traps were baited with Zoecon AM bait. These traps caught significantly more WCFF than the Pherocon AM trap and a funnel trap which was baited using ammonium carbonate (Table 2). When Pherocon traps were baited with ammonium carbonate and treated with Tanglefoot they caught significantly fewer WCFF (35.0 flies per trap per season) than did Pherocon AM traps (207.4) or Pherocon traps baited with ammonium carbonate and treated with Zoecon sticky material (265.6).

In 1985 the 24 traps caught a total of 4117 WCFF. The Pherocon AM traps caught significantly fewer WCFF (114.1 flies per trap per season) than the 2 sets of bell traps (192.8 and 207.8 flies respecctively) which were baited with the Zoecon AM bait and the Zoecon sticky material (Table 2).

Fig 1. Trap for western cherry fruit flies (WCFF), made from bell-shaped upper part of a soft drink bottle.

Table 1. Numbers of western cherry fruit flies trapped per week in an orchard at Moxee, WA.

	Number of flies trapped			
Week	1982	1983	1984	1985
1 (June)		94	17	104
2	5	399	794	545
3	30	979	2206	1071
4	530	3247	3889	1312
5 (July)	1371	2981	3286	615
6	1581	1580	1549	443
7	859	451	992	53
8	454	44	391	24
9 (August)	193	1	104	4
10	54	8	24	0
11	17	2	6	0
12	9	9	15	0
13	8	22	4	0
14 (September)	12	41	8	0
15	7	23	3	
16	2	12	11	
17	1	10	2	
18 (October)		4		
Total	5133	9907	11301	4117

Table 2. Response of western cherry fruit fly to six trap designs in 1982 - 1985, at Moxee, WA.

	Flies per trap per season			
Traps	1982	1983	1984	1985
Pherocon AM	553.3 a	103.3 a	207.4 b	114.1 b
Funnel	311.5 ab	98.0 a	40.4 b	NT
McPhail	202.0 ab	15.0 b	NT *	NT
Board	109.5 ab	70.8 ab	NT	NT
Bell	116.5 ab	2.5 b	478.8 a **	200.3 a **
Rebell	28.0 b	57.0 ab	483.2 a **	NT

Means followed by the same letter within a column are not significantly different ($P \leq 0.05$; Duncan's [1955] multiple range test).

* NT = not tested.

** Traps baited with Zoecon AM bait and sticky material

Observations showed that the Pherocon AM, McPhail and plastic board traps caught large numbers of other, non-economic, species of Diptera. These interfered with finding and counting WCFF that were present on the traps. In 1984 the bell trap caught only 24 large specimens of other Diptera in contrast to over 20 times as many specimens on the other traps. In 1985 the number of other Diptera caught was determined twice, each for a week. The Pherocon AM traps caught a mean of 49.3 specimens of other Diptera per week compared to 2.7 and 1.8 other Diptera per week for the two sets of bell traps, respectively.

DISCUSSION AND CONCLUSIONS

The use of sticky board traps, such as the Pherocon AM type trap, has been recognized for many years as a technique for monitoring fruit fly populations and for guidance in application of sprays for control of these pests. Monitoring requires that traps catch fruit flies when they initially emerge from the puparia and that low populations of fruit flies be detected. Large numbers of other species of non-economic Diptera may obscure the presence of the species being sought. Therefore, an ideal trap would be specific for WCFF. In this study a bell trap baited with Zeocon AM bait and sticker met these requirements. It caught WCFF early in the season, usually caught as many as or more WCFF than the other types of traps and caught significantly fewer non-target species of Diptera than other trap designs tested. Further tests are needed to determine if the bell trap would be effective in attracting other species of fruit flies such as the black cherry fruit fly, *R. fausta* (Osten Sacken).

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REFERENCES CITED

AliNaizee, M.T. 1978. The Western Cherry Fruit Fly, *Rhagoletis indifferens* (Diptera: Tephritidae) 3. Developing a management program by utilizing attractant traps as monitoring devices. Canad. Entomol. 110: 1113-1139.

AliNaizee, M.T. 1981. Improved control of the Western Cherry Fruit Fly, *Rhagoletis indifferens* (Dipt.: Tephritidae), based on area-wide monitoring. J. Entomol. Soc. Brit. Columbia 78: 27-33.

Banham, F.L. 1973. An evaluation of traps for the western cherry fruit fly (Diptera: Tephritidae). J. Entomol. Soc. Brit. Columbia 70: 13-16.

Duncan, D.B. 1955. Multiple range and multiple *F* tests. Biometrics 11: 1-42.

Frick, K.E. 1952. Determining emergence of the cherry fruit fly with ammonium carbonate bait traps. J. Econ. Entomol. 45: 262-263.

Howitt, A.J., and L.J. Connor. 1965. The response of *Rhagoletis pomonella* (Walsh) adults and other insects to trap boards baited with protein hydrolysate baits. Proc. Entomol. Soc. Ont. 95: 134-136.

Moore, R.C. 1969. Attractiveness of baited and unbaited lures to apple maggot and beneficial flies. J. Econ. Entomol. 62: 1076-1078.

Prokopy, R.J. 1975. Selective new trap for *Rhagoletis cingulata* and *R. pomonella* flies. Environ. Entomol. 4: 420-424.

Steyskal, G.C. 1977. History and use of the McPhail trap. Fl. Entomol. 60: 11-16.

COMPARATIVE FLIGHT DYNAMICS OF KNAPWEED GALL FLIES *UROPHORA QUADRIFASCIATA* AND *U. AFFINIS*(DIPTERA:TEPHRITIDAE)

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Abstract

By using laboratory flight mills, I tested the hypothesis that the differential distributions of knapweed gall flies, *Urophora quadrifasciata* and *U. affinis*, among knapweed sites can be predicted by the flight propensity and endurance of the flies. Results from tests did not support the prediction that the former species displays the greater propensity for flight and endurance. I discuss several reasons supporting the values obtained and their validity for use in interspecific comparisons. Finally, I point to the danger of extrapolating laboratory behaviour to the field.

INTRODUCTION

The distribution of insects in space is likely to be some function of the distribution of their resources (Karieva 1985) as well as their propensity (Jones 1977; Roitberg *et al.* 1984) and ability (Ralph 1977; Roitberg *et al.* 1979) to move among resources and resource sites.

An apt example of differential distribution among similar resource sites is represented by two species of palaearctic tephritid flies in British Columbia. The larvae of *Urophora quadrifasciata* (Meigen) and *U. affinis* Frauenfeld induce galls and feed within the seed heads of diffuse knapweed (*Centaurea diffusa* Lam.). Adults of both species were released into knapweed-infested sites in the interior of BC during the early 1970's to control the spread of this highly pestiferous host (Harris and Myers 1984). Following release, however, each species has displayed different spatial distributions, within and between sites. *Urophora affinis* typically achieves moderately high population levels and low rates of spread between sites. By contrast, *U. quadrifasciata* is generally found at low population densities, but spreads rapidly and can be found at remote resource sites (Harris and Myers 1984; Story and Nowierski 1984). Within-site differences in the spread of these flies has been explained in terms of differential use of seed heads (Berube 1980). Here, I propose an hypothesis to explain the different inter-site spread rates of the two species:

H_a : *Urophora quadrifasciata* displays greater flight propensity and endurance than *U. affinis*.

If it was supported, this hypothesis could explain differential fly distribution purely on the basis of emigration tendency. Such differences have been demonstrated among closely related species of milkweed bug and in different geographic populations within the same species (Dingle 1978). In this paper, I describe a test of the differential flight hypothesis that uses laboratory flight mills.

MATERIALS AND METHODS

All experiments were conducted in the laboratory with wild-type, lab-maintained flies. To obtain the flies, knapweed seed heads were collected during November 1985 from roadsides near Penticton, BC. The seed heads, some of which were infested with overwintering *Urophora* larvae, were then held at 2°C for several months. Following this, the seed heads were held at *ca.* 20°C for several weeks until the flies emerged. Emergent flies were placed in 15 X 15 X 15 cm plexiglas-screen cages and were provided with water and food (sugar + enzymatic yeast hydrolysate (Prokopy and Boller 1971)) ad lib, and knapweed stems which served as resting and mating sites for the flies.

Upon reaching 11 ± 1 days-of-age, mature female flies were removed from the maintenance cages and then placed in petri dishes with water and abundant food for 2 h prior to testing. Then the flies were individually placed in glass vials and held at -5°C for *ca.* 30 s or

until they became immobile. The chilled flies were then attached at the dorsal thorax, to flight mills as described in Roitberg *et al.* (1984). Tarsal contact was provided by a glass microscope slide. To induce flight, tarsal contact was removed within a few seconds after it appeared that the flies had recovered from chilling. If no flight occurred, tarsal contact was reinstated and then again removed. If the fly still did not initiate flight, that trial was terminated. Similar procedures were employed to induce further flight from flies that initiated but terminated flights.

I chose 11-day-old females for testing because, at that age, flies had mated and had been reproductively mature for several days. Since flies had been deprived of oviposition sites I reasoned that they would be more likely to display flight response (e.g. Roitberg *et al.* 1984) thus providing a larger data base for comparing fliers of both species. This was an appropriate decision since my comparison of flight parameters were not absolute measures of field performance.

Flight propensity was indexed as the distance flown by individuals (number of 1 m revolutions) during the initial flight only. Flight endurance, by contrast, was indexed as the total distance flown until individuals refused to fly further following two tarsal-contact removals.

Following completion of each flight trial, the fly was frozen and then placed in a desiccator. Desiccated flies were weighed and their wing areas were measured through employment of an Apple™ Computer Graphics Tablet.

RESULTS

Frequency distributions of initial flight distances are shown in Fig. 1. Contrary to predictions, *U. quadrifasciata* did not fly significantly further during initial flights than did *U. affinis* ($\bar{x}$ = 84.3 m ± 45.3 SE, n = 28 vs. $\bar{x}$ = 161.8 m ± 59.1 SE, n = 51; $p > 0.5$ Mann Whitney U). Most initial flights covered less than 100 m for both species (*U. quadrifasciata*, 25/30; *U. affinis*, 38/51).

As with initial flight, and again contrary to the prediction, *U. quadrifasciata* covered less distance during total flight than did *U. affinis* (x = 140.1 m ± 62.1 SE vs. x = 381.5 m ± 108.0 SE; $p > 0.05$ Mann Whitney U). While the majority of total-distance flights again covered less than 100 m, (*U. quadrifasciata*, 24/30; *U. affinis*, 31/51) the distribution had an extended tail for *U. affinis*, with a small proportion of flies covering more than 500 m (*U. quadrifascita*, 2/30; *U. affinis* 10/ 50) (Fig. 2).

No significant correlations were found between the size characteristics of the flies and their initial or total flight distances. Two parameters, dry weight and wing loading (= weight/ wing area) *vs.* initial and total distance had little explanatory power as shown by the values below, all of which are NS:

		U. quadrifasciata	*U. affinis*
Dry weight	vs. intial distance	r = 0.06	r = 0.06
	vs. total distance	r = 0.11	r = 0.16
Wing loading	vs. initial distance	r = 0.17	r = 0.02
	vs. total distance	r = 0.14	r = 0.08

DISCUSSION

Tethered flight can be a reliable, qualitative means of comparing inherent vagility within and among populations and species of insects (Davis 1981; Nakamori and Simizu 1983; Roitberg *et al.* 1984; Dingle and Evans 1987). For both species of fly studied here, the distributions of flight distance were leptokurtic (*i.e.* skewed toward short distance), a common feature of many insect species (Davis 1980). Thus, the results reported here probably reflect relative within-field differences in vagility for these two *Urophora* species.

The conclusion is that species-specific vagility in *Urophora quadrifasciata* and *U. affinis* does not explain their differential distributions among knapweed sites. Indeed, *U. affinis,* the species which I predicted would display lower flight propensity and endurance, actually appeared to be more vagile than its congener. There are reasons for being cautious about

generalizing from these results, in that each individual was tested only once (Davis 1980) and a single age class was tested, but given the restricted set of conditions employed, the experimental design seems appropriate and the conclusions warranted.

A possible explanation of my results is that the flight mill itself caused some bias in the flight propensity and endurance estimates. Since *U. quadrifasicata* is the somewhat smaller species (Fig. 3), any friction within the mill system should have a greater impact on its flight. I

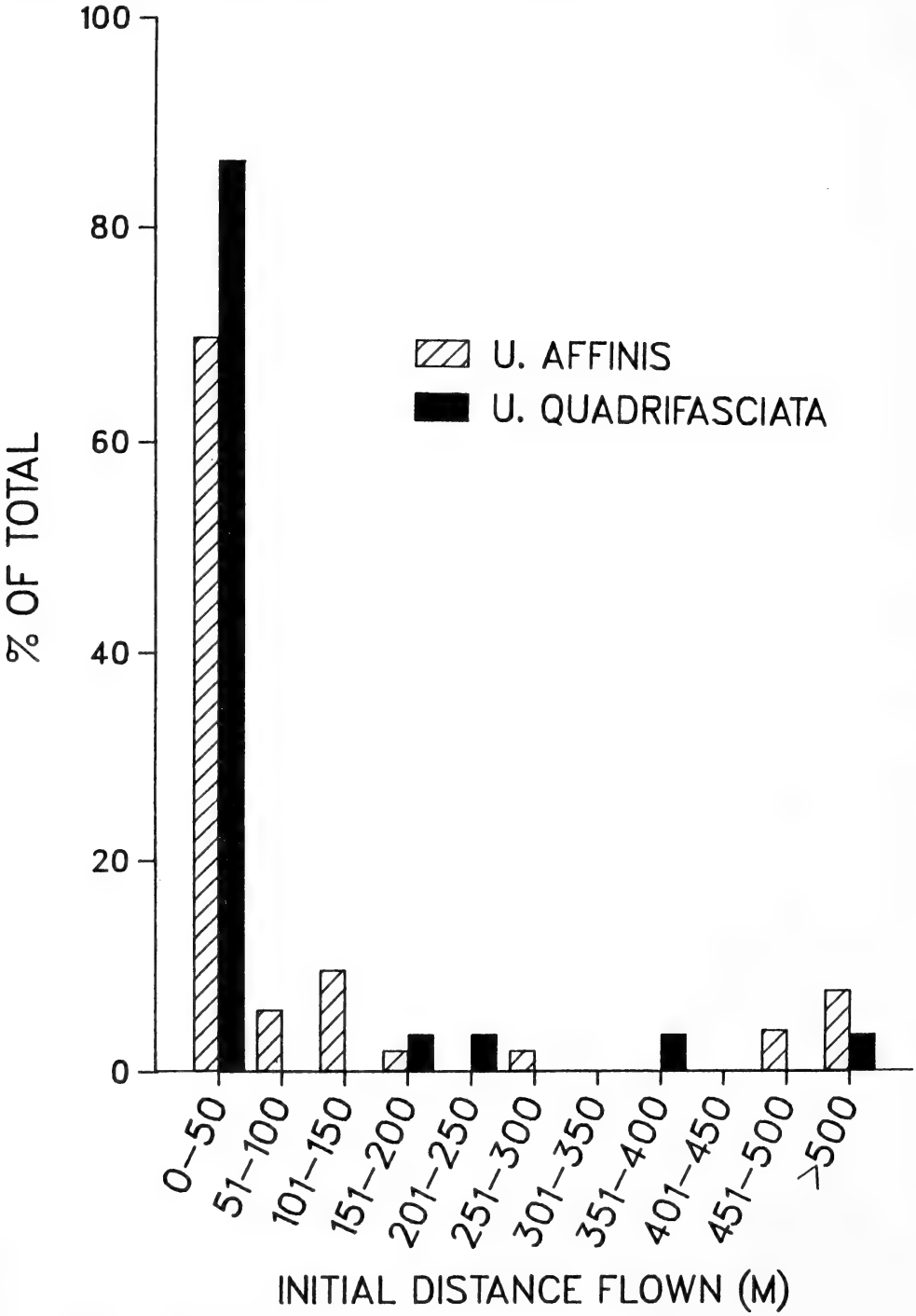

Fig. 1 Frequency distributions of initial flight distances by tethered *U. quadrifasciata* and *U. affinis* females.

tested this hypothesis by comparing the proportion of flights greater than 100 m (= long flight) among the different size classes of flies in both species. The results showed that long flights were independent of fly size in both species (*U. quadrifasciata* $\chi^2 = 2.29$, df = 3, NS; *U. affinis* $\chi^2 = 6.6$, df = 8, NS). Since even the smallest individual within the smaller species appeared equally likely to engage in long flight, I concluded that the mill estimates are not biased against size.

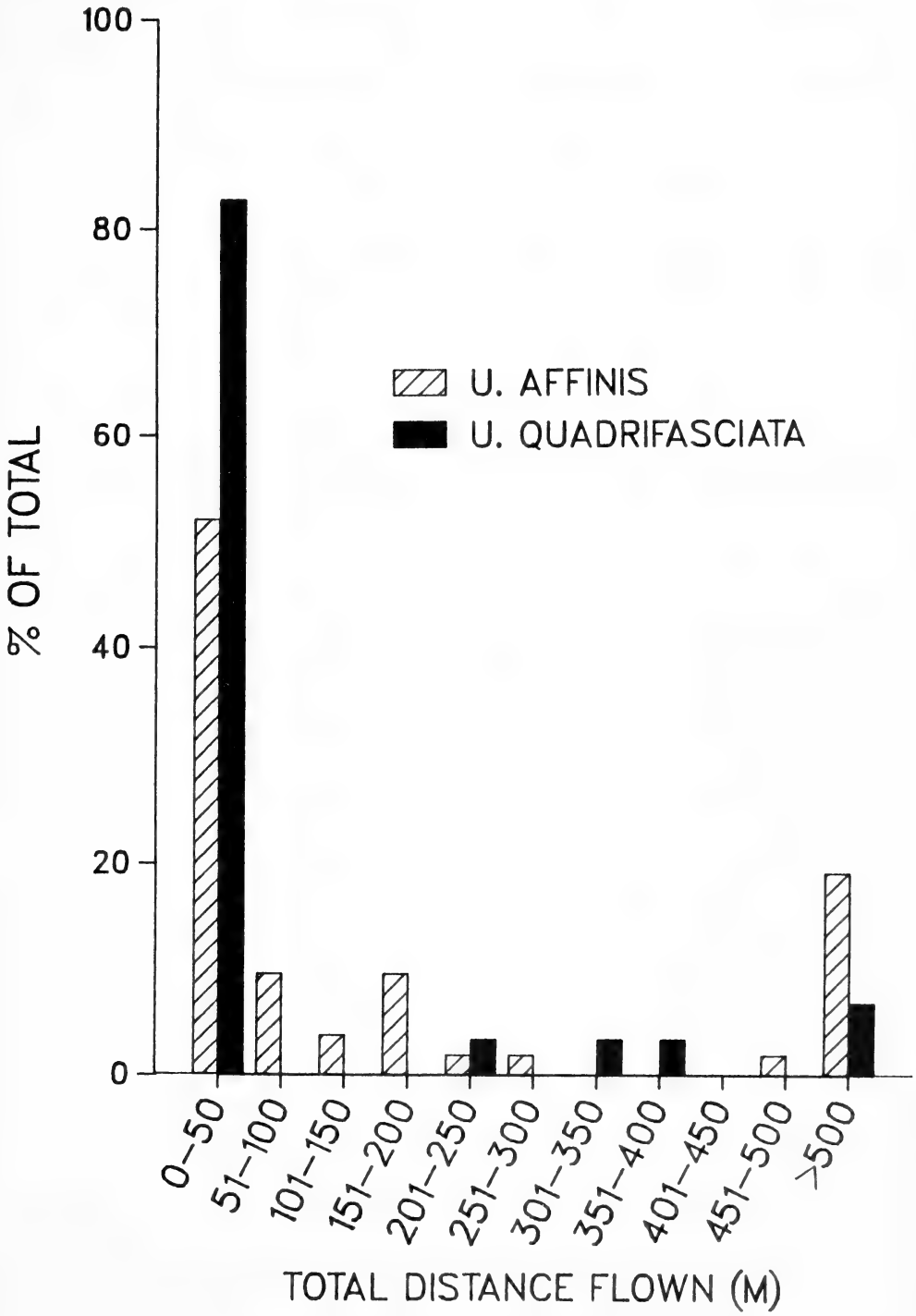

Fig. 2 Frequency distributions of total flight distances by tethered *U. quadrifasciata* and *U. affinis* females.

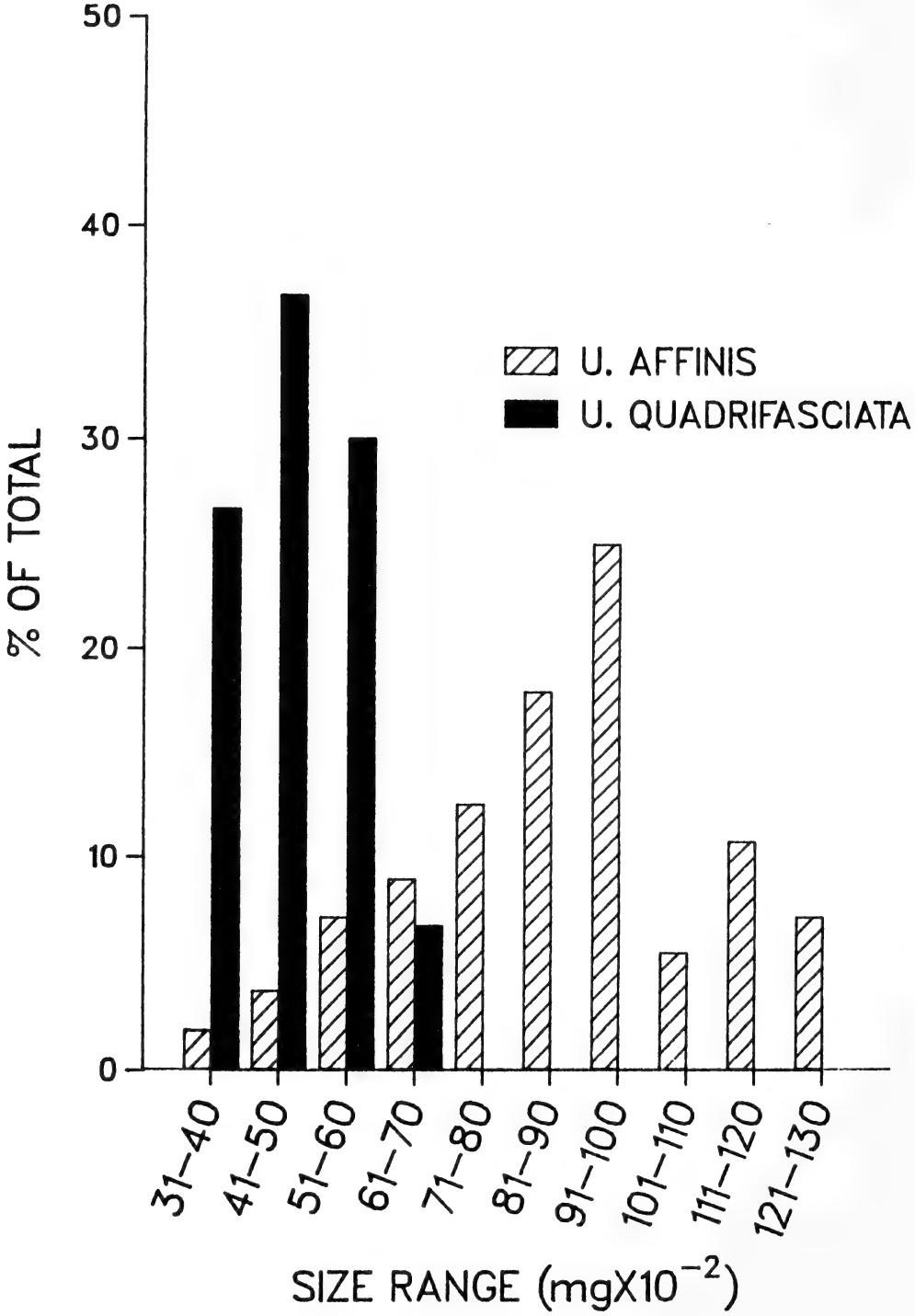

Fig. 3 Frequency distributions for weight classes (dry weight (mg x 10^{-2}) of female *U. quadrifasciata* and *U. affinis*.

The demonstration of size class independence from long flight tendency is at odds with the finding of Roff (1977), who showed that, for *Drosophila melanogaster*, it was the larger individuals that were most prone to disperse from release sites. Similarly, Dingle *et al.* (1980) documented a positive relationship between body size and tethered flight distance both between species of milkweed bugs (*Oncopeltus* spp.) and within populations of *Oncopeltus fasciatus*. My results do indicate that, it is indeed the larger of the two *Urophora* species that may be more prone to engage in long tethered flight. Field samples, however, indicate the opposite trend (Myers and Harris 1984), which points to the danger of extrapolating lab behaviour to the field.

A more realistic explanation regarding the counterintuitive results reported here derives from Myers and Harris' (1980) observation of the distributions of *U. quadrifasciata* and *U. affinis* galls among plants. They reported that, although *U. quadrifasciata* displayed "better dispersion" among sites, that their within-plant distributions were more clumped than those of *U. affinis*. Thus, testing vagility on flight mills possibly ignores some crucial behavioral feature which causes *U. quadrifasciata* to switch from a within plant "clumper" to an active disperser.

Myers and Harris (1980) cite Gilbert's (1977) observation that analysis of insect distributions does not identify causal mechanisms, but might identify insect behaviors deserving further study. A corollary that arises from this study is that investigation of flight behaviour (*i.e.* movement) does not necessarily lead to indentification of insect distribution. Inherent tendencies must be considered against the ecological setting in which they are defined.

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REFERENCES

Berube, D.E. 1980. Interspecific competition between *Urophora affinis* and *U. quadrifasciata* (Diptera: Tephritidae) for oviposition sites on diffuse knapweed (*Centaurea diffusa*: Compositae). Zeit. fur ang. Entomol. 90: 299-306.

Davis, M.A. 1980. Why are most insects short fliers? Evol. Theory 5: 103-111.

Davis, M.A. 1981. The flight capacity of dispersing milkweed beetles, *Tetraopes tetraopthalmus*. Ann. Entomol. Soc. Amer. 74: 385-386.

Dingle, H., N. Blakley, and E.R. Miller. 1980. Variation in body size and flight performance in milkweed bugs (*Oncopeltus*). Evol. 34: 371-385.

Dingle, H. and Evans, K.E. 1987. Responses in flight to selection on wing length in non-migratory milkweed bugs, *Oncopeltus fasciatus*. Ent. exp. app. 45: 289-296.

Gilbert, N. 1977. Appendix to: Movement patterns and egg distributions in cabbage butterflies. J. Anim. Ecol. 46: 195-212.

Harris, P. and J.H. Myers. 1984. *Centaurea diffusa* Lam. and *C. maculosa* Lam. s. lat., diffuse and spotted knapweed. *In* J.S. Kelleher and M.A. Holmes, Biological Control Programmes Against Insects and Weeds in Canada. C.A.B., England.

Jones, R.E. 1977. Movement patterns and egg distribution in cabbage butterflies. J. Anim. Ecol. 46: 195-212.

Karieva, P. 1985. Finding and losing host plants by *Phyllotreta* : patch size and surrounding habitat. Ecol. 66: 1809-1816.

Myers, J.H. and P. Harris. 1980. Distribution of *Urophora* galls in flower heads of diffuse and spotted knapweed in British Columbia. J. Appl. Ecol. 17: 359-67.

Nakamori, H. and Simizu, K. 1983. Comparison of the flight ability between wild and mass-reared melon fly, *Dacus cucurbitae* Coquillett (Diptera: Tephritidae). Appl. Ent. Zool. 18: 371-81.

Prokopy, R.J. and E.F. Boller. 1971. Artificial egging system for the European cherry fruit fly. J. Econ. Entomol. 63: 1413-1417.

Ralph, C.P. 1977. Effect of host plant density on populations of a specialized seed-feeding bug, *Oncopeltus fasciatus*. Ecol. 58: 799-809.

Roff, D.A. 1977. Dispersal in dipterans: its costs and consequences. J. Anim. Ecol. 46: 443-456.

Roitberg, B.D., J.H. Myers and B.D. Frazer. 1979. The influence of predators on the movement of apterous pea aphids between plants. J. Anim. Ecol. 49: 111-122.

Roitberg, B.D., R.S. Cairl and R.J. Prokopy. 1984. Oviposition deterring pheromone influences dispersal distance in tephritid fruit flies. Ent. exp. appl. 35: 217-220.

Story, J.M. and R.M. Nowierski. 1984. Increase and dispersal of *Urophora affinis* (Diptera: Tephritidae) on spotted knapweed in Western Montana. Enivron. Entomol. 13: 1151-1156.

COMPARATIVE LARVAL GROWTH OF THE VARIEGATED CUTWORM, *PERIDROMA SAUCIA*, FROM A LABORATORY COLONY AND A WILD POPULATION

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Abstract

Larval growth of variegated cutworms from a laboratory colony (maintained for over 12 generations) was compared with that of the F_1 generation of field-collected larvae on an artificial medium. After eleven days of feeding, larvae from the wild population weighed, on average, over three times as much as those from the laboratory colony. However, when larvae from each population were reared on media spiked with an inhibitory plant extract, the degree of growth inhibition relative to their respective controls was equivalent.

INTRODUCTION

Insects from laboratory colonies are commonly used in both basic and applied research, especially in studies of pesticidal efficacy where large numbers of uniformly aged individuals are required for bioassay. One implicit assumption underlying such studies is that the response of insects from the laboratory colony is representative of that expected of insects from wild populations. Unfortunately, maintenance of a laboratory colony of insects often results in inadvertant selection of genotypes and phenotypes which diverge from the colony founders of natural origin. Often this fact is overlooked, and the insects chosen for the study are those which can be conveniently produced in the laboratory setting (Berenbaum 1986).

In our laboratory, we have been using a laboratory colony of the variegated cutworm, *Peridroma saucia* (Hbn.)(Lepidoptera: Noctuidae), for bioassay of natural insecticides and antifeedants (Isman and Proksch 1985). This species was selected because it is a polyphagous pest of occasional economic importance throughout North America (Simonet *et al.* 1981), and because it is relatively easy to maintain in the laboratory in continuous culture. In the present study, we compared larval growth and survival of cutworms from a two-year-old laboratory colony with those of the F_1 generation of field-collected larvae.

MATERIALS AND METHODS

The laboratory colony, maintained for over 12 generations, was founded from pupae supplied by Dr. G. Ayer, Agriculture Canada, Winnipeg. They were taken from a laboratory colony maintained at Winnipeg for at least one year. The field population in our study consisted of the offspring of larvae collected from cabbage plants growing at the Department of Plant Science field laboratory on the University of British Columbia campus in Vancouver, as well as from unsprayed gardens in the Kitsilano district.

Larvae were reared on an artificial medium (BioServ Inc., Frenchtown, NJ, no. 9682) as described previously (Isman and Rodriguez 1983). In the first experiment, neonate larvae from each population were reared on the standard diet for 11 days and then weighed. In the second experiment, neonate larvae from each population were reared on either the standard diet treated with 95% aqueous ethanol, or a diet spiked with an ethanolic extract from foliage of big basin sagebrush, *Artemsia tridentata,* at 50% of natural concentration (dwt/dwt). For each

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treatment group, 30 neonate larvae were reared individually in 30 mL plastic cups with a diet cube of approx. 1 g fwt. The cups were placed in a plastic box lined with moistened paper towels to maintain high relative humidity, and the box was placed inside a growth chamber at 27° and 16:8 LD. Larvae were again weighed following 11 days of feeding.

RESULTS AND DISCUSSION

The results of the first experiment are shown in Table 1. Cutworms from the wild population were almost three times heavier after 11 days than were larvae from the laboratory colony. Although we did not collect precise data, larvae from the wild population pupated earlier and produced heavier pupae than their cohorts from the laboratory colony. These results suggest that the laboratory environment may have either selected for slower growing and smaller individuals or may have a general fitness-reducing effect. If larval growth rates are linked to alleles present in wild populations, the quality of laboratory colonies may be improved by careful introduction of wild stock to the colony, a practice which is frequently done (Berenbaum 1986). On the other hand, introduction of wild stock may also introduce natural disease to the laboratory colony. Natural populations of *P. saucia* are known to harbor a nuclear polyhedrosis virus (Harper 1970), which requires labor-intensive precautions to manage it if introduced to the laboratory colony.

Table I. Mean larval weight (S.D.) of neonate varigated cutworm, *Peridroma saucia*, feeding on artificial diet for 11 days.

Source	n	Larval weight (mg)
Laboratory	66	63.7 (21.5)a[1]
Field	66	183.6 (34.6)b

[1] Means followed by the same letter are not significantly different, $F_{(0.05,1,130)}=571.8$

Larval growth is one important determinant of fitness for an insect population. Plants produce a plethora of natural chemicals which are capable of inhibiting larval growth when admixed with artificial media (e.g. Freedman *et al.* 1979). We established that among extracts of weedy Asteraceae growing in British Columbia, those of *A. tridentata* were extremely inhibitory to growth of variegated cutworms (Salloum and Isman 1988).

The results of the second experiment, including diets spiked with an extract of *A. tridentata*, are shown in Table 2. This bioassay confirmed that larvae from the wild population grew faster than those from the laboratory colony. However, the plant extract was equally inhibitory to both populations of cutworms, inhibiting larval growth by approximately 75% relative to controls in each case (Table 2). This latter result suggests that relative comparisons of growth inhibition from our laboratory colony appear to be valid. It justifies the continued use of our laboratory colony as a bioassay tool for screening additional plants and pure plant chemicals in the search for potential pest control materials.

Table II. Mean larval weight (S.D.) of an F_1 field collected population of *Peridroma saucia* compared to the laboratory colony fed the standard diet and diet containing a growth inhibitor[1].

Diet treatment Larval culture	%Survival (n=30)	Mean larval weight (mg)	%RC[2]
Standard diet			
Lab colony	90	56.9 (27.9)	
Field colony	100	136.6 (43.6)	
Growth inhibitor diet			
Lab colony	90	13.5 (8.7)	23.7
Field colony	80	34.8 (14.7)	25.5

[1] 50% ethanolic extract (dwt/dwt) from big basin sagebrush, *Artemisia tridentata*
[2] % of respective control fed standard diet

Two-way Analysis of Variance

Source of Variation	DF	SS	F	Probability
Model	3	16.9	25.6	0.0001
between populations	1	8.3	37.8	0.0001
between diets	1	7.5[a]	34.0	0.0001
popul. * diets	1	0.2	0.8	0.3833
Error	104	22.9		

[a] Sum of squares of larval growth are adjusted for mortality

It should be noted that our results may not necessarily be applicable to other species. A recent evaluation of resistance in Bermuda grass, *Cynodon dactylon,* to the fall armyworm, *Spodoptera frugiperda*, indicated that two laboratory strains of the pest of different geographic origins responded quite differently to four varieties of the host plant tested (Pashley *et al.* 1987). Such results indicate that investigators employing laboratory colonies should periodically compare bioassay performance of their test species to that of wild conspecifics.

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REFERENCES

Berenbaum, M. 1986. Postingestive effects of phytochemicals on insects: On Paracelsus and plant products. pp.121-153. *In*: J.R. Miller and T.A. Miller (eds.). Insect-Plant Interactions. Springer-Verlag, New York.

Freedman, B., L.J. Nowak, W.F. Kwolek, E.C. Berry and W.D. Guthrie. 1979. A bioassay for plant-derived pest control agents using the European corn borer. J. Econ. Entomol. 72: 541-545.

Harper, J.D. 1970. Laboratory production of *Peridroma saucia* and its nuclear polyhedrosis virus. J. Econ. Entomol. 63: 1633-1634.

Isman, M.B. and P. Proksch. 1985. Deterrent and insecticidal chromenes and benzofurans from *Encelia* (Asteraceae). Phytochem. 24: 1949-1951.

Isman, M.B. and E. Rodriguez. 1983. Larval growth inhibitors from species of *Parthenium* (Asteraceae). Phytochem. 22: 2709-2713.

Pashley, D.P., S.S. Quisenberry and T. Jamjanya. 1987. Impact of fall armyworm (Lepidoptera: Noctuidae) host strains on the evaluation of Bermuda grass resistance. J. Econ. Entomol. 80: 1127-1120.

Simonet, D.E., S.L. Clement, W.L. Rubink and R.W. Rings. 1981. Temperature requirements for development and oviposition of *Peridroma saucia* (Lepidoptera: Noctuidae). Can. Ent. 113: 891-897.

Salloum, G.S. and M.B. Isman. 1988. Crude extracts of asteraceous weeds: growth inhibitors for the variegated cutworm. J. Chem. Ecol., press.

FORAGING BEHAVIOR OF HONEY BEES ON MANCHURIAN CRABAPPLE AND RED DELICIOUS APPLE[1]

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Abstract

'Manchurian' crabapple pollinizer trees bloomed several days before red 'Delicious' trees. Of the honey bees collecting nectar, 98% foraged from the top of 'Manchurian' flowers but only 44% topworked 'Delicious' flowers. Topworkers spent less time per flower on 'Manchurian' than on 'Delicious'. Individual bees foraging from the side of the flower on 'Delicious' spent even less time per flower than topworkers.

INTRODUCTION

'Delicious' apple (*Malus sylvestris* Mill.) requires cross-pollination before setting fruit, so suitable pollinizer varieties must be planted throughout the orchard. Honeybee (*Apis mellifera* L.) pollinators are recommended for pollen transfer between varieties. The number and placement of pollinizer trees required for best production are largely determined by the foraging habits of honeybees, which tend to work along tree rows rather than cross the aisle spaces (Mayer *et al.*, 1986). Good pollinizers must bloom at the same time and have pollen compatible with the main variety. In addition, bee behavior must be compatible between varieties.

Pollinizers planted as every third tree in every third row ensure that each main-variety tree is adjacent to a pollinizer but minimizes the number of pollinizers. Having every second tree in every row a pollinizer ensures maximum pollination, but is not economically practical.

Pollinizers take up usable production space in the orchard. An alternative planting arrangement being tested in apple orchards uses flowering crabapples. (Williams and Church, 1983; Mayer *et al.* 1986). Crabapple pollinizers are planted between main variety trees every 72 to 120 m in each row with adjacent rows offset. They take up minimal space and their sole function is to provide pollen. Honey bee behavior on crabapple pollinizers and main varieties must be compatible for maximum pollination. The objective of this study was to compare the foraging behavior of honeybees on 'Manchurian' crabapple and 'Delicious'.

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Material and Methods

Data on honeybee foraging behavior were collected during bloom from 1982 through 1984 in a 9-ha block of 'Oregon Spur Red Delicious.' Part (0.05-ha) of the block was interplanted every 72 m in each row with 'Manchurian' crabapple as a pollinizer. The 'Delicious' trees were planted in 1978 and the 'Manchurian' crabapple in 1980.

Foraging honeybees were observed every second day during the study. Our classification of honeybee behavior was similar to that used by others (Free, 1970; Robinson and Fell, 1981; Kuhn and Ambrose, 1982). Nectar foraging topworkers put all their legs on the stamens and touched the stigma; sideworkers put at least the metathoracic legs on the petals and took nectar without touching the stigma. Pollen collectors scrabbled for pollen on the anthers and touched the stigma.

Counts were made by randomly moving through the test block. The frequency and times of each type of foraging behavior was recorded for a minimum of 500 visits by individual bees per apple variety each year. Only one observation was made per honeybee, and data were collected noting the time taken by a nectar collector to visit five flowers. Bee numbers were determined by slowly moving around 10 individual trees and counting the number of bees seen foraging in one minute. Percent total bloom was estimated on different dates for both varieties. Untransformed data were analyzed as a randomized design by analysis of variance with Duncan's (1951) multiple range test used for mean separations.

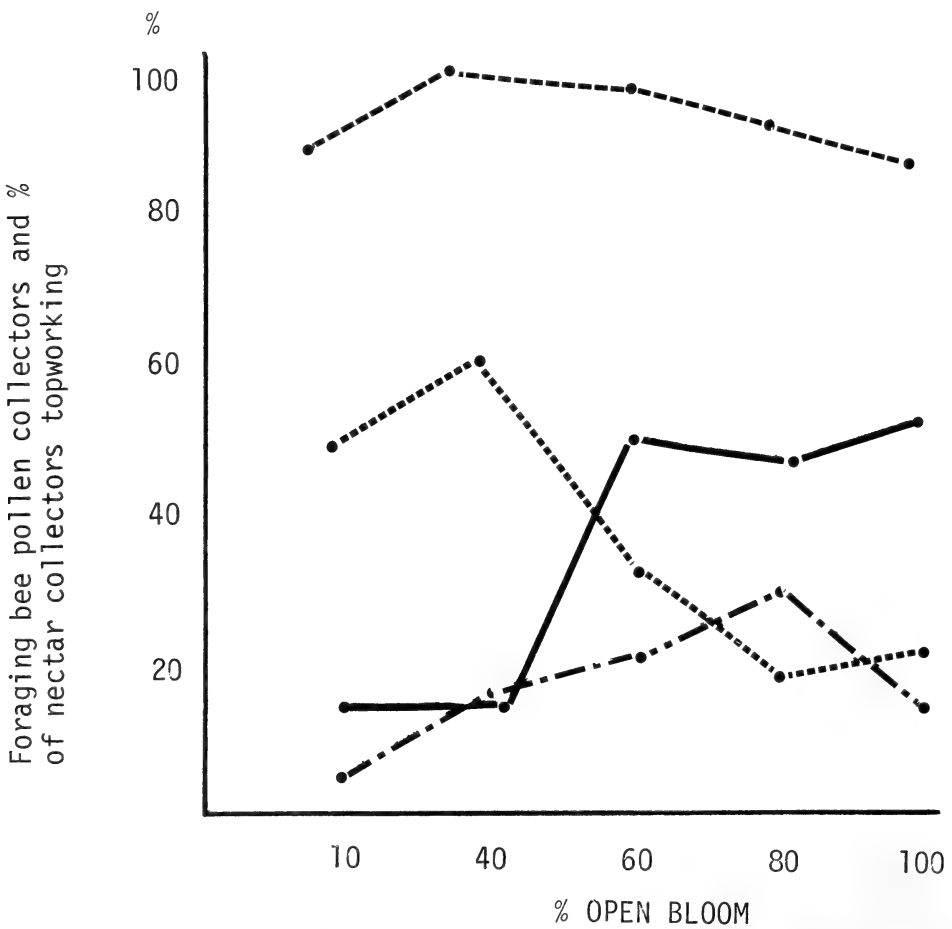

Fig 1. Comparison of topworking and pollen collecting behavior of honey bees at various bloom stages of 'Manchurian' crabapple and 'Delicious' apple. ▬▬▬▬ Topworking on 'Manchurian'; ▪▪▪▪▪▪▪▪ Topworking on Red Delicious; ▬ ▪ ▬ ▪ ▬ Pollen collectors on 'Manchurian'; ▬▬▬▬ Pollen collectors on Red Delicious.

Results and Discussion

On 'Manchurian' crabapple, most of the nectar collectors were topworkers (Table 1). This behavior remained consistent as bloom progressed (Fig.1). Honeybees learn to sidework, taking nectar without touching the stigma and a pollinizer variety may contribute to a higher than normal percent of sideworkers on 'Delicious' (Robinson, 1979). Therefore, a flower shape and structure that encourages topworkers is desirable in a pollinizer since topworkers contact the stigma and accomplish pollination (Free, 1970). 'Manchurian' possesses this character.

On 'Delicious,' less than half of the nectar collectors were topworkers (Table 1) and as bloom progressed, the number of topworking bees decreased (Fig 1). Other observers have noted increases in sideworking behavior as bloom progresses, and we found our ratio of topworkers to be comparable to theirs (Kuhm and Ambrose, 1982; DeGrandi-Hoffman *et al.*, 1985).

Percent pollen collectors was variable between years for both cultivars although the overall means were not significantly different (Table 1). We suspect the ratio of pollen collectors to be determined by the amount of brood in a colony, which varies from year to year, rather than by the crop. We observed an increase in percent pollen collectors on 'Delicious' but little change on 'Manchurian' crabapple as bloom progressed (Fig. 1). On 'Delicious', DeGrandi-Hoffman *et al.* (1985) reported fewer pollen collectors as bloom progressed while Kuhn and Ambrose (1982) observed no changes.

The times required for sideworkers to take nectar, pollen collectors to work a flower, and one nectar collector to visit five flowers was not significantly different between 'Manchurian' crabapple and 'Delicious' (Table 1). We are aware of no other reports on time requirements for these events. There was little difference in these aspects of bee behavior between the two cultivars, except that topworkers worked faster on 'Manchurian' crabapple than on 'Delicious'. 'Manchurian' crabapple did not contribute to any adverse bee behavior.

The times for top- and sideworkers to work a flower were not significantly different on 'Manchurian' crabapple, but were on 'Delicious'. Sideworkers on 'Delicious' took about half the time to work a flower as topworkers (Table 1). Kuhn and Ambrose (1982) suggested that the predominance of sideworkers on 'Delicious' may be due to less energy expenditure needed for this type of nectar collecting. We suggest that sideworkers are more efficient since they can collect nectar faster than topworkers.

'Manchurian' crabapple generally blooms several days ahead of 'Delicious'. This is a desirable pollinizer characteristic. In 1982, it was at 20% bloom 10 days earlier than 'Delicious', but after the 'Manchurian' crabapple trees were more than two years old, the difference was only three days. 'Manchurian' crabapple trees had more bloom and more bees foraging than 'Delicious' trees (Table 2). The peak number of bee foragers coincided with full (90%) bloom.

Differences in bee behavior and bloom dates between 'Manchurian' crabapple and 'Delicious' were observed. None of these events appeared detrimental to the use of 'Manchurian' crabapple as a pollinizer for 'Delicious'.

Table 2. Comparison of blooming dates of 'Manchurian' crabapple and 'Delicious' apple.

	20% bloom open		90% bloom open		80% petal fall	
Year	Manchurian	Red Delicious	Manchurian	Red Delicious	Manchurian	Red Delicious
1982	5/1 (0)*	5/11 (0.3)	5/11 (31)	5/14 (2)	5/16 (6)	5/17 (5)
1983	4/27 (18)	4/30 (3)	5/3 (27)	5/3 (10)	5/7 (11)	5/7 (7)
1984	5/7 (5)	5/10 (6)	5/12 (28)	5/14 (9)	5/15 (23)	5/8 (4)

*Numbers in brackets are number of honey bees per tree per minute.

Table 1. Foraging behavior of honeybees on 'Manchurian' crabapple and 'Delicious' apple.

	Activity (%)				Time (seconds)			
	Nectar collectors		Total foragers		Nectar collectors			1 bee to
Year	top working	side working	Nectar collectors	Pollen collectors	top working	side working	Pollen collectors	visit 5 flowers
'Manchurian' crabapple								
1982	99	1	66	34	8.1	7.0	9.8	---
1983	98	2	86	14	9.1	6.3	14.8	58
1984	96	4	83	17	7.9	7.3	8.4	54
Mean	98a	2a	78a	22a	8.4a	6.9a	11a	56a
'Delicious'								
1982	46	54	60	40	12.1	6.5	9.9	---
1983	38	62	85	15	11.2	6.4	12.0	55
1984	49	51	69	31	13.0	6.9	10.3	46
Mean	44b	56b	71a	29a	12.1b	6.6a	10.7a	51a

Means within a column followed by the same letter are not significantly different ($P \geq 0.05$); Duncan's [1951] multiple range test.

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REFERENCES

DeGrandi-Hoffman, G., R. Hoppingarner, and K.K. Baker. 1985. The influence of honeybee "sideworking" behavior on cross-pollination and fruit set in apple. HortSci. 20(3): 397-99.

Duncan, D.B. 1951. A significance test for differences between marked treatments in an analysis of variance. VA J. Sci. 2: 171-189.

Free, J.B. 1970. Insect pollination of crops. Academic Press, New York.

Kuhm, E.D., and J.T. Ambrose. 1982. Foraging behavior of honeybees on 'Golden Delicious' and 'Delicious' apple. J. Amer. Soc. Hort. Sci. 107(3): 391-395.

Robinson, W.S. 1979. Effect of apple cultivar on foraging behavior and pollen transfer by honey bees. J. Amer. Soc. Hort. Sci. 104(5): 596-598.

Robinson, W.S., and R.D. Fell. 1981. Effect of honeybee foraging behaviors on 'Delicious' apple set and development. HortSci. 16: 326-328.

Mayer, D.F., C.A. Johansen, and D.M. Burgett. 1986. Bee pollination of tree fruits. PNW Coop. Ext. PNW 0282. 10 pp.

Williams, R.R., and R.M. Church. 1983. Growth and flowering of ornamental *Malus* pollinators in apple orchards. J.Hort. Sci. 58 (3): 337-342.

LIFE HISTORY AND COLD STORAGE OF *AMBLYSEIUS CUCUMERIS* (ACARINA:PHYTOSEIIDAE)

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Abstract

Details were determined for the life history of the phytoseiid mite, *Amblyseius cucumeris*, with first-instar western flower thrips, *Frankliniella occidentalis*, as prey. *A. cucumeris* completed development in 11.09, 8.74 and 6.25 days at 20, 25 and 30°C respectively. This is slightly longer than reported for *A. cucumeris* by other authors using eggs of *Tetranychus* mites as prey. The mean egg production was 1.5 ± 0.99 eggs per day. In cold storage tests, after 10 weeks, 63% of *A. cucumeris* survived at 9°C, 1.2% survived at 2°C and 0% survived at -8°C.

INTRODUCTION

The predatory mite, *Amblyseius cucumeris* Oudemans (Acarina:Phytoseiidae), is a potential biological agent for various species of thrips (Thysanoptera) on greenhouse cucumbers and peppers (Ramakers 1983; De Klerk & Ramakers 1986). Previous work on the biology and life history of *A. cucumeris* was done using eggs of various tetranychid mite species (eg. El-Badry & Zaher, 1961, Kolodochka 1985). This did not allow for possibly different effects

of an insect host on predator performance, and since thrips appear to be the primary prey of *A. cucumeris* it was advisable to study its biology on those prey. In addition previous studies have not addressed the effects of temperature on life history. Since temperature can have a dramatic impact on the duration of life stages, the performance of *A. cucumeris* under a range of temperatures typical for greenhouse vegetable culture should be evaluated.

A. cucumeris can be mass reared on grain mites, *Acarus* spp. (Acarina:Acaridae) in bran in numbers approaching 10^5 per litre of bran (Ramakers & van Lieburg, 1982). The ability to raise a biological control agent in such large numbers makes long term storage of colonies feasible.

Here we report details of the life history of *A. cucumeris* at various temperatures with *Frankliniella occidentalis* (Thysanoptera:Thripidae) as prey, as well as results of cold storage experiments with *A. cucumeris*.

MATERIALS AND METHODS

Amblyseius cucumeris, originally obtained from Koppert B.V. in Holland, were reared as described by Ramakers & van Lieburg (1982), in bran with the grain mite, *Acarus siro* L., and a mold mite, *Tyrophagus* sp. as hosts. Fresh *A. cucumeris* eggs were collected from cultures by placing a 2 cm x 2 cm square of black felt in the rearing containers. Eggs deposited on the felt during a 6 h were collected and placed individually on 1 cm diameter disks of bean leaf on a pad of absorbent cotton saturated with water in a petri dish. These were placed in incubators at 20, 25, 30 or 35°C. First-instar *Frankliniella occidentalis* (3-5) were provided daily as food. Mites were observed daily for the presence of cast skins, indicating a molt, until they reached the adult stage.

Oviposition was observed for 10 days in eight freshly mated *A. cucumeris* females which were approximately 24 h old at mating. These were placed individually on 2 cm diameter leaf disks at 20°C as described above and provided daily with fresh thrips nymphs. The eggs were counted and removed daily.

To test cold storage, a 1.5 ml sample of bran from a culture containing 25 mites/ml was transferred from a source culture into a 50 ml plastic snap cap vial. Lids with 1 cm holes drilled in them placed over disks of paper towel over the vials allowed for ventilation. Seven vials were placed in each of 12 plastic bags. A wet paper towel was placed in each bag to maintain humidity, and bags were sealed with sponge stoppers held in place with twist ties. Three bags were placed at 9°C, and six at 2°C. After one week three bags were moved from 2°C to -8°C. The vials in the three remaining bags were processed immediately as described below, for controls.

One vial was removed from each bag at two week intervals. Vials and contents were allowed to return to room temperature for at least two hours. Vial contents were flushed through 50 and 200 mesh sieves with running tap water. The contents of the 200 mesh sieve were washed with water into a counting dish and the number of living and dead mites were counted under a stereomicroscope. The percentage survival was calculated as [Number alive/(number alive + number dead)] x 100.

After counting each sample, ten living mites were individually transferred from the counting dish to leaf cages on a bean leaf and supplied with thrips nymphs for food. These were maintained until *A. cucumeris* eggs were observed.

RESULTS AND DISCUSSION

The average time for development of *A. cucumeris* from egg to adult decreased from 11.1 days at 20°C to 6.3 days at 30°C (Table 1). The time spent in each life stage decreased as temperature increased from 20°C to 30°C. At 35°C the eggs hatched in less than 2 days but the larvae died within 24 h and none moulted to protonymph.

Table 1. Development time of *Amblyseius cucumeris* (mean ± standard deviation (n)) fed on *Frankliniella occidentalis* nymphs at 3 temperatures.

Temp (C)	Egg	Larva	Protonymph	Deutonymph	Total Time
20	2.94±0.77 (30)	1.38±0.52 (8)	3.17±0.38 (18)	3.60±0.84 (10)	11.1
25	3.11±0.71 (30)	1.15±0.38 (13)	2.42±0.72 (24)	2.06±0.43 (17)	8.7
30	1.89±0.27 (30)	0.36±0.50 (11)	2.00±0.82 (21)	2.00±0.82 (13)	6.3

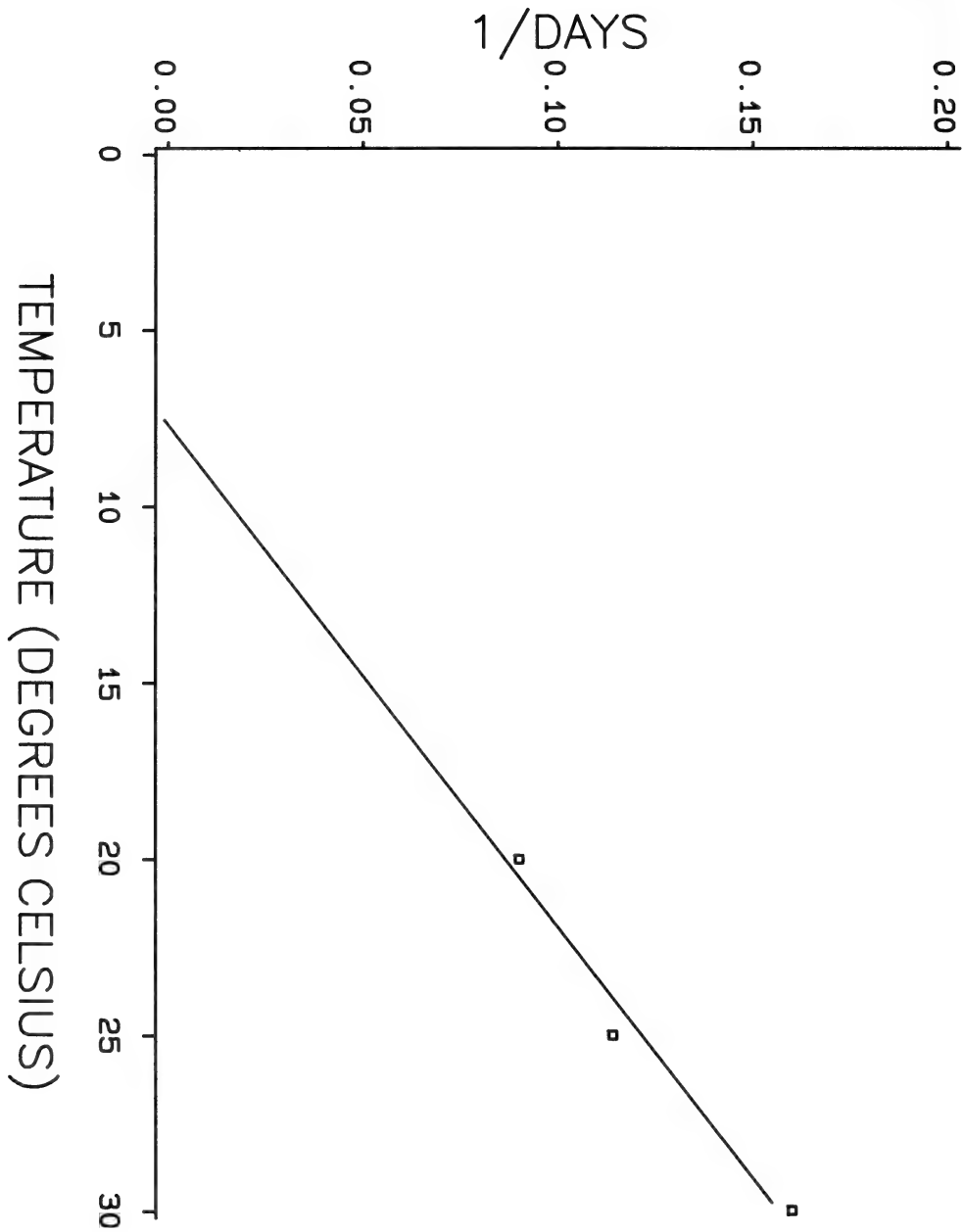

Figure 1. Regression of inverse of developmental time for *A. cucumeris* vs temperature of rearing. Equation of line: y = -0.0537 + 0.007 x (r = 0.97).

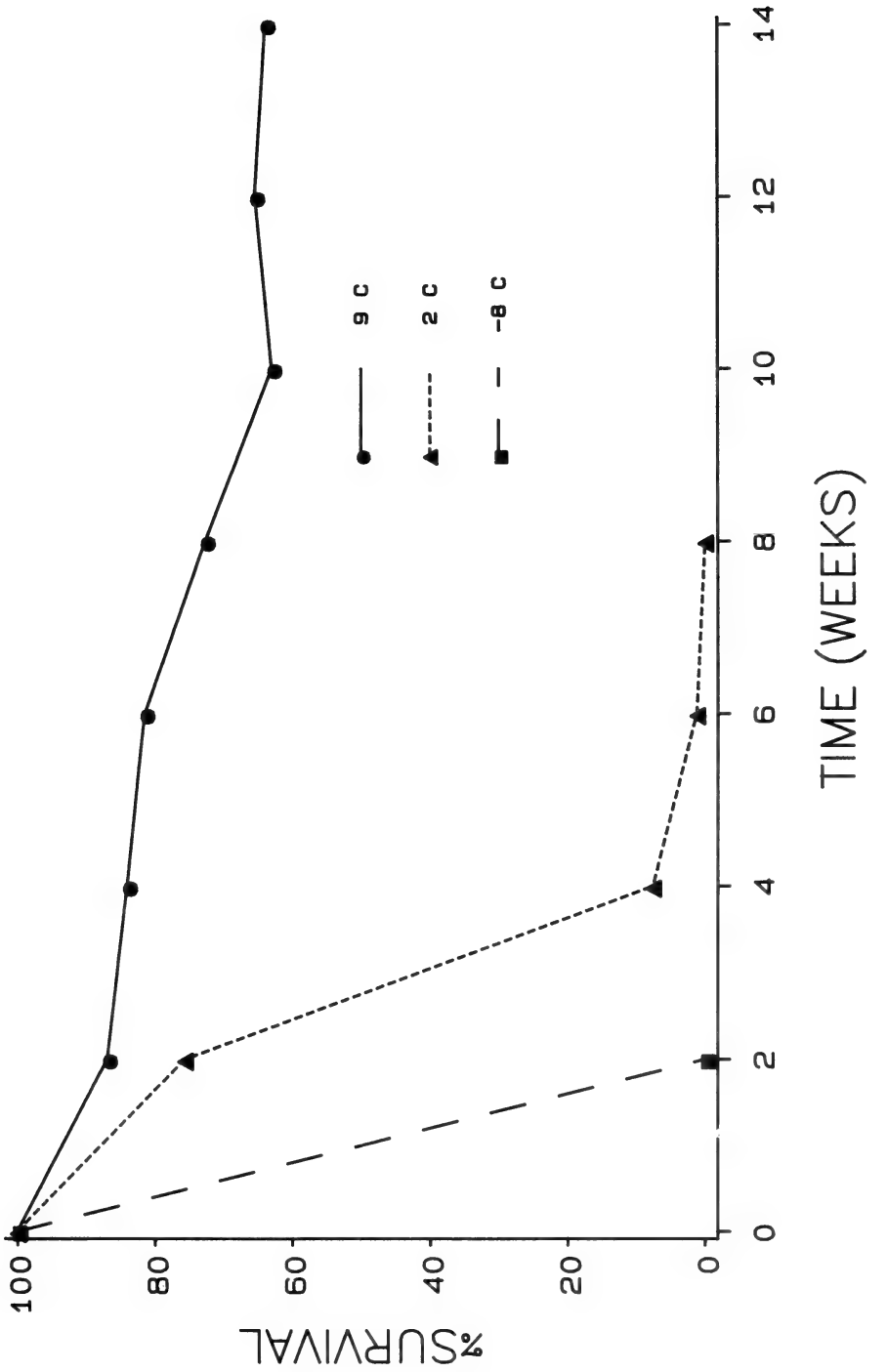

Figure 2. Percent survival of *Amblyseius cucumeris* stored in bran at 9, 2 and -8°C.

El-Badry and Zaher (1961) found a development time of 0.7 days (larva), 1.5 days (protonymph) and 1.4 days (deutonymph) for *A. cucumeris* reared on eggs of *Tetranychus cinnibarinus* eggs at 29°C. Kolodochka (1985) reported a development time of 6.25 days and 6.29 days for *A. cucumeris* males and females, respectively, reared on *Tetranychus* sp. eggs at 26°C. In both cases, the development times were somewhat shorter than those reported here. This may be due to the somewhat greater amount of energy required to capture and kill a thrips larva than that for a *Tetranychus* egg. *F. occidentalis* larvae were observed defending themselves against *A. cucumeris* in the same manner described for *Thrips tabaci* by Bakker and Sabelis (1986).

The threshold temperature for development, as determined by regressing the inverse of development time against temperature and extrapolating (Figure 1), is 7.7°C. This indicates that *A. cucumeris* is able to reproduce and develop across the range of normal greenhouse temperatures, and suggests that it may even be useful in temperate climates in field crop situations where thrips are pests.

Copulation was observed in eight pairs of *A. cucumeris*. The time from copulation until eggs were laid was 3.2 ± 0.83 days. The number of eggs laid by each female per day ranged from 0 to six with two being the most common. The mean egg production for the eight mites was 1.5 ± 0.99 eggs per female per day. This is comparable to an egg production of 1.6 per female per day for *A. cucumeris* eggs (El-Badry & Zaher 1961). It was not possible to observe oviposition over the life span of the females because most of them became entangled in the water-soaked cotton pads in the petri dishes and drowned.

In cold storage at 9°C, *A. cucumeris* survival decreased from 86.9% after 2 weeks to 63% after 10 weeks (Figure 2). At 2°C, a maximum-minimum thermometer placed in the refrigerator showed that the temperature decreased to -2°C on several occasions between the second and sixth week. At -8°C survival was 0% after 2 weeks when sampling was discontinued. All mites that survived cold storage were observed feeding within 24 hours of rewarming, and eggs were produced within 3 days. These results indicate that *A. cucumeris* cannot survive temperatures of less than 0°C. However, long-term storage of several weeks is possible at 9°C with relatively little mortality.

In summary, *A. cucumeris* will feed, develop and reproduce on *F. occidentalis*. It requires slightly longer to complete development with *F. occidentalis* nymphs as prey than with *Tetranychus* eggs. The ability to feed on alternate hosts, particularly mite eggs and pollen suggest that it could survive in a greenhouse in the absence of thrips as noted by De Klerk and Ramakers (1986). The ability of *A. cucumeris* to survive cold storage at 9°C for up to 14 weeks will facilitate mass production and transportation of this useful predator.

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REFERENCES

BAKKER, F.M. and M.W. SABELIS. 1986. Attack success of *Amblyseius mckenziei* and the stage related defensive capacity of thrips larvae. Med. Fac. Landbouww. Rijksuniv. Gent. 51(3a)): 1041-1044.

DE KLERK, M.-L. and P.M.J. RAMAKERS. 1986. Monitoring population densities of the Phytoseiid predator *Amblyseius cucumeris* and its prey after large scale introductions to control *Thrips tabaci* on sweet pepper. Med. Fac. Landbouww. Rijksuniv. Gent. 51(3a): 1045-1048.

EL-BADRY, E.A. and M.A. ZAHER. 1961. Life-history of the predator mite *Typhlodromus (Amblyseius) cucumeris* Oudemans. Bull. Soc. Ent. Egypte. XLV: 427-434.

HEMING, B.S. 1985. Thrips (Thysanoptera) in Alberta. Agriculture and Forestry Bull. 8(2): 19-24.

KOLODOCHKA, L.A. 1985. [Pre-adult development of some species of predacious Phytoseiid mites.] Biocontrol News and Inf. 6(2030): 56-59, (in Russian).

RAMAKERS, P.M.J. and VAN LIEBURG, M.J. 1982. Start of commercial production and introduction of *Amblyseius mckenzei* Sch. and Pr. (Acarina:Phytoseiidae) for control of Thrips *tabaci* Lind. (Thysanoptera:Thripidae) in glasshouses. Med. Fac. Landbouww. Rijksuniv. Gent. 47: 541-545.

ADDITIONS TO THE REVISED CHECKLIST OF THE SPIDERS (ARANEAE) OF BRITISH COLUMBIA

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INTRODUCTION

This list forms an addendum to "A Revised Checklist of the Spiders (Araneae) of British Columbia" by West *et al.* (1984), J. Entomol. Soc. Brit. Columbia 81: 80-90. It adheres to the same sequence and format of presentation as its antecedent, thus only the additional information will be presented. The list contains 137 new species for B.C., and includes one new species for North America, *Lessertia dentichelis* (Simon) (family Erigonidae) and one new family for B.C., Nesticidae containing the single species *Nesticus silvestrii* Fage.

The main specimen collectors were Mr. Donald J. Buckle, Dr. Robert T. Holmberg, Mr. Malcolm Martin and the first author, R. West. The authors wish to thank Mr. J.H. Redner for identifications and the addition of species represented in the Canadian National Collection.

New Family of Spiders in British Columbia

Suborder Opisthothelae
Infraorder Araneomorphae
Nesticidae

S.L. – Specimen Locations

Bennett	– Mr. Robert G. Bennett, University of Guelph, Guelph, Ontario
C.A.S.	– California Academy of Sciences, San Francisco, California
Holmberg	– Dr. Robert T. Holmberg, Athabasca, Alberta
Maddison	– Dr. Wayne P. Maddison, Harvard University, Cambridge, Massachusetts
Martin	– Mr. Malcolm E. Martin, Vernon, B.C.

Det. – Determined by

Bennett	– Mr. R.G. Bennett
Bishop	– Mr. S.C. Bishop
Bragg	– Mr. P.D. Bragg
Buckle	– Mr. D.J. Buckle
Crosby	– Mr. C.R. Crosby
Cutler	– Dr. B. Cutler

Family Dictynidae

Dictyna brevitarsus Emerton. Johnson Bay (Babine Lake)
S.L.: CNC
Det.: Dondale

Dictyna chitina Gertsch. Meadow Mtn. (Kaslo) 7000'
S.L.: CNC
Det.: Dondale

Dictyna subpinicola Ivie. Vernon
S.L.: CNC
Det.: Redner

Dictyna tridentata Bishop & Ruderman. Johnson Bay (Babine Lake), Victoria
S.L.: CNC, UVIC
Det.: Dondale

Family Pholcidae

Psilochorus sp., near hesperus Gertsch & Ivie. Osoyoos
S.L.: Buckle, Holmberg
Det.: Buckle

Family Theridiidae

Euryopis sp., funebris (Hentz) group. 8 mi S. of Peachland
S.L.: Buckle, Holmberg
Det.: Buckle

Euryopis scriptipes Banks. Vernon
S.L.: Martin
Det.: Dondale

Thymoites camano (Levi). ½ mi. N. of Francis Prov. Park, Victoria
S.L.: CNC
Det.: Redner

Theridion bimaculatum (Linnaeus). Vernon, Victoria, Vancouver, Burns Bog, Delta, 9 mi. N. of Enderby, Kamloops, Terrace, Burnaby, Sardis, Goldstream Prov. Park, Pacific Rim Natl. Park.
S.L.: UVIC, Martin, Bragg, CNC
Det.: Dondale, Redner, Bragg, Leech

Theridion sp near pictum (Walckenaer). Parksville
S.L.: Buckle, Holmberg
Det.: Buckle

Theridion petraeum L. Koch. Summerland, Haynes Point, Cache Creek, Kamloops
S.L.: CNC
Det.: Buckle, Dondale, Redner

Theridion tinctum (Walckenaer). Victoria, Vancouver
S.L.: UVIC, CNC
Det.: Dondale

Theridion varians Hahn. Vancouver, Pitt Meadows, Haney, Beaver Lake Park (Victoria), Victoria, Mesachie Lake
S.L.: Bragg, Buckle, Holmberg, CNC
Det.: Leech, Levi, Buckle, Dondale

Theridula emertoni Levi. Upper Shuswap River Ecol. Reserve, N. of Lumby, Prince George
S.L.: CNC
Det.: Dondale

Enoplognatha thoracica (Hahn). Victoria
S.L.: UVIC, CNC
Det.: Dondale

Robertus fuscus (Emerton). Johnson Bay (Babine Lake), Pinkut Creek, Racing River, Mile 419 Alaska Hwy.
S.L.: CNC
Det.: Dondale

Family Nesticidae

Nesticus silvestrii Fage. Sidney
S.L.: AMNH
Det.: Gertsch

Family Linyphiidae

Centromerus longibulbus (Emerton). 9 mi. N. of Enderby, near Cherryville, near Lumby
S.L.: CNC
Det.: Dondale, Redner

Meioneta emertoni Roewer. Departure Bay, Vancouver
S.L.: MCZ
Det.: van Helsdingen

Meioneta pallida (Emerton). Departure Bay
S.L.: MCZ
Det.: Emerton, van Helsdingen

Pimoa haden Chamberlin & Ivie. Kimberley, near Kuskanook
S.L.: Holmberg, Buckle
Det.: Buckle

Microlinyphia impigra (O.P.-Cambridge). Johnson Bay (Babine Lake)
S.L.: CNC
Det.: Redner

Microlinyphia mandibulata (Emerton). 2 mi. S. of Donald Landing (Babine Lake)
S.L.: CNC
Det.: Redner

Microlinyphia pusilla (Sundevall). Johnson Bay (Babine Lake), Emerald Lake, 1 mi. S. of Donald Landing (Babine Lake)
S.L.: CNC, UVIC, Holmberg, Buckle
Det.: Dondale, Buckle

Lepthyphantes alpinus (Emerton). ½ mi. W. of Johnson Bay (Babine Lake)
S.L.: CNC
Det.: Redner

Lepthyphantes calcaratus (Emerton). Johnson Bay (Babine Lake), Liard Hotsprings (Alaska Hwy.)
S.L.: CNC
Det.: Dondale, Redner

Lepthyphantes chamberlini Schenkel. Johnson Bay (Babine Lake), Pink Mtn. (Alaska Hwy.)
S.L.: CNC
Det.: Dondale

Lepthyphantes intricatus (Emerton). Vernon, Revelstoke, Johnson Bay (Babine Lake), near Cherryville, Pinkut Creek
S.L.: CNC, Martin
Det.: Redner, Dondale

Lepthyphantes lyricus Zorsch. Lake Cowichan, Ucluelet, Mesachie Lake, Terrace (Spring Creek), Saanich Peninsula, Mt. Revelstoke Natl. Park
S.L.: CNC
Det.: Redner

Lepthyphantes pollicaris Zorsch. Manning Prov. Park (Valley View)
S.L.: CNC
Det.: Dondale

Lepthyphantes washingtoni Zorsch. 17.5 km S. of Sikanni River (Alaska Hwy.) Pink Mtn. (Alaska Hwy.)

S.L.: CNC
Det.: Redner

Lepthyphantes zelatus Zorsch. Johnson Bay (Babine Lake)
S.L.: CNC
Det.: Redner

Lepthyphantes zibus Zorsch. Comox, ½ mi. N. of Francis Prov. Park, Victoria, Witty's Lagoon, Metchosin, Goldstream Prov. Park, Lake Cowichan, Cassiope Lake, Brooks Peninsula, Frederick Island, 7.9 Km N.W. of Queen Charlotte City (Queen Charlotte Island)
S.L.: CNC
Det.: Redner

Bathyphantes anceps Kulczynski. 1 mi. S. of Donald Landing (Babine Lake)
S.L.: CNC
Det.: Dondale

Bathyphantes canadensis (Emerton). Johnson Bay (Babine Lake)
S.L.: CNC
Det.: Dondale

Bathyphantes pullatus (O.P.-Cambridge). Johnson Bay (Babine Lake),
S.L.: UVIC
Det.: Dondale

Bathyphantes rufulus Hackman. Johnson Bay (Babine Lake)
S.L.: CNC
Det.: Dondale

Linyphantes aeronauticus (Petrunkevitch). Vancouver, Victoria, Summerland
S.L.: CNC
Det.: Dondale, Redner

Linyphantes nehalem Chamberlin & Ivie. near Sumas, Burnaby Mtn.
S.L.: Buckle, Holmberg, CNC
Det.: Buckle, Redner

Linyphantes nigrescens Chamberlin & Ivie. Lake Cowichan
S.L.: CNC
Det.: Dondale

Eulaira dela Chamberlin & Ivie. Goldstream Park, Pitt Meadows, Upper Shuswap River (N. of Lumby), Mission City, Mesachie Lake, Manning Prov. Park
S.L.: CNC
Det.: Dondale

Eulaira microtarsus (Emerton). Manning Prov. Park (Skyline Trail), Johnson Bay (Babine Lake), 1 mi. S. of Donald Landing (Babine Lake)
S.L.: CNC
Det.: Dondale, Redner

Eulaira simplex (Chamberlin). Terrace
S.L.: AMNH
Det.: Chamberlin, Ivie

Aphileta misera (Pickard-Cambridge). Revelstoke (Wap Lake)
S.L.: CNC
Det.: Dondale

Porrhomma sp. North Vancouver, Johnson Bay (Babine Lake)
S.L.: Buckle, Holmberg, CNC
Det.: Buckle, Dondale

Oreonetides filicatus (Crosby). Wap Lake, 20 mi. W. of Golden, 12 mi. W. of Revelstoke
S.L.: CNC
Det.: Dondale, Redner

Oreonetides rotundus (Emerton). 9 mi. N. of Enderby
S.L.: CNC, Martin
Det.: Redner

Oreonetides vaginatus (Thorell). Summit Lake, Pink Mtn. (Alaska Hwy.), 17.5 km S. of Sikanni River, Liard Hotsprings (Alaska Hwy.)
S.L.: CNC
Det.: Redner

Poeciloneta canionis Chamberlin & Ivie. Pine Pass (80 mi. W. of Dawson Creek 5500′), 100 Km E. of Prince George (Hwy. 16)
S.L.: CNC
Det.: Redner

Poeciloneta globosa (Wider). Summit Lake, Pink Mtn. (Alaska Hwy.)
S.L.: CNC
Det.: Redner

Microneta viaria (Blackwall). Mt. Douglas Park (Victoria), Vancouver, Johnson Bay (Babine Lake)
S.L.: CNC, UVIC, Bragg
Det.: Dondale, Leech

Family Erigonidae

Ceraticelus rowensis Levi & Levi. Kingfisher Creek, N. of Enderby
S.L.: CNC
Det.: Dondale

Ceratinopsis aleuticus Holm. Victoria
S.L.: CNC
Det.: Dondale

Ceratinopsis stativa (Simon). Tetsa River (mi. 378 Alaska Hwy.)
S.L.: CNC
Det.: Redner

Diplocephalus cuneatus (Emerton). Johnson Bay (Babine Lake), Liard Hotsprings (Alaska Hwy.)
S.L.: CNC
Det.: Redner

Enidia subarctica (Chamberlin & Ivie). Summit Lake (Alaska Hwy.)
S.L.: CNC
Det.: Redner

Eperigone holda Chamberlin & Ivie. Victoria area
S.L.: ?
Det.: Millidge

Eperigone paludosa Millidge. Goldstream Prov. Park
S.L.: ?
Det.: Millidge

Eperigone taibo Chamberlin & Ivie. Vancouver Island
S.L.: ?
Det.: Millidge

Erigone atra Blackwall. Summit Lake (Alaska Hwy.)
S.L.: Buckle, Holmberg, CNC
Det.: Buckle, Redner

Erigone sp., near blaesa Crosby & Bishop. Kamloops, Osoyoos
S.L.: Buckle, Holmberg
Det.: Buckle

Erigone dentigera (Pickard-Cambridge). Burnaby Mtn., Vancouver, Johnson Bay (Babine Lake)
S.L.: UVIC, CNC, Bragg, Buckle, Holmberg
Det.: Buckle, Dondale, Leech

Erigone labra Crosby & Bishop. Masset
S.L.: AMNH?
Det.: Crosby, Bishop

Erigone metlakatla Crosby & Bishop. Metlakatla, Vancouver
S.L.: Bragg, AMNH?
Det.: Leech, Crosby, Bishop

Erigone sp., psychrophila Thorell group. Burnaby Mtn., Haney, Wickaninnish
S.L.: Buckle, Holmberg
Det.: Buckle

Erigone zographica Crosby & Bishop. Cathedral Prov. Park (Quiniscoe Lake)
S.L.: CNC
Det.: Dondale

Metopobactrus pacificus Emerton. Terrace
S.L.: CNC (type specimen)
Det.: Emerton

Pocadicnemis americana Millidge. 9 mi. N. of Enderby
S.L.: Martin
Det.: Redner

Spirembolus abnormis Millidge. Wellington
S.L.: AMNH
Det.: Millidge (1980), Redner

Spirembolus monticolens (Chamberlin). near Summerland, Johnson Bay (Babine Lake), ½ mi. N. of Francis Prov. Park, Victoria
S.L.: CNC
Det.: Millidge (1980), Redner

Spirembolus mundus Chamberlin & Ivie. Two locations on "Vancouver Island", see Millidge 1980
S.L.: ?
Det.: Millidge (1980)

Tachygyna exilis Millidge. 19.8 mi. W. of Princeton, 11 mi. W. of Allison Pass, Manning Prov. Park
S.L.: CNC
Det.: Millidge

Tachygyna proba Millidge. 11 mi. W. of Allison Pass, Manning Prov. Park
S.L.: CNC
Det.: Millidge

Tapinocyba idahona Chamberlin. 10 mi. N.W. of Oliver
S.L.: CNC
Det.: Redner

Tapinocyba matanuskae Chamberlin & Ivie. 17.5 km S. of Sikanni River (Alaska Hwy.), head of Tagish Lake, Liard Hotsprings (Alaska Hwy.)
S.L.: CNC
Det.: Redner

Tapinocyba parva (Kulczynski). Johnson Bay (Babine Lake)
S.L.: CNC
Det.: Redner

Walckenaeria columbia Millidge. Manning Prov. Park
S.L.: CNC
Det.: Millidge

Walckenaeria communis (Emerton). Johnson Bay (Babine Lake), Summit Lake (Alaska Hwy.), Tetsa River (mi. 878 Alaska Hwy.), Yoho National Park, 9 mi. N. of Enderby, 17.5 km S. of Sikanni River (Alaska Hwy.)
S.L.: CNC
Det.: Millidge, Redner

Walckenaeria cornuella (Chamberlin & Ivie). Haney, 20 mi. E. of Revelstoke, W. of Dawson Inlet, Pine Pass, Johnson Bay (Babine Lake), 7.9 km N.W. Queen Charlotte City, near Cherryville

S.L.: Buckle, Holmberg, CNC, UVIC
Det.: Buckle, Dondale, Millidge, Redner

Walckenaeria fusciceps Millidge. Fletcher Lake
S.L.: CNC
Det.: Redner

Walckenaeria holmi Millidge. 17.5 km S. of Sikanni River (Alaska Hwy.), Tetsa River (mi. 378 Alaska Hwy.), Summit Lake (Alaska Hwy.)
S.L.: CNC
Det.: Redner

Walckenaeria lepida (Kulczynski). Liard Hotsprings (Alaska Hwy.)
S.L.: CNC
Det.: Redner

Walckenaeria monoceras (Chamberlin & Ivie). 40 mi. E. of Vernon
S.L.: CNC
Det.: Redner

Walckenaeria tricornis Emerton). Liard Hotsprings (Alaska Hwy.), Summit Lake (Alaska Hwy.), Tetsa River and 17.5 km S. of Sikanni River (Alaska Hwy.), ½ mi. W. of Johnson Bay (Babine Lake)
S.L.: CNC
Det.: Redner

Walckenaeria vigilax (Blackwall). Meadow Mtn. (Kaslo) 7000′
S.L.: CNC
Det.: Dondale

Lophomma columbia Chamberlin. W. side of Saanich Inlet (20 mi. N. of Victoria), Cameron Lake
S.L.: CNC
Det.: Redner

Grammonota angusta Dondale. Liard Hotsprings (Alaska Hwy.)
S.L.: CNC
Det.: Redner

Grammonota gigas Banks. 9 mi. N. of Enderby
S.L.: Martin, CNC
Det.: Redner

Grammonota kincaidi Banks. Burnaby, Saanich
S.L.: CNC
Det.: Redner

Wabasso cacuminatus Millidge. 17.5 km S. of Sikanni River (Alaska Hwy.)
S.L.: CNC
Det.: Millidge

Tmeticus ornatus Emerton. Johnson Bay (Babine Lake), Mt. St. Paul (mi. 392 Alaska Hwy.)
S.L.: CNC
Det.: Dondale

Baryphyma kulczynski (Jeskov). Johnson Bay (Babine Lake)
S.L.: CNC
Det.: Dondale

Latithorax obtusus (Emerton). Cathedral Prov. Park (Quiniscoe Lake)
S.L.: CNC
Det.: Dondale

Lessertia dentichelis (Simon). Victoria
S.L.: CNC
Det.: Dondale

Family Araneidae

Araniella cucurbitina (Clerck). Johnson Bay (Babine Lake)
S.L.: CNC
Det.: Dondale

Family Agelenidae

Cybaeota concolor Chamberlin & Ivie. W. side of Saanich Inlet
S.L.: AMNH
Det.: Chamberlin, Ivie, Bennett

Cybaeota shasta Chamberlin & Ivie. [*C. vancouverana* and *C. wasatchensis* are junior synonyms of *C. shasta*] Sidney, Bowser, Cowichan Lake, Kyuquot, Victoria, Shawnigan Lake, Goldstream Prov. Park, Francis Prov. Park
S.L.: AMNH, CNC, Bennett
Det.: Bennett, Chamberlin, Ivie

Cicurina sp., intermedia Chamberlin & Ivie group. 4 mi. N. of Osoyoos
S.L.: Buckle, Holmberg
Det.: Buckle

Calymmaria monicae Chamberlin & Ivie. Lillooet
S.L.: CNC
Det.: Gertsch

Calymmaria nana (Simon). 20 mi. N. of Victoria, Cowichan River (Cabin Pool)
S.L.: AMNH, CNC
Det.: Chamberlin, Ivie, Dondale

Calymmaria suprema Chamberlin & Ivie. Goldstream Prov. Park
S.L.: CNC
Det.: Heiss

Ethobuella tuonops Chamberlin & Ivie. Sidney, ½ mi. N. of Francis Prov. Park, Victoria
S.L.: AMNH, CNC
Det.: Chamberlin, Ivie, Redner

Novalena intermedia (Chamberlin & Gertsch). S. Pender Island, Goldstream Prov. Park
S.L.: CNC
Det.: Dondale

Family Mimetidae

Ero canionis Chamberlin & Ivie. Burnaby
S.L.: Holmberg, Buckle
Det.: Buckle

Family Lycosidae

Pirata canadensis Dondale & Redner. 9 mi. N. of Enderby
S.L.: CNC
Det.: Redner

Actosa raptor (Kylczynski). 9 mi. N. of Enderby
S.L.: CNC
Det.: Redner

Pardosa anomela Gertsch. near Cherryville
S.L.: Martin
Det.: Dondale

Hogna frondicola (Emerton). Vernon
S.L.: Martin
Det.: Redner

Family Gnaphosidae

Gnaphosa sp. Platnick & Shadab. near Snohomish, Haney
S.L.: Buckle, Holmberg
Det.: Buckle

Callilepsis eremella Chamberlin. Summerland
S.L.: Buckle, Holmberg, CNC
Det.: Buckle, Dondale

Drassyllus saphes Chamberlin. Osoyoos
S.L.: CNC
Det.: Dondale

Zelotes exiquoides Platnick & Shadab. Telegraph Creek
S.L.: CNC
Det.: Platnick, Dondale

Nodocion rufithoracicus Worley. Victoria
S.L.: CNC
Det.: Dondale

Micaria aenea Thorell. Fountain Valley (near Lillooet), Manning Prov. Park, 20 mi. E. of Revelstoke, Summit Lake, Yoho Natl. Park
S.L.: CNC
Det.: Platnick

Micaria alpina L. Koch. Summit Lake
S.L.: CNC
Det.: Platnick

Micaria coloradensis Banks. Apex Mtn. (near Keremeos)
S.L.: CNC
Det.: Platnick

Micaria constricta Emerton. Apex Mtn. (near Keremeos), Brooks Peninsula, 16 km W. of Barkerville, Manning Prov. Park, Mt. Arrowsmith, Prairie Hills (Selkirk Mtns.), Summit Lake
S.L.: CNC
Det.: Platnick

Micaria foxi Gertsch. Summerland
S.L.: CNC
Det.: Platnick

Micaria idana Platnick & Shadab. Apex Mtn. (near Keremeos), Manning Prov. Park (Valley View)
S.L.: CNC
Det.: Platnick, Dondale

Micaria longipes Emerton. Koocanusa Lake
S.L.: CNC
Det.: Platnick

Micaria riggsi Gertsch. Apex Mtn. (near Keremeos), Salmon Arm
S.L.: CNC
Det.: Platnick

Micaria rossica Thorell. Apex Mtn. (near Keremeos), Comox, Fort Nelson, Goldstream Prov. Park, Kamloops, Prairie Hills (Selkirk Mtns.), Sparwood, Terrace, Victoria
S.L.: CNC
Det.: Platnick

Family Clubionidae

Clubiona furcata Emerton. Johnson Bay (Babine Lake)
S.L.: CNC
Det.: Redner

Clubiona kastoni Gertsch. Pitt Meadows, Haney, Osoyoos Lake, Wellington
S.L.: Buckle, Holmberg, CNC
Det.: Buckle, Dondale

Trachelas californicus Banks. Parksville
S.L.: Buckle
Det.: Buckle

Family Thomisidae

Xysticus ellipticus Thurnbull *et al.* Enderby
S.L.: CNC
Det.: Redner

Thanatus vulgaris Simon. Victoria
S.L.: CNC, UVIC
Det.: Dondale

Family Philodromidae

Ebo parabolis Schick. Osoyoos
S.L.: CNC
Det.: Dondale

Family Salticidae

Habronattus captiosus (Gertsch). Mouth of Trout River at Liard River (km 789 Alaska Hwy.)
S.L.: Maddison
Det.: Griswold

Habronattus decorus (Blackwall). Creston
S.L.: CAS
Det.: Griswold

Sitticus fasciger (Simon). Johnson Bay (Babine Lake)
S.L.: CNC
Det.: Dondale

Tutelina similis (Banks). Vernon
S.L.: CNC, Martin
Det.: Redner

Eris militaris (Hentz). [synonym of E. marginata] Pouce Coupe, Cowichan, Lumby, Creston, Parksville, Victoria, Sparwood, Kelowna, Kamloops, Vernon, Salmon Arm, Nicola, North Vancouver, Enderby
S.L.: UBC, UVIC, BCPM
Det.: Dondale

Metaphidippus flavipedes (Peckham and Peckham). Kettle River, Christina Lake, 3 mi. N.E. of Field
S.L.: Charles, Holmberg, Buckle
Det.: Dondale, Buckle

Synageles canadensis Cutler. Prince George
S.L.: Leech Collection
Det.: Cutler

Synageles leechi Culter. Oliver
S.L.: CNC
Det.: Cutler

Synageles occidentalis Cutler. Christiana
S.L.: Maddison Collection
Det.: Cutler

REFERENCES

Roth, Vincent D. 1985. Spider Genera of North America, with Keys to Families and Genera and a Guide to Literature. Privately published by the author. Available from American Arachnological Society, c/o Dr. Jon Reiskind, Dept. of Zool., Univ. of Florida, Gainesville, FL 32611 Price $10.00 (U.S. Funds).

THE APHIDS (HOMOPTERA:APHIDIDAE) OF BRITISH COLUMBIA 18. FURTHER ADDITIONS

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Abstract

Five species of aphids and new host records are added to the taxonomic list of the aphids of British Columbia.

INTRODUCTION

Thirteen previous lists of the aphids of British Columbia (Forbes, Frazer and MacCarthy 1973; Forbes, Frazer and Chan 1974; Forbes and Chan 1976, 1978, 1980, 1981, 1983, 1984, 1985, 1986a, 1986b, 1987; Forbes, Chan and Foottit 1982) recorded 392 species of aphids collected from 919 hosts or in traps. The records include 1764 aphid-host plant associations. The present list adds 5 aphid species (indicated with an asterisk in the list) and 279 aphid-host plant associations to the previous lists. One hundred and thirty-three of the new aphid-host plant associations are plant species not recorded before. The additions bring the number of known aphid species in British Columbia to 397. Aphids have now been collected from 1052 different host plants and the total number of aphid-host plant associations is 2043.

The aphid names are listed alphabetically by species and are in conformity with Eastop and Hille Ris Lambers (1976), except *Sitobion dorsatum* (Richards) has been changed back to *Aulacorthum dorsatum* Richards based on karyotyping (2n = 12, R.L. Blackman, personal communication). Two new collection sites are tabulated in Table I. The location of each collection site can be determined from Table I or from the tables of localities in the previous papers. The reference points are the same as those shown on the map which accompanies the basic list (Forbes, Frazer and MacCarthy 1973).

Table 1. Collection sites of aphids, with airline distances from reference points.

Locality	Reference Point	Dir	Distance km	Distance mi
Buntzen Lake	Vancouver	NE	32	20
Ellison Lake	Kamloops	SE	70	44

LIST OF SPECIES

ABIETINUM (Walker), ELATOBIUM
Picea glauca: Surrey, Oct19/87.
ABSINTHII (Linnaeus), MACROSIPHONIELLA
Artemisia arborescens 'Powis Castle': Vancouver (UBC), Aug20/87.
AEGOPODII (Scopoli), CAVARIELLA
Anthriscus cerefolium: Vancouver (CDA), Dec15/87.
Hedera helix: Vancouver (UBC), May14/58
Phygelius aequalis 'Yellow Trumpet': Vancouver (UBC), Nov27/87.
AGATHONICA Hottes, AMPHOROPHORA
Rubus idaeus: Abbotsford, Jul9/59; Chilliwack, Jul8/59; Sardis, Jun15/59.
Rubus occidentalis 'Munger': Vancouver (CDA), Jan22/88.
ALBIFRONS Essig, MACROSIPHUM
Lupinus arboreus: Vancouver (UBC), May6/87, Dec7/87.
Lupinus nootkatensis var. *nootkatensis:* Vancouver (UBC), May6/87.
ALNI (de Geer), PTEROCALLIS
Alnus rubra: Buntzen Lake, Jul25/87; Tofino, Aug7/87; Vancouver (UBC), Aug28/87.

ANNULATUS (Hartig), TUBERCULATUS
Quercus robur: Vancouver (UBC), Jul23/87.

ASCALONICUS Doncaster, MYZUS
Arctostaphylos uva-ursi: Vancouver (UBC), Jun19/87.
Capsella bursa-pastoris: Bowen Island, Jun23/87.
Clematis orientalis 'Bill Mackenzie': Vancouver (UBC), Nov19/87, Nov27/87.
Dicentra formosa ssp. *formosa:* Vancouver (UBC), May6/87.
Fragaria x *ananassa 'Burlington':* Vancouver (UBC), Aug20/87.
Fragaria x *ananassa 'Totem':* Vancouver (UBC), Apr8/87.
Geum rivale: Vancouver (UBC), Dec7/87.
Liriope muscari 'Silvery Sunproof': Vancouver (UBC), Nov27/87.
Malva pusilla: Vancouver (UBC), Mar10/87.
Potentilla rubricaulus: Vancouver (UBC), Dec7/87.
Solidaqo missouriensis var. *missouriensis:* Vancouver (UBC), May6/87.

ATRIPLICIS (Linnaeus), HAYHURSTIA
Amaranthus retroflexus: Soda Creek, Jul16/57.

AVELLANAE (Schrank), CORYLOBIUM
Corylus cornuta var. *californica:* Vancouver, May16/87, Jun9/87.

AVENAE (Fabricius), SITOBION
Dactylis glomerata: Vancouver, May27/87.
Danthonia carphoides: Vancouver (UBC), Nov27/87.
Iris pallida 'Variegata': Vancouver (UBC), Sep10/87.

BERBERIDIS (Kaltenbach), LIOSOMAPHIS
Berberis buxifolia: Burnaby, Sep12/87.

*BETULAE (Koch), EUCERAPHIS
Betula pendula: Vancouver (UBC), Nov12/87.

BRASSICAE (Linnaeus), BREVICORYNE
Capsella bursa-pastoris: Richmond, Jul17/87; Vancouver (UBC), Nov12/87.
Raphanus sativus: Richmond, Jul9/87.

CALIFORNICA Hille Ris Lambers, NEARCTAPHIS
Sorbus aucuparia: Vancouver, Jul6/86.

CANADENSE (Robinson), DELPHINIOBIUM
Lonicera involucrata: Tofino, Aug6/87.

CAPILANOENSE Robinson, AULACORTHUM
Rubus spectabilis: North Vancouver, Jul15/65; Vancouver, Jun3/87, Jun22/87; Vancouver (UBC), Jun4/87.

CARDUI (Linnaeus), BRACHYCAUDUS
Arctium minus: Keremeos, Jul28/67.
Senecio vulgaris: Vancouver (UBC), Jan14/87.

CARPINI (Koch), MYZOCALLIS
Carpinus betulus: Vancouver, Nov26/87.

CERASI (Fabricius), MYZUS
Prunus serrulata 'Kwanzan': Vancouver (UBC), Apr28/87.

CERTUS (Walker), MYZUS
Anthriscus cerefolium: Vancouver (CDA), Jan12/88.
Rheum rhabarbarum "Victoria": Vancouver (CDA), Aug19/87.

CIRCUMFLEXUM (Buckton), AULACORTHUM
Akebia quinata: Vancouver (UBC), May5/87, Nov24/87.
Anthriscus cerefolium: Vancouver (CDA), Dec15/87.
Aquilegia 'Mrs Scott Elliott': Vancouver (UBC), Jun4/87.
Arachis hypogaea: Vancouver (CDA), Sep21/87.
Claytonia sibirica var. *sibirica:* Vancouver (CDA), Dec15/87.
Fragaria x *ananassa 'Totem':* Vancouver (UBC), Aug18/87.
Fragaria vesca 'Semperflorens': Vancouver (CDA), Sep21/87.

Gaultheria shallon: Vancouver (UBC), May19/87.
Hypericum calycinum: Vancouver (UBC), Apr8/87, Jun4/87.
Malus sylvestris: Vancouver (UBC), Apr15/87, May15/87.
Onoclea sensibilis: Vancouver (UBC), May12/87.
Oxalis corniculata: Vancouver (UBC), Jun22/87.
Pernettya mucronata 'Pink Pearl': Vancouver (UBC), Apr6/87.
Physalis pubescens: Vancouver (CDA), Dec11/87.
Pityrogramma triangularis var. *triangularis:* Vancouver (UBC), May12/87.
Polystichum lonchitis: Vancouver (UBC), May12/87.
Ranunculus occidentalis: Vancouver, Jun10/87.
Salvia splendens 'St John's Fire': Vancouver (UBC), Jun22/87.
Taraxacum officinale: Vancouver (UBC), Apr8/87.
Vaccinium corymbosum 'Blue Haven': Vancouver (UBC), Jun4/87.
Vaccinium macrocarpon 'McFarlin': Vancouver (UBC), May15/87.
Vaccinium vitis-idaea ssp. *minus:* Vancouver (UBC), Apr6/87.

CORNI (Fabricius), ANOECIA
Fuchsia x *hybrida:* Vancouver, Aug26/87.
Philadelphus lewisii: Vancouver, Aug26/87.
Rosa rugosa 'Alba': Vancouver, Aug26/87.

CORYLI (Goeze), MYZOCALLIS
Corylus cornuta: Vancouver (UBC), Jun4/87.

COWENI (Cockerell), TAMALIA
Arctostaphylos uva-ursi: Vancouver (UBC), May12/87, Jun19/87, Aug6/87.

CRATAEGARIUS (Walker), OVATUS
Mentha sp.: Vancouver (UBC), Jun12/87.
Mentha spicata: Vancouver (UBC), Jun15/87.

*CRATAEGIFOLIAE SSP OCCIDENTALIS Hille Ris Lambers, NEARCTAPHIS
Prunus avium 'Mazzard': Vancouver (UBC), Sep15/87.

CRYSTLEAE SSP BARTHOLOMEWI (Essig), ILLINOIA
Lonicera involucrata: Tofino, Aug6/87.

CYTISORUM Hartig, APHIS
Cytisus scoparius: Bowen Island, May18/87; Tofino, Aug7/87.

DAPHNIDIS Borner, MACROSIPHUM
Daphne x *burkwoodii 'Somerset':* Vancouver (UBC), Nov19/87.
Daphne laureola: Vancouver (UBC), May29/87.
Daphne x *mantensiana:* Vancouver (UBC), Oct9/87.

DAVIDSONI (Mason), ILLINOIA
Arnica sp.: Garibaldi Provincial Park, Aug3/59.

DIRHODUM (Walker), METOPOLOPHIUM
Rosa rugosa 'Hansa': Vancouver (UBC), Oct30/87.
Rosa 'White Grootendorst': Vancouver (UBC), Apr10/87.
Zea mays 'Sunny Vee': Vancouver (CDA), Jan22/88.

DORSATUM Richards, AULACORTHUM
Gaultheria shallon: Vancouver (UBC), May5/87, May19/87.

EPILOBII Kaltenbach, APHIS
Epilobium ciliatum: Williams Lake, Aug4/58.

EQUISETI Holman, SITOBION
Equisetum arvense: Vancouver, Jun27/87.

ERIGERONENSIS (Thomas), UROLEUCON
Conyza canadensis var. *canadensis:* Vancouver (UBC), Sep29/87.

EUPHORBIAE (Thomas), MACROSIPHUM
Amaranthus retroflexus: Brentwood, Aug5/59.

FABAE Scopoli, APHIS
Abutilon 'Moon Chimes': Vancouver (UBC), Jul23/87, Oct7/87.

Allium ampeloprasum porrum group: Brentwood, Jul5/59.
Amaranthus retroflexus: Brentwood, Aug5/59.
Cucurbita pepo: Vancouver, Sep19/58.
Dipsacus fullonum ssp. *fullonum:* Vancouver (UBC), Aug1/86.
Impatiens capensis Vernon, Sep29/42.
Liriodendron tulipifera: Vancouver (UBC), Sep3/86.

FAGI (Linnaeus), PHYLLAPHIS
Fagus sylvatica 'Purpurea Pendula': Vancouver (UBC), Jun3/87.
Fagus sylvatica 'Zlatia': Vancouver (UBC), Jun3/87.

FARINOSA Gmelin, APHIS
Salix sp.: Vancouver, May20/87, May26/87.

FIMBRIATA Richards, FIMBRIAPHIS
Capsella bursa-pastoris: Vancouver (CDA), May25/87.
Fragaria x *ananassa 'Totem':* Abbotsford, Jan21/88.
Fragaria vesca 'Semperflorens': Vancouver (CDA), May22/87.
Rosa 'Beauty Secret': Vancouver (CDA), May22/87.

FLAVA (Davidson), OESTLUNDIELLA
Alnus rubra: Vancouver (UBC), Jul30/87, Aug28/87.

FOENICULI (Passerini), HYADAPHIS
Anthriscus cerefolium: Vancouver (CDA), Sep15/87.
Daucus carota: Vancouver (CDA), Dec14/87.
Lonicera japonica: Vancouver (CDA), Jan22/88.
Lonicera sempervirens 'Flava': Vancouver (UBC), May6/87, Nov14/85.

FRAGAEFOLII (Cockerell), CHAETOSIPHON
Fragaria x *ananassa 'Totem':* Abbotsford, Nov2/87; Vancouver (UBC), Apr8/87, May14/87.
Fragaria vesca 'Semperflorens': Vancouver (UBC), Apr8/87.

FRAGARIAE (Walker), SITOBION
Rubus discolor: Vancouver, May4/87, May6/87.

GALEOPSIDIS (Kaltenbach), CRYPTOMYZUS
Galeopsis tetrahit: Surrey, Jul10/56.

GENTNERI (Mason) FIMBRIAPHIS
Amelanchier laevis: Vancouver (UBC), Sep22/87.
Crataegus monogyna 'Alba': Vancouver, Jun9/87.
Photinia x *fraseri:* Vancouver, May6/87, Jun8/87.

GILLETTEI Davidson, EUCERAPHIS
Alnus rubra: Tofino, Aug6/87, Aug7/87; Vancouver (UBC), Sep4/87.

HELIANTHI Monell, APHIS
Helianthus annuus: Kamloops, Aug13/34, Sep5/57.
Oplopanax horridus: Vancouver (UBC), Apr10/59, Jun27/56.

HELICHRYSI (Kaltenbach), BRACHYCAUDUS
Achillea millefolium: Victoria, Jul12/60.
Arctostaphylos uva-ursi: Vancouver (UBC), May5/87, May 12/87.
Conyza canadensis var. *canadensis:* Vancouver (UBC), Dec30/86.
Erigeron acris ssp. *politus:* Vancouver (UBC), Nov19/87.
Gnaphalium uliginosum: Vancouver, Jun24/87.
Lupinus nootkatensis var. *nootkatensis:* Vancouver (UBC), May6/87.
Pelargonium denticulatum: Vancouver (UBC), Jun12/87.
Salix lanata: Vancouver (UBC), Apr22/87.
Solidago missouriensis var. *missouriensis:* Vancouver (UBC), May6/87.
Tanacetum vulgare: Vancouver, May6/87.
Vinca major: Vancouver (UBC), May6/87.

HERACLELLA Davis, APHIS
Conium maculatum: Prince George, Aug10/55
Heracleum sphondylium ssp. *montanum:* Manning Park, Aug20/87.

HIPPOPHAES (Walker), CAPITOPHORUS
Polygonum persicaria: Richmond, Jul29/87
HUMULI (Schrank), PHORODON
Humulus lupulus: Vancouver, May24/87.
IDAEI van der Goot, APHIS
Rubus idaeus: Vancouver, May28/60.
Rubus ideaus ssp. *melanolasius:* Vancouver, Aug3/56
INSERTUM (Walker), RHOPALOSIPHUM
Malus sylvestris: Penticton, Jul27/67.
LACTUCAE (Linnaeus), HYPEROMYZUS
Lactuca serriola: Tofino, Aug9/87.
Sonchus asper: Vancouver (UBC), Nov11/87.
Sonchus oleraceus: Vancouver, Jun27/87.
LACTUCAE (Passerini), ACYRTHOSIPHON
Lactuca serriola: Richmond, Jul10/87.
LIRIODENDRI (Monell), ILLINOIA
Liriodendron tulipifera:: Vancouver, Aug21/87.
LONGICAUDA (Richards), EOESSIGIA
Spiraea douglasii: Vancouver, Jul8/87.
Spiraea douglasii ssp. *menziesii:* Vancouver (UBC), Nov19/87.
MACROSIPHUM (Wilson), ACYRTHOSIPHON
Amelanchier laevis: Vancouver (UBC), Sep2/87.
MAIDIS (Fitch), RHOPALOSIPHUM
Avena sativa: Vancouver (CDA), Jan22/88.
MALVAE (Mosley), ACYRTHOSIPHON
Geranium sp.: Chilcotin. Jun11/3l.
MAXIMA (Mason), ILLINOIA
Rubus parviflorus: Vancouver (UBC), May24/56.
MODESTUM (Hottes), MYZODIUM
Polytrichum juniperinum: Vancouver (UBC), Jul13/87.
NERVATA (Gillette), WAHLGRENIELLA
Arbutus menziesii: Vancouver (UBC), Dec7/87.
NYMPHAEAE (Linnaeus), RHOPALOSIPHUM
Actinidia chinensis 'Hayward': Vancouver (UBC), Sep15/87.
Alisma plantago-aquatica: Vancouver, Aug28/87, Sep2/87.
Callitriche stagnalis: Vancouver (UBC), Sep11/87.
Menyanthes trifoliata: Vancouver, Aug28/57.
Myriophyllum spicatum: Ellison Lake, Aug18/86.
Prunus avium 'Mazzard': Vancouver (UBC), Sep15/87.
*OLIVEI Moran, UROLEUCON
Aster sp.: Vancouver, Jun18/57.
ORNATUS Laing, MYZUS
Akebia quinata: Vancouver (UBC), Nov24/87.
Arabidopsis thaliana: Vancouver (UBC), Apr10/87.
Arctostaphylos uva-ursi: Vancouver (UBC), Feb25/87.
Chrysanthemum balsamita: Vancouver (UBC), Jun12/87.
Chrysanthemum leucanthemum: Bowen Island, Jun22/87.
Cichorium intybus: Vancouver (UBC), Jun26/87.
Clematis orientalis 'Bill Mackenzie': Vancouver (UBC), Nov19/87, Nov27/87.
Diascia rigescens: Vancouver (UBC), Dec7/87.
Epilobium ciliatum: Vancouver (UBC), Jul16/87.
Erigeron acris ssp. *politus:* Vancouver (UBC), Nov19/87.
Erodium cicutarium ssp. *cicutarium:* Vancouver (UBC), Dec8/87.
Fragaria x *ananassa 'Totem':* Vancouver (UBC), May14/87.

Fritillaria crassifolia: Vancouver (UBC), Apr8/87.
Garrya elliptica: Vancouver (UBC), Jan13/88.
Geum rivale: Vancouver (UBC), Dec7/87.
Gnaphalium uliginosum: Vancouver, Jun24/87.
Helichrysum bracteatum: Vancouver (UBC), Sep29/87.
Lilium candidum: Vancouver (UBC), Apr8/87.
Meconopsis cambrica: Vancouver (UBC), Dec8/87.
Oxalis corniculata: Vancouver (UBC), Jun22/87.
Pernettya mucronata 'Pink Pearl': Vancouver (UBC), Apr6/87, May15/87.
Pernettya mucronata 'White Pearl': Vancouver (UBC), May6/87.
Potentilla caulescens: Vancouver (UBC), Dec7/87.
Potentilla fruticosa: Vancouver (UBC), Dec8/87.
Rhinopetalum bucharium: Vancouver (UBC), Apr8/87.
Rumex acetosella: Vancouver (UBC), May5/87, May6/87.
Salvia officinalis: Vancouver (UBC), Jun12/87.
Salvia officinalis 'Aurea': Vancouver (UBC), Nov27/87.
Salvia splendens 'St John's Fire': Vancouver (UBC), Jun22/87.
Sanguisorba officinalis ssp. *microcephala:* Vancouver (UBC), Nov19/87.
Sonchus oleraceus: Vancouver (UBC), Jul6/87.
Tulipa bakeri: Vancouver (UBC), Apr22/87.
Vaccinium corymbosum 'Northsky": Vancouver (UBC), Jun4/87.
Vaccinium macrocarpon 'McFarlin': Vancouver (UBC), May15/87.
Vaccinium vitis-idaea ssp. *minus:* Vancouver (UBC), Apr6/87.
Vinca major: Vancouver (UBC), May6/87.

PADI (Linnaeus), RHOPALOSIPHUM
Liriope muscari 'Silvery Sunproof': Vancouver (UBC), Nov27/87.
Zea mays: Vancouver (UBC), Aug28/59.

PARVIFLORI Hill, AMPHOROPHORA
Rubus parviflorus: Vancouver, May15/79.

PARVIFOLII Richards, MACROSIPHUM
Pernettya mucronata "Pink Pearl': Vancouver (CDA), Apr21/87.
Vaccinium parvifolium: Vancouver (UBC), Apr22/87, Jun4/87.

PASTINACAE (Linnaeus), CAVARIELLA
Heracleum sphondylium ssp. *montanum:* Manning Park, Aug20/87.

PENDERUM Robinson, UROLEUCON
Grindelia integrifolia: Point Atkinson, May5/57.

PERSICAE (Sulzer), MYZUS
Amaranthus retroflexus: Pemberton, Sep20/87.
Anthriscus cerefolium: Vancouver (CDA), Jan22/88.
Antirrhinum majus: Victoria, Apr4/58.
Beta vulgaris cicla group: Vancouver (UBC), Sep15/87.
Capsella bursa-pastoris: Pemberton, Sep20/87; Vancouver (UBC), Nov12/87.
Galeopsis tetrahit: Pemberton, Sep20/87.
Malva neglecta: Vancouver (UBC), Nov27/87, Dec7/87.
Nasturtium officinale: Pemberton, Sep20/87.
Physalis pubescens: Vancouver (CDA), Dec15/87.
Prunus avium 'Mazzard': Vancouver (UBC), Sep15/87.
Rumex crispus: Pemberton, Sep20/87.
Solanum nigrum: Pemberton, Sep20/87.
Solanum tuberosum: Pemberton, Sep3/87.

PINETI (Fabricius), SCHIZOLACHNUS
Pinus mugo: Lulu Island, Jun7/61

PISUM (Harris), ACYRTHOSIPHON
Cytisus scoparius: Tofino, Aug7/87.
Phaseolus vulgaris: Brentwood, Jul4/59.

PLANTAGINEA (Passerini), DYSAPHIS
Malus sylvestris: Penticton, Jul27/67; Vancouver (UBC), May22/57.
PLATANOIDIS (Schrank), DREPANOSIPHUM
Acer saccharum ssp. *grandidentatum:* Vancouver (UBC), Oct20/87.
*POLARIS Hille Ris Lambers, MYZUS
Cerastium fontanum ssp. *triviale:* Vancouver, Dec30/59.
POMI de Geer, APHIS
Chaenomeles speciosa: Vancouver, Jul20/58.
Crataegus monogyna 'Alba': Vancouver, Jun9/87.
Sorbus aucuparia: Vancouver, Jul6/86.
POPULIVENAE Fitch, PEMPHIGUS
Rumex acetosella: Vancouver (UBC), May5/87.
PRUNI (Geoffroy), HYALOPTERUS
Typha orientalis: Vancouver (UBC), Aug20/87.
PTERINIGRUM Richards, AULACORTHUM
Akebia quinata: Vancouver (UBC), Nov24/87.
Pieris japonica: Richmond, May23/67.
Rosa 'Beauty Secret': Vancouver (CDA), Dec8/87.
Vaccinium parvifolium: Tofino, Aug5/87.
RHAMNI (Clarke), SITOBION
Rhamnus purshiana: Vancouver (UBC), Aug12/87.
RIBIS (Linnaeus), CRYPTOMYZUS
Ribes sativum 'Red Lake': Vancouver (UBC), Jul23/87.
RIBISNIGRI (Mosley), NASONOVIA
Cichorium intybus: Vancouver (UBC), Jun26/87, Aug1/86.
Crepis capillaris: Richmond, Jul9/87.
Lactuca sativa: Cloverdale, May21/87; Vancouver, Sep11/87.
Lactuca serriola: Richmond, Jul17/87.
ROBINIAE (Gillette), APPENDISETA
Robinia pseudoacacia: Vancouver, May24/87.
ROSAE (Linnaeus), MACROSIPHUM
Centranthus ruber: Vancouver (UBC), Jun12/87, Jun26/87.
Centranthus ruber 'Atrococcineus': Vancouver (UBC), May25/87.
Dipsacus fullonum ssp. *fullonum:* Vancouver (UBC), Aug1/86.
Rosa 'A 22': Vancouver (UBC), Apr10/87, Apr29/87, May29/87, Jun25/87.
Rosa 'Admiral Rodney': Vancouver (UBC), Mar6/87.
Rosa 'Agnes': Vancouver (UBC), Aug12/87.
Rosa 'Amatsu Otome': Vancouver (UBC), Aug5/87, Sep2/87.
Rosa canina: Vancouver (UBC), May25/87.
Rosa 'Chicago Peace': Vancouver (UBC), Jan14/87.
Rosa damascena: Vancouver (UBC), Apr10/87.
Rosa 'Electron': Vancouver (UBC), Sep2/87.
Rosa 'Florentina': Vancouver (UBC), Sep2/87.
Rosa helenae: Vancouver (UBC), May29/87.
Rosa 'Iceberg': Vancouver (UBC), Sep2/87.
Rosa 'L 57': Vancouver (UBC), Apr10/87.
Rosa 'L 85': Vancouver (UBC), Apr10/87, Nov2/87.
Rosa 'Matangi': Vancouver (UBC), Feb25/87.
Rosa 'Mr. Chips': Vancouver (UBC), Mar6/87.
Rosa nutkana: Vancouver (UBC), May29/87.
Rosa 'Old Master': Vancouver (UBC), Aug5/87.
Rosa rubrifolia: Vancouver (UBC), May29/87, Jun25/87.
Rosa rugosa 'Alba': Vancouver (UBC), May5/87, May29/87, Sep10/87.
Rosa 'Sympathie': Vancouver (UBC), Apr10/87.
Rosa 'U O 4': Vancouver (UBC), Apr29/87.

Rosa virginiana: Vancouver (UBC), Apr29/87.
Rosa wichuraiana: Vancouver (UBC), Jun25/87.
Valeriana officinalis: Vancouver (UBC), Jun12/87.

ROSARUM (Kaltenbach), MYZAPHIS
Fragaria x *ananassa 'Totem':* Vancouver (CDA), Jan22/88.
Potentilla fruticosa: Vancouver, Sep12/87; Vancouver (UBC), Dec8/87.
Rosa 'A 22': Vancouver (UBC), Aug5/87.
Rosa 'Beauty Secret: Vancouver (CDA), Nov13/87.
Rosa 'Eddie's Jewel': Vancouver (UBC), Jun25/87.
Rosa luciae var. *onoei 'Yakushima Bara':* Vancouver (UBC), Nov19/87, Nov27/87.

RUSSELLAE (Hille Ris Lambers) UROLEUCON
Anaphalis margaritacea: Tofino, Aug6/87.

SALICARIAE Koch, APHIS
Cornus alba' Argenteo-marginata': Vancouver (UBC), May21/59.
Cornus capitata: Vancouver (UBC), May21/59.

SALIGNUS (Gmelin), TUBEROLACHNUS
Salix sp.: Vancouver (UBC), Oct31/41.

SCLEROSA (Richards) NEARCTAPHIS
Crataegus douglasii: Vancouver (UBC), Jun27/56.

SEDI Kaltenbach, APHIS
Sedum spectabile: Vancouver, Nov10/87.

SOLANI (Kaltenbach), AULACORTHUM
Akebia quinata: Vancouver (UBC), May5/87.
Anchusa capensis: Vancouver (UBC), May25/87, Jun12/87.
Callistemon pallidus: Vancouver (UBC), Feb19/87.
Capsella bursa-pastoris: Bowen Island, Jun21/87, Jun23/87.
Cichorium intybus: Vancouver (UBC), Jun26/87.
Claytonia sibirica var. *sibirica:* Vancouver (CDA), Jan22/88.
Conyza canadensis var. *canadensis:* Vancouver (UBC), Dec30/86.
Digitalis lutea: Vancouver (UBC), May6/87.
Disporum hookeri var. *oreganum:* Vancouver (UBC), Apr14/87.
Fragaria x *ananassa 'Totem':* Vancouver (UBC), May14/87.
Fritillaria crassifolia: Vancouver (UBC), Apr8/87.
Fuchsia magellanica: Vancouver, Aug26/87.
Gaultheria shallon: Vancouver (UBC), May5/87.
Geranium molle: Bowen Island, Jun22/87.
Geranium viscosissimum var. *viscosissimum:* Vancouver (UBC), Apr3/86.
Geum peruvianum: Vancouver (UBC), Feb18/87.
Geum rivale: Vancouver (UBC), Dec7/87.
Gnaphalium uliginosum: Vancouver, Jun24/87.
Gomphrena globosa: Vancouver (CDA), Sep18/87.
Iris longipetala: Vancouver (UBC), Feb19/87.
Leucothoe fontanesiana: Vancouver (UBC), May19/87.
Limonium latifolium 'Violetta': Vancouver (UBC), Nov27/87.
Mentha spicata: Vancouver (UBC), Jun15/87.
Monarda fistulosa var. *menthifolia:* Vancouver (UBC), Jun12/87.
Morina coulteriana: Vancouver (UBC), Feb18/87.
Nicotiana glauca: Vancouver (CDA), Jan22/88.
Onoclea sensibilis: Vancouver (UBC), May12/87.
Pelargonium denticulatum: Vancouver (UBC), Jun12/87.
Pernettya mucronata 'White Pearl': Vancouver (UBC), May6/87.
Petasites palmatus: Vancouver, Jun22/87.
Physalis pubescens: Vancouver (CDA), Dec11/87.
Pieris japonica: Richmond, Jun15/87.

Polypodium glycyrrhiza: Vancouver (UBC), Aug5/87.
Potentilla rubricaulus: Vancouver (UBC), Dec7/87.
Prunus laurocerasus: Vancouver, May12/87.
Romneya coulteri: Vancouver (UBC), Jun12/87, Jun26/87.
Rubus calycinoides: Vancouver (UBC), Apr24/87.
Ruta graveolens: Vancouver (UBC), May25/87.
Ruta graveolens 'Variegata': Vancouver (UBC), May25/87.
Salvia officinalis: Vancouver (UBC), Jun12/87.
Sanguisorba officinalis ssp. *microcephala:* Vancouver (UBC), Nov19/87.
Santolina chamaecyparissus: Vancouver (UBC), Jun12/87.
Senecio abrotanifolius: Vancouver (UBC), Feb18/87.
Sibiraea altaiensis: Vancouver (UBC), Feb19/87.
Symphoricarpos albus: Vancouver, May4/87.
Verbena x *hybrida:* Vancouver (UBC), Aug1/86.
Viola tricolor: Vancouver (UBC), Jun12/87.

SPIRAEAE (MacGillivray), ILLINOIA
Spiraea douglasii: Vancouver, Jul8/87.

SPYROTHECAE Passerini, PEMPHIGUS
Populus nigra 'Italica': Langley, Aug6/87.

STANLEYI Wilson, MACROSIPHUM
Sambucus racemosa ssp. *pubens* var. *arborescens:* Bowen Island, Jul22/67; Vancouver (UBC), May6/87.

STAPHYLEAE (Koch), RHOPALOSIPHONINUS
Anagallis monelli: Vancouver (UBC), Feb18/87.
Anemone chinensis: Vancouver (UBC), Feb18/87.
Aquilegia caerulea var. *ochroleuca:* Vancouver (UBC), Feb19/87.
Arum korolkowii: Vancouver (UBC), Feb18/87.
Campanula rotundifolia: Vancouver (UBC), Feb18/87.
Campanula sartorii: Vancouver (UBC), Feb18/87.
Convolvulus althaeoides: Vancouver (UBC), Feb18/87.
Cyclamen cilicium: Vancouver (UBC), Feb18/87.
Dianthus deltoides: Vancouver (UBC), Feb19/87.
Erysimum wilczekianum: Vancouver (UBC), Feb19/87.
Fragaria chiloensis: Vancouver (UBC), Feb19/87.
Geum peruvianum: Vancouver (UBC), Feb18/87.
Goniolimon speciosum: Vancouver (UBC), Feb18/87.
Helleborus lividus: Vancouver (UBC), Feb18/87.
Helleborus niger: Vancouver (UBC), Feb18/87.
Hemerocallis sp. : Vancouver (UBC), Feb19/87.
Incarvillea olgae: Vancouver (UBC), Feb18/87.
Iris longipetala: Vancouver (UBC), Feb19/87
Lilium formosanum var. *pricei:* Vancouver (UBC), Feb18/87.
Linum perenne ssp. *lewisii:* Vancouver (UBC), Feb18/87.
Luzula banksiana: Vancouver (UBC), Feb18/87.
Morina coulteriana: Vancouver (UBC), Feb18/87.
Oenothera odorata: Vancouver (UBC), Feb18/87.
Oenothera pilosella: Vancouver (UBC), Feb18/87.

Oenothera rosea: Vancouver (UBC), Feb18/87.
Papaver alpinum 'Plena': Vancouver (UBC), Feb18/87.
Pardanthopsis dichotoma: Vancouver (UBC), Feb18/87.
Phuopsis stylosa: Vancouver (UBC), Feb18/87.
Polemonium caeruleum ssp. *amygdalinum:* Vancouver (UBC), Feb18/87.
Pratia nummularia: Vancouver (UBC), Feb19/87.
Primula parryi: Vancouver (UBC), Feb19/87.
Salix vestita: Vancouver (UBC), Feb19/87.
Senecio abrotanifolius: Vancouver (UBC), Feb18/87.
Typha orientalis: Vancouver (UBC), Feb19/87.
Waldsteinia fragarioides: Vancouver (UBC), Feb18/87.

STELLARIAE Theobald, MACROSIPHUM
Anthriscus cerefolium: Vancouver (CDA), Jan12/88.
Gomphrena globosa: Vancouver (CDA), Jan22/88.

*TENUICAUDA Bartholomew, MACROSIPHUM
Apium graveolens: Vancouver (CDA), Sep9/87.
Capsella bursa-pastoris: Vancouver (CDA), Sep9/87.
Urtica dioica: Peace Arch Park, Aug3/87

TESTUDINACEUS (Fernie), PERIPHYLLUS
Acer saccharum ssp. *grandidentatum:* Vancouver (UBC), Oct20/87.

TILIAE (Linnaeus), EUCALLIPTERUS
Tilia platyphyllos 'Lacinia': Vancouver (UBC), Aug8/56.

ULMI (Linnaeus), ERIOSOMA
Ulmus americana: Vancouver (UBC), May22/58.

VARIANS Patch, APHIS
Epilobium angustifolium: Kamloops, Aug11/54; Tofino, Aug9/87.

WAKIBAE (Hottes), FIMBRIAPHIS
Capsella bursa-pastoris: Vancouver (CDA), Mar15/87.
Fragaria x *ananassa 'Totem':* Vancouver (CDA), Mar15/87.
Fragaria vesca' Semperflorens': Vancouver (CDA), Mar15/87.
Rosa 'Beauty Secret': Vancouver (CDA), Mar15/87.
Rosa rugosa 'Hansa': Vancouver (UBC), Oct30/87.

XYLOSTEI (de Geer), PROCIPHILUS
Picea engelmannii: Nelson, Nov20/87.
Picea glauca: Quesnel, Oct6/87.

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REFERENCES

Eastop, V.F., and D. Hille Ris Lambers. 1976. Survey of the world's aphids. Dr. W. Junk b.v., Publisher, The Hague.

Forbes, A.R. and C.K. Chan. 1987. The aphids (Homoptera: Aphididae) of British Columbia. 16. Further additions. J. ent. Soc. Brit. Columbia 84:66-72.

Forbes, A.R., and C.K. Chan. 1986a. The aphids (Homoptera: Aphididae) of British Columbia. 15. Further additions. J. ent. Soc. Brit. Columbia 83:70-73.

Forbes, A.R., and C.K. Chan. 1986b. The aphids (Homoptera: Aphididae) of British Columbia. 14. Further additions. J. ent. Soc. Brit. Columbia 83:66-69.

Forbes, A.R., and C.K. Chan. 1985. The aphids (Homoptera: Aphididae) of British Columbia. 13. Further additions. J. ent. Soc. Brit. Columbia 82:56-58.

Forbes, A.R., and C.K. Chan. 1984. The aphids (Homoptera: Aphididae) of British Columbia. 12. Further additions. J. ent. Soc. Brit. Columbia 81:72-75

Forbes, A.R., and C.K. Chan. 1983. The aphids (Homoptera: Aphididae) of British Columbia. 11. Further additions. J. ent. Soc. Brit. Columbia 80:51-53.

Forbes, A.R., and C.K. Chan. 1981. The aphids (Homoptera: Aphididae) of British Columbia. 9. Further additions. J. ent. Soc. Brit. Columbia 78:53-54

Forbes, A.R., and C.K. Chan. 1980. The aphids (Homoptera: Aphididae) of British Columbia. 8. Further additions and corrections. J. ent. Soc. Brit. Columbia 77:38-42.

Forbes, A.R., and C.K. Chan. 1978. The aphids (Homoptera: Aphididae) of British Columbia. 6. Further additions. J. ent. Soc. Brit. Columbia 75:47-52.

Forbes, A.R., and C.K. Chan. 1976. The aphids (Homoptera: Aphididae) of British Columbia. 4. Further additions and corrections. J. ent. Soc. Brit. Columbia 73:57-63.

Forbes, A.R., C.K. Chan and R.G. Foottit. 1982. The aphids (Homoptera: Aphididae) of British Columbia. 10. Further additions. J. ent. Soc. Brit. Columbia 79:75-78.

Forbes, A.R., and C.K. Chan. 1974. The aphids (Homoptera: Aphididae) of British Columbia. 3. Additions and corrections. J. ent. Soc. Brit. Columbia 71:43-49.

Forbes, A.R., B.D. Frazer and H.R. MacCarthy. 1973. The aphids (Homoptera: Aphididae) of British Columbia. 1. A basic taxonomic list. J. ent. Soc. Brit. Columbia 70:43-57.

A NEW HOST-PLANT IN B.C. FOR *RHOPALOSIPHUM NYMPHAEAE* (HOMOPTERA:APHIDIDAE)

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In June, 1986, while sampling insects from Eurasian watermilfoil, *Myriophyllum spicatum*, to evaluate possible biocontrol agents, adult *Rhopalosiphum nymphaeae* (L.) (Homoptera:Aphididae) were recovered from submerged plants in Ellison Lake, Kelowna, B.C. These insects were well established on the plant with probosces inserted into the stem. Individuals were observed daily for two weeks, during which reproduction occurred although the adults remained submerged, cradling bubbles of air between their legs.

R. nymphaeae were also found in samples of *M. spicatum* taken from Long Lake in Nanaimo, B.C. These insects were placed into an aquarium and fed fresh *M. spicatum* at irregular intervals. During a two month period they reproduced and alternated between feeding on the submerged plants and spending time on the surface. *R. nymphaeae* may be draining air from the plant's lacunal spaces, located throughout the stem, in much the same manner as that reported for an aquatic weevil. *Litodactylus leucogaster* (Buckingham *et al.*, 1981).

This is the first report of *R. nymphaeae* from *M. spicatum* in B.C. although it has been reported from two other submerged aquatic plants, *Callitriche stagnalis* and *Elodea canadensis* (Forbes and Chan, 1987). This species has been reported from *M. spicatum* in the southern United States (Balciunas, 1982).

R. nymphaeae has been suggested as a possible biocontrol for aquatic weeds in the past (John and Nair, 1983). This species, however, has a broad host range (Sarup *et al.*, 1973), is not an obligate aquatic, and has been reported as vectoring at least one commercially important mosiac virus from aquatic to terrestrial plants (Wyman *et al.*, 1979). For these reasons, *R. nymphaeae* may not be suitable as a biocontrol agent

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We thank Dr. R. Foottit of B.R.I. for identification of specimens.

REFERENCES

Balciunas, J.K. 1982. Insects and Other Macroinvertebrates Associated With Eurasian Watermilfoil in the United States. Tech. Rep. A-82-5. U.S. Army Engineers Waterways Expt. Stat., C.E., Vicksburg, Miss. 94 pp.

Buckingham, G.R., Bennett, C.A., and B.M. Ross. 1981. Investigation of Two Insect Species for Control of Eurasian Watermilfoil. Tech. Rep. A-81-4. U.S. Army Engineers Waterways Expt. Stat., C.E., Vicksburg, Miss.

Forbes, A.R., and C.K. Chan. 1987. The aphids (Homoptera:Aphididae) of British Columbia 17. A revised host plant catalogue. J. entomol Soc. Brit. Columbia 84: 72-100.

John, K.C., and N.B. Nair. 1983. *Rhopalosiphum nymphaeae* (Homoptera: Aphididae), a control agent for *Salvinia molesta*. Entomol. Mon. 7(3): 381-384.

Sarup, P., Singh, D.S., and R. Lal. 1973. Relative resistance of various aphids infesting terrestrial and aquatic plants to some important pesticides. Indian J. Entomol. 33: 131-135.

Wyman, J.A., Toscano, N.C., Kido, K., Johnson, H., and K.S. Mayberry. 1979. Effects of mulching on the spread of aphid transmitted watermelon mosaic virus to summer squash. J. Econ. Entomol. 72: 139-143.

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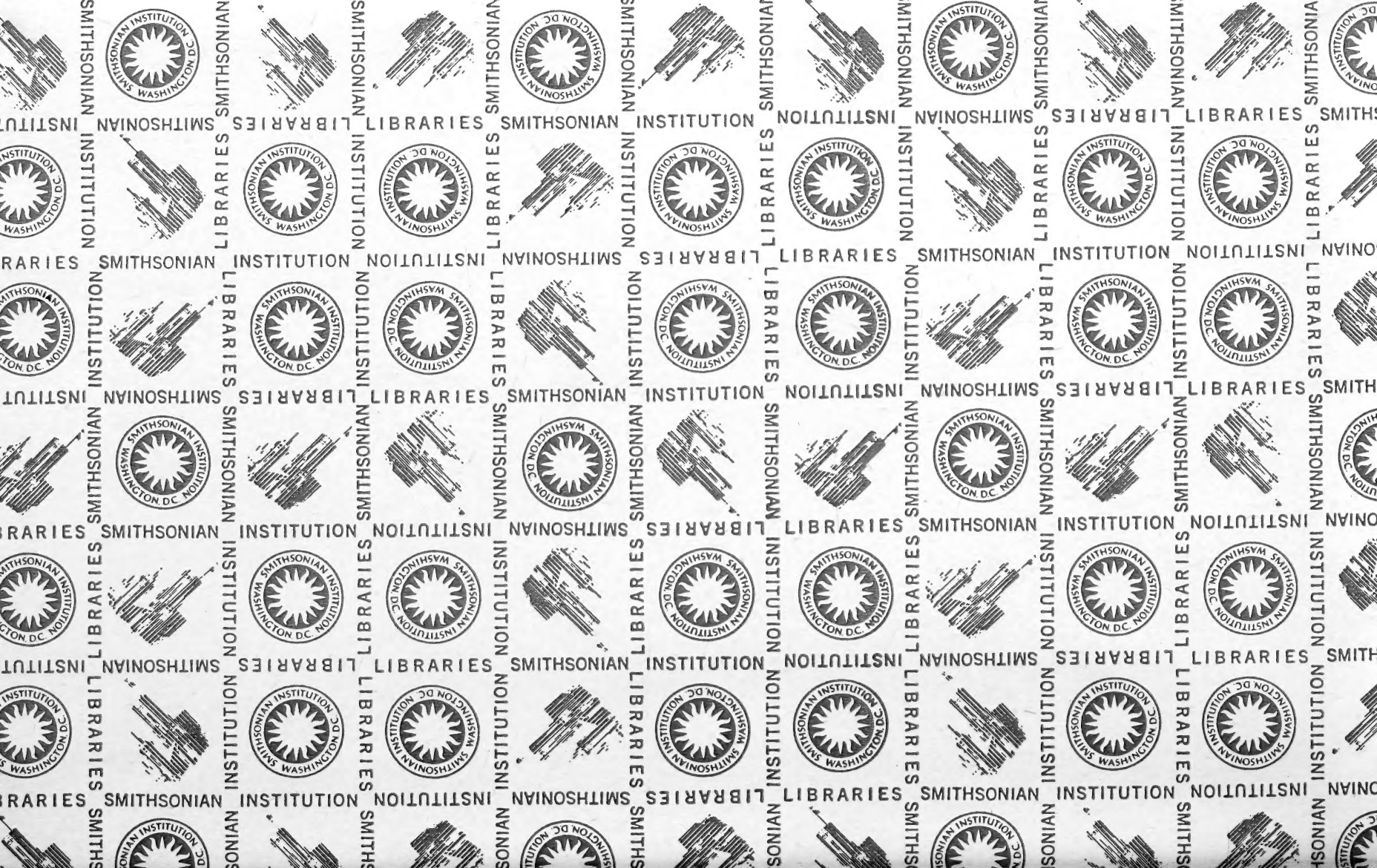
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