NATIVE BEE POLLINATORS OF BERRY CROPS IN THE FRASER VALLEY OF BRITISH COLUMBIA

MARK L. WINSTON AND LINDA H. GRAF
Department of Biological Sciences
Simon Fraser University
Burnaby, B.C. V5A 1S6

ABSTRACT

Collections of native bees were made on blueberry, cranberry, and raspberry fields in the Fraser Valley of southwestern British Columbia to determine whether these bees were present in sufficient diversity and abundance to pollinate berry crops. Bumblebees were present on all three crops but not abundant, and solitary bees were notably scarce. Native bees did not appear to be present in sufficient abundance to effect pollination of any of the berry crops, so that managed honeybees *(Apis mellifera)* are essential for berry production in the Fraser Valley. Reasons for low diversity and abundance of native bees probably included pesticide impact, habitat destruction, competition with managed honeybees, and extended rains during the study period.

INTRODUCTION

Although blueberry, raspberry, and cranberry are each self-compatible, it has been well-documented that bee pollination greatly enhances fruit production (Free, 1970; Daubeny, 1971; Dorr and Martin, 1966; Johansen and Shawa, 1974; Marucci, 1966, 1967; Martin, 1966; Marucci and Moulter, 1977; McCutcheon, 1976; McGregor, 1976; Moeller, 1978; Murrell and McCutcheon, 1977; Whatley and Lackett, 1978). Thus, growers commonly rent or own honeybees *(Apis mellifera* L.) as part of their regular management practices. However, before honeybees were introduced to the New World more than 300 years ago, pollination of these native plants was primarily due to visits of native bees, particularly bumblebees *(Bombus* spp.). In fact, until recent pesticide spraying and other human activities reduced native bee populations, honeybee colonies were not needed for blueberry pollination in Eastern Canada (Kevan, 1977; Wood *et al.*, 1967), New Jersey (Marucci, 1966, 1978; Marucci and Moulter, 1977), Michigan (Dorr and Martin, 1966; Martin, 1966), and Washington (Johansen and Shawa, 1974). More recently, honeybees have been considered essential for commercial berry pollination due to decreased abundance of native pollinators in these regions (cited above, and Kevan 1975; Kevan and LeBerge, 1978; Wood, 1979).

The use of honeybee colonies for pollination in Fraser Valley berry growing is recommended (Berry Production Guide, 1980), and increased yields using honeybees have been demonstrated in local raspberry crops (McCutcheon, 1976; Murrell and McCutcheon, 1977). However, native bee populations have not been studied to determine whether feral or managed native bees might be adequate for pollination. The purpose of this paper is to document the abundance and diversity of native bee species and to determine their role as pollinators for commercial berry production in the Fraser Valley.

METHODS

This study was conducted from April-July 1981 in the Fraser Valley area surrounding Vancouver, B.C. Nine commercial berry farms were used as collecting sites, three each of highbush blueberry *(Vaccinium corymbosum)*, raspberry *(Rusus idaeus)*, and cranberry *(Vaccimium macrocarpon)* (Fig. 1). Their exact locations were as follows: Blueberry 1 (B1) and Cranberry 1 (C1) — directly east of the intersection of Ford and Harris Streets in Pitt Meadows; Blueberry 2 (B2) and Cranberry 2 (C2) — March's berry farm, Sidaway Road, in Richmond; Blueberry 3 (B3) — Freeman's berry farm, No. 6 Road, Richmond; Raspberry 1 (R1) — Agriculture Canada Research Station, Abbotsford Airport, Abbotsford; Raspberry 2 (R2) — Goetzke's berry farm, 24387 - 70th Avenue, Langley and Raspberry 3 (R3) — Driediger's berry farm, 240th Street, Langley; All the sites except R1 had mixed decidious-conifer secondary growth on at least one side, and all nine sites were in agricultural areas with other berry fields and old, uncultivated fields nearby.

Native bees found visiting flowers of the three crops were collected with an insect net during the entire flowering period for each crop. Attempts were made to catch all the native bees seen, but a few bees escaped when the collector was occupied catching another bee. The time spent in collecting was noted to generate a measure of abundance, based on bees collected/hr. Honeybees were generally not collected, since their abundance is largely dependent on whether growers placed hives near their fields. However, some honeybees were collected in order to compare their pollen loads with those of the native bees.

Pollen loads from *Bombus* and *Apis* collected on cranberry were analyzed by examining 500 pollen grains from the bees' corbiculae, and classifying them as either berry or non-berry pollen. To prepare the pollen for analysis, distilled water was

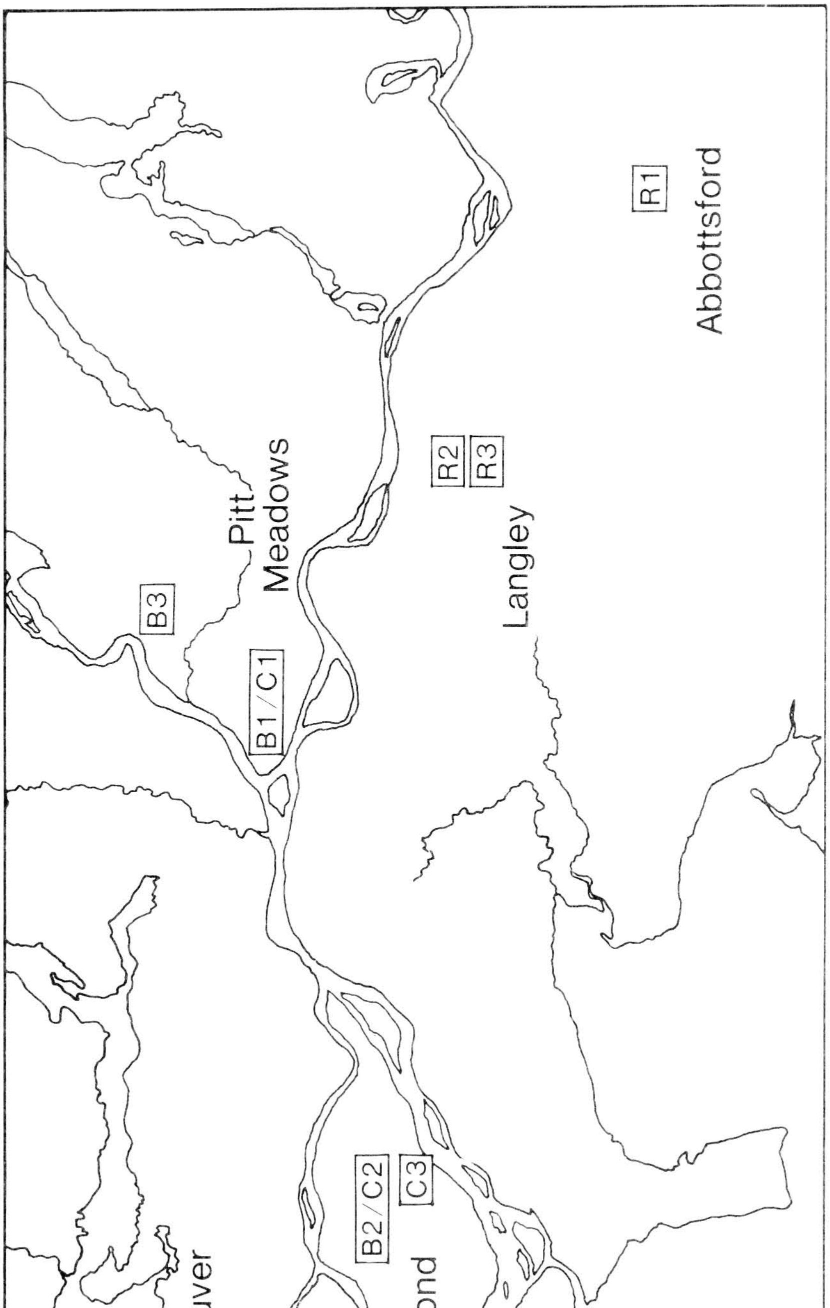

Fig. 1: Collecting sites in the Fraser Valley area, southwestern British Columbia, Canada. B = *blueberry*. *R* = raspberry, C = cranberry.

used to disperse the clumps into single pollen grains. The suspension was then centrifuged for five minutes and the water decanted. The pollen was then dehydrated with glacial acetic acid (GAA), centrifuged, and decanted again. A 9:1 mixture of acetic anhydride:sulfuric acid was then added, and the contents of the tube stirred while it was held in boiling water for 1-2 minutes. GAA was added to cool the mixture, and the pollen was centrifuged, decanted, mixed with distilled water, centrifuged, and decanted again. Tertiary butyl alcohol was added, and the mixture centrifuged and decanted again. A drop of the resultant sample was mounted on a slide and examined.

Weather conditions during the study were unusually cold and rainy. The accumulated rainfall for April-July was 395 mm, a record for the Vancouver area (Vancouver International Airport).

Pesticide applications by growers before and during the study were as follows: Blueberry — unsprayed; C1, C3 — unsprayed; C2 — Parathion 16 May, 8 July; R1 — Furadan 20 May, Dinoseb 30 April; R2 — Malathion 15 May, Guthion 22 May, Captan 17 June; R3 — Malathion 3 June, Guthion 10 June, Captan 26 June.

RESULTS

Thirteen native bee species were collected on the three berry crops, with over 80% of the individuals collected being bumblebees (Bombini, Table 1). The most frequently collected species was *Bombus mixtus*, followed by *B. occidentalis* and *B. melanopygus*. Other Bombini included *B. flavifrons* (4 individuals), *B. californicus* (2), *B. appositus* (1), *B. pleuralis* (1), *Psithyrus suckleyi* (1), and *P. insularis* (3). Solitary bees collected included *Andrena* sp. (11), *Augochlora* sp. (3), *Chelostoma* sp. (1), and *Halictus* sp. (18). Few bumblebees were collected on raspberry, and the number of individuals of the three dominant bumblebee species collected on blueberry and cranberry partly depended on site. *B. mixtus*, *occidentalis*, and *melanopygus* were most abundant at sites B1 and C2, and relatively rare at sites B2 and C1. These results are difficult to interpret, since B1 and C1 were in the same locality, as were B2 and C2. Thus, the same *Bombus* species varied in abundance at crops on the same site.

The abundance patterns as measured by mean number of native bees collected per hour of collecting time are shown in Fig. 2. Collections spanned the entire flowering period for each crop, and showed different patterns of bee visitation. On blueberry, few native pollinators were present early in the season, but the peak flowering period late in May showed increased visitation, with a maximum mean of 25 bees collected/hr. Visits then declined until the end of flowering in mid-June. On cranberry, mean pollinator abundance was generally about 10 bees collected/hr, but rose to 20/hr during mid-July. Few bees were collected on raspberry, never more than a mean of three bees/hr.

Pollen analysis of corbicular pollen from cranberry visitors showed that honeybees and some bumblebees *(B. occidentalis)* contained cranberry pollen almost exclusively, with means of 499/500 (S.E. = 0.5) and 496/500 (S.E. = 3.4) pollen grains respectively ($p > 0.25$, ANOVA). However, *B. mixtus* was less restricted to cranberry, with a mean of 439/500 (S.E. = 22.4) grains of cranberry pollen. This was significantly different from both *B. occidentalis* and *A. mellifera* ($p < 0.005$, ANOVA). Similar results were found with the few bees collected from raspberry, but the sample sizes were too small for statistical analysis.

DISCUSSION

The results of this study have shown a low abundance of native pollinators and low diversity of species other than bumblebees on berry crops in the Fraser Valley of British Columbia. These findings suggest that native bees are not present in sufficient abundance to adequately pollinate B.C. berry crops.

The paucity of pollinators was most noticeable in raspberry fields, where no more than three individuals were collected in any hour of collecting. This was insufficient for adequate raspberry pollination, so that managed honeybees were essential for pollination in the fields examined. The principal reason for this low abundance of native bees was likely pesticide impact. The three raspberry

TABLE 1. Number of native bees collected on nine fields of blueberry, cranberry, and raspberry crops in the Fraser Valley, April - July, 1981.

Species	Blueberry				Cranberry				Raspberry				
	B1	B2	B3	Total	C1	C2	C3	Total	R1	R2	R3	Total	Σ
Bombus mixtus	131	16	43	190	6	70	69	145	1	4	3	8	343
B. occidentalis	64	5	17	86	10	56	38	104	2			2	192
B. melanopygus	32		7	39			3	3		2		2	44
Other Bombus and Psithyrus sp.	1	5	3	9		1	1	2	1			1	12
Solitary bees	8		9	17		1		1	10	5		15	42

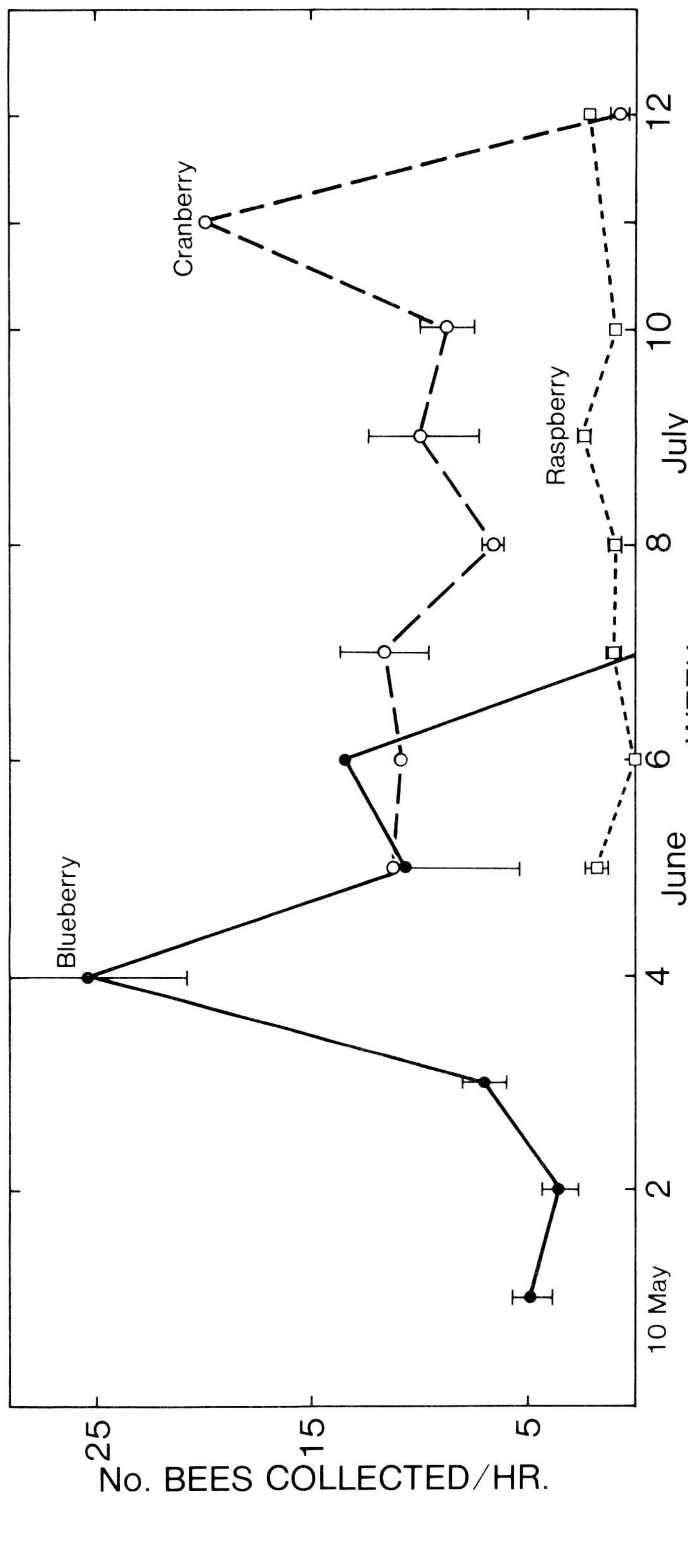

Fig. 2: Mean number of native bees collected/hr collecting time at all three sites in blueberry, raspberry, and cranberry. Collections generally were made once a week at each site, although occasionally two collections/week were made at some sites. Error bars are standard errors.

growers sprayed extensively before and during the blooming period with combinations of furadan, dinoseb, malathion, guthion, and captan, all known to adversely affect native bees (Johansen, 1980). All of the fields studied were in areas with other sprayed fields nearby, which would increase pesticide impact. Although other factors discussed below might also have influenced native bee abundance in commercial raspberry fields, pesticide impact seemed the most important.

Native bees were also not abundant in blueberry fields, particularly early in the flowering season. Even when abundance increased in late May, however, the number of bees present was probably not adequate for pollination. In Nova Scotia, 168 native bees/hr were considered to be sufficient pollinators in the absence of honeybees (Wood *et al.*, 1967), with approximately equal numbers of bumblebees and solitary bees present in that study. Kevan and LaBerge (1978) have suggested that 1200 native bees/hectare are needed for adequate blueberry pollination in New Brunswick, and densities of 700-2700 native bees/hectare are common in unsprayed fields. (Kevan, 1975; Kevan and LaBerge, 1978; Wood, 1979). In fact, until recent forest spray programs against spruce budworm adversely affected pollinators (Kevan, 1977; Kevan and LaBerge, 1978; Plowright *et al.*, 1978; Plowright and Thaler, 1978; Varty, 1977; Wood, 1979), no honeybees were needed for Eastern Canada blueberry management. In contrast, this study in British Columbia showed a maximum collection of only 25 bees/hr, or 260 bees/ha at any one time. These densities are considerably lower than the 168 bees/hr or 1200 bees/hectare considered adequate in Eastern Canada. Our results are similar to studies of blueberry pollination in New Jersey (Marucci, 1967; Marucci and Moulter, 1977) and Michigan (Dorr and Martin, 1966; Martin, 1966) in which native bees were not considered to be present in sufficient numbers to pollinate commercial blueberry crops.

Another difficulty with bumblebee pollination of blueberries is that at least one species *(B. occidentalis)* robs nectar by chewing holes in blossoms at the base of the corolla. This behaviour, described by Eaton and Stewart (1969), results in both bumblebees and honeybees collecting nectar through the hole without transferring pollen. Such behavior was common in the Pitt Meadows area in late May and early June, and likely reduces yields, although the extent of this problem has not been determined.

It is more difficult to interpret the cranberry data, since an adequate level of native bee pollinators has not been well-defined, as for blueberry, nor was bee abundance so low that poor pollination could be assumed, as for raspberry. However, the recommended density of *Apis* colonies for effective cranberry pollination is the same as for the other berry crops, 1-2/acre (Berry Production Guide, 1980; McGregor, 1976), and 1200 bumblebees/ha may be sufficient for pollination (McGregor, 1976), as for blueberry (Kevan and LaBerge, 1978). Since the rate of native bee visitation we found in cranberry was similar to that in blueberry, native bees may not be sufficient to effect seed set in cranberry. Also, honeybees might be more likely than some bumblebees to confine floral visits to the crop. Anderson and Eaton (1981) considered honeybees to be the most useful cranberry pollinators.

However, patterns of floral visits by *Bombus* and *Apis* on cranberry are different, and bumblebees may in fact be the better cranberry pollinators. For instance, only 16% of honeybees collected pollen from New Jersey cranberry fields, while 48% of bumblebees were pollen collectors. Also, bumblebees were less able to discriminate sugar content at a distance than honeybees, suggesting more floral visits for bumblebees (Roberts, 1978). Bumblebees are also thought to be superior to some solitary bees as cranberry pollinators due to their more rapid interfloral movement (Reader, 1978). McGregor (1976) also considered bumblebees superior pollinators for cranberry. Thus, without additional data it is difficult to evaluate the effectiveness of native bees in Fraser Valley cranberry pollination.

Bumblebee species diversity was similar to that found in other studies from Eastern Canada, but the diversity of other bees was exceptionally low. Most of the *Bombus* species occurring in the Fraser Valley were represented in our collections. We found seven species of *Bombus* on the three berry crops, out of 10 *Bombus* species that have been reported from this region (Stephen, 1957). For comparison, nine species of bumblebees were reported as blueberry pollinators in Nova Scotia (Finnamore and neary, 1978) and 10 species in the Eastern United States (Mitchell, 1960; 1962). However, these studies listed 44 and 52 species other than Bombini respectively as blueberry pollinators, whereas in British Columbia only four species were found in our collections from all three berry crops. Also, only 33 of the 624 bees collected were not Bombini. It is not clear whether these results suggest a generally depauperate Apoidea fauna in the Lower Mainland or only limited utilization of commercial berry crops by non-bumblebee species.

A number of factors could be responsible for the low native bee diversity and abundance in the Fraser Valley, including pesticide impact, habitat destruction, competition with managed honeybees, and the extended rainy period in the Spring of 1981. Pesticide impact was greatest on raspberry, as previously noted, but spraying in adjacent agricultural areas may also have adversely affected native bees on the other crops as well. For example, the ill effect on native bees in blueberry fields close to forest areas sprayed with fenitrothion in Nova Scotia, New Brunswick (Kevan, 1975, 1977; Kevan and LaBerge, 1978, Wood, 1978) and Maine (Miliczky and Osgood, 1979) has been well-documented. Destruction of nesting sites may also have affected bee densities, particularly in the blueberry and cranberry fields, since some of the surrounding area has become residential. Competition with honeybees could also have affected native bees; most Lower Mainland growers rent honeybees during the flowering season for pollination (Berry Production Guide, 1980), and there is also a considerable amount of hobby beekeeping throughout the Lower Mainland. Finally, the record-setting rains of 1981 may have suppressed native bee populations by washing out nesting sites and limiting foraging time, as is often the case for yellow jackets (Akre and Reed 1981).

At this point we cannot determine the relative importance of these and possibly other factors in limiting native bee abundance. Additional data are needed, including population surveys on both berry crops and non-cultivated plants over a number of years, experimental studies of pesticide impact and honeybee competition on native populations, and better understanding of the role of climatic conditions in determining bee densities. We hope to address these questions in future studies.

ACKNOWLEDGEMENT

We are grateful to A. March, D. March, P. Freeman, B. Goetzke, J. Driediger, and the Abbotsford Agriculture Canada Research Station for permission to collect on their properties. Dr. R. Mathewes and J. White assisted in the pollen analysis, E. Senger collected some of the bees, D. Gillespie arranged for collecting sites, and J. Ramsay kindly reviewed the manuscript. We are also grateful to K. Richards for identifying the bumble bees. This research was supported by a Youth Employment Program grant from the government of British Columbia and grant no. A7774 from the Natural Sciences and Engineering Research Council of Canada.

REFERENCES CITED

Akre, R. and H. C. Reed, 1981. Population cycles of yellowjackets (Hymenoptera: Vespinae) in the Pacific Northwest. Envir. Entomol. 10: 267-274.

Anderson, D. W. and G. W. Eaton. 1981. Cranberry pollination in British Columbia. Cranberries 45:6, 12.

Berry Production Guide, 1980. Ministry of Agriculture, Province of British Columbia, Victoria, B.C.

Daubeny, H. 1971. Self-fertility in red raspberry cultivars and selections. J. Am. Soc. Hort. Sci. 588:591.

Dorr, J. and E. C. Martin. 1966. Pollination studies on the highbush blueberry **Vaccinium corymbosum** L. Q. Bull. Mich. State Univ. Agric. Expt. Sta. 48:437-448.

Eaton, G. W. and M. G. Stewart. 1969. Blueberry blossom damage caused by bumblebees. Canadian Entomologist 101:149-150.

Finnamore, A. T. and M. E. Neary, 1978. Blueberry pollinators of Nova Scotia, with a checklist of the blueberry pollinators in Eastern Canada and Northeastern United States. Ann. Soc. Entomol. Quebec 23:168-181.

Free, J. B. 1970. Insect Pollination of Crops. Academic Press. New York.

Johansen, C. 1980. How to reduce bee poisoning from pesticides. Western Regional Extension Publication 15:1-8.

Johansen, C. and C. Shawa. 1974. Honey bees increase cranberry production. Cooperative Extension Service No. 3468, Washington State University.

Kevan, P. G. 1975. Forest application of the insecticide fenitrothion and its effect on wild bee pollinators (Hymenoptera: Apoidea) of low bush blueberry (**Vaccinium** sp.) in Southern New Brunswick, Canada. Biol. Conserv. 7: 301-309.

Kevan, P. G. 1977. Blueberry crops in Nova Scotia and New Brunswick — pesticides and crop reductions. Can. J. Agric. Econ. 25:61-65.

Kevan, P. G. and W. E. LaBerge. 1978. Demise and recovery of native pollinator populations through pesticide use and some economic implications. Proc. IV Int. Symp. Pollination. Md. Agric. Exp. Sta. Spec. Misc. Publ. 1:489-508.

Martin, E. C. 1966. Honey bee pollination of the highbush blueberry. American Bee J. 106:366-367.

Marucci, P. E. 1966. Blueberry pollination. American Bee J. 106:250-252, 264.

Marucci, P. 1967. Pollination of the cultivated highbush blueberry in New Jersey. Inter. Soc. Hort. Science Sump. Venlo, Netherlands. pp. 155-162.

Marucci, P. E. and H. J. Moulter. 1977. Blueberry pollination in New Jersey. Acta Horticulturae 61:175-186.

McCutcheon, D. 1976. Raspberry pollination trials. Proc. Lower Mainland Hort. Improvement Assoc., 18:31-32.

McGregor, S. E. 1976. Insect pollination of cultivated crop plants. U.S.D.A. Agriculture Handbook No. 496. Washington, D.C.

Miliczky, E. R. and E. A. Osgood. 1979. The effects of spraying with sevin-4-oil® on insect pollinators and pollination in a spruce-fir forest. Life Sci. and Ag. Expt. Sta. Tech. Bull. 90:5-21.

Mitchell, T. B. 1960, 1962. Bees of the Eastern United States. I and II. N. Carolina Agr. Exp. Sta. Tech. Bull. 141, 152.

Moeller, F. E. 1978. How long must honeybees be present to effectively set a crop of cranberries? Proc. IV Int. Symp. Pollination. Md. Agric. Exp. Sta. Spec. Misc. Publ. 1:171-173.

Murrell, D. C. and D. M. McCutcheon. 1977. Red raspberry pollination in British Columbia. American Bee J. 117:750.

Plowright, R. C., B. A. Pendrel, and I. A. McLaren, 1978. The impact of aerial fenitrothion spraying upon the population bilogy of bumble bees (**Bombus** Latr:Hym.) in South-western New Brunswick. Can.Ent. 110:1145-1156.

Reader, R. J. 1977. Bog ericad flowers: self-compatibility and relative attractiveness to bees. Can. J. Botany 55:2279-2287.

Roberts, R. B. 1978. Energetics of cranberry pollination. Proc. IV Int. Symp. Pollination. Md. Agric. Exp. Sta. Spec. Misc. Publ. 1:431-440.

Stephen, W. P. 1957. Bumble Bees of Western North America (Hymenoptera: Apoidea). Oregon State College Agr. Expt. Sta. Tech. Bull. No. 40, Corvallis.

Varty, I. W. 1977. Environmental surveillance of insecticide spray operations in New Brunswick's budworm-infested forest. Maritimes Forest Research Centre Report M-X-87, Fredericton, N.B.

Whatley, B. T. and J. J. Lackett. 1978. Effects of honey bee pollination on fruit set, yield, and quality of rabbiteye blueberries **Vaccinium ashei** Reade. Proc. IV Int. Symp. Pollination. Md. Agric. Exp. Sta. Sec. Misc. Publ. 1:143-148.

Wood, G. W. 1979. Recuperation of native bee populations in blueberry fields exposed to drift of fenitrothion from forest spray operations in New Brunswick. J. Econ. Ent. 72:36-39.

Wood, G. W., D. L. Craig, and I. V. Hall. 1967. Highbush blueberry pollination in Nova Scotia. Int. Soc. Hort. Sci. Symp. Venlo Netherlands. pp. 163-168.

EVALUATION OF DIFLUBENZURON FOR CONTROL OF LEAFROLLERS (LEPIDOPTERA: TORTRICIDAE) ON APPLE

D. W. ANDERSON AND R. H. ELLIOTT

Department of Plant Science,
University of British Columbia,
Vancouver, B.C. V6T 2A2

ABSTRACT

The toxicity of diflubenzuron (Dimilin) to various stages of the obliquebanded leafroller, *Choristoneura rosaceana* (Harris), was evaluated under laboratory conditions. The compound had no ovicidal effect at concentrations up to 1000 ppm but foliage treated with 100 ppm diflubenzuron plus the surfactant, Tween 20, was toxic to 1st-instar larvae. At similar concentrations, diflubenzuron reduced the longevity of adult moths but had no effect on fecundity or egg viability.

In an orchard of mixed apple cultivars, diflubenzuron cover sprays applied at the pink bud stage significantly reduced fruit damage by leafrollers but failed to provide control comparable to that with azinphos-methyl.

INTRODUCTION

Recent field studies have suggested that the insect growth inhibitor, diflubenzuron (Dimilin), has considerable potential in pest management programs in pome fruits (Wearing and Thomas 1978; Westigard 1979). Against the codling moth, *Laspeyresia pomonella* L., the compound had excellent contact and residual activity to eggs but limited toxicity to larvae and adults (Elliott and Anderson 1982). Despite this, diflubenzuron sprays applied to coincide with peak codling moth activity provided control similar to that of azinphos-methyl in an Okanagan orchard (Anderson and Elliott 1982). In addition, diflubenzuron appeared compatible with integrated mite control in that sprays were non-toxic to predaceous mites and did not increase populations of European red mite, *Panonychus ulmi* (Koch) or rust mites *(Aculus* spp.).

Depending upon the species, leafrollers can cause early and late season injury to apples. In the northern fruit growing region of British Columbia, two univoltine species, *Archips argyrospilus* (Walker) and *Archips rosanus* (L.), predominate and cause early season damage whereas in the