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Forest Pest Management Institute
Institut pour la répression des ravageurs forestiers
Forêts Canada

FPM-X-86

1991

Catalogue Number Fo46-16/86
ISBN 0-662-58317–5
ISSN 07004-772X

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ISBN 0-662-58317–5
ISSN 07004-772X

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Antonovsky, M.Ya.; Fleming, R.A.; Kuznetsov, Yu. A.; Clark, W.C. 1990. Forest–Pest interaction dynamics: the simplest mathematical models. Theoretical Population Biology 37: 343–367.

This paper is devoted to the investigation of the simplest mathematical models of non–even–aged forests affected by insect pests. Two extremely simple situations are considered: (1) the pest feeds on on young trees; (2) the pest feeds only on old trees. The parameter values of the second model are estimated for the case of balsam fir forests and the eastern spruce budworm. It is shown that an invasion of a small number of pests into a steady–state forest ecosystem could result in intensive oscillations of its age structure. Possible implications of environmental changes in forest ecosystems are also considered.

Arif, B.M. 1986. Dialysis of small volumes. Biotechniques 4(6):499.

Arif, B.M. 1986. The structure of the viral genome. Current topics in microbiology and immunology, vol . 131. Springer–Verlag, Berlin, pp. 21–29.

Arif, B.M.; Tjia, S.T.; Doerfler, W. 1985. DNA homologies between genomes of *Choristoneura fumiferana* and *Autographa californica* nuclear polyhedrosis viruses. Virus Research 2:85–94.

The DNA sequence homology between the genomes of *Choristoneura fumiferana* and *Autographa californica* multicapsid nuclear polyhedrosis viruses (CfMNPV and AcMNPV) were compared by hybridization of nick–translated [^{32}P]CfMNPV DNA to restricted AcMNPV genome. In the presence of 5 x SSC and 50% formamide the CfMNPV DNA exhibited extensive homology to the AcMNPV genome. When the stringency conditions of hybridization were lowered, we observed hybridization to almost all the EcoRI fragments of AcMNPV. We then utilized the cloned EcoRI fragments from both genomes to obtain more detailed information, and to localize the hybridizing fragments on the EcoRI physical map of AcMNPV. It was clear that some CfMNPV clones hybridized to more than one fragment of the AcMNPV genome indicating that there has been some DNA sequence rearrangement in the AcMNPV genome.

Arif, B.M.; Guangyu, Z.; Jamieson, P. 1986. A comparison of three granulosis viruses isolated from *Choristoneura* spp. J. Invert. Pathol. 48:180–186.

Three granulosis viruses from the genus *Choristoneura* were characterized by restriction endonucleases, thermal denaturation of their DNAs, polyacrylamide gel electophoresis of the viral proteins, and peptide mapping of the granulins. It was shown that although these viruses are very closely related genetically, they have minor but distinct differences in their restriction patterns. Differences were also observed in their polypeptides when examined on polyacrylamide gels. The sizes of the genomes were in the order of 107, 000 base pairs. The size of the granulins was identical.

Arsenault, B. comp. 1985. Bibliographie de l'institut pour la répression des ravageurs forestiers (1977–1985). Serv. Can. For., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–60F, 30pp.

Beveridge, W.J.G.; Payne, N.J. 1987. A lightweight mast for use in meteorological or spray drift studies. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont. Technical Note 5, 6 pp.

Beveridge, W.J.G.; Payne, N.J. 1987. Mât léger pour études météorologiques ou de dérive de pulvérisations. Serv. Can. For., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont. Note Technique 5, 6pp.

Busby, D.G.; Holmes, S.B.; Pearce, P.A.; Fleming, R.A. 1987. The effects of Zectran on brain cholinesterase in forest songbirds. Arch. Environ. Contam. Toxicol. 16: 623–629.

Cadogan, B.L. 1986. Control of spruce budworm (Lepidoptera:Tortricidae) in eastern Canada with the experimental mexacarbate formulation Zectran UCZF19. J. Econ. Entomol. 79:726–730.

The experimental mexacarbate formulation Zectran UCZF19 was effective in controlling spruce budworm, *Choristoneura fumiferana*, in a trial conducted during 1984 in eastern Canada. The formulation was mixed in both water and an oil–based diluent and applied as double applications at 70 g (ai) in 1.5 L tank mix/ha with an aircraft (Cessna Ag–truck) equipped with four atomizers (Micronair AU3000). The aqueous mix produced significantly greater percentages of <50 µm–diameter droplets than the oil–based sprays. High spruce budworm population reductions (85 and 84% corrected mortality) and low defoliation of balsam fir, *Abies balsamea* (L.) Mill., in blocks treated with oil–based and aqueous sprays (8.6 and 17.3% respectively) were significantly different from those in untreated blocks.

Cadogan, B.L. 1986. Relative field efficacies of Sumithion 20% flowable and Sumithion technical formulations against spruce budworm, *Choristoneura fumiferana* (Lepidoptera:Tortricidae). Can. Ent. 118:1143–1149.

Two Sumithion ® formulations were sprayed aerially to compare their effectiveness in controlling spruce budworm, *Choristoneura fumiferana* (Clemens) in balsam fir, *Abies balsamea* (L.) Mill. Sumithion 20% flowable, a new formulation, and Sumithion technical were applied twice at 210 g AI (in 1.5 L of spray mix)/ha using a Cessna 188 Agtruck equipped with four Micronair atomizers. More than 95% of the technical and <45% of the Sumithion flowable spray droplets were <50 µ 25m in diameter. Larval reduction ranged from 67 to 84% in the Sumithion flowable plots, from 52 to 55% in the Sumithion technical plots, and from 28 to 38% in the untreated plots. Postspray residual populations averaged 4.1, 6.2 and 10.3 larvae per 46–cm branch in the flowable, technical and untreated blocks, respectively. Defoliation in the Sumithion flowable block averaged 18.5% and was not significantly different from the technical block but both were significantly less (a = 0.05) than that in the untreated block, which averaged 46.2%. The results suggest that Sumithion 20% flowable was more efficacious in controlling spruce budworm than Sumithion technical insecticide.

Deux préparations de Sumithion ® ont été pulvérisées par air afin de comparer leur efficacité de répression de la tordeuse des bourgeons de l'épinette, *Choristoneura fumiferana* (Clemens) sur la sapin baumier, *Abies balsamea* (L.) Mill. Le "Sumithion 20% flowable", une nouvelle préparation, et le "Sumithion technical" ont été appliqués deux fois à raison de 210 g IA (dans 1.5 L de mélange)/ha avec un Cessna 188 Agtruck équipé de quatre buses Micronair. Plus de 95% des gouttelettes du "Sumithion technical" et <45% de celles du "Sumithion 20% flowable" avaient un diamètre <50 µm. Le réduction des larves a varié de 67 à 84% dans les parcelles traitées au "Sumithion 20% flowable", de 52 à 55% dans celles traitées au "Sumithion technical", et de 28 à 38% dans les parcelles témoins. Les populations larvaires post–traitement dans les mêmes parcelles étaient de 4,1, 6,2 et 10,3 larves/branche de 46 cm, respectivement. La défoliation moyenne dans le bloc "Sumithion 20% flowable" atteignait 18,5%, ne différant pas significativement (a = 0.05) de celle du bloc témoin qui était de 46,2%. Ces résultats indiquent que le "Sumithion 20% flowable" est plus efficace pour la répression de la tordeuse que la préparation "Sumithion technical".

Cadogan, B.L. 1987. Experimental aerial application of Matacil flowable insecticide to control spruce budworm (Lepidoptera:Tortricidae). Crop Protection 6:130–135.

Matacil ® (Aminocarb) 180F flowable insecticide mixed in both water and insecticide diluent ID585 and Matacil 1.8D oil–soluble concentrate (OSC) mixed in ID585 were sprayed aerially at 70 g

A.I./1.5L of spray mix/ha in two applications to control spruce budworm, *Choristoneura fumiferana* (Clem.). The spray droplet density on Kromekote cards, the spray volume recovered on glass slides, larval population reductions and host tree defoliation were compared. The data indicate that Matacil 180F was as effective in controlling budworm populations and protecting the foliage of host trees as Matacil 1.8D and that the aqueous mix was as efficacious as the ID585 mix.

Cadogan, B.L.; Zylstra, B.F.; Nystrom, C.; Ebling, P.; Pollock, L.B. 1986. Evaluation of a new Futura formulation of *Bacillus thuringiensis* on populations of jack pine budworm, *Choristoneura pinus pinus* (Lepidoptera:Tortricidae). Proc. Ent. Soc. Ont. 117:59–64.

Futura ®, a new concentrated formulation of *Bacillus thuringiensis* Berliner var. *kurstaki* was field tested in 1985 to determine its effectiveness against the jack pine budworm, *Choristoneura pinus pinus*. Two concentrations, 20×10^9 and 30×10^9 international units per hectare (20 and 30 BIU/ha), were applied undiluted with a Cessna AG–truck aircraft fitted with rotary atomizers. The 30 BIU/ha dosage satisfactorily suppressed *C. pinus pinus* populations (71% corrected larval mortality) and prevented serious defoliation of the host trees (64% foliage protection). The 20 BIU/ha treatment was only marginally effective in controlling jack pine budworm (44% corrected mortality) and was ineffective in preventing extensive defoliation (28% foliage protection).

Cadogan, B.L.; Zylstra, B.F.; Nystrom, C.; Pollock, L.B.; Ebling, P.M. 1986. Spray deposits and drop size spectra from a high wing monoplane fitted with rotary atomizers. Trans. ASAE 29(2):402–406.

Single–swath trials were conducted to determine the spray deposit patterns of a Cessna 188–B aircraft equipped with four Micronair rotary atomizers. Oil and water simulated field formulations were applied at three emission rates and three atomizer rotational velocities. The resulting deposits, measured at ground level on Kromekote cards, are presented and discussed. Results show that by manipulating the Micronair delivery system, both aqueous and oil formulations can produce desirable spray spectra, that would be effective against target pests.

Campbell, R.A. 1990. Herbicide use for forest management in Canada: where we are and where we are going. The Forestry Chronicle 66: 355–360.

In 1988, 217, 825 ha were treated with herbicide for forest management purposes in Canada. Ontario treated the largest absolute number of hectares but New Brunswick had the highest intensity of treatment in terms of percentage of productive forest, cutover or planted area treated. Seventy–six percent of the herbicide was applied aerially. Eighty–five percent was for release. Forest managers across Canada have identified a number of gaps in herbicide technology including the need for: alternatives to herbicides, demonstration areas for the public, assessment methodology, long–term cost/benefit analysis, more information on effects on wildlife habitat, and aerial navigation aids.

En 1988, on a traité 217 825 ha au Canada avec des herbicides pour les fins de l'aménagement forestier. L'Ontario a traité le plus grand nombre d'hectares en termes absolus, mais le Nouveau–Brunswick a eu l'intensité de traitment la plus grande en termes du poucentage de forêt productive, de coupe à blanc, ou de superficie de plantations. On a traité 76% de la totale avec des herbicides appliqués par avion. On a traité 85% pour les fins de dégagement. Des gestionnaires forestiers à travers le Canada ont identifié quelques vides dans la technologie pour les herbicides, y compris la manque d'alternatives aux herbicides, de terrains de démonstration pour le public, de méthodologies pour l'évaluation, d'analyses coûts–avantages en longue terme, de plus d'informations sur les effets sur l'habitat de la faune sauvage, et d'aides à la navigation aérienne.

Cunningham, J.C. 1988. Baculoviruses: their status compared to *Bacillus thuringiensis* as microbial insecticides. Outlook on Agriculture 17:10–17.

With the present need to address environmental problems, there is much interest in biological control of insect pests rather than the use of chemical insecticides. This article critically reviews the use of baculoviruses worldwide in agriculture and forestry, directing attention not only to intrinsic activity but to other relevant factors such as shelf–life in storage, fluctuation in demand, and cost of production and applications. It draws particular attention to the relevance of baculoviruses to pest control in developing countries where labor is cheap.

Cunningham, J.C.; de Groot, P.; Kaupp, W.J. 1986. A review of aerial spray trials with Lecontvirus for control of redheaded pine sawfly, *Neodiprion lecontei* (Hymenoptera:Diprionidae), in Ontario. Proc. Ent. Soc. Ont. 117:65–72.

Redheaded pine sawfly nuclear polyhedrosis virus (Lecontvirus) was found to be a highly effective pathogen against redheaded pine sawfly, *Neodiprion lecontei* (Fitch), when applied as an aerial spray. This method of treatment is recommended. Between 1976 and 1980, 14 plantations with a total area of 175.5 ha were sprayed experimentally in Ontario and such factors as dosage, emitted volume, application equipment and tank mix adjuvants were evaluated. A preparation of lyophilized, virus–infected larvae ground to a fine powder and suspended in water was used. That preparation was applied on 1st–, 2nd–, or 3rd–instar redheaded pine sawfly larvae in the field. A dosage of 5×10^9 polyhedral inclusion bodies per ha in emitted volumes ranging from 2.4 to 9.4 L/ha gave excellent control. The best assessment method was found to be examination of 100 trees, each with one sawfly colony from which the following were recorded: the length of time from spray application until first virus–induced mortality; and the length of time until the entire colony was dead. None of the plantations required re–treatment following application of the virus.

Cunningham, J.C.; McPhee, J. 1986. Production of sawfly viruses in plantations. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Tech. Note 4, 4 pp, illus.

de Groot, P. 1985. Chemical control of insect pests of white pine. Proc. Ent. Soc. Ont. 116:67–71.

Chemical control of insect pests is occasionally required to protect the merchantability of eastern white pine (*Pinus strobus* L.). A review of current methods of chemical control for the insect pests of major economic importance is presented, with a brief discussion of future prospects in chemical control.

de Groot, P. 1986. Cone and twig beetles (Coleoptera:Scolytidae) of the genus *Conophthorus*: an annotated bibliography. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Inf. Rep. FPM–X–76, 36 pp.

de Groot, P. 1986. Diptera associated with cones and seeds of North American conifers: an annotated bibliography. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Inf. Rep. FPM–X–69, 38 pp.

de Groot, P. 1986. Diptères des cônes et des graines des conifères d'Amerique du Nord: une bibliographie annotée. Serv. Can. For., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–69F, 34 pp (provides french annotation of pubs listed in FPM–X–69).

de Groot, P. 1986. Mortality factors of jack pine, *Pinus banksiana* Lamb., strobili. Proceedings, 2nd IUFRO Conference on the Cone and Seed Insects Working Party S2 07.01, Sept. 3–5, 1986. Briancon, France. pp. 39–52.

Mortality factors of jack pine ovulate strobili from three plantations in north central Ontario were studied using a cohort life table approach. Preliminary analyses of the data indicate that insects con-

tribute about a 1% loss of flowers and conelets and 4.9% loss of cones. The most frequent mortality factor of flowers and conelets was abortion (12% of the crop) and of cones was the red squirrel (21%).

de Groot, P. 1986. Scolytes des cônes et des rameaux (Coléoptères: Scolytidae) du genre *Conophthous*: une bibliographie annotée. Serv. Can. For., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–76F, 28 pp (provides french annotation of pubs listed in FPM–X–76).

de Groot, P. 1990. The taxonomy, life history and control of *Conophthorus* (Coleoptera: Scolytidae) in eastern North America. pp. 37–46 In: R.J. West, ed. Proceedings, Cone and Seed Pest Workshop. 4 October 1989. Forestry Canada. Newfoundland and Labrador Region, St. John's, Nfld. Information Report N–X–274, 128 p.

The cone beetles in the genus *Conophthorus* Hopkins (Coleoptera: Scolytidae) are serious pests of many species of pines in North America. In eastern North America, three species are recognized, *C. resinosae* Hopkins, *C. banksianae* McPherson, and *C. coniperda* (Schwarz). The beetles are very difficult to identify on the basis of morphological characters, and more taxonomic study is needed to verify the number of species in the genus. The females initiate attack on the cones, which are completely killed. Larvae feed on seeds and on cone tissue. These beetles are univoltine. Control of the beetles can be achieved by removal of the infested cones on the ground in the fall or in the spring before emergence, or by systemic and contact insecticides. The known parasites and predators of the species are listed, and the various control strategies are discussed.

Feng, J.C.; Klassen, H.D. 1986. Forestry field and laboratory manual for herbicide residue sampling, sample processing and reporting. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Inf. Rep. FPM–X–72, 38 pp.

Feng, J.; Klassen, H.D. 1987. Manuel des pratiques de foresterie sur le terrain et en laboratoire pour le prélèvement, le traitement et l'enregistrement d'échantillons de résidus d'herbicide. Serv. Can. For., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–72F.

Feng, J.; Feng, C. 1988. Détermination et devenir des résidus d'hexazinone dans une forêt du Nouveau–Brunswick. Serv. Can. For., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–81F, 22 pp.

Un terrain de coupe rase près de Saint–Léonard (Nouveau–Brunswick) a été traité à l'hexazinone [cyclohexyl–3 (diméthylamino)–6 méthyl–1 triazine 1,3,5 (1H, 3H)–dione–2,4], à des taux nominaux, soit de 3,1 et de 3,8 kg/ha d'ingrédients actifs, à l'aide d'un aéronef à voilure fixe équipé d'une rampe de pulvérisation ordinaire. Le dépôt sur les lots–cibles était fortement variable, étant en moyenne de 2,53 kg/ha avec un C.V. de 37%. Les dépôts à l'extérieur de la zone–cible, évalués à l'aide de plaques á dépôts de 400 cm^2, ont diminué rapidement à 0,006 kg/ha à 70 et 100 m en aval par rapport au vent. Lors d'essais de sol enrichi, le taux de récupération variait selon la concentration et les résidus, les moyennes étaient comprises entre 91,5 et 98,3%, 62,9 et 88,6% ainsi que 101,4 et 104,2% pour l'hexazinone et son métabolite A soit la [–hydroxy–4 cyclohexyl–3 (diméthylamino)–6 méthyl–1 triazine–1,3,5 (1H, 3H)–dione–2,4], et son métabolite B, soit la [cyclohexyl–3 (méthylamino)–6 méthyl–1 triazine–1,3,5 (1H,3H)–dione–2,4], respectivement. Le taux de récupération d'hexazinone dans des échantillons frais et séchés à l'air d'humus enrichi était de 114 et de 110%, respectivement. À partir de 50 échantillons homogénéisés séchés à l'air, on a calculé un C.V. constant de 6,9% pour la préparation de sous–échantillons, l'extraction et l'analyse de l'hexazinone. La lixiviation de l'hexazinone vers les couches inférieures du sol dépendait de la pluie et atteignait 0,6 kg/ha (0.6 µg/g) après 6 jours, quand la valeur cumulative des précipitations de pluie atteignait 29 mm. Les résidus de sol surveillés à diverses distances au–delà de la cible ont été correlés avec les taux de dépôt à l'extérieur de la

cible, mesurés selon des analyses des résidus de dépôts. On a décelé la présence de résidus d'hexazinone dans les cours d'eau pendant toute la période de 45 jours au cours de laquelle on a surveillé les eaux de ruissellement de 6 orages. Les résidus diminuaient en fonction du temps après l'application et de la distance en aval. La concentration de pointe initial à 50 m en aval était de 30,8 ppb au cours du premier orage, 6 jours après l'application, et a diminué rapidement à 3,7 ppb après 45 jours; la concentration à 800 m en aval était de 5,1 ppb au cours de deuxième orage, 13 jours après l'application, et a diminué à moins de 1 ppb entre 20 et 45 jours après l'application.

Feng, J.; Feng, C. 1988. Determination of hexazinone residues and their fate in a New Brunswick forest. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Inf. Rep. FPM–X–81, 15 pp + appendices.

A clearcut site near St. Leonard, New Brunswick was treated with hexazinone, 3–cyclohexyl–6–(dimethylamino)–1–methyl–1,3,5–triazine–2,4(1H,3H)–dione) at nominal rates, 3.1 and 3.8 kg ai/ha by a fixed wing aircraft equipped with a conventional boom and nozzles. On–target deposit at soil plots was highly variable, averaging 2.53 kg/ha with 37% CV. Off–target deposit monitored with 400 cm^2 deposit plates decreased rapidly to 0.006 kg/ha at 70 and 100 m downwind. In spiked soil trials, recovery varied with concentration and residue, with means ranging from 91.5 – 98.3%, 62.9 – 88.6% and 101.4 – 104.2% for hexazinone and its metabolites A, 3– (4–hydroxycyclohexyl)–6– (dimethylamino)–1– methyl–1,3,5– triazine–2,4 (1H,3H)–dione and B, 3– cyclohexyl–6– (methylamino)–1– methyl– 1,3,5– triazine–2,4 (1H,3H)–dione, respectively. Hexazinone recovery in fresh and air–dried samples of spiked humus soils was 114 and 110%, respectively. A consistency of 6.9% CV for hexazinone subsampling, extraction and analysis was determined from 50 homogenized air–dried soils. Hexazinone leaching to the lower soil layer was dependent on rainfall, and peaked at 0.6 kg/ha (0.46 µg/g) after 6 days when cumulative rainfall reached 29 mm. Soil residues monitored at various distances off–target were correlated to off–target deposit rates as determined by analyses of deposit collector residues. Hexazinone residues were detected in streamwater throughout the 45–day period when runoff in 6 storm events was monitored. Residues decreased both with time after application and with distance downstream. The initial peak concentration at 50 m downstream was 30.8 ppb during the first storm event 6 days after application, and decreased rapidly to 3.7 ppb after 45 days; concentration at 800 m downstream was 5.1 ppb during the second storm event 13 days after application and decreased to less than 1 ppb between 20 and 45 days after application.

Feng, J.C.; Thompson, D.G. 1990. Fate of glyphosate in a Canadian forest watershed. 2. Persistence in foliage and soils. J. Agric. Food Chem. 38: 1118–1125.

Residues of glyphosate [N–(phosphonomethyl) glycine] and the metabolite (aminomethyl) phosphonicacid (AMPA) were monitored in foliage, leaf litter, and soils following aerial application of Roundup herbicide (nominal rate 2.0 kg/ha AI) to the Carnation Creek watershed of Vancouver Island, British Columbia. Glyphosate deposit was variable, ranging from 1.85 to 2.52 kg/ha AI, depending upon location within the watershed. Foliar residues in red alder and salmonberry were 261.0 and 447.6 µg/g, respectively, indicating good impingement on the target foliage. Leaf litter residues, which averaged 12.5 µg/g for red alder and 19.2 µg/g for salmonberry initially, declined to less than 1 µg/g within 45 days post–application (DT_{50} < 14 days). In soils, glyphosate and AMPA residues were retained primarily in the upper organic layers of the profile, with >90% of the total glyphosate residue in the 0–15–cm layer. Distribution data for both glyphosate and AMPA suggested strong adsorption and a low propensity for leaching. Glyphosate soil residues dissipated as a function of time with an estimated DT_{50} of 45–60 days. After 360 days, total soil residues of glyphosate were 6–18% of initial levels.

Feng, J.C.; Thompson, D.G.; Reynolds, P.E. 1989. Fate of glyphosate in a forest stream ecosystem. pp 45–64 In: P.E. Reynolds, ed. Proceedings of the Carnation Creek Her-

bicide Workshop. Forestry Canada/ British Columbia Ministry of Forests, Victoria, B. C. FRDA Report 063, 349 p.

Residues of glyphosate and its major metabolite aminomethyl phosphonic acid (AMPA) were monitored in stream water, bottom sediments and suspended sediments for a one year period following aerial application of glyphosate (2.0 kg/ha) to the Carnation Creek watershed of Vancouver Island, British Columbia. Analysis of deposit collector samples indicated an actual deposit of 1.88 kg/ha within the target zone and that less than 0.1% of the full rate impinged on surfaces beyond 8 m from the spray zone boundary. The highest concentrations of glyphosate (6.80 µg/g dry mass) were observed in bottom sediments of a directly sprayed tributary, with low residue levels (<0.2 µg/g) persisting in this substrate throughout the monitoring period. Suspended sediment samples collected from the main stream channel, indicated low levels of glyphosate input (0.10 µg/L) in conjunction with the first five storm events (23–66 days post application). The highest stream water residue observed (162 µg/L) occurred in a directly sprayed tributary 2 h post–application and decreased rapidly to 37 µg/L after 16 h. Transient increases in glyphosate concentrations were associated with first rainfall event (39 mm) which occurred 23 h post–application. Subsequent dissipation of residues in the two tributaries receiving direct glyphosate applications was rapid, such that no quantifiable residues were found after 96 h post–application. No quantifiable residues were found in tributaries buffered with a 10–m vegetation strip during the monitoring period.

Feng, J.C.; Thompson, D.G. ; Reynolds, P.E. 1990. Fate of glyphosate in a Canadian forest watershed. 1. Aquatic and off–target deposit assessment. J. Agric. Food Chem. 38:1110–1118.

Glyphosate and AMPA residues in oversprayed and buffered streams were monitored following application of Roundup (2.0 kg/ha) to 45 ha of a coastal British Columbia watershed. Maximum glyphosate residues (stream water, 162 µg/L; sediments, 6.80 µg/g dry mass; suspended sediments, <0.03 µg/L) were observed in two intentionally oversprayed tributaries, dissipating to <1 µg/L within 96h postapplication. Buffered streams were characterized by very low glyphosate residue levels (2.4–3.2 µg/L in streamwater). Results of the off–target deposit assessment indicated <0.1% of applied glyphosate at 8 m from the spray boundary. Increases in residue levels were observed in relation to the first storm event post–application. Rates of maximum stream water concentrations of glyphosate observed in buffered and oversprayed tributaries relative to literature toxicity values indicated a substantial margin of safety under either operational or worst case scenarios.

Fleming, R.A. 1988. Difficulties in implementing an integrated pest management program for alfalfa in New York state. Mem. Entomol. Soc. Can. 143:47–59.

Fleming, R.; Retnakaran, A. 1985. Evaluating single treatment data using Abbott's formula with reference to insecticides. J. Econ. Entomol. 78:1179–1181.

Abbott's formula is often applied to entomological field data to distinguish the effects of pesticide treatment from those caused by natural factors. Although one would normally hope to use inferential statistics in applying Abbott's formula, logistical and economic constraints sometimes preclude the necessary experimental replication. We show that the use of Abbott's formula in experiments involving a single treatment and a single check plot usually produces a biased estimate of the population reduction due to treatment. The reasons for this bias are presented as guidance in the design of pesticide trials and in the interpretation of their results.

Fleming, R.A.; Sundaram, A. 1989. Evaporation of water from pesticide formulations and adjuvant solutions: modeling and analysis of temperature dependence. J. Environ. Sci. Health B24: 225–250.

The influence of ambient air temperature on the evaporation of water from some pesticide formulations and adjuvant solutions was measured using a gravimetric method. The degree of hydration was estimated as the difference between the empirically observed and theoretically calculated percentages of non-volatile components in each mixture. Mathematical models were developed to describe the time and temperature dependence of evaporation. The exponential decay model of evaporation at constant temperature failed because residual material affected the rate parameter. To overcome this difficulty, an accelerated exponential model was derived. Theoretical and empirical reasoning was then used to include temperature dependence of both the percentage of non-volatile components and the evaporation rate in the model. Similar simplifications of this general temperature dependent accelerated exponential model applied to liquids exhibiting similar degrees of hydration. Implications of the results for measuring volatility are also discussed.

Grant, G.G. 1987. Copulatory behavior of spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae): experimental analysis of the role of the sex pheromone and associated stimuli. Ann. Entomol. Soc. Am. 80:78–88.

Pheromone–stimulated spruce budworm, *Choristoneura fumiferana* (Clemens), males do not attempt copulation unless an appropriate releaser stimulus is associated with the pheromone source. Thus, no copulation attempts were observed when synthetic pheromone (95:5:2 ratio of E/Z–11–tetradecenal and tetradecanal) or pheromone extracts were released from a flat filter paper substrate, but males readily attempted to copulate with pheromone–treated rubber septa or untreated septa adjacent to a pheromone source. Septa spatially separated from the pheromone source were ineffective. Orientation of pheromone–treated septa affected copulatory behavior: horizontal septa were significantly better releasers than vertical septa presumably because they provided more effective tactile stimulation. Presence of tetradecanal in the pheromone blend decreased the latency of the male's copulatory response to these septa and increased the frequency of his copulatory attempts. Conspecific scales from either sex applied to untreated septa or the filter paper substrate released copulatory behavior from pheromone–stimulated males, but pulverized scales and scale extracts did not. The essential cue evoking copulation is associated with mechanical properties of the scales. Rubber septa without pheromone but emitting relatively high levels of hexane or ethanol evoked copulatory behavior from pheromone–stimulated males. These chemicals may act as novel, nonspecific releaser stimuli.

Grant, G.G. 1990. Use of semiochemicals for management of insect pests of coniferous seed orchards. pp. 47–62 In: R.J. West, ed. Proceedings, Cone and Seed Pest Workshop. 4 October 1989. Forestry Canada. Newfoundland and Labrador Region, St. John's, Nfld. Information Report N–X–274, 128 p.

The status of pheromones and kairomones for management of insect pests in coniferous seed orchards is reviewed. Sex pheromone–baited traps are used operationally to detect the presence of lepdiopteran pest species, track their population trends, and determine when they are reaching damaging levels. Traps are also used to time application of insecticidal sprays. Important factors affecting the effectiveness of monitoring traps for seed and cone insects include lure dosage, trap location on host trees and trap design. Volatile monoterpenes from pine cones that affect oviposition behavior of a coneworm pest have been identified. These kairomones may provide a useful tool for monitoring the oviposition activity of gravid females, providing a more accurate warning of potential cone damage.

Grant, G.G.; Fogal, W.H.; West, R.J.; Slessor, K.N.; Miller, G.E. 1989. A sex attractant for the spruce seed moth, *Cydia strobilella* (L.) and the effect of lure dosage and trap height on capture of male moths. Can. Ent. 121:691–697.

Electroantennogram (EAG) responses from male *Cydia strobilella* (L.), indicated that (E)–8–dodecenyl acetate (E8–12:Ac) was the most stimulating of the dodecenyl and tetradecenyl compounds assayed. Field–screening tests, which included compounds previously reported as attractive, demon-

strated that only E8–12:Ac was effective. The optimum trap dosage was 0.3–3 µg on red rubber septa. Catches of males were greater when traps were hung in the upper crown of either white spruce or black spruce.

Les réactions électroantennographiques (EAG) des mâles de *Cydia strobilella* (L.) ont indiqué que le (E)–8–dodécenyl acétate (E8–12:Ac) est le plus stimulant des composés dodécenylés et tétradécenylés testés. Des tests de terrain avec des composés rapportés antérieurement comme attractifs, ont démontré que seul le E8–12:Ac est efficace. La dose optimale était de 0.3–3 µg sur septum de caoutchouc rouge. Les captures de mâles étaient plus élevées lorsque les pièges étaient suspendus dans la couronne supérieure que dans la partie inférieure, à la fois pour l'épinette blanche et l'épinette noire.

Grant, G.G.; MacDonald, L.; Frech, D.; Hall, K.; Slessor, K.N. 1985. Sex attractants for some eastern species of *Rhyacionia*, including a new species, and *Eucosoma gloriola* (Lepidoptera: Tortricidae). Can. Ent. 117:1489–1496.

Field–screening tests using dodecenyl and dodecadienyl acetates and alcohols were conducted in pine plantations in northern Ontario to find attractants for Rhyacionia and Eucosoma moths. *Rhyacionia adana* was attracted by various ratios of (E)–9–dodecenyl acetate and (E)–9–dodecen–1–o1 (99:1 To 70:30) but no clear preference was observed. Similarly, *R. bucksana* was also attracted to the same ratios of these compounds. *Rhycionia granti* Miller, a new species revealed by these tests, was attracted to (E,E)–8,10–dodecadienyl acetate. *Rhyacionia granti* and *R. busckana* are newly recognized sibling species distinguished in this study by differences in their respective attractants, EAG responses and phenologies. The fourth species studied, *E. gloriola*, was optimally attracted by 9:1 and 8:2 ratios of (Z)–9–dodecenyl acetate. Flight data for the 4 species in the same plantation revealed overlapping flight periods. *Rhyacionia granti* was the earliest flier, followed closely by *R. adana* and *R. busckana*, and somewhat later by *E. gloriola*.

Des tests de dépistage sur le terrain, utilisant des acétates et des alcools de dodécène et de dodécadiène, ont été réalisés dans des plantations de pins du nord de l'Ontario, dans le but de découvrir des attractifs pour les papillons Rhyacionia and Eucosma. *Rhyacionia adana* a été attiré par des proportions variables d'acétate de dodécène–9E–yl et de dodécène–1–9E–o1 (99:1 à 70:30), mais sans aucune préférence marquée. De la même façon *R. bucksana* a également été attiré par les mêmes proportions de ces 2 composés. *Rhycionia granti* Miller, une nouvelle espèce qui fut découverte lors de ces tests, a été attiré par l'acétoxy–1 dodécadiène–8E, 10E. *Rhyacionia granti* et *R. bucksana* sont des espèces apparentées nouvellement reconnues qui se distinguent par des différences au niveau de leurs attractifs respectifs, par leur réaction à l'EAG et leurs phénologies. *Eucosma gloriola*, la quatrième espèce étudiée, a été principalement attiré par des proportions d'acétate de dodécène–9Z–yl et dodécène–9E–yl de l'ordre de 9:1 à 8:2. Les données sur le vol des 4 espèces dans la même plantation ont révélé des périodes de vol qui se chevauchent. *Rhyacionia granti* a été le premier à voler, suivi de près par *R.* adana et *R. bucksana* et peu plus tard par *E. gloriola*.

Grant, G.G.; Frech, D.; MacDonald, L.; Slessor, K.N.; King, G.G.S. 1987. Copulation releaser pheromone in body scales of female whitemarked tussock moth, *Orgyia leucostigma* (Lepidoptera: Lymantriidae): identification and behavioral role. J. Chem. Ecol. 13(2):345–356

The copulatory behavior of the male whitemarked tussock moth, *Orgyia leucostigma*, was released by extracts of female body scales applied to rubber septum models baited with a female sex pheromone gland. The major compounds in the scale extracts were identified by GC–MS as a series of *n*–alkanes from C–21 to C–29. Of these, *n*–tricosane, *n*–tetracosane, *n*–pentacosane, and *n*–heptacosane, applied at 10 ng/ septum, caused significantly more males to attempt copulation than hexane–treated controls. Mixtures of the *n*–alkanes, resembling the composition in the scale extracts, were no better than the two most active alkanes, *n*–tetracosane and *n*–pentacosane, alone. The releaser effect of the *n*–alkanes was

dose dependent. EAG responses to the identified *n*–alkanes were small, suggesting, along with the behavioral observations, that their perception occurred at very close range. Other factors releasing male copulatory behavior are discussed.

Grant, G.G.; Prévost, Y.H.; Slessor, K.N.; King, G.G.S.; West, R.J. 1987. Identification of the sex pheromone of the spruce coneworm, *Dioryctria reniculelloides* (Lepidoptera: Pyralidae). Environ. Entomol. 16:905–909.

Only (Z)–9–tetradecenyl acetate (<1 ng per female) could be identified by capillary gas chromatography (GC) and gas chromatography/mass spectrometry (GS/MS) in sex pheromone extracts of spruce coneworm, *Dioryctria reniculelloides* Mutuura & Munroe. Confirmation of this component as the Z isomer and identification of a potential second component, (Z)–7–dodecenyl acetate, were accomplished by electoantennogram bioassay and field tests. Blends of these compounds in ratios of 3:0.15 and 3:0.3 mg were significantly more attractive than (Z)–9–tetradecenyl acetate alone. A third chemical, (Z)–7–dodecenal, when present with the other compounds, produced a lure more competitive with female–baited traps but not significantly better than the two–compound lure. Pheromone–baited traps placed in the middle and upper crown of white or black spruce caught significantly more insects than traps in the bottom of the crown of either tree species.

Griffiths, K.B. (comp.) 1985. Forest Pest Management Institute Bibliography Supplement (1982–1985). Can. For. Serv., For. Pest Manage. Inst. Sault Ste. Marie, Ont. Inf. Rep. FPM–X–60R, 21 pp.

Gringorten, J.L.; Witt, D.P.; Milne, R.E.; Fast, P.G.; Sohi, S.S.; van Frankenhuyzen, K. 1990. An *in vitro* system for testing *Bacillus thuringiensis* toxins: the lawn assay. J. Invert. Pathol. 56: 237–242.

A cell assay system was developed that allows *Bacillus thuringiensis* δ–endotoxins activated at high pH (10.5) to be tested in vitro without causing alkaline injury to target cells. The assay is carried out on a lawn of gel–suspended cells, requires only 1 µl of sample per dose, and is quantitative, rapid and sensitive. The threshold dose for toxicity of *B. thuringiensis* subsp. *kurstaki* HD–73 with IPRI–CF–1 cells was 24 pg protein. The assay is also very useful for identifying antibodies which inhibit toxicity and for detecting β–endotoxin.

Harcourt, D.G.; Guppy, J.C.; Tyrrell, D. 1990. Phenology of the fungal pathogen *Zoophthora phytonomi* in southern Ontario populations of the alfalfa weevil (Coleoptera: Curculionidae). Environ. Entomol. 19: 612–617.

The seasonal phenology of *Zoophthora phytonomi* (Arthur) was studied in southern Ontario from 1976 through 1988. The first incidence of disease in the alfalfa weevil, *Hypera postica* (Gyllenhal), occurred after the accumulation of 204 degree–days (DD) above a base threshold of 9°C from 1 April. In 11 of the 13 yr, epizootics began 57 DD later and lasted for 10 to 14 d, killing up to 99% of the larvae and 50% of the coccooned stages. It is proposed that there are three peaks of conidial production of the fungus in the alfalfa weevil that occur at intervals of 55 to 60 DD. The first occurs when the larvae are small and is coincident with epizootics of the disease in the clover leaf weevil, *H. punctata* (F.), whose larvae mobilize, increase, and transfer the inocula in early spring. The second occurs at peak incidence of the third alfalfa weevil instar, and the last, just subsequent to peak fourth instar. Larvae infected during the fourth instar die in their coccoons and produce resting spores, which overwinter in the ground litter. The influence of microclimatic factors on epizootics is discussed in relation to threshold densities of the host.

Harvey, G.T.; Sohi S.S. 1985. Isozyme characterization of 28 cell lines from five insect species. Can. J. Zool. 63:2270–2276.

Correct identity of cell lines is essential for their use in any investigation; isozyme patterns of cell cultures can give reliable identification. Starch gel electrophoresis was used to develop isozyme profiles of 8 hymenopteran and 20 lepidopteran cell lines and of the insect species from which they were developed. Species identity of 26 of the cell lines was confirmed. For nine of the cell lines these results support the identity established by serological and chromosomal analyses. For the remaining cell lines they provide the first confirmation of species identity. Isozyme profiles of several cell lines from the same species showed unique characteristics that will be useful in monitoring their identity. Two cell lines (IPRI–OL–7 and IPRI–OL–11) considered to be from *Orgyia leucostigma* appear to contain isozymes of *Choristoneura fumiferana*. Other supporting evidence and possible causes of this contamination are discussed. These results demonstrate the usefulness of isozyme profiles for the identification and monitoring of cell cultures.

L'identification exacte des lignées cellulaires est essentielle à leur utilisation dans les études et cette identification peut être obtenue par l'examen des mouvements des isozymes dans les cultures. L'électrophorèse sur gel d'amidon a permis d'obtenir les profils des isozymes des lignées cellulaires de 8 hyménoptères et de 20 lèpidoptères et des espèces d'insectes d'où ces lignées proviennent. L'identification spécifique de 26 de ces lignées cellulaires a pu être confirmée. Pour neuf d'entre elles, les résultats confirment l'identité reconnue par des analyses sérologiques et chromosomiques. Quant aux autres lignées, c'est la première fois qu'elles permettent l'identification spécifique. Les profils des isozymes de plusieurs lignées cellulaires de la même espèce comportent des caractéristiques particulières qui ont une une valeur diagnostique. Deux lignées cellulaires (IPRI–OL–7 et IPRI–OL–11) reconnues comme provenant d'*Orgia leucostigma* semblent contenir des isozymes de *Choristoneura fumiferana*. D'autres aspects de ce phénomène et les causes possibles de cette contamination font l'objet d'une discussion. Ces résultats démontrent l'utilité des profils d'isozymes dans l'identification et l'étude des cultures de cellules.

Harvey, G.T.; Sohi, S.S. 1989. Isozyme characterization of 8 hymenopteran and 20 lepidopteran cell lines. pp. 71–75 In: J. Mitsuhashi, ed. Invertebrate Cell System Applications. vol. 1. C.R.C. Press, Boca Raton, Florida, 237 p.

Helson, B.V. 1985. Chemical insecticides for spruce budworm. pp. In: D.Schmitt, ed. Spruce – fir management and spruce budworm. April 24–26. Burlington, VT. Gen. Tech. Rep. NE–99. Broomall, PA, USDA FS, NE Forest Expt. Stn. 217 p.

Helson, B.V. 1985. Research on chemical insecticides for spruce budworm control at the Forest Pest Management Institute, 1982 to present. pp. In: C.J. Sanders, R.W. Stark, E.J. Mullins, J. Murphy, eds. Recent Advances in Spruce Budworms Research. Proc. CANUSA Spruce Budworms Research Symposium, Bangor, Maine, September 16–20, Supply & Services, Canada. 527 p.

Helson, B.V.; de Groot, P.; Turgeon, J.J.; Kettela, E. 1989. Toxicity of insecticides to first–instar larvae of the spruce budmoth, *Zeiraphera canadensis* Mut. and Free. (Lepidoptera:Tortricidae): Laboratory and field trials. Can. Ent. 121:81–91.

Laboratory tests with selected carbamate, organophosphorus, and pyrethroid insecticides demonstrated that the pyrethroid permethrin has the best potential for controlling newly hatched larvae of *Zeiraphera canadensis* Mut. and Free. Permethrin possessed high crawling contact toxicity (toxicity of insecticide deposits of foliage when contacted by crawling larvae) and direct contact toxicity to first–instar larvae and exhibited long residual effectiveness on potted, white spruce trees. Chlorphrifos, fenitrothion, mexacarbate, and methomyl had high crawling contact toxicity but short residual activity. Azinphos–methyl appeared to possess long residual effectiveness but relatively low crawling contact toxicity. Aminocarb and thiodicarb exhibited short residual effectiveness and relatively low toxicity. In field trials, an aerial application of permethrin (70 g/ha) at egg hatch resulted in an 81%

population reduction and limited the destruction of tree leaders to 9%. Leader destruction was greater than 19% after treatments of permethrin at 35 g AI/ha or aminocarb at 180 g AI/ha or aminocarb twice at 90 g AI/ha. Leader destruction in an untreated plantation was 51%.

Des essais réalisés en laboratoire avec des insecticides ont démontré que parmi les carbamates, les organophospates, et les pyréthroides testés, la perméthrine qui est un pyréthroide était le candidat le plus prometteur pour le contrôle dur le terrain des larves de *Zeiraphera canadensis* Mut. et Free. lors de la période d'éclosion. La toxicité de la perméthrine appliquée directement sur les larves ou sur du feuillage sur lequel on a permis à des larves du premier stade de se déplacer librement avant de s'établir sous les bourgeons fut très élevé. Le taux de mortalité des larves déposées sur le feuillage d'épinettes blanches en pots, 5 jours après l'application de la perméthrine fut similaire à celui obtenu pour les larves déposées 1 h après l'application, indiquant ainsi une longue rémanence. La toxicité du chlorpyrifos, du fénitrothion, du mexacarbate et du méthomyle via le feuillage fur élevée, mais leur rémanence sur le feuillage des épinettes blanches en pot fut de courte durée. Bien que la rémanence de l'azinphos-méthyl sembla de longue durée, sa toxicité via le feuillage fut relativement faible. L'aminocarbe et le thiodicarbe ont démontré une rémanence courte et une toxicité via le feuillage faible. Un épandage aérien de perméthrine réalisé au Nouveau Brunswick, à raison de 70 g AI/ha au début de la période d'éclosion des larves, a réduit la population de *Z. canadensis* de 81 %, et a limité à 9 % la destruction des flèches apicales des épinettes blanches. Pour les placettes traitées avec de la perméthrine à raison de 35 g AI/ha,avec de l'aminocarbe à raison de 180 g AI/ha ou avec deux applications d'aminocarbe à 90 g AI/ha, la destruction des flèches fut supérieure à 19 %. Dans la placette témoin, la proportion des flèches apicales détruites attegnit 51%.

Helson, B.V.; Kingsbury, P.D.; de Groot, P. 1986. The use of bioassays to assess aquatic arthropod mortality from permethrin drift deposits. Aquatic Toxicology 9:253–262.

Three bioassay methods with two aquatic arthropods, *Gammarus pseudolimnaeus* (Crustacea: Amphipoda) and *Aedes aegypti* larvae (Insecta:Diptera), in artificial aquatic habitats were used to assess the acute lethal effects of permethrin due to downwind drift deposits from mistblower applications. In three separate tests, all methods produced similar results, namely that single line sprays of permethrin at 35 g ai/ha resulted in mortality only within 30 m of the insecticide source. An application of 17.5 g ai/ha produced proportionately lower mortality. Mortality of amphipods was generally higher than that of mosquito larvae. The bioassay methods were very sensitive. Standards conducted concurrently with the tests gave LC50 values of 0.25 – 0.37 ppb for *G. pseudolimnaeus* and 0.69 – 1.85 for *A. aegypti* larvae.

Helson, B.V.; Surgeoner, G.A. 1986. Efficacy of cypermethrin for the control of mosquito larvae and pupae, and impact on non–target organisms, including fish. J. Amer. Mosquito Control Assoc. 2(3):269–275.

In laboratory tests, cypermethrin was highly toxic to mosquito larvae and pupae. It was more toxic at low temperatures after a 24 h exposure. Larvae of *Aedes stimulans* were less susceptible than *Culex restuans*. Technical cypermethrin was more toxic than an emulsifiable concentrate formulation. In outdoor simulated pools cypermethrin 40% EC was consistently effective against larvae and pupae of *Ae. stimulans* at 10 g ai/ha and *Culex* spp. at 50 g ai/ha. When stickleback fish were tested, no mortality occurred at the lowest effective dosage in each trial. The residual toxicity of cypermethrin increased with dosage and was much higher in a test at 8°C than at 20°C. In natural snowmelt pools, cypermethrin at 20 g ai/ha provided 92–100% control of *Aedes* spp. larvae and pupae by 7 days after treatment. Non–target amphipod, anostracan, cladoceran and insect populations were usually reduced by 80–100% while copepods, ostracods and hydracarinid mites were generally less affected. No significant mortality of caged stickleback fish occurred in these pools.

Himel, C.M.; Sundaram, A.; Sundaram, K.M.S.; Cadogan, B.L.; Villaveces, A. 1987. Assessment of aerial deposits in a spruce forest using inflight microencapsulation technique. J. Environ. Sci. Health B22:195–219.

Spray drops were counted and sized on Kromekote ® cards at ground level, and on spruce foliage at canopy level, after aerial application of a formulation containing a microencapsulation medium, over a spruce forest in Ontario. The majority of drops (70%) on foliage were in the 20–70 µm range. A coarse drop size spectrum was observed on cards with a maximum diameter (Dmax) of 380 µm, and with 85% of the drops ≤130 µm in diameter. Foliar drop analysis, on the other hand, indicated a finer spectrum with a Dmax of 150 µm, and with 85% of the drops < 75 µm. These results were explained on the basis of formulation ingredients, atomizer setting, weather factors, and drop retention on target surfaces. The assessment of the spray deposits on glass plates at ground level indicated that about 16% of the applied spray volume reached the forest floor, a value which is comparable to those obtained in previous forestry applications using the ultra–low–volume (ULV) technique.

Holmes, S.B. 1988. Behavioral and reproductive correlates of reduced levels of cholinesterase activity in zebra finches following acute exposures to fenitrothion. M. Sc. Thesis, Queen's University, Kingston, Ontario.

Holmes, S.B.; Boag, P.T. 1990. Inhibition of brain and plasma cholinesterase activity in zebra finches orally dosed with fenitrothion. Environ. Contam. & Toxicol. 9: 323–334.

Zebra finches (*Poephila guttata*) were given single oral doses of fenitrothion insecticide dissolved in soya bean oil. Brain and plasma cholinesterase (ChE) activities were measured periodically up to 10 d post–exposure. Dosage rates of 1.04, 3.80 and 11.36 mg active ingredient/kg body weight resulted in maximum brain ChE inhibitions of 50, 70 and 75%, and maximum plasma ChE inhibitions of 78, 82 and 89%, respectively. Recovery of ChE activity in vivo followed an exponential pattern, with plasma ChE activity recovering more rapidly than brain ChE activity. At dosage rates of 1.04 and 3.80 mg/kg, plasma ChE activity recovered to normal in 1 to 2 d. Brain ChE activity was inhibited up to 10 d after dosing at 1.04 mg/kg. There was some mortality of exposed birds at the two higher dosage rates. Birds that died exhibited brain ChE inhibitions ranging from 3 to 84%.

Kaupp, W.J.; Nicholson, D. 1987. The highlighting of nuclear polyhedrosis virus inclusion bodies embedded in thick sections using Naphthaline Black 12B. Can. For. Serv., For. Pest Manage. Inst. Technical Note 8, 2 pp.

Kaupp, W.J.; Cunningham, J.C; Meating, J.H.; Howse, G.M.; Denys, A. 1988. Aerial spray trials with Disparvirus in Ontario in 1986. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont. Inf. Rep. FPM–X–82, 7 p.

Two plots infested with gypsy moth, *Lymantria dispar* (L.) were aerially sprayed with an aqueous formulation of Disparvirus, a nuclear polyhedrosis virus (NPV), containing 25% molasses and 60 g/L Orzan LS, to determine its efficacy. Plot 1 received a double application of 2.2×10^{12} polyhedral inclusion bodies (PIBs)/ha and plot 2 received a double application of 2.7×10^{11} PIBs/ha. Applications at 9.4 L/ha were 5 days apart when insects were in the first and second instars. Excellent spray coverage was achieved and virus epizootics occurred in both plots with the highest levels of larval infection at 46.7% and 66.5% for plots 1 and 2 respectively. Highest infection levels of naturally occurring NPV recorded in check plot 1 and check plot 2 were 17.6% and 27.9% respectively. In treated plots, egg mass density fell from a pre–spray count of 1540/ha to a post–spray count of 10/ha in plot 1 and from 3240/ha to 1560/ha in plot 2. Populations in check plots also declined dramatically. Results from these trials indicate that Disparvirus is potentially effective as a control agent for gypsy moth.

Kaupp, W.J.; Cunningham, J.C.; Meating, J.H.; Howse, G.M.; Denys, A. 1988. Essais de pulvérisations aérienne de Disparvirus en Ontario en 1986. Forêts Canada, Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–82F.

Deux parcelles infestées par la spongieuse (*Lymantria dispar* [L.]) ont été soumises à des pulvérisations aériennes d'une formulation aqueuse de Disparvirus, un virus de la polyédrose nucléaire, contenant 25% de mélasse et 60 g/L d'Orzan LS, afin de déterminer son efficacité. La parcelle 1 a reçu une double application de $2,2 \times 10^{12}$ de corps d'inclusion polyhédriques par hectare (CIP/ha) et la parcelle 2 une double application de $2,7 \times 10^{12}$ CIP/ha. Les traitements dosés à 9,4 L/ha ont eu lieu à 5 jours d'intervalle, lorsque les insectes en étaient à leur premier ou deuxième stade de développement. L'arrosage des blocs a été très uniforme et a déclenché une épizootie virale dans les deux parcelles, les plus forts taux d'infection des larves étant de 46,7 et 66, 5% dans les parcelles 1 and 2 respectivement. Les taux d'infection les plus élevés par le virus naturel de la polyédrose nucléaire enregistrés dans les parcelles–témoins 1 et 2 étaient respectivement de 17, 6 et 27,9%. Dans les parcelles traitées, la densité des masses d'oeufs, de 1540/ha qu'elle était avant le traitement, est passée à 10/ha dans la parcelle 1 après le traitement et de 3240 à 1560/ha dans la parcelle 2. Les populations des parcelles–témoins ont également décliné de façon spectaculaire. Les résultats de ces essais montrent que le Disparvirus est un agent de lutte contre la spongieuse potentiellement efficace.

Kaupp, W.J.; Ebling, P. 1990. Response of third–, fourth–, fifth–, and sixth–instar spruce budworm , *Choristoneura fumiferana* (Clem.) larvae to nuclear polyhedrosis virus. Can. Ent. 122: 1037–1038.

Kaupp, W.J.; Nicholson, D. 1988. Mise en évidence, par le Noir de Naphtalène 12B, de la présence d'inclusions du virus de la polyédrose nucléaire dans des coupes épaisses. Serv. Can. For., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Note Technique 8F, 2 pp.

Kaupp, W.J.; Sohi, S.S. 1985. Quantitation of viral insecticides. pp. 675–694 In: K. Maramorosch and K.E. Sherman, eds. Viral Insecticides for Biological Control. Academic Press, New York, 809 p.

Kaupp, W.J.; Sohi, S.S. 1985. The role of insect viruses in the ecosystem. pp. 441–465 In: K. Maramrosch and K.E. Sherman, eds. Viral Insecticides for Biological Control. Academic Press, New York, 809 p.

Kingsbury, P.D.; Kreutzweiser, D.P. 1987. Permethrin treatments in Canadian forests. Part 1: Impact on stream fish. Pestic. Sci. 19:35–48.

The effects of permethrin on native and caged fish when aerially applied directly to forest streams at dosages between 8.8 and 70 g ha^{-1} were studied between 1976 and 1981. None of the applications caused mortality of caged or native fish in streams. Trout and salmon diets were altered by the treatments due to effects on fish food organisms. The duration of the effects varied from several months to over a year with increasing dosage. Reductions in salmonid growth rates and reductions in fish densities in treated areas, presumably due to emigration, were documented following severe impacts on aquatic invertebrates in salmon nursery streams. Growth rates and population densities both recovered within four months after treatment.

Kingsbury, P.D.; Trial, J.T. eds. 1987. Buffer zones: their application to forest insect control operations. Proceedings of the Buffer Zone Workshop, Eastern Spruce Budworm Council. Quebec City, Quebec, 16–17 April, 1986. 124 p.

Kreutzweiser, D.P. 1990. Response of a brook trout (*Salvelinus fontinalis*) population to a reduction in stream benthos following an insecticide treatment. Can. J. Fish. Aquat. Sci. 47: 1387–1401.

A forest stream was treated with permethrin to determine the response of brook trout to a reduction in the aquatic food resource following an insecticide treatment. The treatment resulted in massive invertebrate drift and significant reductions of benthos, but did not produce trout mortality or evidence of unusual behaviour. The density, population age structure, movement patterns, and condition of brook trout were not measurably affected by the permethrin treatment. The growth rates of 0+ and 1+ age–classes were significantly lower following the insecticide application than those of trout from the same age–classes of pretreatment years. This reduction in growth rate resulted in significantly smaller trout after treatment. A significant reduction in the growth of trout collected during the same period from a nearby untreated control stream indicated that unusually high summer temperatures were at least partially, if not entirely, responsible for the reduced growth rate of treated fish. Growth rates returned to or exceeded pretreatment levels by the overwinter period of the treatment year.

Un cours d'eau en forêt a été traité au perméthrine afin de déterminer la réaction de l'omble de fontaine à une réduction des ressources alimentaires aquatiques après l'application d'insecticide. Le traitment s'est soldé par une dérive massive d'invertebrés et par une réduction importante du benthos, mais n'a pas provoqué la mort de l'omble ou des comportements inhabituels. La densité, la structure de la population en fonction de l'âge, les modes de déplacement et l'état de l'omble de fontaine n'ont pas été touchés de façon mesurable par l'application de perméthrine. Le taux de crosissance des classes d'âge 0+ et 1+ était significativement plus faible après l'application de l'insecticide que celui d'ombles de mêmes classes d 'âge au cours des années qui ont précédé le traitment. Cette baisse du taux de croissance s'est traduite par les ombles beacoup plus petites après l'application d'insecticide. Une diminution de la croissance des ombles prélevées pendant la même période dans un cours d'eau voisin témoin et non traité a montré que des températures estivales anormalement élevées étaient en partie responsables du moins, si no entièrement, de l'abaissement du taux de croissance des poissons exposés à l'insecticide. Les taux de croissance sont revenus au taux mesuré avant le traitment ou l'on dépassé avant la fin de la période hivernale de l'année au cours de laquelle le traitment a été appliqué.

Kreutzweiser, D.P; Kingsbury, P.D. 1987. Permethrin treatments in Canadian forests. Part 2: Impact on stream invertebrates. Pestic. Sci. 19:49–60.

A series of experiments was conducted between 1977 and 1981 to evaluate the effects of aerially applied permethrin on forest stream invertebrates. All permethrin applications to forest streams resulted in large drift increases, and most produced measurable reductions in benthos density. Recovery of benthic fauna following the various permethrin applications was apparent from 1 to 18 months post–spray. In double application experiments, the second treatments reduced benthos density to a point at which recovery of numbers was slower than after the impact resulting from a single application of the same dosage.

Kreutzweiser, D.P; Kingsbury, P.D.; Feng, J.C. 1989. Drift response of stream invertebrates to aerial applications of glyphosate. Bull. Environ. Contam. Toxicol. 42:331–338.

Kreutzweiser, D.P.; Kingsbury, P.D.; Holmes, S.B. 1986. Studies of brook trout, *Salvelinus fontinalis*, density, growth and movement in Icewater Creek, Algoma District, Ontario. pp. 90–92 In: G.H. Geen and K.L. Woodward, eds. Proceedings of the Eleventh Annual Aquatic Toxicity Workshop. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1480, Ottawa, Canada.

Kreutzweiser, D.P.; Sibley, P.K. 1991. Invertebrate drift in a headwater stream treated with permethrin. Arch. Environ. Contam. Toxicol. 20:

MacDonald, J.A.; Kaupp, W.J. 1987. An insect cuticle preparation method for light microscopy. Can. For. Serv., For. Pest Management. Inst. , Sault Ste. Marie, Ont., Tech. Note 6, 2 p.

Millikin, R. 1988. A comparison of spot, transect and plot methods for measuring the impact of forest pest control strategies on forest songbirds. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont. Inf. Rep. FPM–X–83. 23 p + appendices.

Of the methods tested, the plot method would be most preferable to determine the effects of forest spraying on forest songbirds. Relative abundance and species diversity increased with a greater amount of time on the plot, and for the delineation of territories, transect and spot census methods were less precise. Multiple spot censuses, conducted within one day, were as accurate as the same number of censuses conducted over separate days. Three census methods (spot, transect, and plot) were compared, using territory mapping, on one 4 ha plot in 1979 at Wawa, Ontario. The timing of consecutive spot censuses was studied at Searchmont, Ontario, in 1980.

Millikin, R. 1988 Comparaison des méthodes de recensement par points, par transect et par placette pour mesurer l'impact des stratégies de lutte contre les ravageurs forestiers sur les oiseaux chanteurs des forêts. Forêt Canada, Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont. Rap. Inf. FPM–X–83F.

Parmi les méthodes expérimentées, la méthode par placette offre les meilleures possibilités pour déterminer les effets des pulvérisations sur les oiseaux chanteurs des forêts. L'abondance relative et la diversité des espèces augmentaient proportionnellement avec le temps dans le cas du recensement par placette, et la délimitation des territoires n'était pas aussi précise avec les méthodes de recensement par transect et par points. Des recensements multiples par points, faits le même jour, ont été aussi précis que le même nombre de recensements faits en des jours différents. Trois méthodes de recensement (par points, par transect et par placette) ont été comparées à l'aide du relevé cartographique du territoire, sur une placette de 4 ha en 1979, à Wawa (Ontario). L' échelonnement des recensements consécutifs par points a été étudié à Searchmont (Ontario) en 1980.

Milne, R.; Ge, A.Z.; Rivers, D.; Dean, D.H. 1990. Specificity of insecticidal crystal proteins: implications for industrial standardization. pp.22–35 In: L.A. Hickle, W.L. Fitch, eds. Analytical Chemistry of *Bacillus thuringiensis*. ACS Symposium Series 432. American Chemical Society, Washington, DC.

The specificity of *Bacillus thuringiensis* activity resides largely with the insecticidal crystal proteins. The specificity domain of the toxin moiety has recently been identified and is proposed as the receptor binding domain. The bacterial spore and other factors may play a role in insecticide specificity, especially for less susceptible insects. Insect susceptibility is dependent on gut pH, proteases, the presence and type of receptor (toxin–binding) protein, and on membrane interactions with the cytolitic domains of the toxins. The implication for industrial standardization of *B. thuringiensis* products is that assay systems must account for each of the bacterial components which play a role in insecticidal activity.

Morse, D.; Szittner, R.; Grant, G.; Meighen, E. 1986. Bioluminescence in the analysis of insect pheromones. Methods in Enzymology 133: 189–197.

Nealis, V.; van Frankenhuyzen, K. 1990. Interactions between *Bacillus thuringiensis* Berliner and *Apanteles fumiferanae* Vier. (Hymenoptera: Braconidae), a parasitoid of the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). Can. Ent. 122: 585–594.

Interactions between *Bacillus thuringiensis* Berliner and *Apanteles fumiferanae* Viereck as mortality factors of the spruce budworm, *Choristoneura fumiferana* (Clemens), were investigated by placing parasitized and nonparasitized budworm larvae on foliage with and without spray deposits of a commercial formulation of *B. thuringiensis*. The effect of larval age (and thus, the timing of spray applications) was examined by using peak third–instar and peak fourth–instar larvae. We demonstrated that parasitized larvae are more likely to survive exposure to *B. thuringiensis* because they feed less than nonparasitized larvae and are thus less likely to acquire a lethal dose of the bacterium. *Bacillus thuringiensis* nevertheless reduced parasitoid populations by 50–60% by killing their hosts before parasitoid emergence. This negative impact of *B. thuringiensis* on parasitoid survival was decreased when exposure of budworm larvae to spray deposits was delayed from peak third to peak fourth instar. The enhanced survival of parasitoids offset the lower mortality as a result of *B. thuringiensis* in the delayed sprays. We conclude that *B. thuringiensis* applied when budworm larval populations are at peak fourth instar or later would complement rather than interfere with the beneficial effects of *A. fumiferanae*. The implications for budworm management strategies are discussed.

Les interactions entre *Bacillus thuringiensis* Berliner et *Apanteles fumiferanae* Viereck en autant d'être facteurs de mortalité de la tordeuse des bourgeons de l'épinette, *Choristoneura fumiferana* (Clemens), ont été étudiées en plaçant les larves parasitées et non–parasitées de la tordeuse sur le feuillage avec et sans les dépôts d'une préparation commerciale de *B. thuringiensis*. L'effet de l'âge de larves (et ainsi, la détermination de l'heurre des arrosages) a été étudié, en utilisant les larves à fin du troisème et du quatrième stades. Nous avons démontré que les larves parasitisées sont vraisemblablement plus aptes à survivre l'exposition à *B. thuringiensis*, parce qu'elles mangent moins que les larves non–parasitées et ainsi, elles sont moins portées d'ingérer une dose létale de la bactérie. *Bacillus thuringiensis*, néanmoins, a réduit les populations parasitoides de 50–60%, en tuant les hôtes avant la sortie des parasitoides. Cette répercussion négative de *B. thuringiensis* à la survie des parasitoides a été diminuée, quand l'exposition de la tordeuse a été rétardée à partir de la fin du troisième jusqu'à la fin du quatrième stade. La survie améliorée de parasitoides a compensé la mortalité réduite des arrosages retardés de *B. thuringiensis*. Nous avons conclu que l'application de *B. thuringiensis* aux populations larvaires de la tordeuse à la cime du quatrième stade ou plus tard compléterait au lieu de contrarier les effets avantageux de *A. fumiferanae*. Les implications à l'égard des strategies de maniement de la tordeuse sont discutées.

Obarymskyj, A.; de Groot, P. 1987. Adaption of a personnel lift for use in forestry. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Tech. Note 9, 8 pp.

Obarymskyj, A.; de Groot, P. 1987. Adaptation d'une plate–forme élevatrice pour emploi en fôret. Serv. Can. For., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Technique 9F, 8 pp.

Otvos, I.S.; Cunningham, J.C.; Alfaro, R.I. 1987. Aerial application of nuclear polyhedrosis virus against Douglas–fir tussock moth, *Orgyia pseudotsugata* (McDunnough) (Lepidoptera:Lymantriidae): II. Impact 1 and 2 years after application. Can. Ent. 119:707–715.

Following aerial application of a Douglas–fir tussock moth, *Orgyia pseudotsugata* (McDunnough), nuclear polyhedrosis virus (NPV) product called Virtuss on four plots in 1982, observations were made to determine the impact of these treatments in 1983 and 1984. Treated plots as well as buffer zones between and adjoining the treated plots, and three of the four check plots established in 1982, were monitored. The NPV appeared to have spread from the treated plots to adjoining areas in 1982, effectively reducing the Douglas–fir tussock moth population. This observation suggests that a strategy of spraying alternate swaths of Douglas–fir tussock moth infested stands with this viral insecticide may effectively initiate an epizootic that would control the population at a reduced cost. A naturally

occurring NPV epizootic decimated the Douglas–fir tussock moth population in the three check plots in 1983, but severe tree mortality occurred in two of these plots with 60 and 62% of sample trees dead in 1984. Light tree mortality was noted in 1984 in two of the four treated plots with 4 and 7% of sample trees killed. It is concluded that the virus treatments in 1982 were successful in preventing tree mortality.

Un épandage aérien d'un produit appelé Virtuss et contenant le virus de la polyédrose nucléaire (VPN) de la chenille à houppes du douglas, *Orgyia pseudotsugata* (McDunnough), a été effectué sur quatre placettes en 1982. En 1983 et 1984, on a cherché à déterminer les répercussions de ces traitements dans les placettes traitées de même que dans les zones tampons de chaque côté des placettes et on a aussi examiné trois des quatre placettes témoins établies en 1982. Il semblerait que le VPN se soit propagé aux zones voisines où une nette réduction de la population de la chenille a été observée. On peut donc penser qu'une stratégie consistant à alterner les bandes arrosées et non arrosés dans les peuplements infestés pourrait être efficace en déclenchant une épizootie qui permettrait de réduire la population à coût réduit. Une épizootie du VPN d'origine naturelle a décimé la population de la chenille dans les trois placettes témoins en 1983; on a cependant observé en 1984 une mortalité très importante des arbres dans deux de ces placettes, soit de 60 et 62% des arbres d' échantillonnage. Par contre, une faible mortalité des arbres a été observée en 1984 dans deux des placettes traitées où 4 et 7% des arbres d' échantillonnage avaient été tués. On en conclut que les traitements viraux appliqués en 1982 ont permis d'empêcher une mortalité élevée des arbres.

Otvos, I.S.; Cunningham, J.C.; Friskie, L.M. 1987. Aerial application of nuclear polyhedrosis virus against Douglas–fir tussock moth, *Orgyia pseudotsugata* (McDunnough) (Lepidoptera:Lymantriidae). I. Impact in the year of application. Can. Ent. 119:697–706.

Four 10–ha plots located in Kamloops Forest District, British Columbia, containing Douglas–fir trees infested with Douglas–fir tussock moth were aerially sprayed with nuclear polyhedrosis virus (Virtuss) in 1982 when most larvae were in the first instar. A dosage of 2.5×10^{11} polyhedral inclusion bodies (PIB) per hectare was applied in an emulsifiable oil tank mix to one plot and the same dosage in an aqueous tank mix containing molasses was applied to a second plot. The remaining two plots were treated with dosages of 8.3×10^{10} and 1.6×10^{10} PIB per hectare, respectively, in the oil mix. The treatments were applied with a fixed–wing aircraft fitted with boom and nozzle equipment and calibrated to deliver 9.4 L/ha. A further four plots were selected as checks.

Population reduction at 6 weeks post–spray (calculated using a modified Abbott's formula) was 65% in the plot receiving the lowest dosage and from 87 to 95% in the remaining three plots. Incidence of virus infection peaked at 5–6 weeks post–spray with 85–100% of the larvae scored as positive. Levels of naturally occurring virus remained low in the check plots. Adult emergence from the pupae collected in the treated plots ranged from 4 to 19% and from 28 to 43% in the check plots. Reduction in egg–mass density attributed to the treatments was 97% in one plot, 99% in two others, and not determined for the fourth. A virus dosage of 8.3×10^{10} PIB per hectare, which is one–third of the previously recommended dosage, is adequate, and either tank mix is acceptable.

En 1982, quatre placettes de 10 ha situées dans le district forestier de Kamloops, en Colombie–Britannique, qui renfermaient des douglas taxifoliés infestés par la chenille à houppes du douglas ont été traitées par des épandages aériens de diverses préparations du virus de la polyédrose nucléaire (Virtuss) au moment où la plupart des larves se trouvaient au premier stade. Une première placette a reçu une dose de $2{,}5 \times 10^{11}$ corps d'inclusion polyédriques (CIP) par hectare sous forme d'une préparation huileuse émulsionnable, et une autre, la même dose, mais dans une préparation aqueuse contenant des mélasses. Les deux autres placettes ont reçu une préparation huileuse contenant $8{,}3 \times 10^{10}$ CIP/ha dans un cas et $1{,}6 \times 10^{10}$ CIP/ha dans l'autre. Les traitements ont été réalisés à l'aide d'un avion muni

d'une rampe de pulvérisation étalonnée pour un débit de 9,4 L/ha. Quatre autres placettes ont été utilisées comme témoins.

Six semaines après les arrosages, la réduction de la population due au traitement (calculée suivant la formule modifiée d'Abbott) s'élevait à 65% dans la placette ayant reçu la dose la plus faible et elle variait entre 87 et 95% dans les trois autres placettes. L'infection virale a été maximale vers la 5e ou 6e semaine après l'arrosage, de 85–100% des larves étant alors infectées. Le niveau d'infection naturelle dans les placettes témoins est demeuré faible. On a observé des taux d' émergence d'adultes variant entre 4 et 19% chez les chrysalides récoltées dans les placettes traitées et entre 28 et 43% chez celles des placettes témoins. La réduction de la densité des masses d'oeufs attribuable au traitement a été de 97% dans une placette et de 99% dans deux autres elle n'a pas été déterminée dans la quatrième. On estime qu'une dose de $8,3 \times 10^{10}$ CIP/ha, soit le tiers de la dose déjà recommandée, est suffisante et que les deux préparations sont acceptables.

Otvos, I.S.; Cunningham, J.C.; Kaupp, W.J. 1989. Aerial application of two baculoviruses against the western spruce budworm, *Choristoneura occidentalis* Freeman (Lepidoptera: Tortricidae), in British Columbia. Can. Ent. 121:209–217.

Two viruses, one a nuclear polyhedrosis virus and the other a granulosis virus, were applied in an attempt to initiate epizootics in populations of western spruce budworm, *Choristoneura occidentalis* Freeman, on Douglas–fir trees, *Pseudotsuga menziesii* (Mirb.) Franco, in southeastern British Columbia. Two 172–ha plots were aerially treated in 1982 with 9.0 kg of lyophilized, virus–infected larval powder that was formulated in an emulsifiable oil tank mix and applied at 9.4 L per hectare. Each plot was treated when larval populations were at the peak of the fourth instar. The nuclear polyhedrosis virus was applied at 5.4×10^{11} polyhedral inclusion bodies per hectare and the granulosis virus at 1.7×10^{14} capsules per hectare. Results showed that the granulosis virus treatment caused 34.6% population reduction (Abbott's formula) and the nuclear polyhedrosis virus 51.8%. Larvae from treated and check plots were reared individually in the laboratory and the incidence of viruses, parasitoids, and successful adult emergence was recorded. Studies in these plots continued in 1983 and 1984. Although vertical transmission of both viruses was evident, their impact on budworm mortality was less than in 1982. Consequently, the epizootics were not sufficiently intense to control the target insect population.

Deux virus, un virus à polyhédrose nucléaire et un virus à granulose, ont été appliqués lors d'une tentative de déclenchement d' épizooties dans des populations de la tordeuse occidentale de l' épinette, *Choristoneura occidentalis* Freeman, sur le sapin Douglas, *Pseudotsuga menziesii* (Mirb.) Franco, au sud est de la Colombie Britannique. Deux parcelles de 172 ha ont été traités par air en 1982 avec 9,0 kg de larves infectées, pulvérisées et formulées en huile émulsifiable appliquée à 9,4 L par hectare. Chaque parcelle a été traitée lorsque les populations larvaires étaient au pic de stade quatre. Le virus à polyhédrose nucléaire a été appliqué à $5,4 \times 10^{11}$ corps d'inclusion polyhédriques par hectare et le virus á granulose à 1.7×10^{14} capsules par hectare. Les résultats ont montré que le traitement au virus à granulose a causé 34,6% de réduction de la population (formule d'Abbott), et le virus á polyhédrose nucléaire, 51.8%. Des larves des parcelles traitées et témoins ont été élevées individuellement au laboratoire pour estimer les incidences de maladie virale, de parasitisme ou d'émergence d'un adulte. Les études dans ces parcelles se sont poursuivies en 1983 et 1984. Quoiqu'il ait été possible de conclure à la transmission verticale des deux virus, leur impact sur la mortalité de la tordeuse était moindre qu'en 1982. En conséquence, les épizooties n' étaient pas suffisamment intenses pour réprimer la population ciblée.

Pang, A.S.D.; Gringorten, J.L.; Sohi, S.S. 1990. Enhancement of *Bacillus thuringiensis* subsp. *kurstaki* toxin activity by cell lysates. J. Invert. Pathol. 55: 444–446.

Payne, N.J. 1987. Canopy penetration and deposition of small drops. pp. 95– 101 In: G.W. Green, ed. Proceedings of Symposium on the aerial application of pesticides in forest-

ry. October 1987. Associate Committee on Agriculture and Forestry Aviation, Ottawa, Canada. AFA–TN–18, NRC No. 29197.

Payne, N.; Feng, J.; Reynolds, P. 1987. Off–target deposit measurements and buffer zones required around water for various aerial applications of glyphosate. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont. Inf. Rep. FPM–X–80, 23 p.

This investigation was designed to quantify off–target deposit from three types of glyphosate application for forestry use, and to estimate the width of buffer zones required around water to protect fish and their food supply from direct toxicological effects. To overcome the difficulty of estimating different buffer widths to meet the various conditions encountered, e.g., windspeed, boundary layer stability, active ingredient (a.i.) application rate, etc., a realistic worst case scenario was chosen, and data were collected accordingly. Applications of glyphosate (Roundup, Monsanto) were made by helicopter using three types of dispersal system, a Microfoil boom (Union Carbide), a Through Valve Boom (Waldrum Specialties) and a D8–46 hydraulic nozzle. Off–target glyphosate deposits on water and foliar surfaces were measured at various downwind distances from several swaths overlaid on a crosswind track. Airborne glyphosate was also sampled. Using these measurements, mathematical equations were formulated to predict glyphosate deposits on water surfaces downwind of multiple swath applications. Based on reported measurements of the toxicity of glyphosate to salmon, rainbow trout and various aquatic invertebrates, an estimate was then made of buffer widths required around water bodies. In general, measured off–target deposit was highest from the D8–46 application, and lowest from the Microfoil boom application. In all applications off–target deposit on water decreased rapidly with downwind distance. A buffer width of 25 m around water bodies is adequate to protect salmon, rainbow trout and aquatic invertebrates from significant direct effects resulting from off–target deposits from two of the use strategies tested, those using the Microfoil and Through Valve Boom; for the third use strategy a 30 m buffer width is suggested.

Payne, N.; Feng, J.; Reynolds, P. 1989. Mesures du dépôt hors–cible et zones–tampons nécessaire autour des plan d'eau pour diverses applications aérienne de glyphosate. Forêt Canada, Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–80F.

On a voulu détermine le dépôt hors cible résultant de trois types d' épandage de glyphosate sur les forêts et estimer la largeur des zones tampons requises autour des eaux pour protéger les poissons et leurs ressources alimentaires contre des effets toxicologiques directs. Devant la difficulté d'estimer les différentes bandes tampons requises pour les diverses conditions observées (ex.: vitesse des vents, stabilité de la couche limite, dose du principe actif, etc.), on a décidé d'appliquer un scénario réaliste de pire éventualité et de recueillir les données en fonction de ce scénario. Les épandages de glyphosate (Roundup Monsanto) ont été effectués par hélicoptère au moyen de trois types de systèmes de dispersion: une rampe Microfoil (Union Carbide), la Valve Boom (Waldrum Specialties) et un pulvérisateur à buse hydraulique D8–46. Les dépôts hors cible à la surface de l'eau et des feuilles ont été mesurés à diverses distances sous le vent de plusieurs bandes traitées par vent de travers. Les concentrations de glyphosate dans l'air ont également été mesurées. À l'aide des résultats obtenus, on a formulé des équations mathématiques pour la prévision des dépôts de glyphosate sur des étendues d'eau situées sous le vent des bandes traitées. En utilisant les données publiées sur la toxicité du glyphosate pour le saumon, la truite arc–en–ciel et divers invertébrés aquatiques, on a ensuite estimé la largeur des bandes tampons autour des étendues d'eau. En général, on a obtenu les plus forts dépôts hors cible avec la buse et les plus faibles avec la rampe Microfoil. Pour tous les épandages, le dépôt hors cible sur l'eau diminuait rapidement avec la distance sous le vent. Une bande tampon de 25 m autour des étendues d'eau serait adéquate pour la protection du saumon, de la truite arc–en–ciel et des invertébrés aquatiques contre des effets directs importants pour deux des stratégies étudiés, c'est–à–dire avec la Microfoil et la Valve Boom, et une bande de 30 m est suggérée dans le cas de la troisième stratégie.

Payne, N.J.; Feng, J.; Reynolds, P. 1989. Off–target deposit measurements and buffer zones required around water for various aerial applications of glyphosate. pp. 88– 109 In: P.E. Reynolds, ed. Proceedings of the Carnation Creek Herbicide Workshop. March 1989. Forestry Canada/ British Columbia Ministry of Forests, Victoria, B.C. FRDA Report 063, 349 p.

An investigation was conducted to quantify off–target deposit from three types of aerial glyphosate use–strategies for forestry use, and to estimate the width of buffer zones required around water to protect fish and their food supply from direct toxicological effects. To overcome the difficulty of estimating different buffer widths to meet the various conditions encountered, e.g., windspeed, boundary layer stability, active ingredient application rate, etc., a realistic worst case scenario was chosen, and data were collected accordingly. Glyphosate applications were made by helicopter, using three types of dispersal system, a Microfoil Boom, a Thru Valve Boom and a D8–46 hydraulic nozzle. Airborne glyphosate and off–target deposits on water and foliar surfaces were measured at various downwind distances up to 200 m from multiple swaths overlaid on a crosswind track. Using these measurements, calculations were made to predict glyphosate deposits on water surfaces downwind of multiple swath applications with the use–strategies tested. Based on published measurements of the toxicity of Roundup to salmon, rainbow trout and various aquatic invertebrates, an estimate was then made of buffer widths required around water bodies to keep mortality at an acceptable level. In general, measured airborne glyphosate and off–target deposit was highest from the D8–46 application, and lowest from the Microfoil Boom application. In all applications off–target deposit on water decreased rapidly with downwind distance. A buffer width of 25 m around water bodies is adequate to protect salmon, rainbow trout and aquatic invertebrates from significant direct effects resulting from off–target Roundup deposits from the Microfoil and Thru Valve Boom use–strategies: for the D8–46 use–strategy, a 30 m buffer width is required.

Payne, N.J.; Feng, J.; Reynolds, P. 1990. Off–target deposit measurements and buffer zones required around water for aerial glyphosate applications. Pestic. Sci. 30: 183–198.

Payne, N.J.; Feng, J.; Reynolds, P. 1989. Off–target deposits and buffer zones required around water for various aerial silvicultural glyphosate applications. p. 662 In: Expert Committee on Weeds Research Reports: Eastern and Western.

Payne, N.; Helson, B.; Sundaram, K.; Kingsbury, P.; Fleming, R.; de Groot, P. 1986. Estimating the buffer required around water during permethrin applications. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Inf. Rep. FPM–X–70, 26 PP.

This study was conducted to gather data for use in setting buffers required during forestry permethrin applications. Ground–based and aerial applications were studied separately because of important differences between the two, e.g. cloud release height, which result in different downwind spray deposits. To overcome the problem of the multiplicity of buffers required with different meteorological conditions, droplet size spectra, etc., a reasonable worst case scenario was chosen, and data collected for this case. In order not to make buffers unnecessarily large, upwind, crosswind and downwind spray cloud dispersal were considered separately. The study comprised an experiment to measure spray deposit on water surfaces at different downwind distances from a spray line, and a second to measure the mortality concentration relationship for two sensitive indicator species, *Aedes aegypti* mosquito larvae and *Gammarus pseudolimnaeus* water shrimps. A mathematical model based on spray cloud dispersal measurements was used to calculate spray deposit on a water surface from multiple swath applications. Mortality in populations of the two indicator species, and rainbow trout was estimated using model results, and measured mortality–concentration relationships. As a check on the model, predicted mortality was compared with mortality measurements made in bioassays carried out during the spray trials. Downwind buffers of 15 and 230 m respectively for ground–based and aerial forestry permethrin

applications, with a.i. application rates of 35 g/ha or less would limit water shrimp mortality to about 10% in .5 m water depths. Crosswind buffers of 5 and 40 m respectively would provide similar protection.

Payne, N.; Helson, B.; Sundaram, K.; Kingsbury, P.; Fleming, R.; de Groot, P. 1988. Délimitation des zones–tampons autour des plans d'eau lors des épandages de perméthrine. Serv. Can. For., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–70F.

La présente étude a été entreprise en vue d' élaborer une démarche scientifique et de réunir des données devant servir à la délimitation des zones tampons devant être établies pour les épandages de perméthrine sur les forêts. Les épandages au sol et aériens ont été étudiés séparément en raison des différences importantes entre les deux, par exemple la hauteur de libération du nuage de gouttelettes, qui donne lieu à une dispersion différente de l'insecticide. Vu la multiplicité des zones tampons requises pour différentes conditions météorologiques, divers spectres de taille des goutelettes, etc., on a décidé de faire appel à un scénario raisonnable de pire éventualité et de recueillir les données pour ce scénario. Pour que les zones tampons ne soient pas excessivement larges, on a examiné, séparément, la dispersion du nuage de gouttelettes en amont, en aval et latéralement par rapport au vent. L' étude comprenait une expérience consistant à mesurer le dépôt sur l'eau à différentes distances sous le vent de la rampe de pulvérisation et une deuxième expérience visant à mesurer la relation concentration–mortalité chez deux espèces indicatrices sensibles: les larves du moustique *Aedes aegypti* et le gammare *Gammarus pseudolimnaeus*. Un modèle mathématique construit à partir des mesures de la dispersion des nuages de goutellettes a été employé pour calculer le dépôt à la surface de l'eau à la suite d'applications comportant des passages multiples. La mortalité chez les populations des deux espèces indicatrices et de la truite arc–en–ciel a été estimée à partir des résultats du modèle et des rapports établis concentration–mortalité. Aux fins de vérification du modèle, la mortalité prévue a été comparée aux résultats de bio–essais effectués durant les expériences d'arrosage. Des bandes tampons de 12 et 230 m en aval du vent respectivement pour les épandages au sol et aériens de perméthrine sur les forêts à des doses inférieures à 35 g/ha d'ingrédient actif limiteraient la mortalité des gammares à environ 10% dans des profondeurs d'eau de ,5 m. Des bandes tampons de 5 et 40 m respectivement dans le sens latéral par rapport au vent offriraient une protection similaire.

Payne, N.J.; Helson, B.V.; Sundaram, K.M.S.; Fleming, R.A. 1988. Estimating buffer zone widths for pesticide applications. Pesticide Science 24:147–161.

A technique for estimating the width of buffer zones required around sensitive areas during pesticide applications has been devised and tested. The technique has been used to estimate the buffer width required around water bodies during ground–based permethrin applications in Canadian forests to prevent significant impact on fish and their food populations. A worst–case scenario was developed for environmental impact in water bodies resulting from ground–based permethrin applications, and a spray application was made under these worst–case conditions. Permethrin deposit on ground sheets was measured downwind of overlaid crosswind swaths. From these measurements the deposit at various downwind distances from a single crosswind swath was calculated, and a curvilinear regression line fitted to these values. Permethrin deposit downwind of multiple–swath applications was computed by adding the contributions from individual swaths. Mortality resulting from various permethrin concentrations was measured for *Aedes aegypti* larvae. Although these larvae are not an important food species for the fish species of interest, salmon and trout, they are more sensitive to permethrin than most aquatic invertebrates. Predicted mortality in populations of this species and *Salmo gairdneri*, rainbow trout, at various downwind distances from the permethrin application was calculated from the toxicological and spray–cloud dispersal data. Buffer width was estimated by choosing an acceptably low mortality, and determining the downwind distance at which this value was obtained. For example,

a 20 m swath width was found to be adequate to limit mortality in *A. aegypti* and *S. gairdneri* populations to 10 and 0.1% during ground–based permethrin applications.

Payne, N.J.; Schaefer, G.W. 1986. An experimental quantification of coarse aerosol deposition on wheat. Atomisation & Spray Technology 2:45–71.

Deposit and drift were quantified for a line source of coarse aerosol (Volume Median Diameter 35–85 μm) released into neutrally stable turbulent air flow above wheat in windspeeds in the range 2–3 m/s at 1 m above canopy top. Canopy and soil deposits were measured to 40 m downwind using a fluorescent particle tracer suspended in a low volatility oil. Peak canopy deposit occurred at a downwind distance (x) of about six times spray release height (H), nearly independent of windspeed and dropsize. For x beyond 10H, canopy deposit was nearly independent of windspeed and decreased inversely proportional to x^b, b ranging from 0.9 to 1.4. The airborne fraction of the spray beyond 40 m was about 45% and 70%, for the coarser and finer drops, respectively. About 92% of drops deposited were in the top third of the canopy, with an average on ear, stem and flag leaf of about 42, 35 and 15%, respectively, nearly independent of windspeed, dropsize and release height. Soil deposit was typically 3% of canopy deposit. Inertial impaction was the dominant deposition mechanism. The results are discussed in relation to economics of control, efficacy of crop protection and environmental impact.

Percy, J.; Kuhn, K.L.; Kalthoff, K. 1986. Scanning electron microscopic analysis of spontaneous and UV–induced abnormal segment patterns in *Chironomus samoensis* (Diptera: Chironomidae). Roux's Arch. Dev. Biol. 195:92–102.

The embryonic body pattern of *Chironomus samoensis*, as well as other chironomids, can be altered dramatically by irradiating their eggs with ultraviolet light (UV). Anterior UV irradiation leads to the formation of double abdomen embryos whose anterior segments are replaced by posterior segments with reversed polarity. Most double abdomens are symmetrical showing a mirror image duplication of the posterior six or seven segments. However, in some cases the anterior end of the double abdomen is shorter, and comprises fewer segments, than its posterior counterpart. These asymmetries range from moderate to extreme. They involve the juxtaposition, at the plane of polarity reversal, of disparate segments. The same range of symmetrical and asymmetrical double abdomens is also formed spontaneously in an apparent mutant strain of *C. samoensis*. There are striking similarities between this natural variant and the *Drosophila melanogaster* mutant bicaudal, which are also discussed with respect to models of embryonic pattern formation.

Percy, J.; Wacker, K.; Kalthoff, K. 1985. Pattern discontinuities in apparent mutant, spontaneous double abdomen, of *Chironomus* sp. Texas Journal of Science 37:106–107.

Percy–Cunningham, J; Nicholson, D.; Retnakaran, A. 1987. The effect of ingested benzoylphenylurea on the ultrastructure of the cuticle deposited during the last larval instar of *Choristoneura fumiferana* Clem. (Lepidoptera: Tortricidae). Can. J. Zool. 65:2715–2723.

The sequential ultrastructural changes induced by the ingestion of a sublethal dose of a benzoylphenylurea, chlorfluazuron, were investigated in sixth–instar larvae of the spruce budworm, *Choristoneura fumiferana*. The 4–day–old, postecdysis larvae showed the most profound ultrastructural effects. The newly formed endocuticle showed an absence of lamellae, indicating the lack of formation of chitin microfibrils. Vacuolated and fibrous areas containing an amorphous material, possibly proteinaceous, were observed in the region where lamellae would normally be present. The epidermal cells had microvilli with swollen and rounded tips. These cells also contained oval vesicles containing granular amorphous material. The *in vivo* inhibition of chitin deposition by this benzoylphenylurea was readily apparent. It is suggested that the amorphous material observed in the zone where chitin was lacking is

the protein component of the glycoprotein chitin. It is possible that the benzoylphenylurea inhibits the assembly of the amino sugar with the protein to form microfibrils.

La séquence des changements ultrastructuraux générés par une ingestion d'une dose sublétale d' une benzoylphénylurée, le chlorflauzuron, pu être suivie chez des larves de sixième stade de la tordeuse des bourgeons de l' épinette, *Choristoneura fumiferana*. C'est chez les larves 4 jours après la mue que se produisent les changements ultrastructuraux les plus importants. La nouvelle endocuticule ne possède pas de lamelles, ce qui indique qu'il ne se forme pas de microfibrilles de chitine. Dans les régions où se trouvent normalement les fibrilles, il y a plutôt des zones fibreuses et vacuolées qui contiennent un matériaux amorphe, peut– être de nature protéinique. Les cellules épidermiques portent des microvillosités à bouts enflés et arrondis et contiennent des vésicules ovales remplies de matériel amorphe granulaire. L'inhibition *in vivo* de la formation de chitine par cette benzoylphénylurée est assez évidente. La substance amorphe qui se retrouve l à où la chitine fait défaut est probablement la composante protéinique de la chitine qui est une glycoprotéine. Il se peut que la benzoylphénylurée inhibe la jonction entre le glucide aminé et la protéine qui forment les microfibrilles.

Perry, D.F.; Fleming, R.A. 1989. *Erynia crustosa* zygospore germination. Mycologia 81:154–158.

Perry, D.F.; Fleming, R.A. 1989. The timing of *Erynia radicans* resting spore germination in relation to mycosis of *Choristoneura fumiferana*. Can. J. Bot. 67:1657–1663.

Resting spores of *Erynia radicans* germinate after storage for over 2 months at 4°C or by natural overwintering. Percent germination increases with spore age to a maximum of 77% after 8 months at 4°C. During this period, the temperature limits for germination changed from 8–20°C at 3 months to 4–32°C after 8 months at 4°C. Germination time (mean and variance) decreases with spore age. Maximum percent germination and mean germination time decrease as post storage temperature increases. Variance is stable from 12 to 20°C, but increases at post storage temperature extremes. No differences in mean germination time were found in isolates, although differences in maximum percent germination and variance in mean germination time were observed. The resting spore population responses to temperature during storage (overwintering) and at post storage temperatures (spring and summer) act to synchronize the presence of an active inoculum with that of the insect host when conidia are most infective. Entomophthorales mycosis and epizootics occur during fifth and sixth larval instars of *Choristoneura fumiferana*. The timing of events in the life cycle of entomophthoralean fungi with respect to that of host populations is discussed for the spruce budworm, *E. radicans*, and other fungal parasite–insect systems.

Les spores de repos de l'*Erynia radicans* germent après un passage au froid de deux mois à 4°C ou après vernalisation naturelle. Le pourcentage de germination augmente avec l' âge des spores pour atteindre un maximum de 77% après 8 mois à 4°C. Pendant cette période les températures limites qui permettent la germination passent de 8–20°C après 3 mois, à 4–32°C après 8 mois à 4°C. Le temps moyen de germination et la variance diminuent avec l'âge des spores. Le pourcentage maximum et le temps moyen de germination diminuent avec une augmentation de la température après la vernalisation. La variance est stable de 12 à 20°C, mais augmente aux température post–vernalisation extrêmes. Il n'y a pas de différence entre les temps moyens de vernalisation entre les isolats, bien qu'on observe des différences dans le pourcentage maximum et la variance du temps de germination moyens. Les réactions à la température des populations de spores de repos pendant la vernalisation ainsi que celles qui surviennent par la suite (printemps et été) permettent la synchronisation de la présence d'inoculums actifs avec celle de l'insecte hôte au moment où les conidies sont les plus infectieuses. Les mycoses et les épizooties chez les Entomophthorales surviennent au sixième stade larvaire du *Choristoneura fumiferana*. L'auteur discute la chronologie des étapes du cycle vital des champignons appar-

tenant aux Entomopthorales par rapport aux populations de l'hôte dans de système tordeuse des bourgeon de l' épinette, *E. radicans*, ainsi dans d'autres systèmes champignons parasites – insectes.

Picot, J.J.C.; van Vliet, M.W.; Payne, N.J.; Kristmanson, D.D. 1990. Characterization of aerial spray nozzles with laser light–scattering and imaging probes and flash photography. pp. 142–150 In: E.D. Hirleman, W.D. Bachalo, P.G. Felton, eds. Liquid Particle Size Measurement Techniques: 2nd Volume, ASTM STP 1083. American Society for Testing and Materials, Philadelphia PA.

Laser light–scattering and imaging probes plus a flash photography system were used to count and measure droplets from a multiple–jet, nozzle–in–boom system with the jets facing downstream in an airflow. Tests were done in a laminar flow wind tunnel. The method of incorporating data from these different measuring systems is explained. The droplet diameter range measured was from 0.5 to 3600 µm. Tests cover air speeds ranging from 11 to 54 m/s, fluid flows from 1.8 to 8.8 L/min per nozzle, for 10– to 30–jet arrays per nozzle with jet inside diameters (ID) from .76 to 1.8 mm.

A correlation obtained for the volume median diameters from 14 tests shows good agreement with experimental data, for the single fluid studied:

$$\log_{10} [D_{v.0.5}/d_0] = 3.71 - 0.303 \log_{10} Re - 0.746 \log_{10} We$$

where d_0 is the jet ID, Re is defined for the flow through a single nozzle, and We is based on d_0 and the relative velocity of liquid to gas at the nozzle.

Picot, J.J.C.; van Vliet, M.W.; Payne, N.J. 1989. Droplet size characteristics for insecticide and herbicide spray atomizers. Can. J. Chem. Eng. 67: 752–761.

Rotary atomizers and hydraulic nozzles used in forestry spraying were extensively tested with laser light scattering, laser light imaging, and photographic methods in a specially designed wind tunnel. Data on droplet size distribution and cumulative volume fraction versus droplet size are given. Correlation for reduced volume median diameter ($D_{v,0.5}/d_o$) and reduced span ($D_{v,0.9} - D_{v,0.1}/d_o$) are presented. Accuracy of prediction is of the order of 20% for hydraulic nozzle volume median diameter. Accuracy of prediction for high–speed rotating wire mesh atomizers is of the order of 35% for the volume median diameter. When these accuracies are inadequate, a specific test of the device in question is recommended.

Des atomiseurs rotatifs et des injecteurs hydrauliques utilisés dans la vaporisation forestière ont été soumis à une série d'essais en souflerie spécialement conçue et effectués à partir de la diffusion de la lumière, de la mise en image au laser et des méthodes photographiques. On présente des données sur la distribution de taille des gouttes et la fraction de volume cumulatif par rapport à taille des gouttes. Des corrélations pour le diamètre moyen de volume réduit ($D_{v,0.5}/d_o$) et l'intervalle réduit ($D_{v,0.9} - D_{v,0.1}/d_o$) sont également présentées. L'exactitude des prédictions est de l'ordre de 20% pour le diamètre moyen de volume des injecteurs hydrauliques. L'exactitude de prédiction pour les atomiseurs à mailles métalliques en rotation à haute vitesse est de l'ordre de 35% pour le diamètre moyen du volume. Lorsque cette précision est insuffisante, on recommande d'effectuer un essai sur le système en question.

Pitt, D.G., Reynolds, P.E.; Roden, M.J. 1988. Growth and tolerance of white spruce after site preparation with liquid hexazinone. Proceedings of the Northeastern Weed Science Society (Supplement) 42:41–47.

Three rates of hexazinone (2, 3, and 4 kg ai/ha) were aerially applied to a 3–year old, unplanted, New Brunswick cutover in May 1984. Bare–root 2+1 white spruce [*Picea glauca* (Moench) Voss] were subsequently planted in the area in May 1985. In August 1987, 300 trees were randomly selected from within the treated and untreated portions of the block and assessed for health, root–collar diame-

ter, and height (including back measurements to 1984). As well, the percent covers of raspberry [*Rubus idaeus* L. var. *strigosus* (Michx.) Maxim.], fireweed (*Epilobium angustifolium* L.), and grass were recorded within a 1–m radius of each of the trees assessed.

Crop trees in the treated areas were not only rated as being healthier than those in the untreated areas, but were found to have gained a 31% advantage in height, 127% advantage in height increment, and a 27% advantage in root–collar diameter. There were no statistical differences between the rates with respect to health or growth of the crop.

The herbicide treatment has, over the 3–year period, resulted in a dramatic reduction in raspberry cover (75% control vs. 15% treated) and an equally dramatic increase in fireweed cover (13% control vs. 40% treated). Grass cover appeared to remain constant (at 14%) whether the area was treated or not. The relative percent covers of raspberry and fireweed were found to be strongly correlated to the growth and health of the crop. Increases in raspberry cover were directly correlated to decreases in growth and health of the crop. Conversely, increases in fireweed cover were directly correlated to increases in crop height, height increment, diameter, and health. Fireweed cover and nitrate accumulation may provide some explanation for this.

It was concluded that the hexazinone site–preparation treatment was successful in enhancing white spruce growth and health through the reduction of raspberry competition and the stimulation of fireweed.

Pitt, D.G., Reynolds, P.E.; Roden, M.J.1988. Weed efficacy after site prep with liquid and dry–flowable hexazinone formulations. Proceedings of the Northeastern Weed Science Society (Supplement) 42:58–62

Hexazinone (2 kg AI/ha) was aerially applied to a 1–year old, unplanted, New Brunswick clearcut in June 1987, using a Bell 206B helicopter equipped with a Simplex conventional boom and nozzle for spraying liquid hexazinone or a modified Simplex seeder, slung from the aircraft, for dispersing dry–flowable hexazinone. Prior to treatment, and again in August 1987, percent cover and health of live raspberry [*Rubus idaeus* L. var. *strigosus* (Michx.) Maxim.], grass, and fireweed (*Epilobium angustifolium* L.) were measured for all replicate treatments, inclusive of untreated control areas.

Both liquid and dry–flowable formulations of hexazinone effectively controlled raspberry, grass, and fireweed. For all weed species, cover was reduced by 19 to 98 percent by hexazinone treatment, whereas cover increased by 49 to 200 percent in untreated areas. Statistical differences in the performance of the two formulations were observed for all three weed species one growing season following treatment. Specifically, treatment differences were noted in terms of post–treatment cover for fireweed and grass and post–treatment herbicide injury for raspberry and fireweed. Percent control and herbicide damage were greater and less variable with the liquid formulation than with the dry–flowable formulation. Control with liquid hexazinone was approximately 1.5 to 3 times greater than that achieved with dry–flowable hexazinone. It is believed that better performance of the liquid formulation can be attributed to more consistent distribution of the active ingredient.

Pitt, D.G.; Reynolds, P.E.; Roden, M.J. 1989. Crop tolerance and herbicide efficacy after site prep with liquid and dry–flowable hexazinone formulations. Proceedings of the Northwestern Weed Science Society (Supplement) 43:37–43.

Hexazinone (2 kg ai/ha) was aerially applied to a 1–year old, unplanted, New Brunswick clearcut in June 1987, with a Bell 206B helicopter equipped with a Simplex conventional boom and nozzles for spraying liquid hexazinone and a modified Simplex seeder, slung from the same aircraft, for dispersing dry–flowable hexazinone. Prior to treatment, and again in August 1987 and 1988, percent cover and health of raspberry [*Rubus idaeus* L. var. *strigosus* (Michx.) Maxim.], grass, and fireweed (*Epilobium angustifolium* L.) were measured for all replicate treatments, inclusive of untreated control areas. Black spruce [*Picea mariana* (Mill.) B.S.P.] container stock (Multipot 45) was planted in each repli-

cate in August 1987 and 1988. Health values for these trees were recorded at the time of planting and, for 1987 trees, one growing season later.

Both formulations of hexazinone effectively controlled raspberry and fireweed through two growing seasons after application. In August 1988, raspberry and fireweed covers in the treated areas were only 24% and 35% of what they were in untreated areas, respectively. Percent reduction in cover and damage values for these species tended to be greater in the liquid plots than in the dry–flowable plots. However, two years after treatment, these differences between formulations are relatively small and probably insignificant from an operational standpoint. After two growing seasons, grass cover was approximately 11% in both the treated and untreated plots.

Condition of black spruce container stock, near perfect at the time of planting, declined slightly through the first growing season. This decline occurred in all treatments in the same manner (including untreated blocks). Treatment–related health problems could not be detected in these trees after one growing season.

Prasad, R.; Feng, J.C. 1990. Spotgun–applied hexazinone: release of red pine (*Pinus resinosa*) from quaking aspen (*Populus tremuloides*) competition and residue persistence in soil. Weed Technology 4: 371–375.

Weed control and red pine release by spotgun–applied hexazinone in a northern Ontario plantation were evaluated 3 yr after treatment, while hexazinone residues and lateral movement in the sandy loam soil were determined 1 yr after treatment. Hexazinone, grid pattern spot applied at 480 mg ai/spot, approximating 1.6 kg ai/ha, resulted in 88% quaking aspen stem dieback and variable suppression of white birch and pin cherry. The height and basal diameter of treated red pine were 131 and 150 % of control, respectively, after 3 yr. Hexazinone residues were reduced to 1% at the treated spot and did not move laterally beyond 0.5 m, 1 yr after treatment. Detection of small amounts of metabolites A and B (0.2 and 0.3%) indicated the non–cumulative degradation of hexazinone in soils.

Régnière, J.; Boulet, G.; Turgeon, J.J. 1988. Sequential sampling plan with two criteria levels for the spruce budmoth, *Zeiraphera canadensis* (Lepidoptera: Tortricidae). J. Econ. Entomol. 81: 220–224.

Régnière, J.; Turgeon, J.J. 1989. Temperature–dependent development of *Zeiraphera canadensis* (Lepidoptera: Tortricidae) and simulation of its phenology. Entomol exp. & appl. 50: 185–193.

Retnakaran, A. 1986. Chitin biosynthesis in insects and its disruption as a means of pest control. pp. 147–163 In: R. Muzzarelli, C. Jeuniaux, G. Gooday, Eds. Chitin in Nature and Technology, Plenum Press.

Retnakaran, A.; Ennis, T.J. 1985. *In vitro* mutagenicity testing of a potent, new, benzoyl urea insect growth regulator. Experientia 41:1464–1465.

Bacterial mutagenicity assay to detect potential chronic toxicity of a potent, new, benzoyl urea insect growth regulator (CGA–112913 OR IKI–7899, Formerly UC–62644) was conducted using 5 histidine auxotrophs of *Salmonella typhimurium*. Tests within the concentration range of 0.9–500 µg (saturating)/plate of the compound with and without the 5–9 mammalian metabolic activation system showed no mutagenic effects clearing the way for long–term chronic toxicology studies.

Retnakaran, A.; MacDonald, A.; Nicholson, D.; Percy–Cunningham, J. 1989. Ultrastructural and autoradiographic investigations of the interference of Chlorfluazuron with cuticle differentiation in the spruce budworm, *Choristoneura fumiferana*. Pestic. Biochem. & Physiol. 35: 172–184.

A time course study of the ultrastructural and autoradiographic effects of a sublethal dose of chlorfluazuron (a benzoylphenyl urea–insect growth regulator) on sixth–instar spruce budworm, *Choristoneura fumiferana*, which has a stadial length of about 8 days, was conducted to understand the mode of action of benzoylphenyl ureas. The effect of the compound was evident at 48 h, but reached a dramatic level at 60 h, and at 72 h the larvae showed signs of recovery. Accumulation of large numbers of vesicles and loss of microvilli together with the plasma membrane plaque were characteristic effects. Vesicle accumulation could indicate blockage of material being transported outside the epidermal cell, during some stage of post–translational processing, but the exact location of the blockage was not evident. Autoradiographic studies confirmed most of the ultrastructural observations.

Retnakaran, A; Raske, A.G.; West, R.J.; Lim, K.P.; Sundaram, A. 1988. Evaluation of diflubenzuron as a control agent for hemlock looper (Lepidoptera: Geometridae). J. Econ. Entomol. 81:1698–1705.

Diflubenzuron, a benzoylphenyl urea that selectively inhibits chitin synthesis in insect larvae upon ingestion, was aerially applied on an infestation of hemlock looper, *Lambdina fiscellaria fiscellaria* (Guenée), in a stand of balsam fir, *Abies balsamea* (L.), near Bay D'Espoir, Newfoundland. A single application of 70 g (AI) in 4.7 liters/ha, applied when 75% of the larvae were in the second instar, resulted in 92% reduction in pupal population, but when the same amount was applied twice, 2 wk apart, both larval and pupal populations were reduced by >99%. A double application of diflubenzuron at the rate of 70 g (AI)/ 4.7 liters per hectare is recommended for the effective control of the hemlock looper. Merits of spraying at an earlier stage of insect development to obtain better foliage protection, and the use of lower volume rate to increase the payload of the aircraft, are discussed.

Retnakaran, A.; Wright, J.E. 1987. Control of insect pests with benzoylphenyl ureas. Chapter 9 In : J.E. Wright & A. Retnakaran, Eds. Chitin and Benzoylphenyl Ureas. Dordrecht: Dr. W. Junk publishers.

Reynolds, P.E.; King, K.; Whitehead, R.; MacKay, T.S. 1986. One year results for a coastal British Columbia glyphosate conifer release trial. Proceedings of the Western Society of Weed Science 39: 107–117.

In early September 1984, portions of the Carnation Creek watershed, located on the west coast of Vancouver Island 48°54'N, 125°01'W), were aerially treated with 2 kg ai/ha of glyphosate [N–(phosponomethyl) glycine] using a Bell-47 helicopter equipped with a Microfoil Boom to minimize herbicide drift into an adjoining salmon-bearing stream. Since 1970, the watershed has been a focal point for interagency cooperative research designed to assess the effects of forest practices (i.e., harvesting, prescribed burning, herbicide use) on resident salmonid fish populations. The present herbicide study was undertaken in support of this overall objective. From 1975 to 1981, portions of the watershed were logged, and various post-harvesting silvicultural treatments, inclusive of scarification, prescribed burning and planting, were carried out commencing in the fall of 1976 and continuing through the spring of 1983. Crop species planted consisted of sitka spruce [*Picea sitchensis* (Bong.) Carr.], western hemlock *[Tsuga heterophylla* (Raf.) Sarg.], western red cedar (*Thuja plicata* Donn), Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco.], amabilis fir *[Abies amabilis* (Dougl.) Forbes.] and some grand fir *(Abies grandis*). Notable hemlock, cedar, and amabilis fir natural regeneration occurred following harvesting. Prior to glyphosate treatment, major weed competition consisted of red alder *(Alnus rubra* Bong.) and salmonberry (*Rubus spectabilis* Pursh.). Herbicide efficacy following a glyphosate treatment was species dependent, being generally high for most species present. Although salmonberry control was quite satisfactory after one post-spray growing season, control of red alder was quite variable, ranging from no control (i.e. completely healthy) to total control (i.e., totally dead). Salal (*Gaultheria shallow* Pursh.) was uncontrolled by the herbicide treatment. Despite variable alder control through the 45 ha treated watershed, higher alder control was observed on upslope microsites as con-

trasted with alders growing throughout the watershed valley bottom. A similar trend was noted for other important weed species including salmonberry, thimbleberry (*Rubus parviflorus* Nutt.), stink currant (*Ribes bracteosum* Dougl.), and three fern species. The trend suggests that certain weed species growing on upslope microsites may be more physiologically stressed, and more susceptible to herbicide damage. The same weed species growing on valley bottom sites may be less stressed and more resistant to herbicide damage. Some minor crop tree injury resulted following glyphosate treatment for western hemlock and to a lesser extent for western cedar. Initial injury consisted of death or dieback of the primary leader and was unobserved for other crop trees (i.e., sitka spruce, amabilis fir and Douglas fir) present. After one year, trees exhibiting initial injury showed full recovery with the damaged primary leader replaced by a more vigorously growing lateral.

Height growth for the hemlock or cedar laterals, assuming dominance in 1985, far exceeded 1984 height growth for the original primary leader, often being upwards of two times the length of the original leader. A similar height growth increase was not observed for treated sitka spruce. However, height growth response for untreated hemlock, cedar and spruce was site variable. A slight decrease in growth was observed for hemlock in 1985, whereas untreated cedar showed an increase in growth for 1985. Height growth for untreated spruce declined in 1984 from 1983, but increased in 1985 over that observed in 1984. Although height growth increases were observed for treated amabilis fir and Douglas fir in 1985, only a limited number of individuals were measured, and no untreated individuals were observed. The variability in height growth response of untreated crop trees confirms that additional growth measurements are necessary in 1986 and subsequent years to substantiate the apparent dramatic height growth increase noted for treated hemlock and cedar in 1985. Continued monitoring of crop tree growth response may ultimately demonstrate that other species such as sitka spruce also show a growth response to herbicide treatment.

Reynolds, P.E.; MacKay, T.S.; McCormack, M.L., Jr. 1986. Results of a hexazinone–mechanical site preparation trial. Proceedings of the Northeastern Weed Science Society 40: 222–229.

Three rates (2, 3, 4 kg/ha of hexazinone were aerially applied to a three–year–old, unplanted, New Brunswick clearcut site in late May, 1984. Prior to treatment, the area had not been mechanically site prepared, and was heavily covered with slash and numerous residual snags from the previous northern hardwoods forest. Following herbicide treatment, the site was mechanically site prepared in April 1985 using a 125–ton Letourneau crusher to fell snags and break up residual logging slash. In May 1985, the site was planted with bareroot 2+1 white spruce [*Picea glauca* (Moench) Voss] nursery stock. Assessments of herbicide efficacy following the two treatment were made in August 1984 and early September 1985. The soil-applied hexazinone treatment provided excellent control of the major weed competitor, raspberry [*Rubus idaeus* L. var. *strigosus* (Michx.) Maxim], at the lowest rate (i.e., 2 kg/ha). Crushing the chemically treated site increased raspberry cover in a number of vegetation sample quadrats, demonstrating that mechanical preparation after chemical treatment exacerbates the weed problem. Other brush species (i.e., northern hardwoods) were poorly controlled by hexazinone treatment alone. However, hardwoods that were chemically treated and crushed exhibited greater weed control than hardwoods that were crushed but not treated with hexazinone. Since hexazinone enhanced hardwood control beyond that obtained by crushing alone, it is likely that crushing in advance of chemical treatment would have increased hardwood control while precluding any enhancement of the raspberry competition. No notable injury was observed for white spruce planted after crushing in 1985. By contrast, naturally regenerated balsam fir *[Abies balsamea* (L.)Mill] sustained notable injury following crushing.

Reynolds, P.E.; MacKay, T.S.; McCormack, M.L., Jr. 1986. One year results for a hexazinone conifer release trial. Proceeding of the Northeastern Weed Science Society 40: 218–221.

Three rates (2, 3, 4 kg/ha of hexazinone were aerially applied to a two-year-old New Brunswick black spruce [*Picea mariana* (Mill.) B.S.P.] plantation in late August 1984. Prior to treatment, major forest weed competition was approximately 1 meter (m) in height and consisted of raspberry [*Rubus idaeus* L. var. *strigosus* (Michx.) Maxim.] and several northern hardwoods (maple, birch, aspen). Foliar application of hexazinone was generally unsuccessful in controlling these forest weeds present, at all treatment rates, except for raspberry, pin cherry (*Prunus pensylvanica* L.f.), striped maple (*Acer pensylvanicum* L.). Despite poor hardwood control, an interesting trend of control for maple species present was noted. Control was greatest for striped maple followed sequentially by mountain maple (*Acer spicatus* Lam.), red maple (*Acer rubrum* L.), and sugar maple (*Acer saccharum* Marsh.). At the two higher rates, some minor injury was noted for the two–year-old 2+2 black spruce stock. No injury was observed, at any of the rates, for naturally regenerated balsam fir [*Abies balsamea* (L.) Mill.] present in the treated areas.

Reynolds, P.E., Pitt, D.G.; Roden, M.J. 1988. Weed efficacy and crop tolerance after site prep with liquid and granular hexazinone formulations. Proceedings of the Northwestern Weed Science Society (Supplement) 42:74–78.

Hexazinone was soil–applied to a 2–year old, unplanted, new Brunswick clearcut in May 1986 at three rates (1, 2 and 4 kg ai/ha), using skidders equipped for ground spraying of liquid hexazinone or fitted with a hydraulic blower unit (OMNI system) designed for ground distribution of granular hexazinone. Half of the herbicide–treated area was planted with 2+2 bare–root black spruce [*Picea mariana* (Mill.) B.S.P.] in June 1986. The other half of the treated area was planted with similar nursery stock in June 1987. In August, 1986 and 1987, percent cover and health of live raspberry and grass were measured for all replicated treatments, inclusive of untreated controls. Concurrent measurements of crop tolerance were made on 480 and 960 randomly selected crop trees in August 1986 and 1987, respectively.

Both liquid and granular formulations of hexazinone effectively controlled unwanted raspberry and grass. There were no statistical differences in the performance of the two formulations. In addition, there were no statistical differences in the performance of the two different granular formulations tested (5 and 10%). Control at the 1 kg rate was not as effective as control at the 2 or 4 kg rates. After two growing seasons, percent cover increased and health improved for both competitors in the treated areas, but to a much lesser extent than in the untreated areas.

Injury to trees planted immediately following herbicide treatment was very minor and temporary and did not differ statistically from trees planted into untreated areas. There were no statistical differences in crop injury caused by the two formulations (liquid or granular) for trees planted immediately after herbicide treatment or one year after treatment. Similarly, there were no statistical differences in crop injury caused by the two granular formulations (5 or 10%), regardless of planting time. Results confirm that crop trees may be safely planted immediately after treatment.

Reynolds, P.E., Pitt, D.G.; Roden, M.J. 1988. Weed efficacy and crop tolerance after site prep with sulfometuron–methyl and metsulfuron–methyl. Proceedings of the Northeastern Weed Science Society (Supplement) 42:63–67.

Sulfometuron–methyl (150, 300, and 450 g AI/ha) and metsulfuron–methyl (36 and 72 g ai/ha) were soil–applied to a 2–year old, unplanted New Brunswick clearcut in May 1986 using a skidder equipped for ground spraying liquid herbicide. Half of the herbicide–treated site was planted with 2+2, bareroot black spruce [*Picea mariana* (Mill.) B.S.P.] in June 1986. The other half of the herbicide–treated site was planted with similar nursery stock in June 1987. In August 1986 and 1987, percent

cover and health of live raspberry and grass were measured for all replicated treatments, inclusive of untreated controls. Concurrent measurements of crop tolerance were made for 480 spruce in August 1986 and for 960 spruce in August 1987.

Both herbicides effectively controlled unwanted raspberry and grass, although better weed control was achieved with sulfometuron–methyl. There were statistical differences in the performance of the two herbicides. Raspberry herbicide damage was greatest, one and two growing seasons after treatment, for blocks treated with sulfometuron–methyl at 300 and 450 g ai/ha. Raspberry cover increased after two growing seasons for nearly all herbicide rate combinations, except for sulfometuron–methyl at 300 g ai/ha. This increase in raspberry cover, during the second growing season, was greatest for metsulfuron–methyl, increasing nearly five–fold. All herbicide treatments sustained high grass herbicide damage one growing season after treatment. After two growing seasons, grass herbicide damage remained very high for sulfometuron–methyl treatments, but was not observed for metsulfuron–methyl treatments. Grass cover was lowest for blocks treated with sulfometuron–methyl and increased most after two growing seasons for blocks treated with metsulfuron–methyl. Metsulfuron–methyl retarded grass growth. In untreated blocks, both raspberry and grass cover increased dramatically after two growing seasons.

The health of trees planted one year after herbicide treatment did not differ statistically from that of trees planted into untreated areas. However, injury to trees planted immediately after herbicide treatment was statistically significant. Injury was greatest for the higher herbicide rates. Overall, metsulfuron–methyl appeared to cause slightly less crop injury than sulfometuron–methyl, however, this difference was not significant. A comparison of crop injury, first versus second growing season, for trees planted in 1986, revealed no statistically significant differences. A similar comparison of crop injury, first season only, for trees planted in 1986 and 1987 revealed several significant differences. These were confined to sulfometuron–methyl (all rates) and to the lower rate of metsulfuron–methyl. Results confirm that crop trees may be safely planted one year after treatment.

Reynolds, P.E.; Pitt, D.G.; Roden, M.J. 1989. Crop tolerance after spring soil treatment with hexazinone, sulfometuron–methyl and metsulfuron–methyl. Proceedings of the Northeastern Weed Science Society (Supplement) 43:51–57.

Hexazinone (1, 2 and 4 kg AI/ha), sulfometuron–methyl (150, 300 and 450 g AI/ha) and metsulfuron–methyl (36 and 72 g AI/ha) were applied to the soil in a 2–year old, unplanted New Brunswick clearcut in May 1986 with skidders equipped for spraying liquid herbicides or fitted with a hydraulic blower unit (OMNI system) designed for distribution of granular hexazinone. Half of the herbicide–treated area was planted with 2+2, bareroot black spruce [*Picea mariana* (Mill.) B.S.P.] in June 1986. The other half of the treated area was planted with similar nursery stock in June 1987. Measurements of crop tolerance were made for 960 spruce in August 1986 and for 1920 spruce in August 1987 and 1988.

Injury to trees planted immediately following hexazinone treatment (1986 trees) was minor during the first growing season and did not differ statistically from trees planted into untreated areas. The health of these trees improved through the second and third growing seasons. Mortality of these trees was up to 3% greater than control spruce in 1986 and percent mortality increased over time, up to 23% in 1988. By contrast, injury to spruce planted immediately after sulfometuron–methyl (S–M) or metsulfuron–methyl (M–M) treatment (1986 trees) was statistically significant during the first growing season. The health of these trees generally improved after the second growing season, except those planted into plots that had been treated with granular hexazinone at 4 kg AI/ha. Mortality of the trees planted into hexazinone areas was up to 3% greater than control spruce after the first growing season, and in two instances (granular hexazinone at 4 kg AI/ha and liquid hexazinone at 2 kg AI/ha) increased respectively to 19 and 8% greater than control spruce after the second growing season. By contrast, mortality for spruce planted in 1987 into S–M or M–M areas was generally less than that observed for control trees after the first and second growing seasons. For hexazinone, black spruce 2+2, bareroot

stock may be safely planted one year after herbicide treatment at rates less than or equal to 2 kg AI/ha; for S–M and M–M, planting should be delayed for one year following herbicide treatment.

Reynolds, P.E.; Pitt, D.G.; Roden, M.J. 1989. Herbicide efficacy and crop tolerance after fall soil treatment with liquid and granular hexazinone. Proceedings of the Northeastern Weed Science Society(Supplement) 43:30–36.

Hexazinone (2 kg ai/ha) was applied to the soil in a 2–year old, unplanted New Brunswick clearcut in September 1986 with skidders equipped for spraying liquid hexazinone or fitted with a hydraulic blower unit (OMNI system) designed for distribution of granular hexazinone. The site was planted with 2+2, bareroot black spruce [*Picea mariana* (Mill.) B.S.P.] in June 1987. In August 1986, 1987 and 1988, percent cover and health of raspberry [*Rubus idaeus* L. var. *strigosus* (Michx.) Maxim.] and grass were measured for all replicated treatments, inclusive of untreated controls. Concurrent measurements of crop tolerance were made for 220 spruce in June 1987, August 1987, and August 1988.

Liquid hexazinone appears to have provided better weed control than granular hexazinone. Both hexazinone formulations effectively controlled raspberry for one post–treatment growing season. Only liquid hexazinone controlled raspberry for two post–treatment growing seasons, but control declined in the second growing season. Both hexazinone formulations controlled grass for one post–treatment growing season, but neither formulation controlled grass thereafter.

Black spruce mortality increased over time. At present, there are no statistical differences in mortality for the two formulations. After two growing seasons, spruce mortality for granular hexazinone treatments did not exceed that for control trees; however, spruce mortality for liquid hexazinone treatments was 8% greater than that for control trees. At present, spruce mortality for the liquid hexazinone treatment is operationally acceptable since it is <10% greater than that observed for control trees. Continued monitoring of liquid hexazinone mortality in 1989 is warranted. If statistical differences emerge in 1989, these differences may be attributable to variability in soil coverage at time of treatment.

Reynolds, P.E.; Pitt, D.G.; Roden M.J. 1989. Herbicide efficacy and crop tolerance after summer foliar treatment with sulfometuron–methyl and metsulfuron–methyl. Proceedings of the Northeastern Weed Science Society (Supplement) 43:44–50.

Sulfometuron–methyl (150 and 300 g ai/ha) and metsulfuron–methyl (36 and 72 g ai/ha) were foliar–applied to a 2–year old, unplanted New Brunswick clearcut in August 1986 with a skidder equipped for spraying liquid herbicide. The site was planted with 2+2, bareroot black spruce [*Picea mariana* (Mill.) B.S.P.] in June 1987. In August 1986, 1987 and 1988, percent cover and health of raspberry [*Rubus idaeus* L. var. *strigosus* (Michx.) Maxim.] and grass were measured for all replicated treatments, inclusive of controls. Concurrent measurements of crop tolerance were made for 440 spruce in June 1987, August 1987, and August 1988.

Better weed control was achieved with sulfometuron–methyl (S–M). Both herbicides effectively controlled unwanted raspberry for one post–treatment growing season. Only the higher rate of S–M (300 g AI/ha) controlled raspberry for two post–treatment growing seasons. S–M satisfactorily controlled grass for two growing seasons. Metsulfuron–methyl (M–M) did not control grass, and appears to have promoted grass invasion of treated plots. For both herbicides, control of both competitors generally declined in the second post–treatment growing season.

Black spruce mortality after two growing seasons was much higher than that noted after one growing season. After two growing seasons, spruce mortality was approximately equal for the two herbicides. Mortality in treated plots ranged from 4 to 28% greater than in untreated plots. The present results suggest that foliar site preparation with S–M or M–M produces unacceptable levels of crop mortality.

Reynolds, P.E.; Pitt, D.G.; Whitehead, R.; King, K. 1989. Three–year herbicide efficacy, crop tolerance and crop growth response results for a 1984 glyphosate conifer release trial at Carnation Creek, British Columbia. pp. 141–167 In: P.E. Reynolds, ed. Proceedings of the Carnation Creek Herbicide Workshop. Forestry Canada/ British Columbia Ministry of Forests, Victoria, B. C. FRDA Report 063, 349 p.

The Carnation Creek Watershed, located on the west coast of Vancouver Island, was aerially treated with Roundup (glyphosate) from September 6 to 15, 1984 with the intent of examining environmental fate and impact of Roundup treatment on a temperate coastal rain forest. Carnation Creek presents a unique research situation: we possess a 20–year data base on its salmonid population. This data base has permitted whole life history impact assessment of the effects of numerous forest management practices, including the possible impacts of herbicide use on this resource.

Following Roundup treatment at Carnation Creek, various chemical and biological studies were conducted for up to three years post–treatment. These studies revealed no unexpected or long–term adverse effects on coho salmon or other aquatic organisms using tributaries that had been directly oversprayed with the herbicide. Residue movements within the watershed and residue inputs into the aquatic ecosystem were carefully monitored in relation to autumn and winter storms. Glyphosate residues rapidly dissipated and degraded in the natural environment. After one year, remaining residues were strongly adsorbed to organic matter, soil particles, and/or stream bottom sediments, and were deemed to be biologically unavailable.

Reynolds, P.E.; Scrivener, J.C.; Holtby, L.B.; Kingsbury, P.D. 1989. An overview of Carnation Creek herbicide study: Historical perspective, experimental protocols, and spray operations. pp. 15–26 In: P.E. Reynolds, ed. Proceedings of the Carnation Creek Herbicide Workshop. Forestry Canada/ British Columbia Ministry of Forests, Victoria, B. C. FRDA Report 063, 349 p.

Research objectives, proposals and protocols for assessing the environmental impacts of applying Roundup (glyphosate) as a control of forest brush species at Carnation Creek were agreed to in 1984 by the British Columbia Ministry of Forests, B.C. Ministry of Environment and Parks, Canadian Forestry Service, Fisheries and Oceans Canada, and the Council of Forest Industries. Carnation Creek is a 10 km^2 watershed in the high rainfall cedar–hemlock zone of coastal British Columbia, where the impacts of forestry practices on salmonids have been studied since 1970 under the Carnation Creek Experimental Watershed project. Project objectives were to improve our understanding of any impacts and the relative magnitude of clearcut logging and post–logging forestry practices on salmon and trout populations and their stream habitat. The Forest Pest Management Institute coordinated and administered the herbicide study as a component to the overall Carnation Creek Experimental Watershed project. Roundup was applied aerially at 2.0 kg/ha to 41.7 ha of the watershed in September 1984. A 10–m pesticide free zone was maintained along the stream, but two tributary swamps were oversprayed as part of the study design. Short–term direct impacts to stream water, vegetation, soils and stream biota were assessed. Long–term indirect impacts on water quality, erosion processes, and stream biota were studied until at least June 1986.

Reynolds, P.E.; Scrivener, J.C.; Holtby, L.B.; Kingsbury, P.D. 1989. A summary of Carnation Creek herbicide study results. pp. 322–334 In: P.E. Reynolds, ed. Proceedings of the Carnation Creek Herbicide Workshop. Forestry Canada/ British Columbia Ministry of Forests, Victoria, B. C. FRDA Report 063, 349 p.

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Sparks, B.D.; Sundaram, A.; Kotlyar, L.; Leung, J.W.; Curry, R.D. 1988. Physicochemical properties, atomization and deposition patterns of some Newtonian spray mixtures of glyphosate containing two spray modifier adjuvants. J. Environ. Sci. Health B23(3): 253–266.

The effect of two spray modifier adjuvants, Nalco–Trol ® and Nalco–Trol II, on physicochemical properties, spray atomization and deposition patterns was studied in a laboratory chamber. Six spray mixtures were selected with and without the two adjuvants in glyphosate formulation and water. These were atomized using spinning disc, twin fluid and hydraulic nozzles to study the droplet size spectra and deposit levels on Kromekote card/glass plate units. Physicochemical properties such as relative viscosity, surface tension, viscosity–shear rate relationship, volatility, pH, conductance, electrophoretic mobility and zeta potential of the spray mixtures were measured to determine what properties would contribute to differences in atomization and deposition patterns of the spray mixtures with and without the two adjuvants. The data indicated that the two adjuvants significantly increased the proportion of large droplets in the spray clouds produced by all three atomizers. However, the effect was more pronounced with the twin fluid and hydraulic nozzles than with the spinning disc nozzles. Among the physicochemical properties studied, surface tension, electrophoretic mobility and zeta potential could play important roles, since all other properties were very similar for the spray mixtures with and without the two adjuvants.

Sundaram, A. 1986. Understanding volatilities of forestry spray mixtures from their viscosities and viscosity–temperature relationships. pp 37–55 In: L.D. Spicer and T.M. Kaneko, eds. Pesticide Formulations and their Application Systems: 5th volume, ASTM STP 915, American Society for Testing and Materials. Philadelphia.

A simple gravimetric method was developed to determine volatilities of spray mixtures and was compared with the droplet method. The method involved evaporation of a liquid film from a filter paper surface and provided greater precision than the droplet method. It also provided a greater sensitivity in identifying small differences in the volatilities of different spray mixtures. An indirect method was also investigated to provide an understanding of the volatilities of spray mixtures from their viscosities and viscosity–temperature relationships. The data indicated an inverse relationship between the viscosity of a spray mixture and its volatility. With respect to the viscosity–temperature relationships, most spray mixtures obeyed the Arrhenius equation for the viscous flow. The exponential relationship of viscosity with the reciprocal of temperature provided a good correlation. The intercept of the equation was directly related to volatility, and the slope was inversely related to volatility.

Sundaram, A. 1987. Influence of temperature on physical properties of non–aqueous pesticide formulations and spray diluents: relevance to U.L.V. applications. Pesticide Science 20:105–118.

The viscosity, surface tension and volatility of a range of ultra–low–volume (ULV) spray diluents and pesticide formulations were measured at 5°C and 20°C. For a ULV application of 1.0 to 1.5 litre ha^{-1} through conventional boom and nozzle systems or rotary (Micronair) atomisers, it is concluded

that the spray medium should have a viscosity of ≤ 30 mPAs at 20°C. The surface tension values covered only a narrow range and showed little temperature dependence. There was no clear optimum and all surface tensions within the range measured would appear to be acceptable for ULV applications. The volatility factor, 1/(A.T 1/2), where A represents the percentage of non–volatile material in the spray mixture and T 1/2 the half–life (minutes) of evaporation, should be $<40X10^{-5}$.

Sundaram, A. 1987. Intermolecular interactions in aqueous pesticide formulations from viscosity–temperature, viscosity–volatility, and viscosity–shear rate relationships. pp. 48–67 In: D.I.B. Vander Hooven and L.D. Spicer, eds., Pesticide Formulations and Application Systems: sixth vol., ASTM STP 943, American Society for Testing and Materials, Philadelphia.

A study of viscosity–temperature, viscosity–volatility, and viscosity–shear rate relationships was carried out for aqueous formulations of pesticides and adjuvants to understand the influence of intermolecular interactions on physical properties. The data showed a general trend that highly viscous formulations exhibit high viscosity–activation energy, low volatility, and high pseudoplasticity, although there were many exceptions to this trend. The volatility data indicated that the mechanism of evaporation of water from the medium involves intermolecular forces that are different from those encountered in pseudoplastic behavior and viscosity changes with temperature. Of the four surfactants studied – Triton X–114, X–100, Atlox 3409F, and Tween 80, Triton X–114 was unique in providing highly viscous and pseudoplastic formulations. The study also showed that a highly viscous formulation with low pseudoplasticity may pose problems in flowability and fine atomization in the nozzle system. A high evaporation rate implies rapid evaporation of water from the fine droplets emitted in ULV applications, indicating the potential for off–target drift problems.

Sundaram, A. 1987. Optimizing physical properties of diluent oils for maximum target deposition of ultra–low volume spray droplets under laboratory conditions. pp. 101–122 In: D.I.B. Vander Hooven and L.D. Spicer, eds. Pesticide Formulations and Application Systems: 6th volume, ASTM STP 943. American Society for Testing and Materials. Philadelphia.

The influence of absolute viscosity, surface tension, volatility, apparent viscosity–shear rate relationship and distillation point on droplet size spectra and deposit characteristics was investigated for a wide range of petroleum and vegetable oils used in pesticide sprays, using Kromekote cards and glass plates for droplet collection. Air samplers were also used to assess the airborne concentrations of the materials. The results indicated an increasing trend in absolute viscosities and surface tensions and a decreasing trend in volatilities of the diluent oils, as their distillation points increased. However, the relative rate of increase in absolute viscosities was greater than that in surface tensions. As a result, the inverse relationship between viscosity and volatility was much more pronounced than the one between surface tension and volatility. The apparent viscosities of the volatile oils at high shear rates were much lower than those of the nonvolatile oils, indicating a marked difference in intermolecular forces of attraction. The droplet size spectra, and thus the deposit characteristics, and airborne concentrations of the diluent oils varied depending on their absolute viscosities, volatilities and apparent viscosities at high shear rates. The droplet size spectra of the highly volatile oils consisted of very small sizes, and as the volatility decreased gradually, a progressive increase in the droplet sizes and deposits was observed. The most satisfactory combination of droplet size spectra, droplets per unit area, and spray volume deposits, and that with the least amounts of airborne concentrations, was obtained with the Dowanol TPM solvent, which was also the least volatile of the eight volatile oils studied.

Sundaram, A. 1988. Droplet and deposit patterns of one pseudoplastic and three Newtonian spray mixtures following spray application under laboratory conditions. pp. 225 – 241. In: D.A. Hovde and G.B.Beestman, eds. Pesticide Formulations and Application Systems: 8th Volume, ASTM STP 980. American Society for Testing and Materials, Philadelphia.

A pseudoplastic spray mixture was prepared from fenitrothion, polymeric adjuvants and humectants. Three Newtonian spray mixtures were prepared, one each from fenitrothion, aminocarb and mexacarbate respectively, using oils, surfactants and cosolvents. The spray mixtures were sprayed over potted seedlings of balsam fir using a spinning disc atomizer, at an application rate of 1.5 L/ha. aminocarb and mexacarbate were each sprayed at 70 g active ingredient (AI) ha, whereas fenitrothion, at 210 g AI/ha. Spray droplets were sampled with Kromekote® cards and deposits were collected on glass plates. Foliar droplets were counted and pesticide concentrations were measured by gas–liquid–chromatography. Physical properties measured were: viscosity–shear rate relationship, surface tension and volatility. The data indicated that the presence of the polymeric adjuvants imparted pseudoplastic behavior to the spray medium. Because of this, the mixture provided a markedly larger droplet size spectrum and much greater deposit concentration of the insecticide both on conifer foliage and on the sampling units.

Sundaram, A. 1989. Drop size spectra, spreading, and adhesion and physical properties of eight *Bacillus thuringiensis* formulations following spray application under laboratory conditions. pp. 129–141. In: J.L. Hazen and D.A. Hovde, eds. Pesticide Formulations and Application Systems: International Aspects 9th Volume, ASTM STP 1036. American Society for Testing and Materials, Philadelphia.

Three oil–based formulations, Dipel® 6L, Dipel 8L and Dipel 12L, and five aqueous formulations, Thuricide® 48LV, Thuricide 64B, Futura® XLV, Dipel 6AF and Dipel 8AF, of *Bacillus thuringiensis* (*B.t.*) were sprayed at a dosage rate of 30 BIU per ha in a laboratory chamber using a spinning disc atomizer. The formulations were mixed with Day–Glo® fluorescent pigments to facilitate drop detection on sampling surfaces. Spray drops were sampled with Kromekote® cards and deposits were collected on glass plates. Drops were counted on balsam fir foliage of potted seedlings. Physical properties such as, viscosity, surface tension, volatility and pseudoplastic behavior, were determined for the formulations.

Spray drops of the three oil–based Dipel formulations were completely spread on Kromekote cards and fir foliage. The degree of spreading was influenced by viscosity and surface tension values. Drops of the five aqueous formulations were either totally spherical or hemispherical on all sampling surfaces, and the degree of spreading was related to surface tension and pseudoplastic behavior.

The data on drop size spectra indicated little influence from the physical properties of formulations. This is because of the differences in the application rates used. All the three oil–based Dipel formulations were non–volatile and provided 100% recovery of the spray volume on the glass plates. The four aqueous formulations, except Thuricide 64B, provided lower percent recovery of the spray volume on glass plates.

Sundaram, A. 1989. Influence of adjuvants on spray atomization, droplet size spectra, and deposits of four fenitrothion formulations. pp. 75–82 In: P.N. Chow, C.A. Grant, A.M. Hinshalwood, E. Simundsson, eds. Adjuvants and Agrochemicals, Vol. 2. Recent Development, Application and Bibliography of Agro-Adjuvants. CRC Press Inc., Boca Raton, Florida.

A study was conducted to investigate the influence of three adjuvants, viz., two surfactants (Atlox 3409F and Triton X–114) and a cosolvent (Dowanol TPM), abbreviated as Atlo–3409, Trit–114, and Dow–TPM, respectively, on spray atomization, droplet spectra, and deposit patterns of four fenitrothion formulations. Spray atomization was carried out in a laboratory chamber using a spinning disc

atomizer, and droplets were sampled with Kromekote cards and deposits were collected on glass plates. Physical properties measured were relative viscosity, surface tension, volatility, and apparent viscosity–shear rate relationship. Between the two formulations containing Atlo–3409 and Dow–TPM, the one containing 1.5% (v/v) of each adjuvant provided a higher proportion of small droplets and lower deposits than the formulation containing 1.5% of Atlo–3409 and 4% of Dow–TPM. Between the other two formulations containing Trit–114 surfactant, the one containing 7% adjuvant was more pseudoplastic than the one containing 5% adjuvant. However, both formulations provided similar $D_{N.5}$ and $D_{V.5}$, although the formulation with greater pseudoplasticity provided more droplets per square centimeter on the sample cards and greater deposits on glass plates. Thus, the droplet spectra, droplets per square centimeter, and deposits on glass plates were all relatable to the physical properties of the formulations studied.

Sundaram, A. 1990. Effect of Nalco–Trol® II on bioavailability of glyphosate in laboratory trials. J. Environ. Sci. Health B25: 309–332.

The effect of a polymeric adjuvant Nalco–Trol® II on bioavailability of glyphosate (in Roundup® formulation), was studied using trembling aspen, *Populus tremuloids* Michx., seedlings. Absorption and translocation of 14C–labeled glyphosate was determined with and without Nalco–Trol II, after application at a dosage rate of 0.35 kg of active ingredient (AI) in 25 L of aqueous solution per ha surface area of leaves. At 48 h after treatment, less than 40% of the applied amount was absorbed and translocated into the plants, and more than 60% was washed away from the treated leaves.

Toxic effects of glyphosate (nonlabeled) were assessed for a period up to 28 d after treatment using three parameters, viz., changes in plant height and weight (during 28 d) and chlorophyll content of untreated leaves (during 15 d). The glyphosate–treated plants showed little increase in height, compared to the control plants, but showed significant reduction in weight and in leaf chlorophyll.

No significant differences were noted in absorption and translocation patterns, growth parameters or leaf chlorophyll, in plants treated with Roundup alone or with Roundup with Nalco–Trol II, thus indicating no evidence of reduced bioavailability via entrapment of glyphosate into the polymeric chain. Nevertheless, the present study proved useful in detecting small differences in the sublethal effects in plants to glyphosate treatment.

Sundaram, A. 1990. Influence of two polymeric adjuvants on physical properties, droplet spreading and drying rates, and foliar uptake and translocation of glyphosate in Vision® formulation. pp. 93–107 In: L.E. Bode, J.L. Hazen and D.G. Chasin, eds. Pesticide Formulations and Application Systems: 10th volume ASTM STP 1078. American Society for Testing and Materials, Philadelphia, PA.

The effect of Sta–Put® and Silwet® L–7607 on physical properties (viscosity, surface tension and volatility), droplet spreading and drying rates, and foliar uptake and translocation of glyphosate was studied using white birch seedlings and branch tips. Three end–use mixtures were prepared using Vision®, one in water alone and the other two with 0.05% of the adjuvants in water. Physical properties were measured to examine their roles on droplet spreading and drying rates. foliar uptake was investigated to study the effect of droplet spreading and drying rates on foliar retention; and translocation was studied to examine the role of the two polymers on bioavailability of glyphosate.

The adjuvants did not contribute to marked differences in the viscosities or volatilities of the three end–use mixtures, although the surface tensions were altered to some extent. Silwet caused a marked increase in the droplet spread areas, along with a simultaneous decrease in the droplet drying time. Sta–Put did not alter any of these parameters. No simple relationship could be found between surface tensions of the mixtures and droplet spreading or drying rates. Both adjuvants contributed to an increase in the foliar uptake of glyphosate, but Silwet caused a much greater increase than Sta–Put, thus

suggesting a relationship between droplet spreading and foliar uptake. Nevertheless, there was no significant difference in the amount of glyphosate translocated between the three end–use mixtures, thus indicating no evidence of reduced bioavailability because of the presence of the two polymers at the concentration levels used in the study.

Sundaram, A.; Leung, J. 1986. A simple method to determine relative volatilities of aqueous formulations of pesticides. J. Environ. Sci. Health B21:165–190.

A simple gravimetric method was developed to determine relative volatilities of aqueous formulations of pesticides. The technique involved evaporation of a liquid film from a plastic mesh surface. The suitability of the method for volatility determination was tested against liquids of known boiling points and adjuvant solutions of different concentrations. During the initial stage of evaporation, the percentage of weight remaining at time 't' followed a nearly linear decrease with most formulations. At the second stage, however a curvilinear decrease was noted, followed by an asymptotic limit at the final stage. Regression analysis of the data obtained during the first two stages of evaporation indicated that the method is sensitive enough to identify small differences in the evaporation rates of aqueous formulations of pesticides.

Sundaram, A.; Kotlyar, L.; Sparks, B.D. 1987. Influence of surfactants and polymeric adjuvants on physicochemical properties, droplet size spectra and deposition of fenitrothion and *Bacillus thuringiensis* formulations under laboratory conditions. J. Environ. Sci. Health B22:691–720.

The effect of two surfactants and two polymeric adjuvants on droplet size spectra and deposition patterns of nine spray formulations was investigated following atomization in a laboratory chamber using a spinning disc atomizer that can produce a narrow droplet size spectrum. Spray droplets were sampled with Kromekote cards and deposit recoveries were examined on glass plates. Physicochemical properties studied were: viscosity–shear rate relationship, surface tension, volatility, pH, conductance, electrophoretic mobility and zeta potential. Formulations containing low surfactant concentrations provided Newtonian liquids with low viscosities. These liquids atomized into small droplets and provided low recoveries of spray deposits of sampling units. However, formulations containing polymeric adjuvants and a high concentration of a non–ionic surfactant provided pseudoplastic liquids with high viscosities. These formulations resulted in large droplets with high recoveries of spray deposits on sampling units. Among the physicochemical properties studied, viscosity, surface tension, volatility and electrophoretic mobility played important roles in liquid atomization and droplet deposition.

Sundaram, A.; Leung, J.W.; Curry, R.D. 1987. Influence of adjuvants on physicochemical properties, droplet size spectra and deposit patterns: relevance in pesticide applications. J. Environ. Sci. Health 22:319–346.

The influence of adjuvants on physicochemical properties, droplet size spectra and deposit patterns of five aqueous spray mixtures was studied under laboratory conditions, using two surfactants, Atlox ® 3409F and Triton ® X–114; two humectants, propylene glycol and glycerol; and one polymeric adjuvant, Agrisol ® FL–100F. For the sake of comparison, two fenitrothion formulations containing polymeric adjuvants, and water were also included in the study. Spray was applied at 25°C and 75 ±5% relative humidity, in an enclosure using a twin fluid atomizer. Deposits were collected on Kromekote card/glass plate units. Physicochemical properties studied were: relative viscosity, surface tension, apparent viscosity–shear rate relationship, volatility, pH and conductance. The first four of these properties played significant roles on the droplet and deposit patterns on sampling units. However, the chemical nature of the adjuvants also played some role. Between the two surfactants tested, Triton X–114 provided a pseudoplastic medium, but both surfactant solutions provided similar droplet

size spectra and deposit patterns. Between the two humectants, glycerol proved to be more advantageous than propylene glycol. The polymeric adjuvant provided droplet sizes similar to those of the two surfactants, although the recovery of the applied spray volume was higher. Among the two fenitrothion formulations, the one containing lower amounts of polymeric adjuvants showed some advantages, although deposits on the actual biological target should be examined before any definite conclusions can be drawn on the optimum adjuvant concentrations in end–use formulations.

Sundaram, A.; Retnakaran, A. 1987. Influence of formulation properties on droplet size spectra and ground deposits of aerially applied pesticides. Pestic. Sci. 20:241–257.

The influence of the physical properties of the spray liquid on droplet size spectra and ground deposits of aerially applied pesticides was studied using heavy (high viscosity) oil– and water–based suspensions of wettable powders (w.p.), a clear solution in a light (low viscosity) oil, and an emulsion–suspension containing a bacterial control agent. The heavy oil provided a highly viscous spray medium, 52 to 64 mPAs (at a shear rate of 480 s^{-1}), resulting in large droplet sizes and a high deposit on the ground sampling units. When the spray medium was thickened with petroleum jelly to keep the w.p. in suspension during overnight storage, the viscosity became excessively high (102 mPas at 480 s^{-1}), and the droplet spectrum was undesirably coarse and resulted in poor coverage of the spray plot and low deposits. The light oil–based solution (ca 4 mPas), provided a finer droplet spectrum and lower deposits than the heavy–oil–based formulations. The water–based suspensions of the w.p. (ca 2 mPas), showed Newtonian behaviour, whereas the emulsion–suspension (ca 240 mPas at 480 s^{-1}) showed pseudoplastic behaviour. Consequently, the emulsion–suspension provided a markedly different droplet spectrum from that of the suspensions of the w.p. Nevertheless, all three aqueous media provided deposits comparable to those of the light–oil–based solution, markedly lower than the heavy–oil–based suspensions. The study indicated that highly viscous Newtonian formulations should be avoided in pesticide applications using Micronair AU3000 atomizers at the volume rate (4.7 litre ha^{-1}) used here if high atomisation efficiency is required.

Sundaram, A.; Retnakaran, A.; Raske, A.G.; West, R.J. 1987. Effect of application rate on droplet size spectra and deposit characteristics of Dimilin spray mixtures in an aerial spray trial. pp. 104–115 In: G.B. Beestman and D.I.B. Vander Hooven, eds. Pesticide Formulations and Application Systems: 7th volume, ASTM STP 968, ASTM, Philadelphia.

The wettable powder formulation of diflubenzuron, Dimilin ® WP–25, was aerially sprayed as an aqueous suspension over four 15 ha plots in conifer forests in Newfoundland using different volume and emission rates of application. A Piper Pawnee aircraft equipped with six Micronair ® AU5000 atomizers delivered the spray mixtures. Plot P9–35/4.7 was treated with 35 g active ingredient (AI) in 4.7 L/ha, plots P10–70/4.7 and P16–70/4.7 with 70 g AI in 4.7 L/ha, and plot P11–30/2.0 with 30 g AI in 2.0 L/ha. The first three plots were each sprayed at an emission rate of 48.13 L/min, the 4th plot at 20.48 L/min. Spray droplets were sampled with Kromekote cards to determine the size spectra of the spray cloud reaching the ground level. The use of a tracer dye, Erio Acid Red, facilitated droplet measurements on the sampling cards. Glass plates were used to collect deposits of the tracer dye for colorimetric determination of the percent recovery of the spray volume emitted.

The higher emission rate of 48.13 L/min used in plots P9–35/4.7, P10–70/4.7, and P16–70/4.7 resulted in large droplets, higher droplets/cm^2, and greater recovery of the applied spray volume at ground level. The lower emission rate of 20.48 L/min used in plot P11–30/20 to accommodate the lower application rate resulted in smaller droplets, lower droplets/cm^2, and a smaller percent recovery of the spray volume on glass plates. The smaller droplets have a tendency to linger longer near the forest tree canopy, increasing the chance of impaction on the conifer needles. The lower application rate might provide a better target coverage at canopy level, with minimum ground contamination, and

warrants further field testing. The relationship between rate of application and deposit characteristics of Dimilin WP–25 is discussed.

Sundaram, A.; Sundaram, K.M.S. 1989. Influence of spray diluents on physicochemical properties, and physical and chemical compatibility of eight oil–based tank mixes of aminocarb. J. Environ. Sci. Health, B24: 1–22.

Matacil® 180F, a commercial formulation of aminocarb, was diluted with carrier diluents to provide eight different oil–based tank mixes. The diluents included three vegetable oils, Dowanol® TPM (a glycol ether), kerosine and fuel oil (mixtures of aliphatic hydrocarbons), Cyclosol® 63 (a mixture of aromatic hydrocarbons) and a 50:50 mixture of canola oil and Cyclosol 63. The interrelationships between physicochemical properties, solubility aspects, phase separation, resuspensibility of sediments, and chemical compatibility were investigated during storage for 96 h at 10°C.

Among the physicochemical properties studied, only viscosity and solubility played important roles in the physical compatibility of the tank mixes: high–viscosity diluents (vegetable oils) imparted high viscosity to the tank mixes and provided good suspensibility for the milled aminocarb particles present. The medium–viscosity diluent, Dowanol TPM, showed very high solubility for aminocarb and therefore, no phase separation problems were encountered. The two low–viscosity diluents, kerosine and fuel oil, posed some resuspensibility problems for the aminocarb particles. However, none of the diluents promoted lump formation or were chemically incompatible with aminocarb during the 96 h storage period. The study indicated that, of the diluents tested, Dowanol TPM was the most desirable diluent for Matacil 180F, followed by the three vegetable oils. The two aliphatic hydrocarbon mixtures, kerosine and fuel oil, would be the least desirable diluents for forestry applications of aminocarb insecticide.

Sundaram, A.; Sundaram, K.M.S.; Leung, J.W.; Holmes, S.B.; Cadogan, B.L. 1987. Influence of physical properties on droplet size spectra and deposit patterns of two mexacarbate formulations, following spray application under laboratory and field conditions. Pestic. Sci. 20:179–191.

The influence of viscosity, density, surface tension, volatility and apparent viscosity–shear rate relationship on droplet size spectra and deposit characteristics of two mexacarbate (4–Dimethylamino–3,5–xylyl methylcarbamate) formulations, one oil–based and one water–based, was studied following spray application under laboratory and field conditions. The oil–based formulation had a higher viscosity, a higher apparent viscosity at high shear rates and a lower volatility than the water–based formulation; application through rotary atomisers gave larger droplet sizes, more droplets cm^{-2} and deposits of AI ha^{-2} than those from the water–based formulation in both the laboratory and field studies. Both formulations had similar surface tensions and densities and, therefore, the contribution of these properties to droplet size spectra could not be determined. Of the three properties (viscosity, apparent viscosity–shear rate relationship and volatility), volatility contributed most to the deposit patterns of the two formulations.

Sundaram, A.; West, R.J.; Raske, A.G.; Retnakaran, A. 1988. Spray atomization and deposition patterns of one Newtonian and two pseudoplastic formulations after aerial application over a mature conifer forest in Newfoundland. J. Environ. Sci. Health B23:85–99.

Spray atomization and deposition patterns of three formulations were investigated in five aerial spray trials in Newfoundland to understand the inter–relationships between physical properties, drop size spectra and recovery of the spray volume at ground level. Diflubenzuron (DFB) was sprayed at 30 g active ingredient in 2.0 L/ha. Futura XLV (Fu–XLV) and Thuricide 48LV (Thu–48LV), spray formulations of *Bacillus thuringiensis* (B.t.), were both applied undiluted at 30 BIU/ha, in volume rates

of 2.1 and 2.36 L/ha respectively. Each of the three formulations was applied over a 15 ha plot using a Piper Pawnee aircraft fitted with six Micronair AU5000 atomizers. Spray drops were sampled with Kromekote cards and deposits were collected on glass plates. Physical properties measured were: viscosity at variable shear rates, volatility and surface tension. The viscosities increased progressively from low (for DFB), moderate (for Thu–48LV) to high (Fu–XLV) values, showing a gradual increase in pseudoplastic behaviour of the three formulations. The volatility data indicate an inverse relationship to the viscosities, but the surface tensions were similar for all formulations.

The highly pseudoplastic Fu–XLV atomized into the least wide drop size spectrum. The Newtonian formulation of DBF, on the other hand, atomized into the widest drop spectrum; and the moderately pseudoplastic Thu–48LV, into an intermediate drop spectrum. Thus viscosity and volatility were more important factors in liquid atomization and drop deposition, than surface tension. Among the three meteorological factors measured, relative humidity appeared more important in drop deposition than did wind speed and temperature, within the range measured.

Sundaram, K.M.S. 1985. Foliar residues of aminocarb at tree canopy and ground levels in an experimental spray operation in conifer forests. Pesticide Science 16:463–471.

Foliar residues of aminocarb were measured at tree canopy and ground levels in conifer forests in New Brunswick, Canada, following aerial application of three spray mixtures of aminocarb, one water–based, one in a volatile oil of low viscosity, and the third in a non–volatile oil of high viscosity. For a given volume rate of application, all three mixtures provided similar foliar residues at tree canopy level, but the aqueous and the volatile–oil based sprays provided significantly lower residues on cut foliage positioned at ground level, than the non–volatile oil spray mixture.

Sundaram, K.M.S. 1986. A comparative evaluation of dislodgable and penetrated residues, and persistence characteristics of aminocarb and fenitrothion, following application of several formulations onto conifer trees. J. Environ. Sci. Health B21: 539–560.

A comparative evaluation of dislodgable and penetrated residues, and persistence patterns of aminocarb and fenitrothion, was made using several formulations containing diluents with different physicochemical characteristics. Spray was applied onto single spruce trees in a tree farm in Shawville, Quebec, using a dosage rate of 90 g AI (active ingredient)/ha for aminocarb and 340 g AI/ha for fenitrothion. Droplet and deposit data were also obtained simultaneously on sampling units. The data indicated that, with both insecticides, low–volatility diluents provided larger droplets, higher deposits and foliar residues than high–volatility diluents. The rate of dissipation and persistence patterns of the dislodgable and penetrated residues were also related to the type of diluents used. However, the penetrated residues dissipated slower than the dislodgable residues, indicating their tendency to resist environmental loss by volatilization, photodegradation and leaching by rain. The amounts of dislodgable residues obtained were related to the dosage rate applied, i.e., those of aminocarb were much lower than those of fenitrothion, whereas the penetrated residues were very similar for both insecticides, suggesting a maximum limit beyond which little increase can occur by increasing the dosage rate of application.

Sundaram, K.M.S. 1986. Persistence and degradation of diflubenzuron in conifer foliage, forest litter and soil, following simulated aerial application. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Inf. Rep. FPM–X–74, 19 pp.

Persistence and degradation of diflubenzuron [1–(4–chlorophenyl)–3–(2,6–difluorobenzoyl) urea] in spruce foliage, forest litter and soil were studied under forestry conditions by applying the chemical as a simulated aerial spray in acetone (DAc) and in fuel oil:Arotex 3470 mixture (DFAr), each at 90 g AI (active ingredient) in 18L/ha. The residues of diflubenzuron in the substrates were determined by gas–liquid chromatography, after derivitization as its dimethyl analog. The highest

concentrations of the chemical in foliage, litter and soil were 30.6, 4.6 and 3.2 µg/g (fresh weight), detected at 1 h after application of the DFAr formulation. The corresponding concentrations in the three substrates were comparatively low for the DAc formulation. With both formulations, residues found in the substrates correlated well with the droplet density and deposit levels found on the Kromekote card/glass plate units placed at ground level. In soil and litter, the residues decreased more rapidly with time than those from foliage. The half–lives (in days) for the chemical in foliage, litter and soil (fresh weight) for the DAc formulation were respectively 9.3, 8.36 and 7.49; and for the DFAr formulation 12.8, 7.34 and 6.52. Forty–five days after application, the residue levels in foliage were 3.9 and .8 µg/g respectively for DFAr and DFAc formulations. The soil and litter samples did not contain detectable levels of the chemical.

Sundaram, K.M.S. 1987. Distribution, dissipation and persistence of aminocarb in aquatic components of the forest environment after aerial application of two Matacil 180F formulations. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Inf. Rep. FPM–X–78, 19 p.

The aminocarb flowable formulation, Matacil 180F, was mixed in water (180FE) and in an oil–based diluent (180FO) and both formulations were applied as double applications at 70 g (A.I.) in 1.5 liters tank mix/ha. An aircraft (TBM Avenger) equipped with 1010 flat fan (Teejet) nozzles was used to spray the insecticide over mixed mature conifer forests in eastern Canada. The amount deposited (g/ha) and the percent deposited varied considerably among the four applications. The average amount of aminocarb that deposited (g/ha) and the percent of the applied dosage found on the forest floor were 18.1 and 22.9 respectively. The emulsion formulation, 180FE, usually produced a higher deposit on the forest floor and in stream waters than the oil–based 180FO. The 1 h postspray peak concentrations of aminocarb found in stream waters sprayed with 180FO and 180FE were respectively 3.06 ppb and 22.64 ppb. The residues dissipated rapidly within 24 h. The small amount of chemical (5.8 ppb) that was found in sediment also dissipated quickly. Concentrations of aminocarb found in water–cress (880 ppb) and moss (210 ppb) were significantly higher than the peak concentrations found in the water. Peak concentrations in plants usually occurred at 1 or 3 h postspray sampling time, and in all cases decreased gradually thereafter. Highest residues in fishes were 6.1 and 13.8 ppb but they were eliminated rapidly. No mortality or behavioral changes were observed in fish. At the dosage rate used and from the data gathered, it is apparent that aminocarb does not pose any undue hazard to the aquatic environment.

Sundaram, K.M.S. 1987. Persistance et dégradation du diflubenzuron dans le feuillage des conifères, la litière et le sol suivant les essais de simulation d' épandage aérien. Serv. Can. For., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–74F, 15 p.

La persistance et la dégradation du diflubenzuron [(chloro–4 phényl)–1 (difluoro–2, 6 benzoyl)–3urée] dans le feuillage de l' épinette ainsi que dans la litière et le sol forestiers ont été étudiées dans des conditions réelles, après application de l'antiparasitaire simulant un traitement aérien, à la concentration de 90 g de matière active à raison de 18 L/ha dans l'acétone (DAc) et dans un mélange de fuel et d'Arotex 3470 (DFAr). Les résidus ont été déterminés par chromatographie en phase gazeuse, après synthèse d'un dérivé diméthylique. Les plus fortes concentrations dans le feuillage, la litière et le sol étaient de 30, 6 de 4, 60 et de 3, 20 mg/g (de poids frais), et elles ont été décelées 1 h après l'application de la préparation DFAr. Dans le cas de la préparation DAc, les concentrations correspondantes étaient relativement faibles. Dans les deux cas, les résidus retrouvés dans les substrats étaient bien corrélés à la densité des goutelettes et aux dépôts observés sur des surfaces de verre et de cartes Kromekote disposées au niveau du sol. Dans le sol et la litière, la concentration des résidus a diminué plus rapidement que dans le feuillage. La période de persistance de la préparation DAc dans le feuillage, la

litière et le sol (en poids frais) était respectivement de 9, 30, de 8, 36 et de 7, 49 jours; celle de la préparation DFAr, de 12, 8; 7, 34 et 6, 52 jours, respectivement. 45 jours après le traitement, les résidus des préparations DFAr et DFAc étaient respectivement de 3, 9 et de 0, 80 µg/g. Les échantillons de sol et de litière ne contenaient aucune quantité décelable de la substance.

Sundaram, K.M.S. 1988. Cuticular penetration and *in vivo* metabolism of fenitrothion in spruce budworm. J. Environ. Sci. Health B23: 643–659.

Oil and emulsion formulations of ^{14}C–fenitrothion were applied topically to fifth instar budworm larvae. Cuticular penetration and metabolic breakdown of the chemical were studied over a period of 300 min using thin layer chromatography and liquid scintillation counting. Rates of penetration and depletion of the external residue over time were determined (recovered by washing the treated insects with ethyl acetate). The quantity of fenitrothion penetrated was determined by macerating and extracting the tissues of washed insects with acetonitrile. Cuticular penetration of the chemical was higher for the oil than for the emulsion formulation. In addition to fenitrothion, demethyl fenitrothion, fenitrooxon, nitro–cresol and unidentifiable polar moieties were found in the insect washes and homogenates. Differences in amounts of the active material and its metabolites were found in the washes and homogenates depending on formulation type and rate of metabolism of the chemical over time. Demethylation of $-OCH_3$ group to –OH and P–O–aryl cleavage played major roles in the metabolic degradation of fenitrothion. The oxidation of P = S to P = O was apparent but the oxon levels were low and sporadic. No amino fenitrothion was found either in the insect washed or homogenates. Based on these findings, a tentative metabolic pathway of fenitrothion in budworm is proposed.

Sundaram, K.M.S. 1988. High performance liquid chromatographic determination of three tracer dyes used in forestry spray formulations. J. Environ. Sci. Health B23:53–68.

A simple high performance liquid chromatographic method is described for the determination of Rhodamine B (RB), Erio Acid Red (EAR) and Automate Red B (ARB) dyes, which are used as tracers in forestry spray formulations. The dye solutions were analyzed at 30°C by reversed phase chromatography on an HP:RP–8, 10 mM MOS Hypersil column using a mobile phase of methanol and water at a flow rate of 1.0 ml/min. Responses were linear over the concentration range of 0.1 to 10 µg/ml for RB and EAR, whereas the range was 1.0 to 10 µg/ML for ARB. The limits of detection were 0.1 µg/ml for RB and EAR and 1 µg/ml for ARB. The method was used successfully to quantify RB and EAR present in two aqueous formulations of fenitrothion insecticide. However, interference peaks were observed with the oil–based formulation and prevented the quantification of ARB present.

Sundaram, K.M.S., comp. 1988. Proceedings of the XXth Annual Eastern Canada Workshop on Pesticide Residues and Environmental Contaminants. May 31–June 3, 1988. Sault Ste. Marie, Ontario. 243 p.

Sundaram, K.M.S. 1989. Distribution, dissémination et persistance de l'aminocarbe dans les composantes aquatiques du milieu forestier après l' épandage aérien de deux formulations de Matacil 180F. Forêts Canada, Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont. Rap. Inf. FPM–X–78F.

On a mélangé une formulation d'aminocarbe fluents, le Matacil 180F, avec de l'eau (180FE) et avec un diluant à base d'huile (180FO); on a fait une double application de ces deux préparations à raison de 70 g d'ingrédient actif dans 1,5 L par ha. On s'est servi d'un avion (TBM Avenger) doté d'un dispositif de buses avec ventilateur plat 1010 (Teejet) pour pulvériser ces préparations insecticides dans des forêts mixtes de conifères matures de l'est du Canada. La quantité (g/ha) et la proportion (%) de produit qui se déposaient variaient beaucoup d'une application à l'autre. En moyenne, la quantité d'aminocarbe déposée (g/ha) était de 18,1 et la proportion de la dose appliquée retrouvée sur le sol forestier était de 22,9. En général, avec la préparation émulsionée (180FE), le dépôt sur le sol fores-

tier et dans les cours d'eau était plus important qu'avec la préparation à base d'huile (180FO). La concentration d'aminocarbe maximale mesurée 1 heure après le traitement dans les cours d'eau était de 3,06 ppb dans le cas de la préparation 180FO, et de 22,64 ppb dans le cas de la préparation 180FE. Les résidus se sont rapidement évaporés dans un délai de 24 heures. Le peu de produit (5,8 ppb) qui s'est retrouvé dans les sédiments est aussi disparu rapidement. Les concentrations d'aminocarbe mesurées dans le cresson de fontaine (880 ppb) et dans la mousse (210 ppb) dépassaient dans une mesure significative la concentration maximale mesurées dans l'eau. En général chez les végétaux, les concentrations atteignaient leur valeur maximale une ou trois heures après l'application et, dans tous les cas considérés, elles baissaient ensuite graduellement. Les concentrations de résidus maximales mesurées chez les poissons s' élevaient à 6,1 et 13,8 ppb mais le produit était rapidement éliminé. Il n'y a pas eu de mortalité chez les poissons, ni de changement de comportement. Avec la dose utilisée et si l'on en juge d'après les données recueillies, il semble que l'aminocarbe ne pose aucun danger excessif pour les milieux aquatiques.

Sundaram, K.M.S. 1989. Fenitrothion deposits on different components of a forest ecosystem during an aerial spray trial. pp. 244–253. In: J.L. Hazen and D.A. Hovde, eds. Pesticide Formulations and Application Systems: International Aspects 9th Volume, ASTM STP 1036. American Society for Testing and Materials, Philadelphia.

Initial deposits of aerially applied fenitrothion insecticide over a boreal forest area near Searchmont, Ontario, were studied. Two plots (P1, 23 ha and P2, 49 ha) were sprayed with an emulsion formulation of fenitrothion at 280 g in 1.5 L per ha using a Cessna 188 aircraft equipped with 4 Micronair® AU3000 atomizers. Kromekote® card/glass plate collection units were placed around the sample trees to determine spray deposit at ground level. Balsam fir and white birch foliage, caged and wild pollinators, moths and wild flower species were collected for deposit assessment. Water samples were collected, at different intervals of time after treatment, from a creek inside the spray plot (P2), and from a nearby river into which the creek drained. All samples were analyzed by gas–liquid–chromatography.

Droplet analysis on Kromekote cards showed that the mean droplet frequency (droplets/cm^2), number and volume median diameters were nearly the same at all sampling sites in both plots. Fenitrothion deposits (in ng/cm^2) at mid–crown level of the sample trees were slightly higher on birch leaves than on fir foliage. The tubular chokecherry flowers showed higher deposits than the bell–shaped blueberry flowers. The caged pollinators showed higher fenitrothion concentrations than the wild pollinators.

The insecticide concentration in the creek rose to a maximum of 31.0 µg/L within five min after treatment, but fell to 0.5 µg/L after 24 h. The concentration–time profile showed that nearly half of the initial concentration in the creek water was lost within 21.8 min. In the river water sampled outside the spray area, the post–spray concentration, on average, was 2.2 µg/L.

Sundaram, K.M.S. 1989. Role of adjuvants on droplet size spectra, deposit patterns, and dislodgable and penetrated residues of fenitrothion in conifer needles. pp. 83–92 In: P.N. Chow, C.A. Grant, A.M. Hinshalwood, E. Simundsson, eds. Adjuvants and Agrochemicals. Vol. 2 . Recent Developments, Application and Bibliography of Agro-Adjuvants. CRC Press, Boca Raton, Florida.

The role of adjuvants on droplet size spectra, deposit patterns, and dislodgable and penetrated residues of fenitrothion in conifer needles was studied following spray application of three aqueous formulations onto balsam fir seedlings under laboratory conditions and one aqueous and three oil–based formulations onto white spruce trees under field conditions. Spray was applied using spinning disc nozzles in both studies. Droplet size spectra and deposits were assessed using Kromekote cards and glass plates. Foliar residues were measured by gas–liquid chromatography (GLC). In both studies, the

adjuvants used in the formulations imparted different volatilities to the spray media. The low–volatility formulations provided larger droplets and greater deposits; foliar residues were also correspondingly higher. The penetrated residues, however, remained the same, irrespective of the differences in the total foliar concentrations. Thus, the study indicated an upper limit for the partitioning capability of the chemical into the subsurface tissues. A comparative evaluation of the partitioning capability between the balsam fir seedlings and white spruce trees indicated a marked difference in the penetrated residues, in spite of the moderate differences observed in the dislodgable residues. This is probably due to the differences in the cuticular development of the two conifer species, or the age difference of the trees used, i.e., the young balsam fir seedlings vs. the moderately mature white spruce trees. These aspects require further investigation.

Sundaram, K.M.S. 1989. Toxicity and metabolism of mexacarbate in freshwater crayfish under laboratory conditions. pp. 270–286 In: U.M. Cowgill, L.R. Williams, eds. Aquatic Toxicology and Hazard Assessment: 12th Volume, ASTM STP 1027. American Society for Testing and Materials, Philadelphia, PA.

Adult crayfish (*Orconetes limosus*) were exposed to 0.1, 1.0, 2.5, 4.0, 7.5, 8.0, 8.5, 9.5, 15.0, 20.0 and 25.0 µg/mL of mexacarbate [4–dimethylamino–3,5–xylyl N–methylcarbamate (Zectran)] in water at 15° under laboratory conditions. Behavioral abnormalities were noted at levels ≥1.0 µg/mL, but as the duration of exposure increased the animals recovered and behaved similarly to the control group. Signs of acute toxicity and mortality were observed at concentration levels ≥2.5 µg/mL. The 96–h LC_{50} value was 8.8 µg/mL. Body weight depression was significant only in the three high dose groups (at 15, 20 and 25 µg/mL). The study was terminated 144 h after treatment. The parent compound (M) and seven metabolites, namely, 4–methylformamido mexacarbate (MFM), 4–formamido mexacarbate (FAM), 4–methylamino mexacarbate (MAM), 4–amino mexacarbate (AM), 4–dimethylamino–3,5–xylenol (DMAX), 4–methylamin–3,5–xylenol (MAX), and 4–amino–3,5–xylenol (AX) were detected in crayfish 144 h after exposure. The primary metabolites detected were MFM and FAM, which accounted for 30 and 20%, respectively, of the body residue. Other metabolites detected accounted for about 9% of the body residue altogether. About 41% if the body residue was contributed by the parent material M. The bioconcentration factor of mexacarbate in crayfish was very low, about 0.58, compared to 2000 to 3000 reported in the literature for fenvalerate and permethrin in fathead minnows.

Sundaram, K.M.S. 1990. Gas chromatographic method for the analysis of permethrin isomers in some forestry substrates. J. Environ. Sci. Health B25: 357–378

A simple and specific method was developed to quantitate individually the *cis* and *trans* isomers of permethrin present in forestry substrates at residue levels. Permethrin isomers were extracted from the substrates with hexane, followed by acetonitrile partition, purification by Florisil®, Nuchar SN® charcoal–cellulose microcolumn adsorption chromatography, elution by dichloromethane and eventual quantification by gas–liquid chromatography with electron capture detector (GLC–EC) with a glass column (1.2 x 2 mm i.d.) packed with 6% QF–1 + 3% DC–200 on 80–100 mesh Chromosorb W–HP. The method exhibits good recovery (>80%) and reproducibility (SD <10% and C.V. <12%) for both the isomers of permethrin at fortification levels ranging from 0.05 mg/kg to 1.00 µg/kg in conifer foliage, leaf litter, forest soil, sediment and fish and from 0.05 µg/kg to 1.00 µg/kg in natural waters. Limits of detection and quantification levels are 0.01 and 0.02 µg/kg respectively for terrestrial substrates, fish and sediment and 0.01 and 0.02 µg/kg for natural waters.

Sundaram, K.M.S.; Boyonoski, N; Feng, C. 1987. Degradation and metabolism of mexacarbate in two types of forest litters under laboratory conditions. J. Environ. Sci. Health B22: 29–54.

The degradation and metabolism of mexacarbate were studied in two types (sandy loam and clay loam) of sterile and nonsterile forest litters after incubation for 45 days under aerobic and submerged conditions. Degradation of the chemical in non–autoclaved litters was rapid initially and reached a maximum after 30 d. The rate of formation of $^{14}CO_2$ and the amount, the extractable metabolites produced and the nonextractable ^{14}C adsorbed onto the litters varied depending on the litter type and experimental conditions. Rate constants and half–lives (t 1/2) of evolution of $^{14}CO_2$ were very similar for the aerobic and submerged conditions. However, the t 1/2 values for the clay loam litter were slightly higher than those for the sandy loam litter. Litter microbes played a major role in the degradation of mexacarbate and formation of $^{14}CO_2$. Metabolites detected included demethylated carbamates, various xylenols, polar and other unknown products. The principal degradative pathway for the chemical appears to be N–demthylation, hydroloysis, ring–cleavage and eventual conjugation to litter matrix.

Sundaram, K.M.S.; Boyonoski, N.; Wing, R.W.; Cadogan, B.L. 1987. Simultaneous determination of fenitrothion and aminocarb in blueberry foliage and fruits: application to the analysis of residues in field samples. J. Environ. Sci. Health B22: 565–578.

Samples of blueberry foliage and fruits were collected from spray blocks in Ontario after aerial application of fenitrothion and aminocarb at dosage rates of 210 g active ingredient (AI)/ha and 70 g AI/ha respectively. Residues were extracted from the samples by homogenizing with ethyl acetate, cleaned up by microcolumn chromatography using alumina as adsorbent, and analyzed by GLC–AFID with a glass column packed with 1.5% OV–17 and 1.95% OV–210 on 80–100 mesh Chromosorb W–HP. Average recoveries for fenitrothion and aminocarb from foliage at three fortification levels (1.0, 0.10 and 0.01 ppm) were respectively 99 and 96%. The corresponding values for the fruits were 99 and 95%. Foliage samples collected 1 h post–spray contained on average 1.13 ppm of fenitrothion and 1.14 ppm of aminocarb. However, residue levels reached below the detection limit (<0.01 ppm) in foliage collected 15 d after treatment. In addition, the fruit samples collected after 15 d post–spray contained extremely low levels (0.03 ppm for fenitrothion and 0.02 ppm for aminocarb) of residues, and were barely above the detection limit.

Sundaram, K.M.S.; de Groot, P.; Sundaram, A. 1987. Permethrin deposits and airborne concentrations downwind from a single swath application using a back pack mist blower. J. Environ. Sci. Health B22: 171–193.

An experiment was conducted during the fall of 1983, in a conifer plantation near Thessalon, Ontario, to assess the downwind deposits and airborne concentrations of permethrin [3–phenoxybenzyl (±) cis–, trans–3–(2,2–dichlorovinyl)–2,2–dimethylcyclopropanecarboxylate], following application as an emulsion formulation, over a single 100 m spray line at 35 g AI (active ingredient)/ha. The insecticide was collected at up to 150 m downwind by using various static collectors and air samplers. Simultaneous measurements of droplet deposition on Kromekote cards permitted calculation of droplets/cm^2 and size spectra. The data indicated that permethrin deposits on all static collectors were greatest within 30 m of the spray swath. Deposits per unit area of the collectors, droplets /cm^2 of the sampling cards and airborne concentrations all decreased exponentially with increasing downwind distance. Beyond 30 m downwind, the amounts of the insecticide trapped by various collectors were extremely low, and were barely detectable.

Sundaram, K.M.S.; Feng, C.; Boyonoski, N.W.; Manniste–Squire, V. 1985. Leaching, degradation and fate of ^{14}C–mexacarbate in columns packed with forest soil. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Inf. Rep. FPM–X–71, 34 pp.

Leaching, degradation and fate of ^{14}C–mexacarbate (4–dimethylamino–3,5–xylyl N–methylcarbamate) were studied under simulated field conditions in the laboratory using hand–packed and fortified 30 cm soil columns containing sandy and clay loam forest soil profiles. Flooding and subsequent analysis of the soil horizons and the leachates, following extraction, combustion, liquid scintillation

counting, and thin layer chromatography showed the presence of free, loosely bound and tightly bound residues. The bulk of the ^{14}C–material was strongly adsorbed onto the litter layers unless the columns were saturated with 454 µg of the labelled mexacarbate, in which case the radioactivity moved beyond the column length into the leachate, although most of the radioactivity was retained in litter layers. Analysis of the sandy and clay loam litters and the corresponding leachates showed carbamate moieties, phenols and other metabolites, indicating that the chemical degraded rapidly. Incubation of the soil columns under aerobiosis for 30 and 45 days showed that the radioactivity was retained in the litter layers in both soil types. The persistence and degradation of the chemical as well as the quantity of metabolites formed were influenced by soil type and duration of incubation. The chemical was completely degraded under 15 d anaerobiosis (moist), and after 30 d aerobic (dry) incubation. Although on the average about 40% of the total applied radioactivity was found in the litter and humus layers, and in the leachates, no carbamate moiety was found in them; only some phenols and other water–soluble metabolites. Incubation of sterile and non–sterile litter samples fortified with ^{14}C–mexacarbate for 45 days produced negligible amounts of $^{14}CO_2$ in sterile samples, whereas the non–sterile sandy and clay loam litters yielded 25.3 and 18.9% $^{14}CO_2$ respectively, showing that soil microbes played an important role in the degradation of the chemical. Analysis of the litter samples after the incubation period confirmed the presence of free, loosely bound and tightly bound residues. The characteristics of the free and loosely bound residues were similar to the aerobic soil–column study conducted earlier. Breakdown of mexacarbate in forest soils is a rapid process and therefore it would in all likelihood be innocuous to the biota at the suggested use pattern of 70 g AI/ha. The metabolic pathway for its degradation in forest soils that is proposed, is consistent with the observed results.

Sundaram, K.M.S.; Feng, C.; Boyonoski, N.W.; Manniste–Squire, V. 1986. Percolation, dé gradation et devenir du méxacarbate marque au ^{14}C dans des colonnes de sols forestiers. Serv. For. Can., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–71F, 55 pp.

Nous avons étudié en laboratoire la percolation, la dégradation et devenir du mexacarbate (N–méthylcarbamate de diméthylamino–4 xylyle–3,5) marqué au ^{14}C, dans des lysimètres de 30 cm emplis à la main de loams forestiers sableux et argileux enrichis de ce produit, où les conditions étaient fidèles à celles du terrain. L'analyse des horizons et des percolats a révélé, après mouillage abondant, extraction, combustion, comptage par scintillation en milieu liquide et chromatographie sur couche mince, la présence de résidus libres, faiblement liés et fortement liés. Le gros des matières marquées était fortement adsorbé sur les constituants des couches de litière, sauf dans les cas où, le sol ayant été saturé avec 454 µg de mexacarbate marqué, la radio–activité s'est retrouvée dans les percolats, même si, en grande partie, elle était retenue dans la litière. L'analyse des litières des différents loams et des percolats correspondants a mis en évidence des groupements carbamate, des phénols et d'autres métabolites, signes d'une dégradation chimique rapide. Le maintien des sols en aérobiose durant 30 et 45 jours a montré la rétention de la radioactivité dans la litière des deux loams. La rémanence et la dégradation de la matière chimique ainsi que la quantité des métabolites formés ont varié selon le sol et la durée de l'aérobiose. La dégradation a été complète après 15 j d'anaérobiose postérieurs à 30 j d'aérobiose. En moyenne, 40% de la radioactivité d'origine s'est retrouvée dans la litière, l'humus et les percolats, mais on n'a retrouvé dans ces milieux aucun groupement carbamate, seulement quelques phénols et d'autres métabolites hydrosolubles. L'incubation, pendant 45 j, d' échantillons stériles et non stériles de litière, enrichis de mexacarbate marqué, s'est, dans le premier cas, accompagnée d'une production négligeable de $^{14}CO_2$, mais, dans le second, elle a donné, pour les loams sableux et argileux, 25,3 et 18,9% de $^{14}CO_2$ respectivement, ce qui met en évidence le rôle de premier plan des microbes du sol dans la dégradation. L'analyse des échantillons de litière, après l'incubation, a confirmé la présence de résidus libres, faiblement liés et fortement liés. Les caractéristiques des deux premiers types de résidus étaient semblables à celles qui avaient été observés en aérobiose dans une étude antérieure en lysimètres. La

dégradation du mexacarbate dans les sols forestiers est rapide, et le produit, selon toutes les probabilités, serait inoffensif pour les organismes vivants s'il était utilisé à la dose conseillée de 70 g de matière active à l'hectare. Le cycle métabolique de sa dégradation dans les sols forestiers que nous suggèrons est confirme aux résultats.

Sundaram, K.M.S.; Feng, C.; Broks, J. 1985. Determination of mexacarbate and five of its derivatives by high–performance liquid chromatography. J. Liq. Chromatogr. 8:2579–2593.

A simple, sensitive and reliable analytical method has been developed and reported for mexacarbate (4–dimethylamino–3,5–xylyl N–methylcarbamate) and five of its possible degradation products likely to be found in environmental samples using reversed–phase high–performance liquid chromatography with isocratic and gradient solvent systems. All chromatogram peaks were identified through comparison to standards. The method has been used to identify and separate the six compounds from a mixture of the standards. It has been evaluated under different column conditions and with different mobile phases. Best resolution of the analytes was obtained by using a gradient solvent system consisting of CH_3CN and H_2O detecting at 200 nm and 30°C using a HP–RP8, 10mm, 20 cm x 4.6 nm column.

Sundaram, K.M.S.; Feng, C.; Broks, J. 1985. High performance liquid chromatographic method for the determination of permethrin deposits in a forestry spray trial. J. Liq. Chromatogr. 8: 2607–2624.

A convenient and sensitive reversed–phase high performance liquid chromatographic method has been developed for the determination of permethrin [3–phenoxybenzyl (±)–cis, trans–3–(2,2–dichlorovinyl)–2,2–dimethylcyclopropanecarboxylate] insecticide. Various isocratic and gradient mobile phases, consisting of acetonitrile:water (CH_3CN:H_2O) and methanol:water (CH_3OH:H_2O) solvent systems at two flow rates, were tested to separate and quantify the isomers of permethrin using octadecylsilyl (ODS) (Regis 5 mm) and octylsilyl (OS) (RP–8, 10 mm) bonded columns. The optimal mobile phase for permethrin using the ODS column was 70:30 (v/v) CH_3CN:H_2O mixture at flow rates of either 1.0 or 1.5 mL/min. The measurement was done with a UV detector at 200 nm and 50°C. The OS column gave a less satisfactory separation than the ODS. Gradient elution systems examined did not improve the isomeric separation of permethrin. Using the method developed, deposit levels obtained on various sampling units during a permethrin spray trial were analyzed after elution or extraction followed by necessary column cleanup. Minimum levels of detection for permethrin varied from 1 to 3 ng depending on the nature of the sampler used.

Sundaram, K.M.S.; Millikin, R.: Sundaram, A. 1989. Assessment of canopy and ground deposits of fenitrothion following aerial and ground application in a Northern Ontario forest. Pestic. Sci. 25: 59–69.

Spray deposit patterns on simulated and live foliage of balsam fir and white birch were determined at different heights and at periphery and interior locations of the tree crown, following aerial and ground applications of fenitrothion formulations over a boreal forest near Searchmont, Ontario. Droplet size spectra and AI deposits were assessed at ground level with Kromekote card/glass plate units. Aerial application was made with a Cessna 188 aircraft fitted with Micronair AU3000 atomizers. For ground application, a Soloport 423 backpack mistblower fitted with an extension tube and a diffuser nozzle at the tip was used.

Deposit data on the ground samplers indicated significantly larger droplets and greater deposits from the aerial spray trial than from the mistblower treatment. However, foliar deposits at tree canopy level were only slightly higher in the former trial than in the latter. Analysis of spray deposits on simulated and live fir foliage showed definite gradients in deposit levels, decreasing from top to bottom

crown, and from periphery to inner tree crown. In the birch tree crown, such gradients were not observed. The simulated leaves generally acted as better collectors of spray droplets that the natural leaves. The overall mean deposit values, expressed in ng cm^{-2}, showed a wide variation, although there was generally a close relationship between the deposits on the simulated and natural surfaces.

Sundaram, K.M.S.; Nott, R. 1985. Distribution and persistence of aminocarb in terrestrial components of the forest environment after semi–operational application of two mixtures of Matacil 180F. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Inf. Rep. FPM–X–67, 10 pp.

Two spray mixtures, one oil–based (180FO) and one water–based (180FE), of Matacil 180 flowable (Matacil 180F) were applied twice by fixed wing aircraft at a dosage rate of 70 g AI/ha to selected plots in a mixed coniferous forest near Fredericton, New Brunswick. Spray distribution and deposition varied considerably between two applications of the same spray mixture and between the two mixtures. The average amount of aminocarb deposited and the percent deposition at the forest floor were 12.4 g/ha and 17.7%, respectively. The highest concentration of aminocarb in balsam fir [*Abies balsamea* (L.) Mill] foliage was 1220 ng/g (fresh wt.), detected 1 h after the second application of 180FE. With both spray mixtures the residues were lost in an exponential decay pattern with time, and the half–lives ranged from 78 to 143 h. The postspray samples collected 12 days after the second application contained only about 20% (as sampled) of the initial concentration of the material, showing that the chemical is short lived. In forest litter and soil environments, aminocarb was present in amounts as low as the detection limit (10 ng/g), indicating that at the dosage rate used, aminocarb should not pose any undue hazard to the soil microorganisms.

Sundaram, K.M.S.; Nott, R. 1985. Mexacarbate residues in selected components of a conifer forest following aerial applications of oil–based and aqueous spray formulations. J. Environ. Sci. Health B20(4): 425–444.

Mexacarbate (4–dimethylamino–3,5–xylyl N–methylcarbamate) insecticide has potential for use in spruce budworm (*Choristoneura fumiferana* Clem.) control operations in Canada. Its persistence and fate in balsam fir (*Abies balsamea* (l.) Mill.), litter and soil samples were studied by spraying aerially oil–based and water–based formulations, each at 70 g AI/ha over a coniferous forest near Bathurst, New Brunswick. The oil–based formulation gave the maximum concentration of chemical in the substrates studied. In fir needles, the highest concentrations observed were 0.51 ppm and 0.19 ppm (fresh weight) for oil–based and emulsion formulations respectively, 1 h after application. The residue levels decreased very rapidly with a half–life of approximately 5 h. Three and eight days after the spray application of the emulsion and oil formulations respectively, the concentrations of mexacarbate in foliage decreased to trace levels (0.008 ppm). Only very low levels of residue were detected in litter and soil. The peak concentrations for the two formulations ranged from 0.02 to 0.11 ppm (fresh weight) in litter and from 0.01 to 0.06 ppm (fresh weight) in soil. The residue levels in both litter and soil decreased to below the detection limit (0.005 ppm) within 1 d. The ground deposit levels found on glass plates and the droplet density and size spectra measured on Kromekote cards reflected the variations in concentrations found in fir needles, litter and soil samples and correlated with the observed maximum concentrations in them. Under the stipulated use pattern, mexacarbate concentrations found in the terrestrial components studied were low and not likely to have any undue adverse effects on non–target species.

Sundaram, K.M.S.; Nott, R. 1986. Persistence of fenitrothion residues in a conifer forest environment. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Inf. Rep. FPM–X–75, 13 p.

Persistence of aerially sprayed fenitrothion in various forestry substrates sampled from 8 plots in New Brunswick's forests were investigated. Following established sampling methods, air, water, sedi-

ment, aquatic plants, fish, balsam fir (*Abies balsamea* [L.] Mill.), foliage, forest soil, and litter samples were collected from unsprayed plots during the 1982 operational spray program in the province and again resampling them from the same plots a year later just prior to the commencement of operational spraying. Control samples were collected from an unsprayed site near Sault Ste. Marie, Ontario. All samples collected during the two regimes and the control samples were carefully analyzed for fenitrothion residues. The data collected were analyzed statistically. All the substrates, except fish, sampled during the operational spraying contained fenitrothion. Samples collected a year later, prior to any operational spray, did not contain detectable levels (10 ng/m^3 for air, 0.01 ppb for water and 0.01 ppm for others) of the insecticide, except the fir foliage. The findings confirmed that all 8 sampling plots received drift from nearby operational spray areas in 1982 and were contaminated. New and old fir needles sampled a year later from all 8 plots contained on average about 0.55 µg of the chemical (0.55 ppm) per gram of fresh foliage. The study conclusively proved that the conifer needles acted as a micro sink for the chemical, which has a tendency to persist in them.

Sundaram, K.M.S.; Nott, R. 1986. Rémanence des résidus de fénitrothion dans l'environnement d'une forêt de conifères. Serv. Can. For., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–75F, 14 pp.

La rémanence du fénitrothion épandu par voie aérienne a été étudiée dans divers substrats dans 8 placettes établies dans les forêts du Nouveau–Brunswick. Des échantillons de l'air, de l'eau, des sédiments, des plantes aquatiques, des poissons, du feuillage du sapin baumier (*Abies balsamea* [L.] Mill.), du sol de la forêt et de la litière y ont été prélevés, dans des placettes non arrosées durant le programme d'arrosages opérationnels en 1982; d'autres échantillons ont été prélevés dans les mêmes parcelles un an plus tard, juste avant le début des arrosages opérationnels. Des échantillons témoins ont été prélevés à un endroit non arrosé près de Sault Ste. Marie, en Ontario. Tous les échantillons recueillis ont été analysés minutieusement. Les données obtenues ont été évaluées selon des méthodes statistiques. Le fénitrothion a été décelé dans tous les substrats qui ont été échantillonnés au cours de l'arrosage opérationnel, sauf le poisson. Les échantillons recueillis un an plus tard n'en renfermaient pas en concentrations décelables (limites de détection: 10 ng/m 23 pour l'air, 0,01 ppb pour l'eau et 0,01 ppm pour les autres), sauf ceux du feuillage. Les résultats confirment que les huit placettes d'échantillonnage ont été touchés et contaminés à la suite des arrosages opérationnels effectués à proximité en 1982. Les nouvelles et vieilles aiguilles de sapin prélevées un an plus tard dans les 8 placettes renfermaient en moyenne environ 0,55 µg de l'insecticide (0,55 ppm) par gramme à l' état frais. Les résultats prouvent de façon concluante que les feuilles de conifères ont agi comme un micropiège pour le produit chimique et que celui–ci tendance à persister chez elles.

Sundaram, K.M.S.; Nott, R. 1989. High performance liquid chromatographic method for the determination of diflubenzuron from forestry substrates. J. Liq. Chromatog. 12: 2333–2343.

Diflubenzuron (DFB) [Dimilin®, 1–(4–chlorophenyl)–3–(2,6–difluorobenzoyl) urea] was extracted from maple foliage, pine needles, manna grass, fish and pond water with dichloromethane and forest soil, litter and pond sediment with aqueous acetonitrile. An aliquot of the filtered extract, after necessary partition and concentration, was cleaned using a Florisil® column. Following elution, the final residue was dissolved in acetonitrile and analyzed by liquid chromatography on an RP–8 10 µm column with a mobile phase consisting of acetonitrile–water and UV detection at 254 nm. Average recoveries were over 80%. Minimum detectable and quantifiable levels respectively were 0.05 and 0.10 ppb for water and 0.05 and 0.10 for the other substrates.

Sundaram, K.M.S.; Nott, R. 1989. Mobility of diflubenzuron in two types of forest soils. J. Environ. Sci. Health B24:65–86.

Diflubenzuron (DFB) [1–(4–chlorophenyl)–3(2, 6–diflurobenzoly) urea] and its two formulations, Dimilin WP–25 and Dimilin SC–48, were applied separately at 17.23, 51.69 and 155.07 µg of active ingredient (A.I.) (corresponding to 70, 210 and 630 g A.I./ha) to the top layers of columns (30 x 5.6 cm i.d.) packed with either sandy or clay loam forest soils. Water (1.251 L) equivalent to 50.8 cm of precipitation was allowed to leach through each column. After leaching, the columns were divided into 5 unequal segments and the DFB residues in soils were extracted and analyzed by high performance liquid chromatography (HPLC). Mobility of DFB was low and did not increase with dosage. At a deposit rate equivalent to 70 g A.I./ha, nearly all the residues were found within 2.5 cm of the top of the column. Mobility of DFB did not increase with dosage. Even at 630 g A.I./ha, only about 9% of the technical DFB, 7% of Dimilin SC–48 and 4% of Dimilin WP–25 moved below the 2.5 cm level in sandy loam. Mobility of DFB in clay loam was lower than in sandy loam. No residues were found below the 10 cm level or in the leachates in either soil type at all dosage levels. In addition to soil type, mobility of DFB was also influenced by the additives present in the formulation with technical DFB > Dimilin SC–48 > Dimilin WP–25.

Sundaram, K.M.S.; Nott, R. 1989. Distribution et persistance de l'aminocarbe dans les éléments terrestre de l'environnement forestier après un épandage semi–opérationnel de deux mélanges de matacil 180F. Forêts Canada, Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–67F.

Deux préparations de Matacil 180F, une à base d'huile (180FO) et une à base aqueuse (180FE), ont été épandues par avion à deux reprises, à la dose de 70 g/ha d'ingrédient actif, dans des parcelles choisies dans une forêt mixte de conifères à maturité, près de Frédéricton au Nouveau–Brunswick. La dispersion et le dépôt des produits ont varié considérablement entre les deux arrosages de la même préparation et entre les deux préparations. La quantité moyenne d'aminocarbe s' étant déposé et le pourcentage de dépôt à la surface du sol se sont élevés respectivement à 12,4 g/ha et 17,7%. La plus forte concentration d'aminocarbe mesurée sur le feuillage du sapin baumier (*Abies balsamea* [L.] Mill.) a été de 1 220 ng/g (masse à l'état frais) et a été obtenue 1 h après le deuxième arrosage de la préparation 180FE. Avec chacune des deux préparations, la disparition des résidus en fonction du temps a suivi une courbe d'affaiblissement exponentielle et les périodes (demi–vie) s' étendaient de 78 à 143 h. Les échantillons recueillis 12 jours après le deuxième arrosage renfermaient seulement 20% de la concentration maximale initiale du produit, indiquant que celui–ci avait une courte durée de vie. Dans la litière forestière et le sol, les concentrations étaient présentes en quantités aussi faibles que le taux de détection (10 ng/g), indiquant qu'à la dose utilisée, l'aminocarbe ne devrait représenter aucun risque indu pour les micro–organismes du sol.

Sundaram, K.M.S.; Nott, R.; Holmes, S.B.; Boyonoski, N. 1986. The distribution and fate of mexacarbate in a forest aquatic ecosystem. Can. For. Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont., Inf. Rep. FPM–X–73, 23 pp.

The distribution and persistence of aerially applied mexacarbate were studied in a New Brunswick aquatic forest environment after spraying twice at a dosage of 70 g A.I./ha using a fixed–wing aircraft. Average droplet density (drops/cm^2) and ground deposition (g A.I./ha) between the two applications differed considerably. The values for the first and second applications were respectively 1.7 and 0.73 and 5.2 and 2.0. But the average NMD (20 µm) and VMD (36 µm) for both applications were nearly the same. The maximum 1 h postspray concentrations of mexacarbate in the stream and pond waters were respectively 0.73 ppb and 18.74 ppb. Concentrations fell rapidly to below detection limits within 12 h in stream and within 3 d in pond water. Cattails (*Typha latifolia*), manna grass (*Glyceria borealis*) and bog moss (*Sphagum* sp.) collected from the pond contained peak 1–h post–spray concentrations of 720 ppb, 482 ppb and 81 ppb respectively. The concentration levels decreased rapidly and the average half–lives of the chemical in them were about 3.9, 8.5 and 2.0 h. Bog moss, stream moss (*Fontinalis* sp.), watercress (*Nasturtium officinalis*), buttercup (R*anunculus aquatilis*) and green alga (*Draparnaldia*

sp.) sampled from the stream sites did not contain measurable levels of mexacarbate. Also, caged and wild tadpoles (*Rana clamitans melanota*) from the pond, brook trout (*Salvenilusfontinalis*) (caged and wild), Atlantic salmon (*Salmo salar*) (wild) and mayfly nymphs (*Ephemerella* sp.) collected from the stream did not contain any of the material. Mexacarbate was not detected in stream and pond sediments. The demelthylated products, 4–methylamino and 4–amino–3,5–xylyl methylcarbamates and the phenol, 4–dimethylamino–3,5–xylenol as transformation products were frequently detected in water and in the aquatic plants which had accumulated the insecticide. The presence of these compounds showed that demethylation and hydrolytic routes are the major metabolic pathways for the dissipation of mexacarbate from these substrates.

Sundaram, K.M.S.; Nott, R.; Holmes, S.B.; Boyonoski, N. 1986. Distribution et devenir du méxacarbate dans un écosystème aquatique forestier. Serv. For. Can., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont., Rap. Inf. FPM–X–73F, 21 p.

La distribution et la persistance du méxacarbate ont été étudiées dans un environnement forestier aquatique au Nouveau–Brunswick après deux arrosages à la dose de 70 g/ha d'ingrédient actif effectués à l'aide d'un avion. Une différence considérable a été observée entre les deux arrosages pour la densité moyenne des gouttelettes (gouttes/cm^2 et le dépôt au sol (g/ha d'ingrédient actif). Les valeurs obtenues pour le premier et le deuxième arrosages sont respectivement de 1,7 et 0,73 et de 5, 2 et 2, 0. Cependant, les diamètres médians en fonction du nombre (20 µm) et du volume (36 µm) pour les deux arrosages étaient pratiquement les mêmes. Une heure après l'arrosage, les concentrations maximales de méxacarbate dans le cours d'eau et l' étang s' élevaient respectivement à 0,73 et 18,74 parties par milliard. Les concentrations sont descendues rapidement au–dessous de la limite de détection, en moins de 12 h dans le cours d'eau et en moins de 3 jours dans l' étang. Les quenouilles (*Typha latifolia*), les glycéries (*Glyceria borealis*) et les sphaignes (*Sphagum* sp.) recueillies dans l' étang une heure après l'arrosage présentaient des concentrations maximales de 720, 482 et 81 parties par milliard respectivement. Les concentrations ont diminué rapidement, et les périodes (demi–vies) moyennes du méxacarbate dans ces plantes ont été d'environ 3,9, 3,4 et 2,0 h. Dans le cours d'eau, les sphaignes, les fontinalis (*Fontinalis* sp.), les cressons (*Nasturtium officinalis*), les renoncules (*Ranunculus aquatilis*) et les algues vertes (*Draparnaldia* sp.) qui ont été recueillis à divers endroits ne renfermaient pas de méxacarbate en concentrations mesurables. Il en est de même pour les têtards de grenouille (*Rana clamitans melanota*) en cage et libres qui se trouvaient dans l' étang ainsi que pour les ombles de fontaine (*Salvenilus fontinalis*) (en cage et libres), les saumons de l'Atlantique (*Salmo salar*) (libres) et les éphémères (*Ephemerella* sp.) qui ont été prélevés dans le cours d'eau. On n'a pas décelé de méxacarbate dans les sédiments de l' étang et du cours d'eau. Certains produits de transformation du méxacarbate ont été décelés fréquemment dans l'eau et les plantes aquatiques où s' était accumulé l'insecticide; il s'agit de deux produits déméthylés, le méthylcarbamate de méthylamino–4 xylyl–3,5 et le méthylcarbamate d'amino–4 xylyle–3,5, ainsi que d'un phénol, le diméthylamino–4 xylénol–3,5. La présence de ces composés indique que la déméthylation et l'hydrolyse sont les deux principales voies métaboliques de transformation méxacarbate dans ces plantes.

Sundaram, K.M.S.; Raske, A.G.; Retnakaran, A.; Sundaram, A.; West, R.J. 1987. Effect of formulation properties on ground and foliar deposits of two insecticides in flushed and one year–old balsam fir needles following aerial application. Pestic. Sci. 21:105–118.

A study was conducted in 1985 in Newfoundland to investigate the interrelationships between the physical properties of spray formulations, droplet–size spectra and deposits on ground sampling units, and deposits on flushed and one–year–old balsam fir foliage following aerial application of aminocarb and fenitrothion at different dosage rates, but using the same volume rates. The fenitrothion formulations were pseudoplastic, because of the presence of polymeric ingredients, and provided higher deposits on the ground sampling units and foliage than the aminocarb formulations, which were nearly Newtonian. At similar dosage rates, the ground deposits of fenitrothion were about twice those of ami-

nocarb, whereas the corresponding foliar deposits were about 6 to 8 times higher than those of aminocarb, suggesting possible advantages of pseudoplastic formulations in providing optimum droplet sizes for enhanced deposition on balsam fir needles.

The foliar deposits generally showed an increase when the dosage rates of the two insecticides were increased. Deposits in flushed foliage were slightly higher than those in mature foliage, probably due to the location of the flushed needles at the extreme periphery of the tree canopy.

Sundaram, K.M.S.; Sundaram, A. 1987. Influence of formulation on spray deposit patterns dislodgeable and penetrated residues, and persistence characteristics of fenitrothion in conifer needles. Pestic. Sci. 18:259–271.

The influence of formulation on spray droplet spectra, deposit patterns, dislodgeable and penetrated residues, and persistence characteristics of fenitrothion in balsam fir needles was studied using three formulations containing different types of adjuvants. Spray was applied on to potted trees under controlled conditions in a laboratory chamber. Droplet size spectra and deposits were assessed using Kromekote card/glass plate units. Foliar residues were measured by gas–liquid chromatography.

The formulation containing polymeric adjuvants provided significantly larger droplets and higher foliar residues than those containing surfactants and co–surfactants. It also provided a higher ratio of dislodgeable–to–penetrated residues, and a slower initial rate of loss of fenitrothion. None of the formulations posed a long–term persistence problem because only very low amounts remained on foliage at 42 days post–treatment. The significance of these findings in terms of the possible increase in bioavailability of the pesticide via crawling contact is discussed.

Sundaram, K.M.S.; Sundaram, A. 1987. Role of formulation ingredients and physical properties on droplet size spectra, deposition, and persistence of aerially sprayed aminocarb and mexacarbate in forest litter and soil samples. pp. 139–151 In: G.B. Beestman and D.I.B. Vander Hooven, Eds., Pesticide Formulations and Application Systems: 7th volume ASTM STP 968, American Society for Testing and Materials, Philadelphia.

Experimental observations made in five aerial spray trials on the inter–relationships between formulation ingredients, physical properties, droplet size spectra, deposit concentration, litter and soil residues, and persistence characteristics of aminocarb and mexacarbate are described. Spray was applied over conifer forests in New Brunswick, using a Cessna 188 aircraft and Micronair atomizers. Droplets were sampled at ground level using Kromekote cards. Deposits of the active ingredient (AI) were collected on glass plates. The physical properties measured were relative viscosity, surface tension, volatility, and viscosity–shear rate relationship; of these, relative viscosity and volatility played significant roles on droplet size spectra and deposition patterns of the sprays. The aqueous formulations of the two insecticides were the least viscous and most volatile. They provided the smallest droplets and lowest droplets/ cm^2, AI deposits on glass plates, and litter and soil residues; they also had shorter persistence than the oil–based formulations. As the relative viscosity of the formulations increased their volatility decreased gradually, and there was a progressive increase in droplet sizes, droplets/cm^2, deposits of AI, and litter and soil residues. The heavy–oil–based, non–volatile formulation of aminocarb showed slight deviation from this trend with respect to droplet sizes, but the AI deposits and litter and soil residues were still the highest for this formulation, which persisted for a relatively longer period of time than all other formulations. However, none of the formulations caused any undue persistence of the residues in soil, since the levels reached below the detection limit (4 ppb) within five days after treatment.

Sundaram, K.M.S.; Sundaram, A. 1988. Assessment of foliar and ground deposits of aminocarb after aerial spraying over conifer forests using two types of application parameters. pp. 211–224. In: D.A. Hovde and G.B. Beestman, eds. Pesticide Formulations and

Application Systems: 8th Volume, ASTM STP 980. American Society for Testing and Materials, Philadelphia.

Experimental observations made in eight aerial spray trials on the inter–relationships between physical properties of two spray mixtures, application parameters, meteorological conditions, drop size spectra, ground deposits and foliar concentrations of aminocarb are described in this paper. In 1981, the spray mixtures were applied using a small aircraft (Cessna 188) equipped with four rotary (Micronair® AU3000) atomizers. In 1982, the mixtures were sprayed using a large aircraft (TBM avenger) fitted with 24 hydraulic (1010 Flatfan Teejet®) nozzles. Spray drops were collected at ground level with sampling cards, and ground deposits were assessed using glass plates. Canopy deposits were determined directly on live foliage. Physical properties measured were: viscosity, surface tension and volatility. In the 1981 study, the drop size spectra of both spray mixtures were narrow and contained small drops with a volume median diameter ($D_V.5$) less than 50 μm. In the 1982 study, the drop size spectra were wide and contained large drops with a $D_V.5$ greater than 100 μm. The ground deposits were higher in 1982 than those in 1981. Foliar deposits, on the other hand, were similar in both years. Among the three physical properties studied viscosity and volatility played significant roles on the drop size spectra and ground deposits obtained in 1981; but no similar relationships could be found in 1982.

Sundaram, K.M.S.; Sundaram, A. 1989. Relative volatilization of three insecticides from deposits on fir foliage following spray application under laboratory conditions. J. Environ. Sci. Health B24: 167–182.

Volatilization of three forestry insecticides, aminocarb, fenitrothion and mexacarbate, from balsam fir seedlings was investigated after spray application of these chemicals as aqueous emulsions in a laboratory chamber at a dosage rate of 21 g (active ingredient)/ha. Highest airborne residues were found in the spray chamber at 0.25 h after mexacarbate application (21.7 μg/L) and lowest after aminocarb (6.3 μg/L). The treated seedlings were transferred to airtight chambers for investigation of volatilization over a 12 h post–spray period. Mexacarbate was the most volatile, while aminocarb was the least. From the initial amounts of deposits on the seedlings, about 30% of mexacarbate, 15% of fenitrothion and 9% of aminocarb were lost within 12 h by volatilization. Residue levels that remained in the seedlings at 12 h post–spray were ca. 70% of the initial values for aminocarb and fenitrothion, but were only ca. 9% for mexacarbate. Calculations on the mass–balance indicated that 60% of the deposited amounts were unaccountable (possibly due to tissue binding and metabolism) for mexacarbate, whereas the corresponding vales for the other two chemicals were less than 20.

Sundaram, K.M.S.; Sundaram, A.; Leung, J.W. 1989. A simple method for quantifying Erio Acid Red Dye in spray deposits of some pesticide formulations on conifer foliage. J. Environ. Sci. Health B24: 675–703.

A simple method was developed to quantify a fluorescent dye tracer [Erio Acid Red (EAR)] in spray deposits of forestry insecticides on balsam fir foliage. Three types of instruments, Beckman DU–7 Spectrophotometer, Beckman Model 772 Ratio Fluorometer, and Turner Model III Fluorometer, were investigated for sensitivity and precision during quantification of EAR in aqueous tank–mix formulations of fenitrothion, aminocarb and mexacarbate. Turner Fluorometer was found to be the most suitable out of the instruments tested, and the minimum detection limit was 0.5 ng/mL. Foliage samples were spiked with variable concentrations of EAR, extracted at different intervals of time after treatment, and cleaned using an $A1_2O_3$ column to remove plant pigments. EAR concentrations were quantified using Turner Fluorometer. Recovery was the greatest when extracted 12 to 15 min after spiking, but decreased rapidly as the time lapse between treatment and extraction increased. The minimum quantification limit (MOL) was 10 ng/g at 90% recovery, but was lower at a recovery value <90%.The three insecticide formulations were sprayed onto fir seedlings in a laboratory spray cham-

ber using dosage rates that would provide a deposit, on glass plate, of 16% of the field dosage rates. Foliar deposits were extracted, cleaned and quantified for the active ingredients (AI) by gas–liquid–chromatography, and for EAR by fluorometry. Foliar deposits of AI were similar to those obtained in previous field studies. Under these conditions, foliar deposits of EAR were ca. 70 ng/g which was well above the MQL of the method developed. The data, thus, demonstrated the suitability of the present method to quantify insecticide deposits on canopy foliage in aerial spray trials over conifer forests.

Sundaram, K.M.S.; Sundaram, A.; Nott, R. 1986. Mexacarbate deposits on simulated and live fir needles during an aerial spray trial. Trans. ASAE 29:382–388.

Mexacarbate (4–dimethylamino–3,5–xylyl N–methylcarbamate) deposits on simulated and live balsam fir needles were measured at different crown heights using aluminum coils as the simulated foliar surface, following aerial application of two spray formulations (one oil–based and one water–based) in New Brunswick, Canada. Ground deposits and air concentrations of the material were measured by using Kromekote card–glass plate units and impingers respectively. Deposits on the aluminum coils and foliar concentrations decreased from the top to the middle, and to the bottom levels in the ratio of 3:1:1. Regression analysis showed an approximately linear relationship between the deposits on the two surfaces. Correlation was good between mean deposits at the tree crown level and those on the ground samplers. The air concentrations showed a poor correlation with the rest of the deposit data, probably due to the trapping of both droplets and vapor, whereas the other samplers collected only the droplets.

Sundaram, K.M.S.; Szeto, S.Y. 1987. Distribution and persistence of carbaryl in some terrestrial and aquatic components of a forest environment. J. Environ. Sci. Health 22: 579–599.

An oil–based formulation of carbaryl (1–naphthyl n–methylcarbamate) (Sevin–2–oil) was applied twice by a fixed–wing aircraft at a dosage rate of 280g AI/ha/application to a coniferous forest near Allardville, New Brunswick. The highest concentrations of the chemical in fir foliage, litter and forest soil 1 h after application were respectively 4.20, 1.21 and 0.59 ppm (fresh weight). The residues dissipated rapidly and the DT50 values obtained from the depletion curves were 2.3 d for foliage and 1.5 d for litter and soil samples. Very low levels (<0.1 ppm) of carbaryl persisted in foliage and litter beyond the 10 d sampling period. The maximum residue level found in stream water was 0.314 ppm and more than 50% of it had dissipated within 1 h. Low but detectable levels (0.001 ppm) of the chemical persisted in water until the end of the 10 d sampling period. Sediment samples contained a maximum level of 0.04 ppm, which dissipated below the detection limit within 5 h. Brook trout and slimy sculpins captured in the stream 1 d after the spray contained on average about 0.04 ppm of carbaryl and none of it was found in 3 d postspray samples.

Szeto, S.Y.; Sundaram, K.M.S.; Feng, J. 1985. Inhibition of brain AChE in brook trout by aminocarb and its toxic metabolites. J. Environ. Sci. Health B20:559–575.

In vitro inhibitions of brain AChE in brook trout, *Salvelinus fontinalis* (Mitchill), by aminocarb (4–dimethylamino-*m*-tolyl N-methylcarbamate) and its toxic metabolites, MAA (4–methylamino-*m*-tolyl N–methylcarbamate), AA (4–amino–*m*–tolyl N-methylcarbamate), MFA (4–methylformamido-*m*-tolyl N–methylcarbamate) and FA (4–formamido–*m*–tolyl N- methylcarbamate) were investigated. The molar concentrations of inhibitors causing 50% inhibition (I_{50}s) were AA (3.62×10^{-6}) < MAA (7.92×10^{-6}) < aminocarb (1.01×10^{-5}) < MFA (4.29×10^{-5}) < FA (7.11×10^{-5}). After exposure of fish to various concentrations of aminocarb (25, 250, and 2500 ppb) and MAA (25, 250, 500 and 2500 ppb) at 9°C in dechlorinated tap water for 96 h, inhibitions of brain AChE ranged from 13 to 77%. Mortality occurred only in fish exposed to 500 ppb (22%) and 2500 ppb (100%) of MAA. Enzyme activities recovered to the control levels 12 to 96 h after the fish had been transferred to clean

water for clearing; in survivors of the 500–ppb MAA exposure, however, AChE activities decreased again thereafter.

Thompson, D.G.; Cowell, J.E.; Daniels, R.J.; Staznik B.; MacDonald, L.M. 1989. Liquid chromatographic method for quantitation of glyphosate and metabolite residues in organic and mineral soils, stream sediments, and hardwood foliage. J. Assoc. Off. Anal. Chem. 72:355–360.

A liquid chromatographic method for determining glyphosate (GLYPH) and its major metabolite aminomethylphosphonic acid (AMPH) in various environmental substrates is described. Ion–exchange column chromatography is coupled with post–column ninhydrin derivatization and absorbance detection at 570 nm. Use of a valve–switching technique allowed quantitation of both analytes in a single chromatographic run and eliminated slow–eluting, coextracted interferences. The method was successfully used to quantitate GLYPH and AMPA in organic and mineral soils, stream sediments, and foliage of 2 hardwood brush species. Mean recovery efficiencies for GLYPH, as determined from fortified blank field samples were as follows: bottom sediment 84%, suspended sediment 66%, organic soils 79%, mineral soils 73%, alder leaf litter 81%, salmonberry leaf litter 84%, and artificial deposit collectors 87%. Precision for GLYPH determination was good with less than 14% coefficient of variation on mean recovery for all substrates. Limits of detection were lowest for sediments (0.01 µg/g dry mass) and highest for foliage substrates (0.10 µg/g dry mass). Using this system, 6 samples/person/day were routinely analyzed.

Turgeon, J. 1985. Life cycle and behavior of the spruce budmoth, *Zeiraphera canadensis* (Lepidoptera: Olethreutidae) in New Brunswick. Can. Entomol. 117:1239–1247.

The life cycle, feeding behavior, and feeding damage of the spruce budmoth, *Zeiraphera canadensis*, were studied in northern New Brunswick. Larval emergence, which began in late May, was usually completed within 10 days. First–instar larvae did not feed on the previous year's foliage and took less than 30 min to settle inside a growing shoot, from which they exited only at the end of larval development. Larvae then dropped to the ground and remained as prepupae for approximately 6 days. Mating could be observed the first night following adult emergence. The majority of the mated females contained only 1 spermatophore (92%); others had 2 (7%) or 3 (1%). Although 95% of the egg clusters had 7 eggs or less, 5% had up to 19 eggs. Eggs required embryonic development before successful diapause could be initiated. The importance of these observations in the development of management strategies for this pest is discussed.

Le cycle vital, le comportement lors de la période d'alimentation et le type de dégâts infligé par la tordeuse de l' épinette, *Zeiraphera canadensis*, ont été étudiés dans le nord du Nouveau Brunswick. L' émergence des larves, qui a débuté á la fin du mois de mai, fut généralement complétée en moins de 10 jours. Les individus du 1er stade larvaire se nourrissage exclusivement du feuillage de l'année courante, prirent moins de 30 min pour s' établir à l'intérieur d'une pousse de l'année et ce, pour y demeurer, habituellement à l'intérieur de la même pousse, pour toute la durée du développement larvaire. Une fois le développement larvaire complété, les larves tombaient au sol et prenaient environ 6 jours avant de se transformer en nymphe. Des adultes ayant émergé tôt le matin furent observés en train de s'accoupler le soir même. Les femelles accouplés contenaient 1 (92%), 2 (7%) ou 3 (1%) spermatophores. Bien que la majorité des masses d'oeufs contenaient 7 oeufs ou moins, une faible proportion (5%) en contenait jusqu' à 19. Pour être en mesure d'amorcer la diapause, les oeufs devaient compléter une période de développement embryonnaire. L'importance de ces études sur le développement de stratégies pour le contrôle de cet insecte nuisible est également l'objet de la discussion.

Turgeon, J. 1986. The phenological relationship between the larval development of the spruce budmoth, *Zeiraphera canadensis* (Lepidoptera: Olethreutidae), and white spruce in northern New Brunswick. Can. Ent. 118:345–350.

The relationship between the phenological development of the spruce budmoth (SBM), *Zeiraphera canadensis*, and that of its primary host, white spruce, was studied in New Brunswick using descriptive indices for both insect and host development. Larval emergence of SBM was synchronized with bud burst of white spruce, the species on which most eggs are laid. Subsequent SBM larval development can be estimated through reference to the development index for white spruce. For black, Norway, and red spruce, initial bud burst occurred approximately 15, 3 and 15 days, respectively, later than white spruce and this asynchrony is probably one of the reasons why the SBM is not an important pest on these tree species.

La relation phénologique entre le développement de la tordeuse de l' épinette, *Zeiraphera canadensis*, et celui de son hôte primaire, l' épinette blanche, a été étudiée dans le nord du Nouveau–Brunswick à l'aide d'indices numériques. L'utilisation des indices a permis de démontrer que l'émergence des larves de la tordeuse de l' épinette était synchronisée avec l' éclosion des bourgeons de l' épinette blanche, l'espèce sur laquelle la majorité des oeufs étaient pondus. A l'aide des indices, on peut également prédire le stage de développement des larves de la tordeuse, en déterminant d'abord l'indice de développement de l' épinette blanche. L' éclosion des bourgeons végétatifs de l' épinette noire, de l' épinette de Norvège et de l' épinette rouge, est survenue approximativement 15, 3 et 15 jours respectivement, plus tard que celle de l' épinette blanche. Il est probable que ce retard puisse expliquer partiellement l'absence de dégâts de la tordeuse de l'épinette sur ces 3 espèces d' épinettes.

Turgeon, J.J.; Grant, G.G. 1988. Response of *Zeiraphera canadensis* (Lepidoptera: Tortricidae: Olethreutinae) to candidate sex attractants and factors affecting trap catches. Environ. Entomol. 17(3):442–447

Electroantennogram responses to isomers of dodecenyl, tetradecenyl, and hexadecenyl acetates and alcohols followed by field screening tests indicated that (E)–9–tetradecenyl acetate (E9–14:Ac) is attractive to male *Zeiraphera canadensis* Mutuura and Freeman. Traps baited with dosages of either 1 or 10 mg of E9–14:Ac on rubber septa were the most attractive. Traps hung in white spruce trees caught significantly more males than those hung on poles between trees. Vertical location of traps within the tree crown was important; mean catches were greatest in the upper third of the crown. No consistent differences in the numbers of males caught were obtained in a comparison of two nonsaturating traps (Multi–Pher and Uni–Trap), and one sticky trap (Pherocon ICP).

Turgeon, J.J.; Nelson, N.; Kettela, E.G. 1987. Reproductive biology of the spruce budmoth, *Zeiraphera canadensis* Mut. & Free. (Lepidoptera: Tortricidae: Olethreutinae) in New Brunswick. Can. Ent. 119: 361–364.

Studies on the reproductive biology of the spruce budmoth, *Zeiraphera canadensis* Mut. & Free., were conducted in northern New Brunswick. Observations of adults under insectary conditions revealed that peak mating occurred around midnight, and that copulation lasted on average 4.3 h. The age of males and females at mating as well as their longevity is provided for both years. The pre–oviposition period was similar for both years, 6.1 and 6.3 days in 1984 and 1985, respectively. The oviposition period decreased from 6.1 days in 1984 to 4.4 days in 1985. The total fecundity was 32.9 eggs per female in 1984 and 21.8 eggs per female in 1985. The mean age–specific oviposition rate under 1984 field conditions is also presented. The importance of these results in determining the proper timing of adulticide sprays against *Z. canadensis* is discussed.

La stratégie de reproduction de la tordeuse de l' épinette, *Zeiraphera canadensis* Mut. & Free., a été étudiée dans le nord du Nouveau Brunswick. La période optimale d'accouplement d'adultes en cages, survint aux environs de minuit. L'accouplement moyen dura 4,3 h. Le période de pré–accouplement et la longévité des femelles et des mâles furent obtenus pour les 2 années d' études. En moyenne, la ponte débuta, 6,1 et 6,3 jours, en 1984 et 1985 respectivement, après l' émergence des femelles. La période de ponte passa de 6,1 jours en 1984 à 4,4 jours en 1985. Le nombre moyen

d'oeufs pondus fut de 32,9 oeufs par femelle en 1984 et de 21,8 oeufs par femelle en 1985. La relation obtenue en 1984, entre la ponte journalière moyenne et l'âge des femelles, est présentée. Notre discussion porte sur la détermination d'un moment opportun pour l'application d'un insecticide contre les adultes de *Z. canadensis*.

Turgeon, J.J.; Régnière, J. 1987. Development of sampling techniques for the spruce budmoth, *Zeiraphera canadensis* Mut. and Free. (Lepidoptera: Tortricidae). Can. Ent. 119:239–249.

The spatial and statistical distribution of *Zeiraphera canadensis* Mut. and Free. (spruce budmoth) within the crown of white spruce (< 4m high) was investigated in northern New Brunswick. A 15–cm branch segment, measured distally from the scales of the branch's apical growth and taken from the upper one–third of the crown is considered an adequate sample unit for density estimates of spruce budmoth eggs and larvae. Sample sizes required to estimate spruce budmoth larval densities with given levels of precision and confidence were determined. A sequential sampling plan to classify spruce budmoth populations as low or high (potentially leading to growth reduction and deformed leaders in white spruce) was also developed.

La distribution spatiale et statistique de la tordeuse de l'épinette, *Zeiraphera canadensis* Mut. and Free., dans la cime d'épinettes blanches (<4m), a été étudiée dans le nord du Nouveau–Brunswick. Ces travaux ont permis de déterminer qu'un segment de branche de 15 cm, mesuré à partir des écailles de la pousse apicale vers la base et prélevée dans le 1/3 supérieur de la couronne, est une unité d'échantillonnage adéquate pour l'estimation de la densité des populations d'oeufs ou de larves de cet insecte. Le nombre d'échantillons nécessaires pour l'estimation des densités larvaires à certains niveaux de précision et de confiance a été déterminé. Un plan d'échantillonnage séquentiel permettant de classer les populations de la tordeuse de l'épinette comme faibles ou élevées (pouvant causer une perte de croissance ou la déformation de la flèche chez l'épinette blanche) a aussi été élaboré.

Tyrrell, D. 1988. Survival of *Entomophaga aulicae* in dried insect larvae. J. Invertebr. Pathol. 52:187–188.

Tyrrell, D.; Ben–Ze'ev, I.S. 1990. An emended description of *Furia crustosa* (Entomophthorales: Entomophthoraceae). Mycotaxon 37: 211–215.

Secondary conidia, cystidia and rhizoids of *Furia crustosa* (MacLeod & Tyrrell) Humber are described. The morphology of the cystidia and rhizoids supports the assignment of this species to the genus *Furia* (Batko) Humber. An emended description of *F. crustosa* is given.

Tyrrell, D. 1990. Pathogenesis of *Entomophaga aulicae*. 1. Disease symptoms and effect of infection on weight gain of infected *Choristoneura fumiferana* and *Malacosoma disstria* larvae. J. Invert. Pathol. 56: 150–156.

Larvae of the eastern spruce budworm, *Choristoneura fumiferana*, and the forest tent caterpillar, *Malacosoma disstria*, infected with strains of *Entomophaga aulicae* gained weight at the same rate as uninfected control larvae injected with sterile culture filtrates in which *E. aulicae* had been grown, until the day prior to their death. At this time, infected insects lost weight and exhibited a marked reduction in frass production. No evidence for toxic substances was found in culture filtrates of *E. aulicae* grown under a variety of environmental conditions nor in homogenates of near or freshly dead *E. aulicae*–infected budworm larvae. External symptoms of fungal infection on spruce budworm, which first became evident about 4 h prior to death of the larvae, are described.

van Frankenhuyzen, K. 1987. Effect of wet foliage on efficacy of *Bacillus thuringiensis* spray against the spruce budworm, *Choristoneura fumiferana* Clem. (Lepidoptera: Tortricidae). Can. Ent. 119:955–956.

van Frankenhuyzen, K . 1990. Development and current status of *Bacillus thuringiensis* for control of defoliating forest insects. The Forestry Chronicle 66:498–507.

Bacillus thuringiensis (*Bt*) is a naturally occurring bacterium that is now widely used for control of spruce budworm and several other defoliating forest insects in Canada. It took more than 25 years of research and development to bring *Bt* from first experimental use in the early 1960s into full operational use in the mid 1980s. Critical to this process was the adoption of HD–1 for commercial use. The standardization of formulations based on international units, and the development of higher potency products. An increase in product potency from 4 BIU/L in the early 1970s to 16.9 BIU/L in the mid 1980s, concomitant with improvements in formulation and application technology, reduced treatment costs while at the same time improving reliability of efficacy. A shift in political climate pushed *Bt* into operational use by 1985. Since then, *Bt* has been used in more than half of all spruce budworm control programs. The use of high–potency formulations (12.7 to 16.9 BIU/L) applied undiluted at 30 BIU in 2.4 L/ha or less has significantly reduced but not eliminated initial constraints of high treatment costs and inconsistent efficacy. Current research is focused on further reducing these constraints. In the short term, registration of formulations containing 25 BIU/L or more is expected to permit application of reduced dosages in less than 1 L/ha and to clear the way for adoption of a split application scheme to increase reliability of efficacy. Selection and commercialization of more effective strains and the enhancement of natural strains by genetic or genetic engineering techniques offer exciting prospects for improvements in the longer term.

Bacillus thuringiensis (*Bt*) est une bactérie naturelle, aujourd'hui largement utilisée contre la tordeuse des bourgeons de l'épinette et plusieurs autres défoliateurs des forêts du Canada. Depuis son premier emploi expérimental, au début des années 60, jusqu'a son utilisation en grand, dans le milieu des années 80, il s'est passé plus de 25 années de recherche–développement. Une étape critique de cette évolution a été l'adoption du HD–1 pour emploi industriel, la normalisation des préparations grâce à l'emploi des unités internationales ainsi que la mise au point de produits plus puissants. Ainsi, l'accroissement de la puissance, de 4 unités biologiques internationales au litre (UBI/L), au début des années 70, à 16,9, au milieu des années 80, en même temps que les améliorations des techniques de préparation et d'application, ont permis de réduire les coûts du traitement tout en améliorant la fiabilité de l'efficacité. Un nouveau climat politique a favorisé l'emploi en grand de *B.t.* dès 1985. Depuis *B.t* a servi dans plus de la moitié de tous les programmes antitordeuse. Le recours à des préparations très puissantes (de 12,7 à 16,9 UBI/L) appliquées sans dilution à raison de 2,4 L/ha a permis de réduire considérablement, sans les éliminer complètement, les contraintes initiales posées par les coûts élevés du traitement et l'efficacité inconstante. La recherche actuelle se propose de réduire ces contraintes. À court terme, l'homologation des préparations renfermant 25 UBI/L ou plus est prévue afin de permettre l'application de doses réduites à raison de moins de 1 L/ha et de préparer la voie à un plan d'application répétée, pour une efficacité plus fiable. La sélection et la commercialisation de souches plus efficaces ainsi que l'amélioration des souches naturelles par des techniques génétiques ou du génie génétique recèlent des promesses excitantes d'amélioration à la longue.

van Frankenhuyzen, K. 1990. Effect of temperature and exposure time on toxicity of *Bacillus thuringiensis* Berliner spray deposits to spruce budworm, *Choristoneura fumiferana* Clemens (Lepidoptera: Tortricidae. Can. Ent. 122: 69–75.

Experiments were conducted using balsam fir twigs treated with *Bacillus thuringiensis* Berliner to examine the influence of temperature and exposure time on mortality of spruce budworm, *Choristoneura fumiferana* Clemens. Twigs were sprayed with a commercial formulation (8.4 BIU/L) using droplets of 40–70 µm diameter at densities ranging from 0.5 to 5.5 droplets per needle. Temperature affected progression but not the level of cumulative mortality during 14 days of feeding on sprayed foliage. The LT_{50} decreased from 12–17 days at 13°C to 2–4 days at 25°C, depending on droplet densi-

ty. Temperatures between 13 and 25 °C had a limited effect on dose acquisition because 40–60% of the larvae were able to acquire a lethal dose within 1 day of feeding on foliage with 0.5–1.5 droplets per needle, regardless of temperature. Under these conditions dose acquisition was not limited by temperature–dependent consumption of foliage, but rather by feeding inhibition associated with the dose initially ingested. This also limited the influence of exposure time; a 7– or 14–fold increase in exposure time increased larval mortality at most by 25%. Implications of these findings for improving efficacy of *B. thuringiensis* in forestry applications are discussed.

Des expériences ont été menées utilisant des branches de sapin baumier traitées avec *Bacillus thuringiensis* Berliner afin d'étudier l'influence de la température et du temps d'exposition sur la mortalité de la tordeuse des bourgeons de l'épinette, *Choristoneura fumiferana* Clemens. Les branches on été arrosées d'une formule commerciale (8,4 BIU/L) utilisant des gouttelettes des 40–70 µm de diamètre à des densités variant entre 0,5 et 5,5 gouttelettes par aiguille. Pendant 14 jours de nutrition sur du feuillage traité, la température a affecté la progression de la mortalité mais pas son niveau cumulatif. Le TL_{50} est passé de 12–17 jours à 13° C, à 2–4 jours à 25° C, dépendant de la densité des gouttelettes. La température entre 13 et 25° C n'a eu qu'un effet limité sur l'acquisition de dose puisque 40–60% des larves ont été capables d'ingérer une dose létale à l'intérieur d'une journée de nutrition sur du feuillage avec 0,5–1,5 gouttelettes par aiguille, quelque soit la température. Sous ces conditions, l'acquisition de dose n'a pas été limitée par un niveau de consommation du feuillage dépendance de la température, plutôt par l'inhibition de la nutrition associée à la dose initialement ingérée. Ceci a aussi limité l'influence du temps d'exposition; une augmentation du temps d'exposition par un facteur de 7 à 14 n'a augmenté la mortalité larvaire qu'au plus de 25%. Les implications de ces résultats pour l'amélioration de l'efficacité de *B. thuringiensis* en foresterie sont discutées.

van Frankenhuyzen, K.; Fast, P.G. 1989. Susceptibility of three coniferophagous *Choristoneura* species (Lepidoptera: Tortricidae) to *Bacillus thuringiensis* var. *kurstaki*. J. Econ. Entomol. 82:193–196.

Susceptibility of three *Choristoneura* species to the HD–1 and NRD–12 strains of *Bacillus thuringiensis* var. *kurstaki* Berliner was compared using the diet–incorporation method. Susceptibility of *C. fumiferana* (Clemems) and *C. pinus* Freeman did not differ significantly, whereas *C. occidentalis* Freeman was significantly more susceptible to preparations produced in our laboratory and commercial formulations. There was no significant difference between pathogenicity of HD–1 and NRD–12 for any of the budworm species. That *C. occidentalis* was more susceptible than *C. fumiferana* also was demonstrated in assays with treated foliage of balsam fir, *Abies balsamea* L., using spray deposits that are representative of ultra–low–volume applications.

van Frankenhuyzen, K.; Geen, G.H. 1986. Microbe–mediated effects of low pH on availability of detrital energy to a shredder, *Clistoronia magnifica* (Trichoptera: Limnephilidae). Can. J. Zool. 64:421–426.

We tested the hypothesis that microbe–mediated changes in nutritional quality of leaf litter conditioned at low pH enhanced larval growth of the caddisfly shredder, *Clistoronia magnifica*. Alder leaves conditioned for more than 3 weeks at pH4 had greater fungal biomass and bacterial abundance than leaves conditioned at pH6. Differential microbial colonization did not affect ingestion rates. Radioisotope experiments indicated that late–instar larvae assimilated microbe–derived energy from leaves conditioned at pH4 with a 10–15% higher efficiency than microbial energy from leaves conditioned at pH6 and suggested a concomitant 5% increase in assimilation of leaf–derived energy. Enhanced growth of *C. magnifica* at low pH could be accounted for by increased fungal biomass on leaves conditioned at low pH and increased availability of leaf energy, presumably due to additional modification of the leaf substrate by fungal enzymes.

L'hypothèse selon laquelle les changements que causent les microbes dans la qualité nutritive de litières de feuilles gardées à pH faible favorisent la croissance larvaire du trichoptère déchiqueteur *Clistoronia magnifica* a été mise à l' épreuve. Des feuilles d'aulne gardées durant plus de 3 semaines à pH 4 avaient une plus grande biomasse de champignons et une flore bactérienne plus abondante que des feuilles gardées à pH 6. L'importance de la colonisation microbienne n'a pas affecté les taux d'ingestion. Des expériences au moyen de radioisotopes ont démontré que les larves des derniers stades assimilaient l' énergie dérivée des microbes dans les feuilles gardées à pH4 avec une efficacité de 10–15% plus grande que dans les feuilles gardées à pH 6 et qu'il y avait aussi une augmentation concomitante de 5% dans l'assimilation de l' énergie dérivée des feuilles. L'augmentation de la croissance de *C. magnifica* à pH faible s'explique peut–être par l'augmentation de la biomasse de champignons dans les feuilles gardées à pH faible et par l'augmentation de la disponibilité de l' énergie dérivée des feuilles, elle–même due sans doute à la modification du substrat de feuilles par les enzymes des champignons.

van Frankenhuyzen, K.; Geen, G.H. 1987. Effects of low pH and nickel on growth and survival of the shredding caddisfly, *Clistoronia magnifica* (Limnephilidae). Can. J. Zool. 65:1729–1732.

In laboratory experiments with larvae of the shredding caddisfly *Clistoronia magnifica*, toxicity of nickel chloride hexahydrate was highly pH dependent. Larvae were exposed from first instar until pupation to three nickel concentrations (55, 215, 700 µg Ni^{2+}/L) in soft water adjusted to pH 4.1, 5.5 and 6.2. Nickel reduced the survival of larvae and pupae at all pH levels but toxicity decreased with increasing H^+ concentration. In addition, Ni at 215 µg/L temporarily ameliorated H^+ toxicity to early instar larvae at pH 4.1. Reduced toxicity with decreasing pH fits the hypothesis that free metal ions compete with H^+ for the same binding–uptake sites. Available data suggest that this phenomenon is not restricted to a particular metal or organism but that it applies to pH–metal interactions in general.

D'après des expériences en laboratoire sur des larves du Trichoptère déchiqueteur *Clistoronia magnifica*, la toxicité du chlorure hydraté ($6H_2O$) de nickel est fortement influencée par le pH. Des larves ont été exposées du premier stade jusqu' à la nymphose à trois concentrations de nickel (55, 215, 700 µg Ni^{2+}/L) dans de l'eau douce ajustée à des pH de 4,1, 5,5 et 6,2. Le nickel diminue la survie des larves et des nymphes à tous les pH, mais la toxicité diminue lorsque la concentration d'ions H^+ augmente. De plus, le Ni à 215 µg/L améliore temporairement la toxicité des ions H^+ chez les larves de premier stade à pH 4,1. La diminution de toxicité aux pH plus bas corrobore l'hypothèse selon laquelle les ions libres d'un métal font compétition aux ions H^+ pour les sites de liaison disponibles. Les données de la littérature semblent indiquer que ce phénomène n'est pas limité à métal au à un organisme en particulier, mais s'applique en général à toutes les interactions pH–métal.

van Frankenhuyzen, K.; Howard, C.; Churcher, J.; Howse, G.; Lawrence, D. 1989. Deposition and efficacy of Dipel 8AF applied diluted and undiluted against the gypsy moth (Lepidoptera: Lymantriidae) in southeastern Ontario. Forestry Canada, Forest Pest Management Institute, Sault Ste. Marie, Ont., Inf. Rep. FPM–X–84. 11 p.

The feasibility of ultra–low volume application of undiluted *Bacillus thuringiensis* formulations for control of the gypsy moth was examined by treating three oak stands with Dipel 8AF at 15 BIU in 0.9 L/ha (undiluted) or at 30 BIU in 1.8 L/ha (undiluted) and 6.0 L/ha (diluted). Branches were collected from upper, middle and lower canopy and assayed for spray deposits as well as toxicity to third–instar gypsy moth larvae. Droplet size distributions in the two undiluted treatments were similar with a number median diameter (NMD) of 49–55 µm and a volume median diameter (VMD) of 117–126 µm. The diluted application resulted in a broader size distribution, with an NMD of 98 µm and a VMD of 180 µm. Droplet density was significantly higher in the 1.8 and 6.0 L/ha treatments (5–10 droplets/cm^2) than in the 0.9 L/ha treatment (3–5 droplets/cm^2). Droplet density decreased significantly from

upper to lower canopy in each spray block. Mortality of gypsy moth larvae in the bioassays reached about 50% in the 1.8 and 6.0 L/ha treatments and 30% in the 0.9 L/ha treatment. Regression analysis of mortality versus observed droplet density in the bioassays did not differ between treatments. For both diluted and undiluted applications, a density of 8–10 droplets/cm^2 was required to obtain 50% mortality. All treatments resulted in lower defoliation and egg mass density than in untreated areas, but declining populations confounded the assessment. Application of undiluted formulations containing 16.9 BIU/L in 1.8 L/ha can be recommended for operational control of gypsy moth. The feasibility of using higher potency products in even lower volumes needs to be assessed in future programs.

La possibilité d'appliquer en très faible volume des formulations non diluées de *Bacillus thuringiensis* pour lutter contre la spongieuse a été examinée: on a traité trois peuplements de chênes avec du Dipel 8AF à 15 UBI par 0,9 L/ha (forme non diluée) ou 30 UBI par 1, 8 L/ha (forme non diluée) ainsi que 6, 0 L/ha (forme diluée). Des branches ont été prélevées aux niveaux supérieur, intermédiaire et inférieur de la cime; les dépôts laissés par pulvérisation ainsi que la toxicité chez les larves du troisième stade de la spongieuse ont été étudié. La distribution par taille des gouttelettes était semblable dans les deux traitements avec le produit non dilué, soit avec un diamètre médian en fonction du nombre (DMD) de 49–55 µm et un diamètre médian en fonction du volume (DMV) de 117–126 µm. L'application du produit dilué a eu pour effet d' élargir la distribution des gouttelettes; le DMN était de 98 µm et le DMV était de 180 µm. Il y a avait une densité significativement supérieure des gouttelettes lors des traitements à 1, 8 et 6,0 L/ha (5–10 gouttelettes/cm ^{2}) que lors du traitement à 0,9 L/ha (3–5 gouttelettes/cm ^{2}). Il y avait une réduction significative de la densité des gouttelettes du niveau supérieur au niveau inférieur de la cime dans chaque parcelle traitée. Lors des essais biologiques, la mortalité des larves de la spongieuse se chiffrait à environ 50% dans les groupes traités á 1, 8 et 6,0 L/ha et atteignait 30% dans le groupe traité à 0,9 L/ha. Il n'y avait pas de différence entre les différents traitements quant à l'analyse par traitements et quant à l'analyse par régression de la mortalité dans les bioessais par rapport à la densité observée des gouttelettes. Que ce soit sous forme dilué e ou non, il fallait une densité de gouttelettes de 8–10 gouttelettes/cm ^{2} pour atteindre une mortalité 50%. Tous les traitements ont atténué la défoliation et diminué la densité des masses d'oeufs, par rapport aux secteurs–témoins, mais les populations généralement faibles de larves n'ont pas aidé à l' évaluation. L'application de formulations sous forme non diluée et contenant 16,9 UBI/L dans 1,8 L/ha peut être recommandée pour les traitements opérationnels de la spongieuse. Il est suggéré de vérifier las possibilité d'utiliser des produits plus actifs et un volume encore moindre lors des futurs programmes.

van Frankenhuyzen, K.; Nystrom, C.W. 1987. Effect of temperature on mortality and recovery of spruce budworm (Lepidoptera: Tortricidae) exposed to *Bacillus thuringiensis* Berliner. Can. Ent. 119:941–954.

Spruce budworm larvae were bioassayed against *Bacillus thuringiensis* Berliner to study the effect of temperature on the expression of toxicity. Temperatures between 16 and 28°C did not affect the ultimate level of toxicity (LC_{50}). However, LT_{50}'s increased from 2–8 days at 28°C to 11–20 days at 16°C, depending on concentration of the pathogen. When larvae were force–fed with a single dose, temperature had a similar effect on the time course of mortality without affecting the level of mortality. Feeding inhibition of force–fed larvae commenced immediately after dosing. Larvae that did not recover died without further feeding, even at lower temperatures when death occurred 2–3 weeks after dosing. Recovering larvae resumed feeding after 2 (28°C) to 6 (13°C) days. Recovered larvae took longer to develop and produced lighter pupae than untreated larvae. Our data suggest that temperature –dependent feeding and recovery did not contribute to quicker death at higher temperatures. Expression of the toxin itself appears to depend on temperature possibly through the influence of temperature on metabolic rate of affected gut cells. Implications of these findings for the efficacy of spruce budworm control operations are discussed.

On a étudie l'effet de la température sur l'expression de la toxicité du *Bacillus thuringiensis* Berliner à l'encontre des larves de la tordeuse des bourgeons de l' épinette. Entre 16 et 28°C, la température n'a pas affecté le niveau ultime de toxicité (LC_{50}). Cependant les LT_{50} ont augmenté de 2–8 jours à 28°C, jusqu' à 11–20 jours à 16°C, selon la concentration du pathogène. Lorsque les larves ont été forcées d'ingérer une dose unique, la température a eu un effet similaire sur la chronologie de la mortalité, sans affecter son niveau. L'arrêt de l'alimentation chez les larves forcées d'ingérer le produit est apparu dès après le traitement. Les larves qui n'ont pu récupérer sont mortes sans reprendre de nourriture, même aux basses températures alors que la mort ne survenait que 2–3 semaines après la traitement. Les larves qui ont récupéré ont recommencé à s'alimenter après 2 (28°C) à 6 jours (13°C). Les larves ayant récupéré ont mis plus de temps à se développer et ont produit des pupes plus petites que les larves non traitées. Nos données indiquent que la thermo–dépendance de l'alimentation et de la récupération ne contribuent pas à la mortalité accélérée observée à haute température. C'est l'expression même de la toxine qui semble dépendre de la température, possiblement via l'effet de celle–ci sur le taux métabolique des cellules entériques affectées. On discute des implications de ces observations pour les opérations de lutte contre la tordeuse.

West, R.J.; de Groot, P. 1990. Red squirrels and cone crops: damage and management. pp. 118–128 In: R.J. West, ed. Proceedings, Cone and Seed Pest Workshop. 4 October 1989. Forestry Canada. Newfoundland and Labrador Region, St. John's, Nfld. Information Report N–X–274, 128 p.

Squirrels are the major vertebrate pest of cone crops and can substantially reduce the availability of cones by harvest. Cone depredation by the red squirrel, *Tamiasciurus hudsonicus* (Erxleben), on pine and spruce is reviewed. The following management strategies are discussed: utilization of cone caches; early harvesting; repellents; mechanical barriers; squirrel relocation; shooting, poisoning and kill–traps; and cultural practices. Use of cone caches and early cone–harvesting are recommended; repellents and live–trapping are considered as potentially suitable options. Permanent removal by lethal methods is suggested as a last resort.

Les écureuils sont les principaux vertébrés ravageurs des cônes et peuvent grandement réduire l'importance de la récolte. On examine ici les déprédations causées par l'écureuil roux, *Tamiasciurus hudsonicus* (Erxleben), dans les forêts de pins et d'épinettes. On présente ensuite les stratégies de répression suivantes: utilisation de caches de cônes, récoltes hâtive, emploi de répulsifs, barrières mécaniques, relocalisation des Écureuil, élimination au moyen d'armes à feu, de poison et de pièges, ainsi que le recours à certaines méthodes culturales. On recommande l'emploi de caches de cônes et la récolte hâtive; de plus, les répulsifs et les pièges permettant de capturer l'animal vivant constituent des choix également acceptables. L'élimination permanente au moyen de mesures entraînant la mort des animaux n'est suggérée qu'en dernier ressort.

Wilson, G.G. 1984. Dose–mortality response of *Choristoneura fumiferana* (Lepidoptera: Tortricidae) to a microsporidium, *Pleistiphora schubergi*. Proc. Ent. Soc. Ont. 115:93–94.

Wilson, G.G. 1986. A comparison of the effects of *Nosema fumiferanae* and a *Nosema* sp. (microsporida) on *Choristoneura fumiferana* (Clem.) and *Choristoneura pinus pinus* Free. Can. For Serv., For. Pest Manage. Inst., Sault Ste. Marie, Ont. Inf. Rep. FPM–X–77, 10 pp.

This report details the effects two microsporidia, *Nosema fumiferanae* and a *Nosema* sp. have when fed to 4th– and 5th–instar larvae of *Choristoneura fumiferana* and *Choristoneura pinus pinus*. Both microsporidia caused increased insect mortality and decreases in pupal weight and adult longevity. In

the majority of cases, *N. fumiferanae* caused the greatest detrimental effects on both species of pest insects.

Wilson, G.G. 1986. The effects of *Vairimorpha necatrix* (microsporida) on the spruce budworm, *Choristoneura fumiferana* (Lepidoptera: Tortricidae). Proc. Ent. Soc. Ont. 117:91–93.

Wilson, G.G. 1987. Comparaison des effets de *Nosema fumiferanae* et de *Nosema* sp. (Microsporida) sur *Choristoneura fumiferana* (Clem.) et *C. pinus pinus* Free. Serv. Can. For., Institut pour la répression des ravageurs forestiers, Sault Ste. Marie, Ont. Rap. Inf. FPM–X–77F, 9 p.

Sont présentés de façon détaillée les effets de deux microsporidies, *Nosema fumiferanae* et *Nosema* sp., lorsqu'elles sont consommées par des larves au 4e et au 5e stade de *Choristoneura fumiferana* et de *C. pinus pinus*. On a observé que les deux microsporidies causaient une augmentation de la mortalité des insectes ainsi qu'une diminution du poids des chrysalides et de la longévité des adultes. Dans la majorité des cas, *N. fumiferanae* a causé les effets les plus dommageables chez les deux espèces d'insectes.

Wilson, G.G. 1987. Observations on the level of infection and intensity of *Nosema fumiferanae* (microsporida) in two different field populations of the spruce budworm, *Choristoneura fumiferana*. Can. For. Serv., For. Pest Manage. Inst. , Sault Ste. Marie, Ont. Inf. Rep. FPM–X–79. 15 pp.

The levels of infection and intensity (spores/insect) of the microsporidium *Nosema fumiferanae* were investigated in two contrasting field populations of the spruce budworm, *Choristoneura fumiferana*, over a 4–year period. In Gargantua, an area of decreasing budworm infestation, the average yearly infection level of *N. fumiferanae* increased only slightly from 52% in 1982 to 62% in 1985. However the average intensity decreased sharply from 30.7×10^6 spores/insect in 1982 to 4.5×10^6 in 1985. This spruce budworm population collapsed in 1985. In a population of spruce budworm at Black Sturgeon Lake (area of increasing infestation), the average infection levels for 1983 and 84 were the same at 18%, this increased to 33 and 31% for 1985 and 86 respectively. The average yearly intensity in this population increased for the first 3 years but declined in 1986. The intensity was 0.9×10^6, 3.0×10^6, 9.4×10^6 and 2.3×10^6 spores/host for 1983, 84, 85 and 86 respectively. In both host populations the number of spores per mg of tissue fluctuated with sampling date, but in general also increased with host age.

Les pourcentages d'infection par la microsporidie *Nosema fumiferanae* et l'intensité de l'infection (spores par insecte) ont été étudiés sur le terrain chez deux populations très différentes de la tordeuse des bourgeons de l' épinette (*Choristoneura fumiferana*), pendant quatre ans. Dans la région de Gargantua où l'infestation par la tordeuse est à la baisse, le pourcentage moyen annuel d'infection par *N. fumiferanae* n'a augment é que légèrement, passant de 52% en 1982 2' 62% en 1985. Toutefois, l'intensité moyenne à diminué nettement, soit de $30,7 \times 10^6$ spores par insecte en 1982 à $4,5 \times 10^6$ en 1985. Il y a eu effondrement de cette population de la tordeuse en 1985. Chez une autre population se trouvent dans la région du lac Black Sturgeon (où l'infestation est à la hausse), le pourcentage moyen d'infection est resté le même à 18% en 1983 et 1984, mais il est monté à 33 et 31% en 1985 et 1986 respectivement. L'intensité moyenne annuelle de l'infection dans cette population a augmenté au cours des trois premières années, mais a diminué en 1986. Les chiffres pour les quatre années sont respectivement de $0,9 \times 10^6$, $3,0 \times 10^6$, $9,4 \times 10^6$ et $2,3 \times 10^6$ spores par hôte. Chez les deux populations hôtes, le nombre de spores par milligramme de tissus fluctuait en fonction de la date d' échantillonnage, mais, en général, il augementait avec l' âge de l'hôte.

Zhang, G.; Kaupp, W.J. 1988. Use of monoclonal antibodies in an ELISA to detect the *Choristoneura fumiferana* nuclear polyhedrosis virus. Chinese J. Virol. 4: 61–64.

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