STRATEGIC CHEMICALS FOR PROTECTION OF CONIFEROUS FORESTS FROM INSECT PESTS

by

P. C. NIGAM

Chemical Control Research Institute

Ottawa, Ontario

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P. C. Nigam, Project Leader

Chemical Control Research Institute
Canadian Forestry Service
Environment Canada
Ottawa Canada

ABSTRACT

The selection of fenitrothion, phosphamidon, Matacil® (aminocarb) and Zectran® (mexicarbate) for the control of coniferous forest insect pests is described. Characteristics of acceptable insecticides on the basis of their toxicity to target insect pests and to other components of the forest ecosystem i.e. fish, birds and mammals are discussed. The operational application of fenitrothion, phosphamidon, Matacil and Zectran is also summarized.

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PRODUITS CHIMIQUES IMPORTANTS UTILISÉS POUR LA PROTECTION DES FORÊTS DE CONIFÈRES CONTRE LES INSECTES NUISIBLES

P.C. Nigam, Directeur de recherche
Institut de recherche en répression chimique
Service canadien des forêts
Environnement Canada
Ottawa, Canada

RÉSUMÉ

Le présent rapport décrit comment s'est fait le choix du fénitrothion, du phosphamidon, du Matacil et du Zectran comme moyens de lutte contre les insectes nuisibles aux forêts de conifères. Il décrit également les caractéristiques d'insecticides acceptables, d'après leur toxicité pour les ravageurs auxquels ils sont destinés et pour d'autres éléments de l'écosystème forestier, c'est-à-dire, les poissons, les oiseaux et les mammifères. Il expose en outre les méthodes d'application des insecticides déjà mentionnés.

PRODUCTOS QUIMICOS PROTECTORES DE BOSQUES DE CONIFERAS CONTRA PLAGAS DE INSECTOS

P. C. Nigam, Director de Proyectos

Instituto de Investigación de Control por Productos Químicos

Servicio Forestal Canadiense

Ambiente Canadá

Ottawa, Canadá

RESUMEN

Se describe la selección de fenitrotión, fosfamidón, Matacil y Zectrán para la lucha contra pestes de insectos de bosques de coníferas. Se describen las características de insecticidas aceptables, a base de su toxicidad hacia su objetivo de plagas de insectos y otros componentes del ecosistema forestal, v.gr. peces, aves y mamíferos. También se muestra la aplicación operativa del fenitrotión, fosfamidón, Matacil y Zectrán.

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Coniferous forests, especially in North America are plagued by a number of devastating insect pests (Davidson and Prentice 1967). The most destructive pests are lepidopterous defoliators, followed by various species of sawflies, beetles and weevils. Until 1969, economic losses due to these pests were minimized by aerial application of persistent chlorinated hydrocarbon insecticides e.g., DDT and BHC or lindane (Nigam, 1975). To replace these persistent insecticides a number of compounds have been investigated by the forestry services of Canada and United States against a variety of insect pests of coniferous forests since the early sixties (Fettes 1960, 1968; Moore 1965; Nigam 1968, 1970, 1971, 1972, 1975; Lyon et al. 1970; Randall 1970).

About 80 chlorinated hydrocarbon, organophosphorus, carbamate or botanical compounds have been tested against 20 or more species of forest insect pests in the laboratory, and 28 of these insecticides have been field tested by aircraft against 24 species of insects in Canada. This paper will deal with lepidopterous defoliators, especially spruce budworm (Choristoneura fumiferana Clem.). The spruce budworm is the most destructive pest of balsam fir, Abies balsamea (L) Mill. and white spruce, Picea glauca (Moench) Voss. Millions of dollars are spent in Canada to protect vast areas of spruce-fir forest from its ravages (Prebble 1968, Prebble 1975). Much of the experience gained with this defoliator is directly applicable, with minor modifications, to the control of other defoliators.

The principal criteria used in selecting new candidate insecticides are high toxicity to target insects, and acceptable toxicity to man and other components of the forest ecosystem e.g., low toxicity to fish, birds and mammals (Fettes 1968). Selected compounds should be adapatable for various formulations and modes of application. They should be economical and sufficiently stable under environmental conditions to give protection against the pest species. For practical reasons they must be available in sufficient quantities for aerial application over large areas (Nigam 1971, 1975; Prebble 1968).

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New compounds are selected, on the basis of manufacturers claims and test data, as potential substitutes for DDT. The candidate compounds are tested in the laboratory for contact, stomach and residual toxicity or systemic activity against a number of forest insect pests (Nigam 1970, 1971). Compounds found effective in laboratory tests are then field tested on individual trees, and subsequently by mist blower, hydraulic or compressed air sprayers on 0.1 to 20 acre plots (DeBoo and Hildahl 1971). Compounds that show promise in these tests are recommended for experimental aerial application over large blocks of forest, using operational spray aircraft of various types from the Stearman to Grumman TBM and to a much larger type, e.g., DC-6B or DC-7B (DeBoo and Hildahl 1967, Armstrong and Randall 1969, Nigam 1975, Prebble 1975).

Laboratory and field data on toxicity of the candidate insecticides to fish and birds are obtained with the cooperation of the Fisheries and Marine Service and the Canadian Wildlife Service of the Canada Department of Environment, and may be supplemented by additional information from the Fish and Wildlife Service of the United States Department of the Interior. Mammalian toxicity is usually provided by the companies supplying the compounds.

Of about 35 compounds tested against spruce budworm in the laboratory, 21 were considered promising for aerial evaluation. To date, four insecticides have been used in large scale operations or registered for aerial application for the control of spruce budworm in Canada as substitutes for DDT. They are fenitrothion and phosphamidon, belonging to the organophosphorus group, and Matacil ® (aminocarb) and Zectran ® (mexicarbate) in the carbamate group.

Data on the contact and residual toxicity of ten insecticides to 5th instar spruce budworm and toxicity to fish, birds and mammals are presented in Table 1 to illustrate the criteria used for final selection of the four insecticides and the rejection of others. The dosages for experimental and operational aerial application and the final recommended dosages for control of spruce budworm are also indicated.

The contact toxicity of DDT to the budworm is relatively low (i.e., the required deposits for 50% and 95% mortality are high) compared with most of the other insecticides. However, its toxicity to fish is high, consequently effective field dosages were commonly associated with injury to fish. Phosphamidon is quite toxic to the budworm, safe for fish, but toxic to birds, as was discovered in aerial operations in New Brunswick (Prebble 1968). Fenitrothion is about as effective as phosphamidon against budworm, yet it is safer for birds and generally safe for fish, although some mortality of fish food organisms has occurred in field applications at a dosage rate of 4 oz/acre. Dibrom ® (naled) has a substantially higher contact toxicity to the budworm than the preceding three but in field application it was ineffective, owing to its poor residual toxicity.

Among the carbamates, Zectran and Matacil exhibit high contact and residual toxicities. The former is slightly hazardous to birds and the latter to fish, but at application rates of about 2 oz/acre or less they are effective against the budworm, with no apparent effects on birds or fish. A third carbamate, Baygon ® (propoxur) was eliminated from field trials, because of poor contact and residual toxicity against budworm.

The synthetic and plant derivative pyrethroids, SBP 1382 (resmethrin) and stabilized natural pyrethrins 7014 are highly toxic to the budworm and exceedingly toxic to fish. In field tests, when used at less than 1 oz/acre, to avoid injury to fish, these materials were ineffective against spruce budworm. Low residual toxicity is an added disadvantage.

From the available data on the efficacy and toxicity of the insecticides, the following specifications are suggested as suitable criteria for future selection of insecticides against spruce budworm or other defoliators: contact toxicity LD_{50}, 0.5 $\mu g/cm^2$ or less, for later stage larvae; at least 50% mortality of test insects from residues of applied dose after 3 days of weathering; LC_{50} for fish not less than 5 to 10 ppm; oral LD_{50} to birds not less than 5 to 10 mg/kg; oral and dermal mammalian toxicities greater than 100 mg/kg and 200 mg/kg, respectively. Of the ten insecticides listed (Table 1) fenitrothion, Zectran and Matacil come reasonably close to meet these specifications, and have proven effective at 2 to 4 oz/acre in the operational application.

The organophsophate Orthene ® (acephate) appears to meet most of the specifications. Its very low toxicity for fish, birds and mammals, combined with its systemic activity, and toxicity to the budworm as a contact and stomach poison in the laboratory, warrants operational testing of its efficacy, and close monitoring of its impact on other components of the forest ecosystem.

Phosphamidon was the first insecticide substituted for DDT in Canadian forests, followed by fenitrothion, Zectran and Matacil. Because of adverse effects on birds at high dosages used initially, phosphamidon application was restricted to watershed areas where fish kill was prime concern. About 1.2 million lb. of phosphamidon have been applied to 4.4 million acres from 1961 to 1973 against budworms, loopers and sawflies. Fenitrothion has been used successfully with few adverse side effects against budworms, loopers and sawflies since 1965. Approximately 9 million lb. of fenitrothion have been sprayed on 36.5 million acres from 1965 to 1973 in Canada. It is registered for use in the control of spruce budworm and other defoliators in Canada. Sixteen thousand lb. of Zectran have been sprayed against spruce budworm on 246,000 acres in Canada from 1965 to 1973. Although it is registered in the United States and Canada for the control of spruce budworm, the chemical is no longer produced commercially. Matacil has been used against budworms and about 22,400 lb. have been sprayed over 431,000 acres from 1967 to 1973. Matacil is on temporary registration for spruce budworm control in Canada as its metabolic products are still under investigation. The aircraft used for application of these insecticides were Stearman, Ag-Wagon, Cessna, Ag-Cat and Grumman TBM but more recently DC-6B, DC-7B and Super Constellations are being used to cover millions of acres in a short time (Randall 1974, Prebble 1975). The cost of these operations varied from sixty cents to one dollar per acre, depending upon the chemicals, aircraft, and size of operations. Fenitrothion applications were most economical and spraying of Zectran was the most costly.

At the present state of knowledge, fenitrothion is the No. 1 strategic chemical, followed by phosphamidon and Matacil, for the protection of coniferous forests from defoliating insects, taking into consideration efficacy against the target insects, safety to the other components of the forest ecosystem, economics, availability, adaptability to various formulations and modes of application.

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OTTAWA, Canada.

Table 1. Toxicity of Insecticides to Fifth-Stage Spruce Budworm Larvae and Other Fauna Under Laboratory Conditions and Emission Rates Employed or Recommended for Aerial Applications

INSECTICIDE AND TYPE	Budworm Larvae: Contact Toxicity (72 hr) (μg/cm²)		Budworm Larvae: Residual toxicity (72 hr)						Fish (salmon) LC_{50} ppm (48 hr) (3)	Birds (mallards) LD_{50} mg/kg (4) oral	Mammals (rats) LD_{50} mg/kg (5)		Aerial application rate, oz*/acre** (6)		
			Application rate oz/acre (1)	Mortality after weathering period (days) (2)											
	LD_{50}	LD_{95}		0	1	3	5	10			Oral	Dermal	Exp	Oper	Rec. (11)
DDT (7) (ch)	1.32	6.64	8.0	73	84	52	37	30	0.05	2240.0	87-500	1931-3263	2-96	32,16 8,4	-
Phosphamidon (op)	0.39	0.75	3.2	85	70	50	45	15	11.00	3.1	15-33	640	2-32	4-8	2X2 or 1X4
Fenitrothion (op)	0.31	0.67	3.2	81	71	46	43	32	1.40	1190.0	250-670	200->3000	2-21	4-10	2X2 or 1X4
Dibrom (op)	0.16	0.34	3.2 8.0	0 16	0 15	0 10	0 0	0 0	0.55	52.2	430	1100	3.2	-	-
Zectran (carb)	0.04	0.13	3.2	96	89	78	67	59	13.0	3.0	19-22	> 500	0.25-8	.75-1.2	2X.75
Matacil (carb)	0.04	0.11	3.2	95	89	66	70	66	1.30	22.5	30	275	0.5-4	2X.75	2X.75
Baygon (carb)	3.43	18.03	3.2 8.0	2 0	0 0	0 0	0 0	0 0	2.00	11.9	95-175	>1000	1.2-2.5	-	-
SBP 1382 (pyr)	0.17	0.51	3.2 8.0	7 79	10 8	0 43	11 13	1 0	0.028 (8)		2500	3040	0.72	-	-
Stab. pyrethrins (7014) (pyr)	0.04	0.11	3.84	76	10	2	0	0	0.054 (9)	>10,000	200-2600	>1800	0.67	-	-
Orthene (op)	0.42	3.5	8.0	95	88	38	15	18	1000 (10)	350	1,494	10,250	3-9	-	-

(1) Equivalent in oz. active ingredient per acre
(2) Per cent mortality corrected for natural deaths in check lots (3 year average)
(3) Data from research establishments of Fisheries and Marine Service, Canada Department of the Environment
(4) Data from Tucker and Crabtree (1970)
(5) Data from Kenaga and Allison (1969)
** Acre = 0.405 hectares
* Ounce (Imp. fluid) = 28.41 milliliters
* Ounce (Avoir.) = 28.35 grams
Registered names are given as they are more commonly known.

(6) Application rates used in experimental tests (exp) in operational programs (oper.), or rates recommended on basis of toxicity data and field experience.
(7) Ch = chlorinated hydrocarbon; op = organophosphate; carb = carbamate; pyr = pyrethroid
(8) 28 parts per billion (toxicity for trout)
(9) 54 parts per billion (toxicity for gold fish)
(10) Toxicity for trout
(11) No. of applications x oz. applied/acre.