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EXPERIMENTAL AERIAL APPLICATION OF INSECT GROWTH REGULATORS AGAINST THE SPRUCE BUDWORM, CHORISTONEURA FUMIFERANA (CLEMENS) IN THESSALON (1976) AND HEARST (1977).

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Experimental aerial application of Insect Growth Regulators against the spruce budworm, *Choristoneura fumiferana* (Clemens) in Thessalon (1976) and Hearst (1977)

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ABSTRACT

Experimental aerial application of several Insect Growth Regulators against the spruce budworm at Thessalon (1976) and Hearst (1977) showed that -

(i) Dimilin at 140 g/ha (2 oz./acre) is ineffective with or without a sticker.

(ii) Dimilin when applied twice with an interval of 1 week between sprays at 140 and 70 g/ha (2 and 1 oz./acre) caused 78.1 % reduction in spruce budworm population and provides good foliage protection on white spruce. However, it is less effective on balsam fir.

(iii) RO-103108, like other juvenile hormone analogs has marginal effects and does not merit further testing.

(iv) PH 60-41, which is not a moult inhibitor even though it is an analog of Dimilin at 140 g/ha (2 oz./acre) caused around 70.1% population reduction on both balsam fir and white spruce and warrants further study.

(v) EL-494 which is a moult inhibitor, at 140 g/ha (2 oz./acre) caused 60.1% reduction in population on both tree species and requires further testing.

RÉSUMÉ

L'auteur effectua des pulvérisations aériennes expérimentales avec des régulateurs de la croissance des insectes pour lutter contre la Tordeuse des bourgeons de l'Epinette à Thessalon (1976) et a Hearst (1977). Voici les résultats:

(i) Le Dimilin à 140 g/ha (2 oz/acre) reste inefficace avec ou sans une matière collante.

(ii) Le Dimilin pulvérisé deux fois (intervalle d'une semaine) à 140 et 70 g/ha (2 et 1 oz/acre) réduisit de 78.1% la population de Tordeuses et protégea bien la feuillage des Epinettes blanches. Cependant il fut moins efficace contre le Sapin baumier.

(iii) Le RO-103108, comme les autres hormones juvéniles analogues, produit des effets marginaux et ne mérite pas qu'on l'essaye plus longtemps.

(iv) Le PH 60-41 (qui n'inhibe pas la mue bien qu'il soit analogue au Dimilin) fut pulvérisé à raison de 140 g/ha (2 oz/acre) et il causa une réduction de la population d'environ 70.1% sur le Sapin baumier et l'Epinette blanche. Il mérite d'être encore essayé.

(v) L'EL-494, cet inhibeur de mue, à 140 g/ha (2 oz/acre) réduisit la population d'insectes de 60.1% sur les deux espèces d'arbres et il faut l'essayer encore.

TABLE OF CONTENTS

INTRODUCTION

Insect Growth Regulators are essentially slow acting insecticides which adversely affect the normal growth and development of insects. They are more selective than conventional insecticides and have very little impact on the environment. At present 3 groups of insect growth regulators are known. These are (i) anti-juvenile hormones (antiallatotropins) (ii) juvenile hormone analogs and (iii) moult inhibitors.

Anti-juvenile hormones either inhibit the production of juvenile hormone, or prevent the release of the hormone or negate the activity of the hormone. At present only 2 such compounds are known and they have been named Precocene I and II (Bowers, 1976). When early instars of certain Hemiptera are treated with these materials, they undergo precocious metamorphosis resulting in sterile miniature adults. Unfortunately, both these compounds are inactive on Lepidoptera.

Juvenile hormone analogs mimic the activity of the natural hormone. Many of these compounds are not only less labile than the natural hormone but also more active. The titer of natural hormone is relatively high in early larval instars and is necessary to ensure continuance of the larval morphogenetic condition. In the last larval instar the titer of juvenile hormone drops rapidly initiating pupal development. When juvenile hormone analogs are applied to the last larval instar, they induce abnormal pupation leading to mortality. The mode of action and the physiological basis, disruption of normal metamorphosis with juvenile hormone analogs, have been extensively reviewed (Burdette, 1974; Gilbert, 1976; Menn and Beroza, 1972; Slama et al., 1974; Staal, 1975). Obviously juvenile hormone analogs will be most effective on insects where the adult is the damaging form.

In the case of spruce budworm, no foliage protection can be realized in the year of application but if immigration of moths is minimal into a treated area, it is possible to protect the forest in the subsequent year. Several juvenile hormone analogs have been tested on the spruce budworm with varying degrees of success (Retnakaran et al., 1977). It is possible to obtain over 90% reduction in population at high doses (Granett, 1976).

In 1973, it was found that some benzoyl ureas being developed for herbicide activity when tested on insects disrupted the normal moulting process (Post and Vincent, 1973; Welliga et al., 1973). This serendipitous discovery led to the development of the first moult inhibitor, Dimilin®. This compound blocks chitin synthesis at the last biosynthetic step involving polymerization of UDP-N-acetyl glucosamine units. Dimilin is highly insoluble in water and most other solvents and, therefore, has to be ingested in order to be effective. It has been extensively tested on the spruce budworm both in the field and in the laboratory. Dimilin is more effective on the last larval instar than the earlier stages indicating stadial sensitivity of the budworm towards this insect growth regulator (Granett and Retnakaran, 1977; Retnakaran and Smith, 1975). The EC_{50} is 3.7 ppm for the 6th, 8.3 for the 5th, 15 for the 4th, 36 for the 3rd and 91 for the 2nd instars. EL-494, a moult inhibitor developed by Elanco appears to be more active on the spruce budworm than Dimilin.

PH 60-41 is an analog of Dimilin that has no moult inhibiting activity but induces muscle paralysis (Mulder et al., 1975). The larvae drop off from the foliage and branches and are unable to crawl up the tree and utimately die of starvation.

The results of (i) 1976 field tests with Dimilin (moult inhibitor) and RO-103108 (juvenile hormone analog), (ii) laboratory and greenhouse evaluation of EL-494 (moult inhibitor) and PH 60-41 (analog of Dimilin), and (iii) 1977 field tests with Dimilin, EL-494 and PH 60-41 are presented in this report. The chemical names and structures of the compounds are shown in Table 1.

Field trial in 1976:

In 1976 Dimilin and RO-103108 were tested as oil formulations at Kirkwood township, near Thessalon, Ontario (Table 1). Dimilin was sprayed on plot 4 at the rate of 140 g active ingredient (a.i.) in 4.67 l per hectare (2 oz./0.5 U.S. gal./acre) and RO-103108 was sprayed at 2 concentrations, 280 (a.i.) and 560 g (a.i.) in 1.9 l per ha (4 and 8 oz./0.5 U.S. gal./acre) on plots 5 and 6 respectively (Table 2). The location of the 3 treatment plots are shown in Fig. 1. All plots excepting plot 6 had 27% white spruce, 23% balsam fir and 50% hardwood and pine. Plot 6 had 72% white spruce, 18% balsam fir and 10% hardwood and pine.

The formulated materials were sprayed from a Grumman Agcat equipped with 4 ULV-micronair, AU-3000 units. The aircraft was calibrated to deliver 4.67 l/ha (0.5 U.S. gal./acre) prior to spraying.

The entire spray operation including the post-spray sampling was carried out during the month of June. Dimilin was sprayed during the evening on June 2 and RO-103108 was sprayed during the morning of June 3 (Table 2). The sampling procedure, monitoring of spray conditions, and spray plate analysis were similar to the methods used in previous years (Retnakaran et al., 1977; Retnakaran, 1978).

The temperature during the month of June ranged from a minimum of -3°C to a maximum of 39°C. The average rainfall was 1.66 cm (Table 3). (OMNR - weather record)

Unlike previous years, the candidate compounds were formulated in oil. Sunspray oil no. 11 was mixed with no. 2 fuel oil for spraying Dimilin. The viscosities of the spray mixtures were 7.69 cps for Dimilin and around 30 cps for RO-103108 (Table 4). For detection of spray deposit on plates an oil soluble dye, Automate red B, was mixed at a concentration of 1:1 (v/v). The actual volume of spray that came down was calculated by eluting the dye from the glass slides on the spray plate with xylene and measuring the optical density at 523 nm as described elsewhere (Retnakaran et al., 1977; Retnakaran, 1978). About 20% of the volume sprayed reached the ground and the number of droplets per cm^2 ranged from 28 to 43 in the 3 plots (Table 5).

The tests materials were sprayed when the insect was predominantly in the 4th instar. In earlier years spraying was carried out when the insect had advanced into the 6th instar.

Results

i) Dimilin at 140 g/ha (2 oz./acre) reduced the population on balsam fir by 59% and white spruce by 51% (Table 6). Foliage protection was 18% on balsam fir and 3% on white spruce. Unlike previous years, failure of pupae to eclose was minimal.

ii) RO-103108 at 280 g/ha (4 oz./acre) had no visible effect but at 560 g/ha (8 oz./acre) there was an 18% population reduction on balsam fir and 55% on white spruce. Defoliation was higher in the treated plots since juvenile hormone analogs prolong the last larval stadium.

Discussion

The 1976 spray operation was different in 3 respects from the 1974 and 1975 spray programs. The material was sprayed in oil instead of water, at 4.67 l/ha (0.5 gal./acre) instead of 9.35 l/ha (1 gal./acre), and when the insect was in the 4th instar instead of the 6th. Use of an oil formulation improved the deposit in that about 20% of the material reached the ground; with water formulated compounds in 1975, 10% of the material reached the ground. Application of 4.67 l/ha of the oil formulation resulted in an average of 37 droplets/cm^2 on the spray card. When 9.35 l/ha of a water formulation was sprayed in previous years, the average number was around 10 droplets/cm^2 (Retnakaran et al., 1977). The latter result was perhaps due to loss of smaller droplets due to evaporation.

Dimilin at 140 g/ha gave only around 50-60% population reduction. Even though it was known that earlier stages of the insect are less susceptible, it was felt that spraying on 4th instars might result in better foliage protection because the larvae that escaped the initial exposure might be affected by the residual Dimilin on the foliage when they reached the 6th instar. Unfortunately this did not occur. The pupal failure being low indicated that perhaps the material did not stay on the foliage long enough to affect most of the 6th instar larvae.

RO-103108 had very little effect even at 560 g/ha. Perhaps spraying at the 6th instar stage when the insect is in the susceptible stage might have yielded better results. The rationale for spraying earlier was two-fold: (i) the insect population is developmentally better synchronized in the 4th instar stage; (ii) juvenile hormone analogs tend to be stored in the insect and remain active for a long time and therefore would eventually affect most of the 6th instar larvae. When 840 g/ha (12 oz./acre) was used in Maine, over 90% reduction in population was obtained (Granett, 1977).

Prognosis

Unlike the hemlock looper (Retnakaran et al., 1974), the spruce budworm is not very sensitive to juvenile hormone analogs like RO-103108. The high cost, the lack of foliage protection in the year of application and the high doses required for controlling the spruce budworm make this class of compounds economically unattractive at present.

Although our success with Dimilin on spruce budworm is limited there is one possibility that remained to be explored. It is conceivable that if the material persists from the 4th to the 6th instar, one can achieve substantial larval mortality and pupal failure. This can be done either by adding a sticker to the formulation, to ensure persistence or by spraying twice, once on the 4th instar and the second time on the 6th instar.

Laboratory and greenhouse trials in 1976-77

The efficacy of PH 60-41 and EL-494 were studied in the laboratory and greenhouse to determine their control potential. The effect of EL-494 on the larval stages of the spruce budworm is summarized in Table 7. This material is more active than Dimilin (about 10X) and does not show stadial sensitivity. Both EL-494 and PH 60-41 were active when they were tested in the greenhouse on potted balsam fir and spruce trees (Table 8). Greenhouse tests also showed that they were relatively resistant to weathering (Table 9).

Field trials in 1977

In 1977, three compounds, Dimilin, PH 60-41 and EL-494 were tested as water formulations at Shetland Township, near Hearst, Ontario (Table 10). Dimilin was sprayed on two plots. One plot was sprayed at 140 g/ha with the addition of Chevron sticker; the second plot was sprayed twice, once at 140 g/ha without sticker followed after 6 days by 70 g/ha without sticker. PH 60-41 was tested on two plots at the rates of 70 and 140 oz./ha. EL-494 was sprayed at 140 g/ha. The location of these plots are shown in Fig. 2. The composition of trees in the plots was 68% balsam fir, 12% white spruce, and 20% hardwood and pine.

The spray program was carried out during the month of June. The temperatures ranged from a minimum of -8 to a maximum of 36°C, and the average rainfall was 7.59 cm during this month (Table 11). Spraying was carried out on the 1st, 5th, 6th and 7th of June when conditions were optimal (Table 7). Most of the larvae were in the 5th instar at this time (Table 12). As in 1976, the materials were sprayed from a Grumman Agcat equipped with 4 micronair units. Rhodamine-B was mixed with the spray formulations for detecting the spray droplets (Retnakaran et al., 1974). Details of the spray droplet analyses are summarized in Tables 13, 14 and 15. The 140 g/ha application of Dimilin and PH 60-41 showed the best deposit pattern both in the spectrophotometric and droplet analyses.

Results

The results obtained in spray operation are summarized in Table 16. Double application of Dimilin (140 + 70 g/ha) reduced budworm population by 78% on white spruce whereas the single application (140 g/ha) with Chevron had little or no effect. Although defoliation estimates were seriously hampered by frost damage, the double application of Dimilin had a substantial effect (60%) on protecting new growth on white spruce.

EL-494 at 140 g/ha caused about 60% population reduction in both balsam fir and white spruce. PH 60-41 at 140 g/ha showed a population reduction around 70% whereas at 70 g/ha it had no effect. Foliage protection was marginal.

Discussion

PH 60-41 was by far the best compound tested. At 140 g/ha it not only caused a 70% reduction in population but also provided some foliage protection.

Although EL-494 caused only ca. 60% population reduction at 140 g/ha, the material is quite active since the spray deposit analysis (Table 13) showed that very little of the material came down. Unfortunately this spraying was done under sub-optimal conditions when the temperature was below freezing (Table 11, June 6).

The low reduction in population on balsam fir is difficult to explain. Addition of Chevron did not appear to improve its effectiveness. However, double application resulted in a 78% reduction in population with 60% foliage protection on white spruce.

Prognosis

EL-494 and PH 60-41 at 140 g/ha appear promising and require further testing. A single application of Dimilin at 140 g/ha can be ruled out for budworm control, however, double application appears to be promising at least on white spruce and merits further study.

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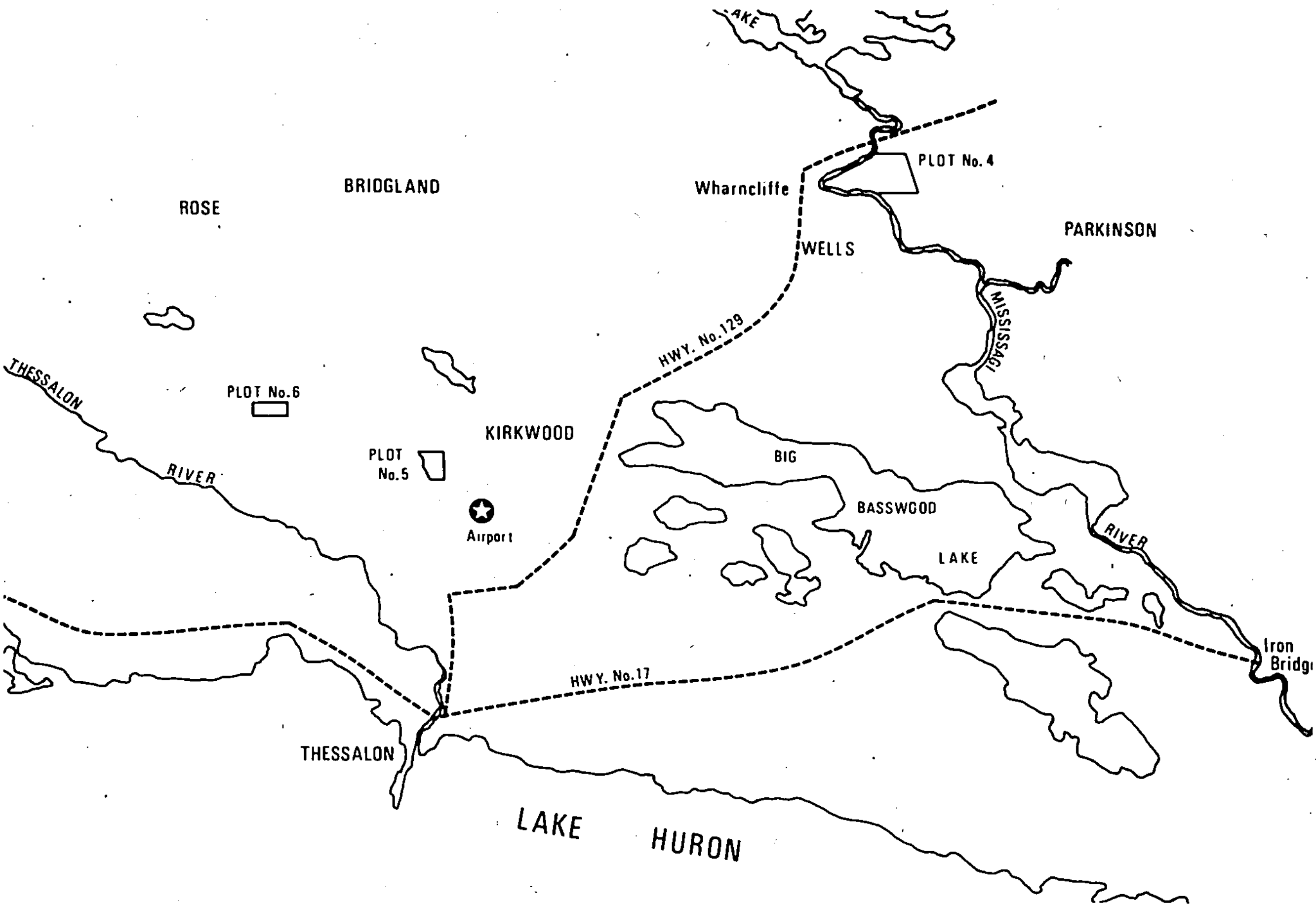


Fig. 1. Location of the 1976 spray plots at Kirkwood, near Thessalon, Ontario.

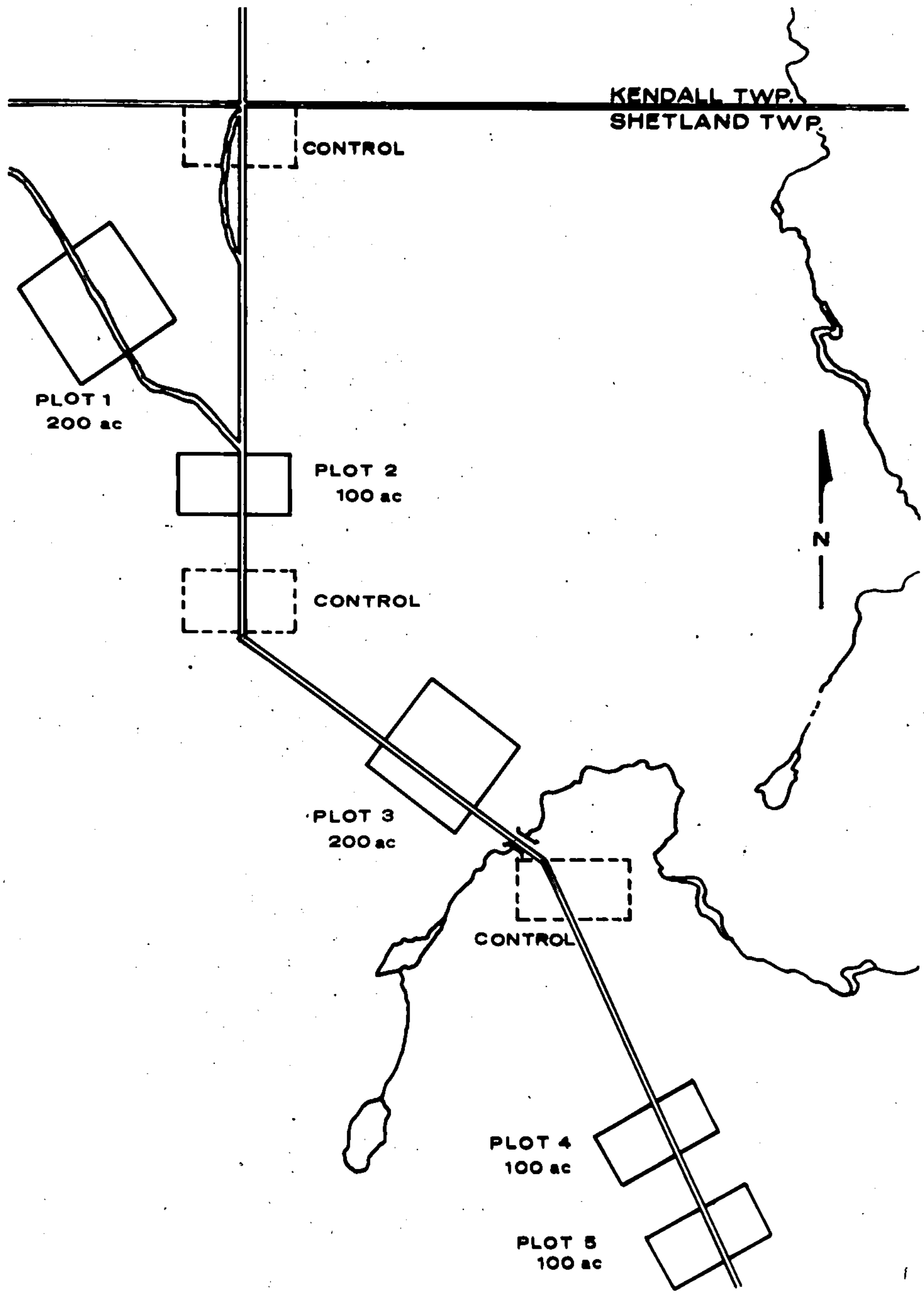


Fig. 2. Location of the 1977 spray plots at Shetland Township, near Hearst, Ontario.

TABLE 1. IGRs TESTED IN 1976 AND 1977

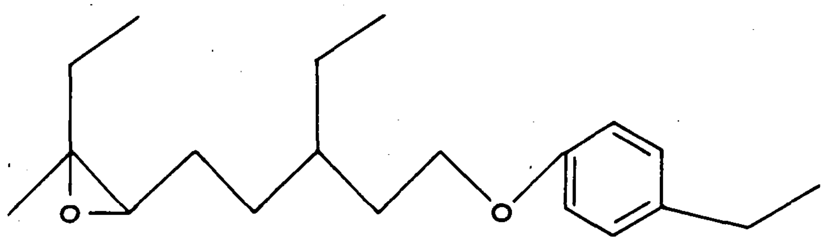
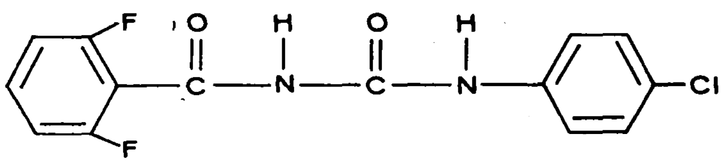
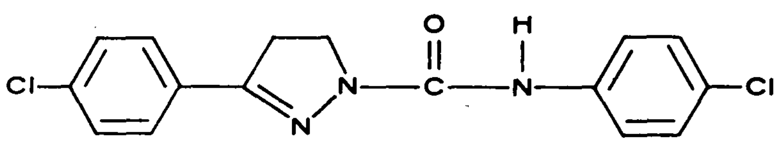
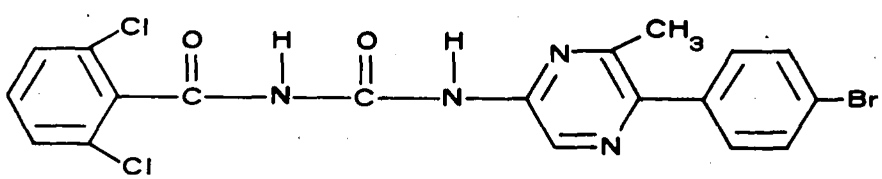
STRUCTURE AND CHEMICAL NAME	COMMON NAME AND SOURCE
 6,7-EPOXY-3-ETHYL-1-(p-ETHYLPHENOXY)-7-METHYLNONANE	EPOPHENONANE RO-103108 DR. MAAG, SWITZERLAND
 1-(2,6-DIFLUOROBENZOYL)-3-(4-CHLOROPHENYL)-UREA	DIMILIN TH 60-40 THOMPSON-HAYWARD, U.S.A.
 3-(4-CHLOROPHENYL)-1-(4-CHLOROPHENYL-CARBAMOYL)-2-PYRAZOLINE	PH 60-41 PHILIPS-DUPHAR, NETHERLANDS
 N-[[[5-(4-BROMOPHENYL)-6-METHYL-2-PYRAZINYL] AMINO]-CARBONYL]-2,6-DICHLOROBENZAMIDE	EL-494 ELI LILLY, U.S.A.

Table 2. The 1976 Insect Growth Regulator Spray program at Thessalon, Ontario.

Plot No.	Material	Amount (Active Ingredient)	Area	Date	Time of Application
4	Dimilin	140 g/ha (2 oz/acre)	226 ha (565 acre)	June 2	Evening
5	RO-103108	280 g/ha (4 oz/acre)	40 ha (100 acre)	June 3	Morning
6	RO-103108	560 g/ha (8 oz/acre)	48 ha (128 acre)	June 3	Morning

Table 3. Maximum and Minimum Temperatures at Thessalon (1976) during spray trials.* (OMNR - weather record)

Date	Min.	Max.	Date	Min.	Max.
June 1	0 °C (32°F)	31°C (88°F)	June 13	11°C(52°F)	36°C(97°F)
2	- 3 (26)	32 (90)	14	(51)	34 (92)
3	-2 (28)	36 (96)	15	(47)	35 (93)
4	4 (40)	35 (94)	16	(48)	23 (74)
5	2 (36)	34 (92)	17	(44)	28 (82)
6	3 (37)	38 (100)	18	(40)	25 (78)
7	3 (38)	37 (98)	19	(40)	25 (78)
8	11 (52)	33 (92)	20	(33)	36 (97)
9	9 (48)	33 (91)	21	(39)	38 (100)
10	9 (48)	32 (90)	22	11 (52)	39 (102)
11	8 (47)	34 (92)	23	(48)	36 (96)
12	1 (34)	28 (83)	24	(56)	30 (86)

*Average rainfall was 1.66 in (0.645 inches)

Table 4. Viscosities of the different spray formulations (Thessalon, 1976)

Plot No.	Active Material	Oil	Actual viscosity in cps at 12.5°C
4	Dimilin - 40% oil dispersible	30% Sunspray 11 N in full oil No. 2	7.69
5	RO-103108	Sunspray 11N	31.04
6	RO-103108	Not diluted	29.79

Table 5. Summary of spray deposit analysis.

Plot	Volume emitted from aircraft (l/ha)	Volume calculated from spray plate analysis.* ($\overline{X}$ l/ha ± SD)	No. of droplets per cm^2 ($\overline{X}$ ± SD)
4	4.68	0.92 ± 0.56	43 ± 24
5	4.68	0.81 ± 0.93	39 ± 14
6	4.68	1.35 ± 0.68	28 ± 15

*Automate Red B (1% v/v) was used as the indicator dye and optical density was measured at 523 nm.

Table 6. Population reduction, pupal survival and foliage protection attributable to various insect growth regulator spray treatments on balsam fir and white spruce near Thessalon, Ontario, 1976. Budworm development at time of spraying was L4.

Plot*	Prespray larvae/ 46 cm (18 in.) branch tip		Surviving pupae/ 46 cm (18 in.) branch tip		% Population reduction due to treatment		% Successful pupal emergence**		% 1976 defoliation	
	bF	wS	bF	wS	bF	wS	bF	wS	bF	wS
4	19.6	22.5	1.75	3.25	59	51	42	52	42	46
Check	20.7	23.3	4.53	6.80			46	70	60	49
5		13.1		3.88		25		59		21
Check		13.4		5.30				68		20
6	12.4	15.7	2.20	3.25	18	55	47	53	51	67
Check	13.9	18.7	3.00	8.66			48	70	43	29

*Plot 4 - Dimilin 140 g/4.67 l/ha (2 oz/0.5 gal. U.S./acre)
Plot 5 - RO-103108 280 g/4.67 l/ha (4 oz " " ")
Plot 6 - RO-103108 560 g/4.67 l/ha (8 oz " " ")

$$\text{**\% Successful pupal emergence} = \frac{\text{emerged budworm}}{\text{budworm alive on sample date}} \times 100$$

Table 7. Effect of EL-494 on the larval instars of the spruce budworm in laboratory tests. (L_3-L_6 = larval instars)

Dose (ppm) in diet	% Mortality of larval instars treated			
	L_3	L_4	L_5	L_6
Control	26	10	26	26
0.107	32	18	8	16
0.185	40	28	16	12
0.320	62	56	60	34
0.548	92	94	90	42
1.080	98	100	100	90

Table 8. Greenhouse evaluation of EL-494 and pH 60-41 against 5th instar larvae of the spruce budworm

Treatment	Dosage (% a.i.)	Vol/tree (µl)	Tree Species	% Mortality
pH 60-41	1.0	20	bF	84
(25% water			wS	92
flowable)		10	bF	80
			wS	84
		5	bF	100
			wS	84
EL-494				
(50% WP)	1.0	20	bF	100
			wS	100
Control	-	-	bF	24
			wS	18

bF = balsam fir
wS = white spruce
a.i. = active ingredient

Table 9. Persistence and resistance to leaching and short wave UV (254 nm) degradation of EL-494 and PH 60-41. Each tree was sprayed with 20 µl of a 1% (active ingredient) solution containing the candidate compound.

Test for	Treatment of Tree	Post-treatment of tree prior to transferring larvae (25 L_5/tree)	Tree Species	% mortality
Control	No treatment	No treatment - larvae transferred immediately	bF wS	44 26
	PH 60-41	"	bF wS	100 100
	EL-494	"	bF wS	100 100
Leaching	PH 60-41	Spray of water at the rate of 11.5 l/min for 5 sec/day for 10 days	bF wS	96 84
	EL-494	"	bF wS	96 92
Persistence	PH 60-41	5 days in greenhouse 10 days in greenhouse 15 days in greenhouse	bF bF bF	100 92 100
	EL-494	5 days in greenhouse 10 days in greenhouse 15 days in greenhouse	bF bF bF	100 84 100
U.V. resistance	PH 60-41	1 Mineralight[R] (254 nm) placed 18 cm above tree and turned on for 1h/day for 10 days	bF wS	96 80
	EL-494	"	bF wS	100 96

Table 10. The 1977 Insect Growth Regulator Spray program near Hearst, Ontario.

Plot No.	Material	Area	Amount Active Ingredient	Application Date	Application Time
1	Dimilin	81 ha (200 acres)	140g/ha (2 oz/acre)	June 1	Morning
		"	70g/ha (2 oz/acre)	June 7	"
2	pH 60-41	40.5 ha (100 acres)	140g/ha (2 oz/acre)	June 6	"
3	Dimilin with Chevron sticker	81 ha (200 acres)	140g/ha (2 oz/acre)	June 5	Evening
4	EL-494	81 ha (200 acres)	140g/ha (2 oz/acre)	June 6	Morning
5	pH 60-41	40.5 ha (100 acres)	70g/ha (1 oz/acre)	June 6	Evening

Table 11. Maximum and minimum temperatures at Hearst (1977)* during the spray operation. (OMNR - weather record)

Date	Min.		Max.		Date	Min.		Max.	
June 1	3°C	(37°F)	35°C	(94°F)	June 16	8°C	(47°F)	19°C	(66°F)
2	-1	(30)	19	(66)	17	10	(50)	17	(62)
3	-3	(27)	28	(81)	18	10	(50)	19	(66)
4	-3	(26)	31	(88)	19	2	(36)	14	(58)
5	7	(44)	32	(89)	20	4	(40)	32	(89)
6	-6	(22)	32	(89)	21	-2	(28)	28	(82)
7	-5	(24)	25	(77)	22	-2	(28)	36	(97)
8	-8	(18)	21	(70)	23	2	(36)	35	(94)
9	-6	(22)	30	(86)	24	13	(56)	32	(90)
10	-5	(24)	35	(94)	25	11	(52)	32	(90)
11	0	(32)	14	(58)	26	7	(44)	34	(93)
12		(26)	26	(78)	27	12	(54)	36	(96)
13	-7	(20)	27	(80)	28	12	(54)	32	(90)
14	0	(32)	34	(93)	29	1	(34)	17	(62)
15	0	(32)	36	(96)	30	1	(34)	28	(82)

*Average rainfall was 7.59 cm (2.99 inch)

Table 12. Development sample (Hearst, June 2, 1977) taken from plot 3.

Host	Larval stages (%)			
	L_3	L_4	L_5	L_6
White spruce	0	0	100	0
Balsam fir	15	20	65	0

Table 13. Spectrophotometric analysis of spray plates, Hearst 1977.

Plot No.	Material	Emitted rate	Calculated spray deposit	
			U.S. gal/acre	l/ha
1. (1st application)	Dimilin (140 g/ha)	4.67 l/ha (0.5 U.S. gal/acre)	0.321	0.492
1. (2nd application)	Dimilin (70 g/ha)	"	0.180	0.276
2.	PH 60-41 (140 g/ha)	"	0.484	0.742
3.	Dimilin (with Chevron) (140 g/ha)	"	0.049	0.075
4.	EL-494 (140 g/ha)	"	-*	-*
5.	PH 60-41 (70 g/ha)	"	-*	-*

* spray deposit was not detectable.

Table 14. Mean number of droplets per cm^2 on spray cards (Hearst, 1977)

Plot	Application	Mean number drops/cm^2	Standard deviation
1 first application	Micronair	37	23
second application	Micronair	10	4
2	Micronair	30	8
3	Micronair	10	6
4	Micronair	15	9
5	Micronair	10	6

Table 15. Percentage of droplets on spray cards in different size categories (Hearst, Ont. 1977)

	Size of droplets in microns									
Plot	1-50	51-100	101-150	151-200	201-250	251-300	301-350	351-400	401-550	451-500
1	18.3	40.7	28.6	10.9	1.1	0.4	0	0	0	0
	13.6	78.4	6.2	1.8	0	0	0	0	0	0
2	25.0	30.8	24.0	19.2	0.7	0.3	0	0	0	0
3	52.3	32.6	8.1	5.8	0	0	0	1.2	0	0
4	1.1	18.7	25.5	39.3	9.0	4.1	1.5	0	0.4	0.4
5	85.7	9.8	3.6	0	0.9	0	0	0	0	0

Table 16. Population reduction, pupal survival and foliage protection attributable to various insect growth regulator spray treatments on balsam fir and white spruce near Hearst, Ontario, 1977. Budworm development at time of spraying was L5.

Plot	Prespray larvae per 18" tip		Surviving pupae per 18" tip		% Population reduction due to treatment		% Successful pupal emergence*		% Frost damage		% 1977 Defoliation	
	bF	wS	bF	wS	bF	wS	bF	wS	bF	wS	bF	wS
1	6.1	12.4	.66	.60	31	78	51	39	15	11	18	3
Check	5.9	13.4	.92	2.90			69	59	2	4	27	63
2	5.3	5.8	.30	.10	64	69	54	29	1	0	19	3
Check	5.9	5.4	.92	.30			69	48	2	0	27	12
3	26.3	17.7	3.26	4.28	36	0	53	65	13	0	93	56
Check	29.1	17.8	5.68	2.90			63	60	0	0	99	93
4	5.7	5.2	.51	.12	54	59	48	25	0	0	13	8
Check	5.9	5.4	.92	.30			69	48	2	0	27	12
5	21.0	23.3	5.24	5.68	0	0	67	65	1	2	68	64
Check	18.6	29.1	4.60	5.13			65	55	0	7	87	63

Plot 1 - Dimilin 140 g + 70 g/ha (2 oz + 1 oz/acre)
2 - PH 60-41 140 g/ha (2 oz/acre)
3 - Dimilin 140 g/ha + Chevron (2 oz/acre)
4 - EL 494 140 g/ha (2 oz/acre)
5 - PH 60-41 70 g/ha (1 oz/acre)

*% Successful pupal emergence

$$= \frac{\text{emerged budworm}}{\text{budworm alive on sample date}} \times 100$$