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## EFFECT OF AN INSECT GROWTH REGULATOR ON NON-TARGET ARTHROPODS IN AN AERIAL APPLICATION AGAINST THE SPRUCE BUDWORM, *CHORISTONEURA FUMIFERANA* (LEPIDOPTERA: TORTRICIDAE), IN NEW BRUNSWICK, CANADA

B. Sechser
Ciba-Geigy Ltd., Agrochemicals Division, 4002 Basle, Switzerland

I. W. Varty
Maritimes Forest Research Centre, Canadian Forestry Service, Fredericton, New Brunswick

**Abstract** *Can. Ent.* 110: 561–567 (1978)

Airplane application of the insect growth regulator CGA 13353, a juvenile hormone mimic used experimentally against spruce budworm, *Choristoneura fumiferana* (Clem.), did not drastically reduce percentage parasitism in field samples of that host, but there was some evidence of susceptibility. Exploratory sampling of maple defoliators suggested that one species and its parasitoids suffered some mortality, but another species and its parasitoids did not. The treatment did not influence the viability of ant colonies.

**Résumé**

L'application par avion de CGA 13353, régulateur de la croissance des insectes et imitation d'hormone juvénile, fut essayée contre la Tordeuse des bourgeons de l'Epinette, *Choristoneura fumiferana* (Clem.) mais cette substance n'a pas réduit drastiquement le pourcentage de parasitisme dans l'hôte. On a cependant relevé des preuves de vulnérabilité. Contre certains défoliateurs de l'Erable, des premières expériences ont porté à croire que chez une espèce et ses parasitoïdes il se produisit une certaine mortalité, mais une autre espèce et ses parasitoïdes ne furent pas affectés. Le traitement n'a pas affecté les colonies de fourmis.

### Introduction

Insect growth regulator (IGR) insecticides (juvenile hormone mimics) have variable effects on survival of endoparasitoids dependent upon the compound, dosage, specific susceptibility, and the instar. In a review of side effects, Bagley and Bauernfeind (1972) noted that hymenopterous parasitoids are not particularly susceptible, but added that *Apanteles* and *Trichogramma* wasps are affected by at least one compound. Wilkinson and Ignoffo (1973) and Wright and Spates (1972) found no IGR influence on the survival or reproductive capacity of endoparasitoids at dosages effective against hosts, when topically applied in the laboratory. However, the laboratory investigations of spruce budworm hosts by Outram (1974) and of aphid hosts by McNeil (1975) detected substantial diminution of survival of parasitoids. Our experimental compound, the juvenile hormone mimic CGA 13353, was already known to be effective against some lepidopterous larvae such as diamondback moth, large cabbage white, and gypsy moth, but inactive against some of their parasitoids (Scheurer *et al.* 1975). A preliminary aerial spray trial of this compound against the spruce budworm in 1973 in New Brunswick resulted in no overt effects on non-target arthropod fauna in general, and on budworm parasitoids in particular. A second investigation of effects on non-target insects conducted in 1974 is now reported.

### Materials and Methods

The juvenile hormone analogue ethyl 4 (4′benzylphenoxy-3-methyl-2-butenoate) was formulated in water from an emulsifiable concentrate (40% a.i.). The trial site was

the Acadia Forest Experiment Station near Fredericton, N.B., Canada. Seven experimental blocks each about 40 ha, situated in fir–spruce forests (*Abies balsamea* (L.) Mill., *Picea rubens* Sarg., *Picea mariana* (Mill.) B.S.P.), were designated and six blocks were sprayed from the air on 13 and 22 June 1974 with the following treatments:

| Emitted dosage a.i. IGR g/ha | Early spray (June 13) | Late spray (June 22) |
|---|---|---|
| 105 | Block I | Block VI |
| 210 | II | V |
| 420 | III | IV |

The range of dosage rates was selected to be potentially cost-competitive with conventional insecticides. Block VII was an untreated check area.

The aircraft used to apply the spray was a Cessna Agwagon, flown at 160 km/h about 3 m above the tallest trees in early morning under clear stable weather conditions. The formulation was emitted under pressure (2.8 kg/cm$^2$) at 4.7 l./ha. Swath width was estimated at 30 m, and coverage of the blocks was reported by airborne observers to be excellent. The calculated volume median diameter of droplets was 220 $\mu$. One weakness of the spray documentation was our inability to determine the distribution of IGR deposit on the midcrowns of the sampling trees. A fluorescent tracer was added to the formulation but was not measured due to instrument failure.

Sample plots were standardized as middle-aged stands about 10–15 m tall. To obtain values of percentage parasitism in spruce budworm samples from the various treatment blocks, about 200 immature budworms were collected in each sample plot at intervals of several days from 10 June to 11 July. The earliest collections were of fourth- and fifth-instar larvae; the latest were almost entirely pupae. Each collection was made by clipping midcrown branches with pole pruners, one branch from each of 10 fir trees chosen at random within the sample plot. The early collections of larvae were reared in groups of five on an artificial diet in plastic containers. The later collections were reared en masse on fresh foliage in cages, until either the moth or the parasitoid emerged. In total, 9994 budworm hosts were reared from the periodic collections, and only healthy parasitoid adults were tallied for estimates of parasitism. To detect changes in host–parasitoid relationships in other defoliators, 248 larvae of the lesser maple spanworm, *Itame pustularia* (Gn.), and 968 larvae and pupae of the maple leafroller, *Cenopis pettitana* Rob., were collected from red maple, *Acer rubrum* L., in blocks IV (420 g/ha, late treatment) and VII (check) for comparison of parasitoid emergence. These larvae were reared on fresh foliage in cages until moths or parasitoids had emerged and matured. In addition, *I. pustularia* prepupae almost ready to pupate in the litter, were collected on 25 July and placed in open peatmoss cone traps to attract ovipositing pupal parasitoids. In block IV, 31 prepupae were collected and "planted" in 10 cones; in block VII, 125 were collected and "planted" in 22 cones. The aim was to compare rates of parasitism in heavy-dosage late treatment with the untreated check.

Ants were the subject of a minor study. Two nests of *Formica ulkei* Emery were located in block III (420 g/ha, early spray), and were provisioned at 3-day intervals for 3 weeks with unit collections of 20–50 budworm larvae exposed to spray from the 420 g/ha dosage applied to blocks III and IV. One nest of *Formica podzolica* Franc. was located in the check block and provisioned in the same way from the 210 g/ha dosage blocks II and V. The ants collected these budworm from the surface of the nest and carried them within as food for broods. Nests were checked 1 year later for survival of the colony.

Table I. Host failure rates, independent of parasitism, in rearing immature spruce budworm from experimental blocks

| Blocks | I | II | III | IV | V | VI | VII |
|---|---|---|---|---|---|---|---|
| IGR g/ha | 105 | 210 | 420 | 420 | 210 | 105 | 0 |
| Hosts reared | 1528 | 1605 | 1554 | 1218 | 1239 | 1127 | 1723 |
| Failure % | 12 | 15 | 12 | 24 | 17 | 19 | 9 |

## Results

Of the 9994 immature budworm collected, the mean rearing-failure rate was 15%, that is, hosts which failed to result in either moth or parasitoid emergence. Host failure resulted from natural pathogens, defects in collecting and rearing techniques, and IGR treatment. Late treatments appeared to be more influential than early treatments, but both added substantially to normal mortality (Table I). The rearing method, diet versus foliage, made little or no difference in host failure rates.

The percentage parasitisms of spruce budworm samples are listed in Table II. The early collections (fourth- and fifth-instar hosts) were parasitized only by ichneumonoids (*Glypta fumiferanae* (Vier.) and *Apanteles* spp. mostly *fumiferanae* Vier.) which had overwintered inside the host. Collections at the end of June included these two species in diminishing percentages because of on-going emergence, plus increasing numbers of immature parasitoids recently deposited on or in the host larvae. These parasitoids were mainly the tachinids *Actia interrupta* Curr. and *Phryxe pecosensis* Tns. and frequently the ichneumonoids *Meteorus trachynotus* Vier. and *Macrocentrus iridescens* French. The later collections, in early July, contained mostly pupal hosts, with such immature parasitoids as the tachinid *Omotoma fumiferanae* (Tot.) and infrequently the ichneumonoids *Itoplectis conquisitor* (Say) and *Ephialtes ontario* (Cress.).

Values of parasitism (Table II) are somewhat erratic both within and between treatments, and no irrefutable trends are apparent. The discrepancies of recorded parasitisms between adjacent dates within a plot cast doubt as to the adequacy of sample size. In particular, the two values on 19 June (blocks I, III) are anomalous with other values from those plots, but these low values are probably due to rearing failure in two cages. Nevertheless stable values over time within one plot are not to be expected; from

Table II. Percentage total parasitism in pre- and post-spray samples of spruce budworm from balsam fir in stands subjected to aerial sprays of an IGR compound at various dosages and timings

| Date and median host instar | Early treat. (June 13) g/ha | | | Late treat. (June 22) g/ha | | | Check |
|---|---|---|---|---|---|---|---|
| | I 105 | II 210 | III 420 | IV 420 | V 210 | VI 105 | VII 0 |
| June 11 (4th) | 4.9 | 2.8 | 9.6 | –* | – | – | 3.0 |
| 16 (5th) | 5.6 | 4.9 | 9.9 | 8.6 | 4.1 | 8.0 | 3.3 |
| 19 (5th) | 1.1 | 5.7 | 1.1 | – | – | – | 4.1 |
| 22 (6th) | 7.3 | 5.1 | 13.6 | – | – | – | 1.7 |
| 25 (6th) | 5.4 | 2.7 | 12.0 | 4.4 | 3.1 | 5.6 | 3.8 |
| 28 (6th) | 2.5 | 3.6 | 8.1 | 1.8 | 5.3 | 11.6 | 8.3 |
| July 2 (pupa) | 4.0 | 3.6 | 2.6 | 1.8 | 1.9 | 3.6 | 8.3 |
| 5 (pupa) | 3.3 | 2.9 | 9.0 | 0.8 | 3.3 | 0.9 | 4.0 |
| 10 (pupa) | 3.9 | 4.6 | 4.5 | 2.1 | 3.4 | 4.0 | 4.4 |

*No sample taken.

Table III. Percentage parasitism by *Apanteles* sp. and *Glypta fumiferanae* in samples of spruce budworm larvae from fir stands with IGR treatments

| | Early spray blocks | | | Late spray blocks | | | Check |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII |
| IGR g/ha | 105 | 210 | 420 | 420 | 210 | 105 | 0 |
| *Apanteles* sp. | | | | | | | |
| Pre-spray | 2.1 | 1.9 | 7.0 | 6.1 | 3.0 | 1.1 | 1.6 |
| Post-spray | 1.3 | 1.4 | 3.0 | 1.0 | 1.3 | 2.3 | 1.1 |
| Ratio post/pre | 0.6 | 0.7 | 0.4 | 0.2 | 0.4 | 2.1 | 0.7 |
| *Glypta fumiferanae* | | | | | | | |
| Pre-spray | 2.8 | 0.9 | 2.6 | 1.8 | 1.2 | 6.9 | 1.6 |
| Post-spray | 2.3 | 2.2 | 4.1 | 0.8 | 2.3 | 3.4 | 1.3 |
| Ratio post/pre | 0.8 | 2.4 | 1.6 | 0.4 | 1.9 | 0.5 | 0.8 |

mid June to early July parasitism is quite dynamic because some species of parasitoids are issuing from hosts, while other species of parasitoids are entering them in sequence.

The possible effect of IGR becomes more apparent on closer analysis. Table III shows grouped values for pre- and post-spray parasitisms for *Apanteles* spp. and *G. fumiferanae*; these were the only maturing parasitoids within the host at spray times and were therefore most susceptible to abnormal growth regulation via their hosts. In late June, percentage parasitism by these two species invariably declines as mature larvae issue from the hosts, and the ratios of 0.7 for *Apanteles* and 0.8 for *Glypta* shown in the check column are as expected. There was an unusually sharp decline in *Apanteles* parasitism in the 420 g/ha dosage block, which opens the possibility that parasitoids were adversely affected by IGR. The values for *Glypta* are much more erratic and no trend is detectable. In neither species is there evidence of catastrophic reduction at any dosage, nor was there unusual evidence of abnormal pupal development, such as Outram (1974) noted in his investigation of *G. fumiferanae*.

The effects on the group of parasitoid species which attack large larvae and pupae in late June (mainly tachinids) appear to be more marked. Data from the rearings of this group, 28 June to 10 July inclusive, are shown in Table IV. The lowest percentage parasitism is in the 420 g/ha dosage, late treatment, matching the response of *Apanteles*. There is thus a suggestion, admittedly not backed by a statistical statement of sampling precision, that the late treatment, 420 g dosage, caused a marked reduction in the survival of these parasitoids. The data from other dosages and dates indicate lower parasitism than in the check block, yet it is evident that these treatments were not seriously deleterious.

Table IV. Percentage parasitisms by the group of species attacking large larvae and pupae in samples of spruce budworm collected 28 June – 10 July 1974

| | Early spray blocks | | | Late spray blocks | | | Check |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | VI | VII |
| Immature hosts reared | 775 | 887 | 891 | 873 | 878 | 775 | 754 |
| Moth emergence | 673 | 750 | 709 | 611 | 700 | 586 | 635 |
| Adult parasitoids reared | 24 | 24 | 28 | 12 | 20 | 21 | 35 |
| % parasitism | 3.1 | 2.7 | 3.1 | 1.4 | 2.3 | 2.7 | 4.6 |

Table V. Moth emergence, pre-adult mortality, and parasitism of *I. pustularia* from 420 g/ha dosage block (IV) and the check block (VII) in IGR trials

| Collection date | Block | No. of reared larvae | % mortality factors | | | % moths emerged |
|---|---|---|---|---|---|---|
| | | | Parasitism | Larval deformation | Pupal failure | |
| June 19, pre-spray | IV | 65 | 6 | 2 | 13 | 79 |
| 26, post-spray | IV | 57 | – | 42 | 14 | 44 |
| 27, check | VII | 126 | 8 | 6 | 16 | 70 |

The mortality factors operating on field-collected samples of *I. pustularia* are analyzed in Table V. The larvae were in the fifth and sixth instars on 22 June, the late spray date. Growth-aberrant larvae were common in the heavy dosage late-treatment block IV, and moth emergence was much less successful than in pre-treatment and check samples. The absence of parasitism in the heavy-dosage block is suggestive of severe discrimination against internal parasitoids, but the sampling effort was too weak for firm conclusions. However, any residues from the IGR spray did not diminish the post-spray activity of adult parasitoids attacking pupae or the successful development their offspring. When *I. pustularia* prepupae were "field-planted" in peatmoss traps to expose pupae to parasitoids, the resulting parasitism was higher in the heavy-dosage block (31 pupae: 23% parasitism) than in the check (125 pupae: 10% parasitism).

There was no evidence of a response to heavy-dosage, late-treatment IGR by the maple leafroller, *C. pettitana*, and its parasitoid complex (Table VI). This leafroller is a difficult target for insecticidal sprays because it is sheltered from direct impact by the woven case of leaves. Also at spray date (22 June), about half the population was already non-feeding in the prepupal and pupal stages. Samples collected on 26 June in the treated block show a low moth emergence rate, partly due to parasitism, but there was no evidence of larval deformation or abnormal pupal failure. The samples of pupal cases collected on 19 July, show very similar success rates (moth emergence) in treated and check plots. *Cenopis pettitana* larvae were attacked by a broad spectrum of ichneumonoid (*Apanteles, Macrocentrus, Ascogaster*) and tachinid parasitoids, but there was no evidence of reduced parasitism in the treated block.

Ants were investigated because they are known to respond to some IGR chemicals (Troisi and Riddiford 1974); they might be hypersensitive indicators of chemical stresses because each colony has a complex social structure dependent upon the programmed growth of specialized morphs across the season. Forest ant colonies ordinarily survive in the same nest for many years. Therefore, the sudden death of a colony after treatment would be evidence of IGR stress on brood production. The

Table VI. Moth emergence, pre-adult mortality, and parasitism of *C. pettitana* from a 420 g/ha dosage block (IV) and the check block (VII) in IGR trials

| Collection date | Block | No. of reared larvae/pupae | % mortality | | % moths emerged |
|---|---|---|---|---|---|
| | | | Parasitism | Causes unknown | |
| June 19, pre-spray | IV | 119 | 23 | 11 | 66 |
| 26, post-spray | IV | 159 | 35 | 28 | 37 |
| 26, check | VII | 228 | 11 | 34 | 55 |
| July 19, post-spray | IV | 211 | 3 | 4 | 93 |
| 19, check | VII | 251 | 3 | 9 | 88 |

colonies were re-examined in September 1975, about 15 months after treatment, and all were vigorous. The conclusion is that the treatment had not drastically influenced the viability of the ant communities.

## Discussion

IGR compounds are aimed at reducing the insect pest population of the next generation by limiting the survival and reproduction of the target generation. Forests are stable habitats suitable for long-term studies of IGR effects (Novak and Sehnal 1973), and forest pests are good economic targets because unrestrained defoliation damage in the treatment year is a tolerable trade-off for suppression of pests in the following year. IGR compounds are environmentally acceptable because they leave no residues toxic to vertebrates (Schneidermann 1972) and are more target-specific than conventional insecticides; this is because they are most effective against a particular growth stage of a pest, and thus, many non-target species are likely to be at a non-susceptible stage at application time.

The expectation that IGR compounds might enhance biological control by killing or sterilizing host populations without damaging biocontrol mechanisms (Wright and Spates 1972) is not supported by the laboratory studies of Outram (1974) and McNeil (1975). In practice there has been no reported field assessment of biological control efficacy following forest application; thus our survey breaks new methodological ground and has reaped only limited success.

In our experiment, two groups of parasitoids were involved: larval parasitoids (*Apanteles, Glypta*) already maturing when the IGR was applied; and immature larval parasitoids (*Actia, Omotoma*), most of which entered the host some days after the application. The first group encountered the maximum quantity of IGR at a time of active metamorphosis; the second group, on average, was exposed to lower quantities. However, even the target budworm had a relatively small response to the heaviest dosage. Thus, the weak evidence of a response by *Apanteles* and the tachinids suggests that the experimental dosages were too low to offer a clear demonstration of the prospective risks to biocontrol mechanisms. Furthermore, the sampling effort was too light to eliminate the problem of variance in host samples. In retrospect, it was necessary to make an on-site study of the variance components of budworm parasitism due to trees and branches in midcrown sampling, and to estimate optimal sample size for the levels of parasitism prevailing in each block in advance of treatment. Further, an experiment should have been established to check emergence of parasitoids in deformed and healthy fractions of a sample population; it would have determined whether parasitoids were more or less prone to mortality and sterility than their hosts; and it would have explored the possibility that ovipositing parasitoids might avoid attacking deformed or moribund hosts.

Similar assessments of the effects of IGR on other non-target defoliators and their parasitoids, and on predaceous arthropods, would face enormous sampling problems because spatial and temporal distributions of most candidate species have a data base much less complete than for spruce budworm. The arthropod community of fir–spruce forests in eastern Canada includes hundreds of species of defoliators and their predators and parasitoids but very few species are abundant enough to be sampled by modest effort. In 1974, the maple defoliators *I. pustularia* and *C. pettitana* were present in epidemic numbers, and therefore were available for parsimonious sampling resources.

There were major problems in sampling these various indicator species in the non-target fauna. We reduced the variability of parasitoid distribution by collecting all hosts from the midcrown of middle-sized trees. But the variability in percentage parasitisms in successive samples in the same plot implies that our unit sample size was too small. Furthermore we were unable to measure the spatial variability in the

deposition of the spray materials within the block and even within single trees. With such field variability of the insect and of the IGR, smooth laboratory-type correlations between emitted dosage and insect survival are not to be expected from field evaluation data. With our available sampling resources, the approach could be sensitive only to gross changes in the rates of parasitism.

The results are not clearcut, but broadly indicate that this IGR material, at timings and dosages tested, did not produce catastrophic changes in the survival of parasitoid and ant species. A marked reduction in the survival of one non-target lepidopterous defoliator species was observed. These meagre conclusions from a substantial research input underline the difficulty and costliness of field evaluation of side effects from such insecticides.

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