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Lethal effects of five molt inhibitors fed to the western spruce budworm (*Choristoneura occidentalis* Freeman) (Lepidoptera: Tortricidae) and the Douglas-fir tussock moth (*Orgyia pseudotsugata* [McDonnough]) (Lepidoptera: Lymantriidae)[1]

By N. G. Rappaport and J. L. Robertson

Abstract

Five insect molt inhibitors (MI's) were mixed with artificial diet and fed to 3rd and 6th stage western spruce budworm *(Choristoneura occidentalis)* larvae and 2nd stage Douglas-fir tussock moth *(Orgyia pseudotsugata)* larvae. In general, tussock moth larvae were more susceptible than western spruce budworm larvae to these MI's. SIR 6874 was by far the most toxic to 3rd and 6th stage western spruce budworm, and diflubenzuron the least toxic. TH 75331 and EL-494 both showed substantial activity against this insect, while SIR 8514 was relatively less active but was still at least 3 times as toxic as diflubenzuron. Except for EL-494, there were no large differences in toxicity of these compounds to 2nd stage tussock moth larvae; EL-494 was 30–90 times less toxic than the others at the LC_{50}. The other four MI's caused at least 50 % mortality of 2nd stage tussock moth which were fed a diet containing less than 0.1 ppm of the MI's.

1 Introduction

Diflubenzuron, an insect growth regulator which disrupts molting in a wide variety of lepidopterous insects, shows considerable promise for control of certain forest insect pests. This molt inhibitor (MI) was tested previously against laboratory colonies of western spruce budworm and Douglas-fir tussock moth (Gillette et al. 1977), and it has been tested extensively on other lymantriids (Granett and Dunbar 1974; Neisses et al. 1976) and tortricids (Retnakaran and Smith 1975; Granett and Retnakaran 1979). In general, diflubenzuron seems most promising for control of some lymantriids: it performed well in field trails against the Douglas-fir tussock moth (Neisses et al. 1976) and the gypsy moth (*Porthetria dispar* [L.]) (Granett and Dunbar 1974). However, this MI is not as effective against the western spruce budworm (Gillette et al. 1977; Granett et al. 1980) and seems not to be economically feasible for use on the spruce budworm (*Choristoneura fumiferana* Clemens) (Granett 1976).

[1] This paper reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate U.S. Government or State agencies or both before they can be recommended.

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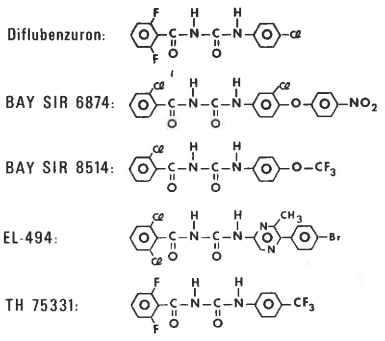
Structural formulas of five molt inhibitors



Since diflubenzuron was first synthesized many analogs have been developed, some of which show striking specificity (WELLINGA et al. 1973). We tested four of the more promising analogs to determine if any were more active than diflubenzuron, particularly against the western spruce budworm. The MI's tested were (figure): diflubenzuron (N-[(4-chlorophenyl)-carbamoyl]-2,6-difluorobenzamide), BAY SIR 6874 (N-([3-chloro-4-(4-nitrophenoxy)phenyl]carbamoyl)-2-chlorobenzamide), EL-494 (N-([3-(4-bromophenyl)-2-methyl-1,4-diazabenzen-6-yl]carbamoyl)-2,6-dichlorobenzamide), TH 75331 (N-[(4-chlorophenyl)carbamoyl]-2,4,6-trifluorobenzamide), and BAY SIR 8514 (N-([(trifluoromethoxy)phenyl]carbamoyl)-2-chlorobenzamide).

2 Materials and methods

2.1 Insects

Western spruce budworm larvae were reared on an artifical diet using the procedures of ROBERTSON (1979). Douglas-fir tussock moth larvae were reared on the same diet using a modification of the methods of ROBERTSON and LYON (1973). Third and 6th stage western spruce budworm were chosen as targets representing early and late field application strategies; 2nd stage Douglas-fir tussock moth were chosen as representing an early application strategy. Viable 6th stage Douglas-fir tussock moth were not available in quantities needed for testing, so the late application strategy was not tested for that insect.

2.2 Molt inhibitor formulations

Technical grade (95 % pure) samples of the MI's were dissolved in reagant grade dimethylformamide. Methylene blue dye (0.1 % w/v) was added to the solvent as a visual guide to thorough mixing of the chemicals with the liquefied diet.

2.3 Treatment procedure

Aliquots of liquefied artificial diet were mixed with the molt inhibitors in small plastic molds (GILLETTE et al. 1977). When solidified, the diet molds were removed and fed to larvae in 100 × 20 mm sterile plastic petri dishes lined with filter paper. Ten larvae and two diet molds were placed in each dish. From 5 to 10 dosages of each compound were tested with 20 insects/dosage;

this procedure was replicated at least 3 times, giving a minimum of 60 insects/dosage. Control insects were fed diet molds containing only solvent and dye. Insects were held on treated diet for 14 days, then mortality was scored. Dose-response lines were estimated with the probit option of the computer program POLO (RUSSELL et al. 1977).

3 Results and discussion

The Douglas-fir tussock moth was more susceptible than the western spruce budworm to these MI's (table), which agrees with results of previous tests with diflubenzuron (GILLETTE et al. 1977). Except for EL-494, there were no large differences in toxicity of the MI's to 2nd stage Douglas-fir tussock moth; EL-494 was from 30–90 times less toxic than the others at the LC_{50}. All other MI's caused at least 50 % mortality of 2nd stage Douglas-fir tussock moth which were fed diet containing less than 0.1 ppm of the MI's.

In tests with the western spruce budworm, SIR 6874 was by far the most toxic compound to both 3rd and 6th stages (from 6–1800 times as toxic as the other compounds at the LC_{50}). TH 75331 and EL-494 both showed substantial activity against both stages of this insect. SIR 8514 was somewhat less active, but was still at least 3 times as toxic as diflubenzuron. For three of the MI's (SIR 8514, diflubenzuron, and TH 75331) the LC_{50}'s for 3rd stage larvae were higher than LC_{50}'s for 6th stage larvae. Although this bioassay was not designed to assess stadial sensitivity, these results may indicate the type of differential susceptibility noted in diflubenzuron-treated spruce budworm (*C. fumiferana*) by RETNAKARAN and SMITH (1975), and GRANETT and RETNAKARAN (1977). For both 3rd and 6th stages, EL-494 was more toxic than diflubenzuron; similar results were reported for *C. fumiferana* (RETNAKARAN 1979).

Summary

TH 75331 and SIR 6874 were consistently effective on both insect species; SIR 8514 also performed well. Diflubenzuron was one of the most effective of the molt inhibitors on Douglas-fir tussock moth and one of the least effective on the western spruce budworm. Conversely, EL-494 was effective on the western spruce budworm, but was less active than the other compounds on the Douglas-fir tussock moth. TH 75331, which is structurally the most like diflubenzuron of all the analogs tested, was slightly more effective on the western spruce budworm. SIR 6874 was clearly the most effective on the western spruce budworm.

Our experiments confirm the specificity of these five analogues. Diflubenzuron, the MI which is the closest to registration, is very effective against the Douglas-fir tussock moth but is ineffective for western spruce budworm control (GILLETTE et al. 1977; GRANETT et al. 1980). In our tests we have found that certain MI analogues are much more effective than diflubenzuron against western spruce budworm. One of them, SIR-6874, especially warrants more intensive testing against that insect, should it be developed commercially. Furthermore, these bioassays underscore the importance of avoiding generalizations about the lethal effects of related chemicals on insects of different species within the same order.

Zusammenfassung

Über letale Wirkungen von fünf an Choristoneura occidentalis Free. (Lep.: Tortricidae) und Orgyia pseudotsugata (McDonn.) (Lep.: Lymantriidae) verfütterten Häutungshemmstoffen

TH 75331 und SIR 6874 zeigten eine sehr gute Wirkung auf beide Insektschädlinge. Auch SIR 8514 wirkte gut. Diflubenzuron zeigte sich als bester auf *Orgyia pseudotsugata* wirkender

Lethal effects of five insect molt inhibitors fed to 2nd stage Douglas-fir tussock moth and 3rd and 6th stage western spruce budworm

Molt Inhibitor	Insect stage	Number of larvae treated	Number in control	Control mortality (%)	Slope ± S.E.	LC_{50}	95 % Confidence limits	LC_{90}	95 % Confidence limits
Douglas-fir Tussock Moth									
SIR 6874	2	750	60	4.4	8.83 ± 1.06	0.0786	0.0644–0.0928	0.144	0.120–0.187
SIR 8514	2	775	60	8.9	2.03 ± 0.19	0.0594	0.0378–0.0810	0.134	0.0964–0.254
EL–494	2	550	60	4.3	1.66 ± 0.14	2.56	1.05–7.84	15.2	5.64–355
TH 75331	2	471	70	9.7	4.88 ± 0.44	0.0286	0.0182–0.0362	0.0400	0.0320–0.0660
Diflubenzuron	2	931	60	6.4	3.63 ± 0.41	0.0584	0.0324–0.0828	0.250	0.166–0.567
Western Spruce Budworm									
SIR 6874	3	796	70	0.0	2.72 ± 0.16	0.108	0.0704– 0.177	0.319	0.191–1.03
SIR 8514	3	1002	70	5.8	1.83 ± 0.16	6.97	3.48–11.2	35.0	19.9–123
EL–494	3	1104	69	8.0	2.97 ± 0.29	1.15	0.860–1.45	3.10	2.31–5.30
TH 75331	3	935	69	2.6	1.81 ± 0.18	1.94	0.934–3.11	9.86	5.30–67.2
Diflubenzuron	3	1012	90	1.7	0.61 ± 0.05	192.	56.1–654	23,400	3,730–212,000
SIR 6874	6	400	40	2.8	2.45 ± 0.23	0.173	0.0678–0.495	0.574	0.257–9.42
SIR 8514	6	350	30	9.8	1.61 ± 0.18	2.18	1.40–3.08	13.7	9.72–21.3
EL–494	6	490	40	3.6	4.04 ± 0.52	1.83	1.40–2.61[1]	3.81	2.66–11.9[1]
TH 75331	6	820	80	7.3	2.23 ± 0.18	0.639	0.449–0.832	2.40	1.78–3.79
Diflubenzuron	6	530	50	8.1	1.09 ± 0.13	6.67	2.59–11.6	101	55.1–300

[1] 90 % confidence limits.

Chitinsynthesehemmer, war aber bei *Choristoneura occidentalis* weniger wirksam. Umgekehrt wirkte EL-494 ziemlich stark auf *C. occidentalis*, war aber bei *O. pseudotsugata* eines der schwächsten Präparate. TH 75331, der dem Diflubenzuron ähnlichste Chitinsynthesehemmer, zeigte sich wirksamer auf *O. pseudotsugata* als jener SIR 6874 war der stärkste Hemmstoff bei *C. occidentalis*.

Unsere Versuche bestätigten die Spezifität aller 5 Präparate. Diflubenzuron ist im Begriff, in den USA registriert zu werden. Es ist sehr wirksam gegen *C. pseudotsugata*, aber nicht anzuwenden gegen *C. occidentalis* (GILLETTE et al. 1977; GRANETT et al. 1980). Unsere Versuche zeigten, daß gewisse Chitinsynthesehemmer-Präparate wirksamer als Diflubenzuron gegen *C. occidentalis* sind. SIR 6874 benötigt vor dem Erscheinen auf dem Handelsmarkt weitere Untersuchungen mit *C. occidentalis*. Die Untersuchungen weisen nachdrücklich darauf hin, daß man nie die toxikologischen Eigenschaften verwandter Präparate gegen verschiedene Insektenarten innerhalb derselben Ordnung verallgemeinern soll.

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