Juveno-Mimetic Effects of Lannate in Sublethal Doses on Western Spruce Budworm (Choristoneura occidentalis)

The most widely distributed destructive forest insect in North America is the “spruce budworm,” a complex of species including Choristoneura fumiferana, C. pinus, and C. occidentalis. In the past it has been controlled chiefly by DDT, but carbamate pesticides may be preferable, since they have the advantage of rapid detoxification in the field.

One of the newer carbamates is Lannate (S-methyl N-(methyl-carbaanoyloxy)-thioacetimidate, E. I. duPont de Nemours & Co.). It closely resembles other carbamate pesticides such as Zectran (Dow Chemical Co.) and NIA-10242 (Niagara Chemical Division, F.M.C. Corp.) in its toxic effects on insects (L. D. Anderson and H. Nakakihira, J. Econ. Entomol. 61, 1477–1482, 1968) and mice (T. L. Andrews and R. P. Miskus, Science 159, 1367–1368, 1968). In sublethal doses, however, Lannate departs from the usual pattern of carbamate toxicity.

Treatment of sixth-instar larvae of western spruce budworm (Choristoneura occidentalis) with sublethal doses of Zectran caused them to lose weight and form undersized but otherwise normal pupae up to a week earlier than untreated controls. In holometabolous insects this is a common response to physical or chemical stress. On the other hand, when sixth-instar larvae were treated with comparable doses of Lannate, they showed an increased rate of weight gain, delayed pupation, and a higher incidence of pupal abnormalities.

The following tabulated data shows the transition from Lannate concentrations producing toxic symptoms to concentrations producing the increased weight gain. Five groups of 10 sixth-instar budworms were totally immersed in the test solution for 1 sec on five successive days. Each day the insects were weighed and the average individual weight changes were calculated (Table 1).

These differences were quite apparent to the naked eye. Toxic effects predominated at $1 \times 10^{-4}$ and $1 \times 10^{-5}$ M concentrations of Lannate; 80–90% of the budworms died in the prepupal stage; the remainder pupated normally. At $1 \times 10^{-5}$ and $1 \times 10^{-6}$ M concentrations of Lannate, pupation was delayed 2–7 days, with the eventual production of 20–50% abnormal pupae. Most of these failed to complete metamorphosis; a few emerged as abnormal adults.

The pupal abnormalities included retention of larval heads, abdominal molts, and underdeveloped or unequally developed wing-buds. In some cases development ceased during a normal stage of prepupation: the insect continued to live for a week or more, unchanged except for tanning and sclerotization. The most common abnormality was the occurrence of a patch of “larval” cuticle on the ventral side of the first few abdominal segments, a condition closely resembling the “partial-pupae” syndrome described by Taylor, except that the last larval cuticle was not completely shed in his experiments as it was here (R. L. Taylor, J. Invertebr. Pathol. 7, 489–492, 1965). Death by dehydration commonly followed this lesion.

The rarest pupal abnormality encountered was retention of the larval prolegs. This was noted only twice in a series of experiments involving more than a thousand budworms.

All of the effects were obtained whether the insect was totally immersed in the test solution or received a 1-μl dose from a microapplicator on the mesothorax. The
same responses generally followed a single
dose, or the same dose given successively
on 3-5 days. No cumulative effect was
ever observed. Occasionally a single dose
failed to produce any response. Repeated
doses increased the likelihood of obtaining
the responses, but not the severity of the
responses themselves.

An attempt was made to mimic the
Lannate effects with Compound IIc, a
potent juvenile hormone analog synthesized
by W. S. Bowers (Science 164, 323-325,
1969). Purity of the compound was tested
by thin-layer chromatography before use.
Single doses of 0.01 µg/budworm effectively
reproduced the weight gains and delayed
pupation, but no pupal abnormalities were
observed. However, the Bowers compound
effects were markedly cumulative. Doses
of 0.01 µg/budworm repeated on 3 suc-
cessive days produced 80% abnormal
pupae. The partial-pupae were often found
among these, but almost always in con-
junction with more conspicuous abnor-
malities such as the retention of the larval
head or prolegs.

Potentiation between Lannate and Bowers
IIc occurred, but only when one or the
other was present at an extremely low level.
For example 1 µl of $1 \times 10^{-10}$ M Lannate,
which alone had no effect on budworms,
markedly increased both the delay in
pupation and the incidence of pupal abnor-
malities in budworms treated with 1.0 µg
Bowers IIc. Likewise, applying 0.01 µg
Bowers IIc to budworms treated with 1 µl
of $1 \times 10^{-2}$ M Lannate (a level approaching
the LD$_{50}$) caused 100% mortality in these
insects.

The kind and amount of solvent used
was not a negligible factor in these experi-
ments. Acetone by itself is an agent of
chemical stress for the budworm, whether
given at 100% in 1-µl doses, or at 50% in
the immersion experiments. In either case,
repetitive applications tended to accelerate
pupation and reduce the rate of weight gain
(up to 40%). The ability of Lannate to
counter these tendencies resulted in more
striking differences being obtained between
test and control groups when acetone was
the solvent than when water alone was the
solvent.

This suggested antagonism between stress
and juvenile-mimesis may eventually help
explain the mechanisms of both processes
and thus merits further study.

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Richard F. Smith
Pacific Southwest Forest and Range Experi-
ment Station
Forest Service, U. S. Department of Agri-
culture
Berkeley, California 94701

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