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THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION NEW HAVEN

How *Bt* Works

Bacillus thuringiensis (Bt) kills only insects, primarily caterpillars. It is relatively slow-acting, has no contact toxicity, and must be eaten to be toxic to the caterpillars. It is sensitive to ultraviolet light.

Bt is a bacterium of the genus *Bacillus*. It is a spore-forming, rod-shaped bacterium, which has a toxic protein contained within a crystal.

Shortly after ingestion, the alkaline midgut of the digestive system causes the toxin to be released and it destroys the cells. Paralysis of the gut occurs and causes feeding to cease. Some of the gut content spills into the circulatory system, and within hours to a day or two, the caterpillar is dead. Susceptibility of a caterpillar to *Bt* is related to its age and size; younger caterpillars are more susceptible than older ones.

Bacillus thuringiensis applied by air works against the gypsy moth

By Paul Gough

The gypsy moth has periodically caused widespread defoliation in Connecticut and much of the Northeastern United States. In 1981, a record 1.5 million acres—about half of the state's land area—was defoliated and many landowners turned to insecticides for relief. Although ground spraying provides control, aerial application costs less per acre, uses less insecticide, and is the only practical means of treating large acreages.

State regulations prohibit aerial application of chemical insecticides on residential and forest land, so only biological materials, such as the bacterial insecticide, *Bacillus thuringiensis (Bt)*, may be used. *Bt* has been available for gypsy moth control since 1961, but it has not been used extensively because its performance has been erratic. Also, the repeated spraying, which was considered necessary, made application costly. New strains and improved formulations more toxic to gypsy moth caterpillars have recently been developed. Therefore, the Experiment Station, the U.S. Forest Service, and the State Department of Environmental Protection cooperated in two years of testing of three new strains and formulations of *Bt* for gypsy moth control.

Bt significantly reduced caterpillar numbers and protected foliage

In 1981 the general effectiveness of *Bt* was tested in the Town of Harwinton, in cooperation with local officials. In 1982, the Nehantic State Forest in Lyme and East Lyme was selected as the experimental site to compare a single application with two.

In 1981 two experimental strains of *Bt*, HD-243 and HD-263 which were highly toxic to gypsy moth caterpillars in laboratory studies, and the commercial strain HD-1, all formulated as Dipel 4L®, were compared. All *Bt* was applied by helicopter at a rate of 1 qt/acre in 1 gal of water containing 3% Acrylocoat® sticker.

Two weekly applications of each strain and a single application of HD-1 were tested. The first spray was applied on May 21, 1981 when most gypsy moth caterpillars were in the first and second stages and defoliation had not exceeded 10%. The second application was made on May 28 when most of the caterpillars were in the second

Table 1. Results of treatment with *Bacillus thuringiensis* in Harwinton in 1981.

Strain	Dose qts/acre	Number of applications	% Reduction in caterpillar numbers relative to untreated plots	Average % defoliation Final
HD-1	1	2	89	15
HD-243	1	2	86	24
HD-263	1	2	86	31
HD-1	1	1	73	37
Untreated	—	—	—	61

Table 2. Defoliation after treatment with *Bacillus thuringiensis* in Lyme in 1982.

Strain	Dose qts/acre	Number of applications	% Reduction in caterpillar numbers relative to untreated plots	Average % defoliation Final
HD-1	1	2	96	4
HD-1	1.5	1	84	6
HD-1	2	1	89	8
Untreated	—	—	—	72

and third stages. Foliage was dry and skies overcast on both dates.

Each strain of *Bt* significantly reduced caterpillar numbers and protected foliage as shown in Table 1. Two applications of the commercial strain, HD-1, were most effective. The numbers of caterpillars were 89% lower in the treated plots, and defoliation was 15% as compared to 61% in the untreated plots. HD-243 and HD-263 were as effective but no better than HD-1. One application of HD-1 reduced caterpillar numbers and decreased defoliation from 61 to 37%.

A single aerial application of *Bt* is less costly and easier to apply at the proper time than two spaced 7 to 10 days apart. Therefore, the 1982 experiments in Lyme and East Lyme tested the effectiveness of a single application of *Bt* at higher dosages. In this test, one application of 1.5 and 2 qts/acre were compared with the "standard" two applications of 1 qt/acre. As in 1981, the initial treatment was made against young, susceptible caterpillars when defoliation was still insignificant. The first application was made on May 17 and the second on the plots receiving the "standard" treatment, on May 26.

Once again caterpillar numbers were reduced significantly and defoliation was reduced from 72 to 4% by two weekly applications of HD-1 at 1 qt/acre (Table 2). More importantly, defoliation averaged less than 10% following single applications at the higher doses as compared to 72% observed in the untreated plots.

In these experiments one application of an increased dose of 1.5 qts/acre was virtually as effective as two treatments at the standard rate of 1 qt/acre per treatment. Therefore, equal protection was obtained at the cost of one application.

Suggested Reading

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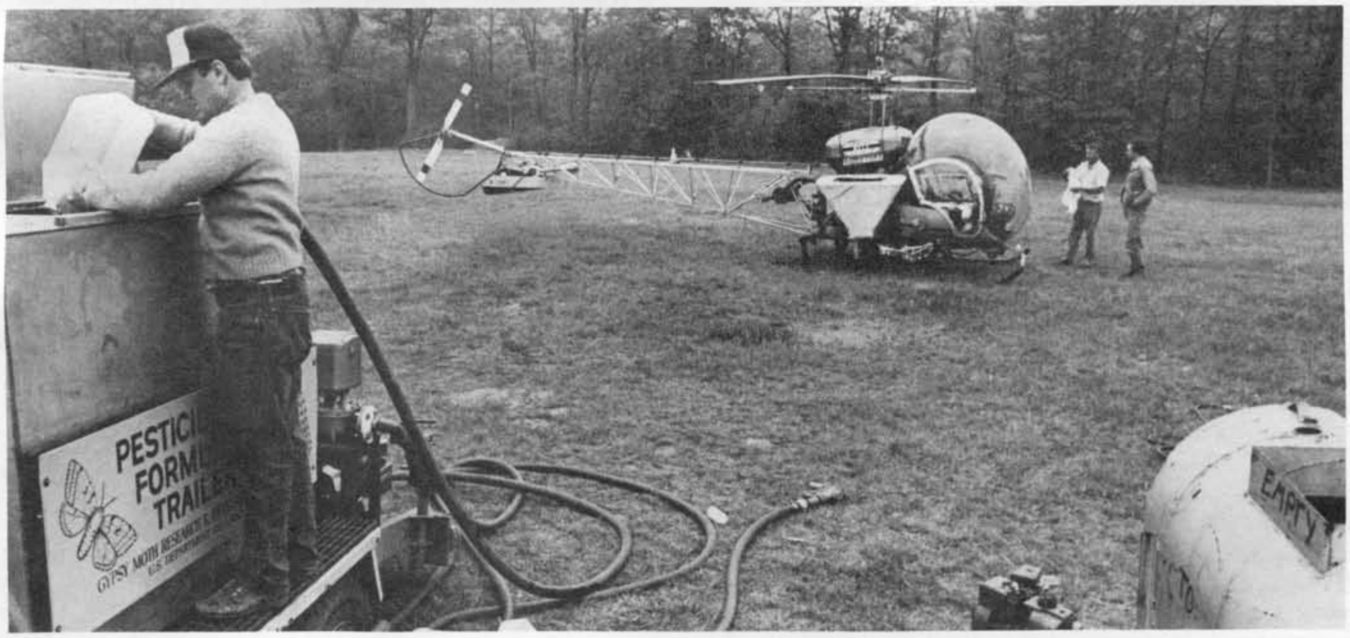

Figure 1 Mixing *Bt* for the experiments in Harwinton.

Gypsy Moth in 1982

As the infestation moved eastward in 1982, defoliation caused by the gypsy moth was 50% less than in 1981.

An aerial survey by staff of the Experiment Station indicated that 803,802 acres were defoliated in the spring. Of the total, more than half, 489,557 acres, was defoliated 75% or more. The 1982 defoliation figure was the second highest recorded. In 1981, the gypsy moth defoliated 1.5 million acres.

Defoliation was recorded in all eight counties, but most occurred in Tolland, Windham, and New London Counties. A total of 97 of 169 cities and towns had noticeable (10% or more) defoliation.

The counties and the total acres of defoliation observed were: Fairfield: 5,562; Hartford: 40,536; Litchfield: 88,307; Middlesex: 54,578; New Haven: 4,437; New London: 257,017; Tolland: 166,300; and Windham: 187,065.

During the winter of 1981-2 staff of the Experiment Station surveyed 70 towns at the request of first selectmen. In several towns the decline in gypsy moth was anticipated by the survey and needless spraying was avoided.

Testing for carbaryl in raw milk and pesticides in other foods

By J. Gordon Hanna

The contact insecticide, carbaryl (l-naphthyl-N-methylcarbamate) commonly referred to by its trade name, Sevin, has been used extensively from the ground to combat gypsy moths in Connecticut during the past few years. Mammals are considered relatively safe from the effects of this compound. A legitimate concern, however, was that traces of carbaryl could enter the food chain and ultimately be consumed by humans. A most important pathway would be by way of milk from dairy cows that may have been exposed to the spraying or fed forage that had been contaminated by the insecticide.

To evaluate the potential problem, inspectors of the Connecticut Department of Agriculture collected twenty samples of raw milk from representative sprayed areas during May 1982. The area covered ranged from Salisbury to New Milford to Stonington. On analysis in our laboratory no carbaryl was detected in any of the samples. An extremely sensitive procedure based on high pressure liquid chromatography had been developed by William Glowa of our laboratory several years before to determine carbaryl in the presence of significant amounts of fat and wax such as in bees and honey. This analytical procedure was tested and found applicable to milk and was used to test these samples.

This study was an extension of the continuous monitoring of pesticide residues in foods by the Station analytical laboratory. The Connecticut raw milk supply is checked regularly in cooperation with the Commissioner of Agriculture. Attention is focused mainly on chlorinated organic pesticides because this type is most persistent in the environment, is accumulated in the body fat of animals and can be retained in the fat of milk. None of the 219 samples of raw milk tested in the first 10 months of 1982 was found to contain residues in excess of the officially established safety tolerances.

Fruits, vegetables and other foods are collected by inspectors of the Connecticut Department of Consumer Protection from fields and stands during the growing season and from stores and storage at other times of the year for testing in the Station laboratory. The analytical methods routinely applied reveal the presence of any chlorinated and organophosphate pesticides in these foods. Applied also are tests for specific pesticides that have been used on the crops or may be present from other sources and are not detectable by the general methods. A total of almost 300 samples of food in addition to the milk samples have been tested in 1982 and no sample was found to exceed the safety tolerances for pesticide residues.

Table 1. Food products tested most frequently for pesticide residues in the station laboratories from January through October 1982.

Food	Number of Samples
Milk for carbaryl	20
Milk for chlorinated pesticides	219
Apples	32
Carrots	21
Corn	23
Squash	19
Strawberries	55
Tomatoes	18
Breakfast cereals	20

Plants take up PCBs from contaminated soil

By Brij L. Sawhney and Lester Hankin

In Connecticut, the Housatonic River system has been contaminated by entry of PCB-laden sediment from impoundments upstream. The principal source of contamination is bottom sediments in Woods Pond, located just below Pittsfield, Massachusetts, which has been a major repository of PCBs from past manufacturing operations. The pond feeds the Housatonic River system, and as the bottom sediments are disturbed during periods of high flow, the PCB-containing sediments enter the river. Calculations of the amount of PCBs contained in the entire Housatonic River system show that about 50% is contained in Woods Pond. The sediments in both Woods Pond and the Housatonic River contain primarily the three PCBs known as Aroclors 1248, 1254 and 1260. The last two digits indicate the percentage of chlorine in each Aroclor; as chlorine content increases, solubility in water decreases.

One proposal to prevent further contamination of the river is to dredge Woods Pond and dispose of the PCB-containing sediment in a safe manner. Disposal on land has been suggested. It is essential, therefore, to know whether plants growing on contaminated soil would take up PCBs and thus provide another means of their entry into the food chain.

To investigate uptake of PCBs by plants, we mixed 200 gallons of sediment (about 30% solids) from Woods Pond in the surface 6″ of soil in a field plot contained within a 6′ × 6′ wooden frame. The soil was allowed to dry and was then thoroughly mixed once again. A plot of the same dimensions, similarly treated with 200 gallons of water, was used as a control.

After fertilizing and liming, beets and turnips were planted in the two plots on June 30, 1981. On October 2, 1981, plants were harvested, roots and leaves separated, washed thoroughly with water and scrubbed with a brush to remove any adhering soil particles, and dried in a forced-air oven at 21°C. The dried roots and leaves were ground in a stainless steel Wiley mill to pass through a 20 mesh sieve. Samples were then extracted with petroleum ether and the extracts purified by filtering successively through anhydrous sodium sulfate and florisil columns to remove any interfering substances. The purified extracts

PCBs are taken up by plant roots and are also translocated into the leaves

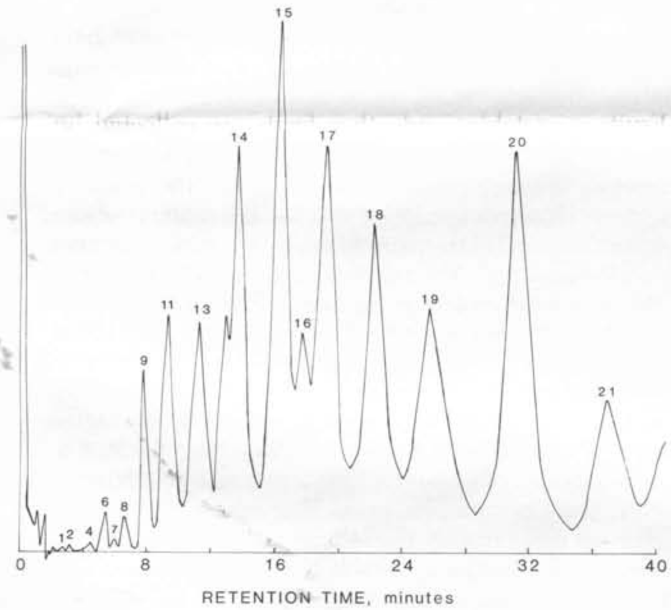

Figure 1 A gas chromatogram showing PCBs in a contaminated soil sample. The numbered peaks indicate the presence of three different PCBs.

PCBs (polychlorinated biphenyls) are stable organic compounds which have been extensively used in the manufacture of electrical capacitors and transformers as well as in hydraulic fluids, resins, rubber, carbonless paper and other products. Because of their potential toxicity, PCBs are no longer manufactured in this country. However, they have entered the environment, particularly in water courses where they can be consumed by fish and thus enter the food chain.

Table 1. PCBs in soil amended with contaminated sediment and in vegetables grown in amended soil.

Aroclor	Soil	Beet Roots			Beet Leaves			Turnip Roots			Turnip Leaves		
	ppb	ppb	SR*	RSR*	ppb	SR*	RSR*	ppb	SR*	RSR*	ppb	SR*	RSR*
1248	80	15	.187	94	22	.275	69	30	.375	188	32	.400	200
1254	1,880	16	.008	4	94	.050	12	16	.008	4	40	.021	11
1260	14,440	35	.002	1	52	.004	1	20	.002	1	27	.002	1

* SR is selectivity ratio calculated by dividing the amount (ppb) of an Aroclor in the plant part by its amount in the soil. RSR is the ratio of Aroclor 1248 or 1254 compared to 1260.

were analyzed by gas chromatography.

The results of these analyses revealed that PCBs are taken up by plant roots and are also translocated into the leaves.

Figure 1 shows a gas chromatogram of an extract from the contaminated soil. A number of peaks which correspond to individual PCB components or isomers are shown. The lower numbered peaks represent isomers with lower chlorine content and the higher numbered peaks with higher chlorine content. Similar peaks were observed in chromatograms of extracts from plants grown in the contaminated soil, indicating that plants can take up various PCB isomers. Based on computer analysis of the individual peak heights, we estimated the amounts of the three Aroclors, 1248, 1254 and 1260 in the soil amended with sediment from Woods Pond and in plants grown in this soil. No Aroclors (PCBs) were detected either in the control soil or in plants grown in the control soil.

Figure 2 Using a chromatographic column to purify vegetable extracts for analysis for PCBs.

As shown in Table 1, plant roots and leaves accumulate appreciable quantities of the three Aroclors when grown in soil amended with PCB contaminated sediment. The concentrations of PCBs in the beet roots and leaves were 66 and 168 ppb (parts per billion) and in turnip roots and leaves 66 and 99 ppb (dry weight). In both plants, leaves contained higher concentrations of PCBs than roots. These concentrations are lower than the tolerance limits established by the U.S. Food and Drug Administration for various foods. These limits vary from 300 ppb for eggs to 5000 ppb for fish.

The results in Table 1 also show that plants take up Aroclors of lower chlorine content more selectively. To measure selective uptake we divided the concentration of each PCB found in the plant tissue by the concentration in the amended soil. We call this ratio the selectivity ratio (SR). The relative selectivity ratio (RSR) was then determined by dividing the SR of Aroclors 1248 and 1254 by that of 1260.

These calculations show that of the three Aroclors present in the soil, the relative uptake of 1248 is the highest and that of 1260 is the lowest. For example, the RSR for beet roots for 1248 is 94, for 1254 it is 4, and for 1260 it is 1. Thus, Aroclors with a lower chlorine content appear to be taken up more readily than those with a higher chlorine content. This occurs in spite of the larger amounts of the Aroclors with higher chlorine content.

In a separate investigation of the degradation of PCBs by soil microorganisms, we found that the less chlorinated PCBs which are taken up more readily by plants are also degraded more quickly than the more chlorinated compounds. However, the rates of PCB degradation vary not only with Aroclor but also with previous land use (e.g. corn field, orchard, forest soil).

The mechanism of uptake of these Aroclors by plants is not clear at the present time. Aroclors are only very slightly soluble in water, and their solubility increases with decreasing chlorine content. The greater relative uptake of Aroclor 1248, the most soluble of the three PCBs in water, suggests that these compounds are taken up by roots from solution and are translocated to other plant parts during water movement and transpiration.

Acknowledgements

William Glowa performed the gas chromatographic analyses and Michelle Birks and Jane Damschroder provided technical assistance during this investigation.

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Modernizing the scarecrow to protect crops from birds

By Michael R. Conover

Birds see that scarecrows never catch anything

Birds can cause considerable damage to agricultural crops: Pigeons eat germinating seeds, crows peck ripening vegetables, song birds eat berries, and flocks of blackbirds destroy fields of maturing corn. Lethal control techniques are inappropriate for most bird problems given the esthetic and other beneficial attributes of birds. Consequently, I am trying to develop non-lethal methods to reduce crop damage by birds to promote a harmonious coexistence between agriculture and wildlife.

One non-lethal method of bird control, used since prehistoric times, involves fear-provoking stimuli such as scarecrows. Despite their long history, scarecrows are ineffective because birds have become used to humans and bird pests are no longer commonly shot by people. Therefore, I abandoned the traditional scarecrow, a straw-stuffed image of a human, and concentrated on models of natural predators, such as hawks and owls. Research has shown that these models are more effective than scarecrows.

While hawk and owl models work better than scarecrows, like all fear-provoking models, they lose their effectiveness because birds rapidly habituate to them. To improve these models, I examined why birds habituate to predator models but not to real predators. One major difference between live predators and models of predators is that live predators are active while most models are passive. I found one type of predator model, however, that is capable of movement. This model is a plastic kite upon which is printed a picture of a soaring hawk. This kite is suspended so that any breeze causes it to move and soar (see cover photo). My research showed that this model repels birds and that much of its effectiveness was, in fact, due to its mobility.

I then tested this hawk-kite to see if it could protect blueberries and corn from bird damage. These experiments were conducted on blueberry plantings ranging from 0.1 to 1.5 acres in Hamden and Glastonbury and corn fields ranging from 1 to 10 acres in Hamden and Lyme, Connecticut. The kites usually were suspended 60 feet beneath a helium balloon and flown 90 feet above the ground. These distances varied somewhat according to topography, weather and other factors. One hawk-kite was used in each field. The amount of bird damage sustained in these fields was compared to nearby unprotected fields.

The hawk-kites reduced bird damage to blueberries by 35%. Although this is a higher level of loss than on berries protected by netting or a chemical repellent, these latter techniques are sometimes impractical or too costly. Therefore, the hawk-kite may be the best alternative under some conditions.

When I tested the hawk-kites in ripening field corn, they reduced damage by 83%. Other commonly-used techniques, deterrents such as the chemical Avitrol, or propane-powered cannons which explode every 10–15 minutes, reduced damage by 22% and 77%, respectively.

To improve predator models further, I continued to study how birds gain information about predators, and I hypothesized that birds can learn about them by watching their fellow birds and their interactions with predators. To test this, I examined whether starlings, *Sturnus vulgaris*, alter their behavior after observing a stationary owl model that appears to be grasping a struggling starling. My results showed that starlings were more wary of this model than they were of a similar owl not holding simulated prey. Furthermore, the birds' heightened fear of

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Figure 1 An attacking owl model protecting tomatoes.

the new model remained even after the struggling starling model was removed and the owl returned to its original appearance. Such results indicate that starlings learn about predators from the misfortune of their neighbors and that one reason why birds habituate rapidly to the scarecrow is that they see that scarecrows never catch anything.

Having recognized two major problems with predator models, their lack of mobility and lack of life-threatening qualities, I tried to incorporate these features into a new model capable of repelling crows from small fields and gardens where they can do considerable damage. I first took a plastic owl model and attached to its talons a plastic crow model, making the crow appear to be struggling to get away and the owl appear to be killing it. I then added movement to this model by placing it on a weather vane, enabling it to turn in the wind (Figure 1). I also used a flexible joint between the owl and the crow model, allowing the crow model to rotate at this juncture. I made the wings of the crow model flexible at two joints so they could be easily moved like real wings. The wings were constructed so that they would flap when there was a breeze or when connected to a battery-powered motor.

I compared the ability of "attacking owl" models to that of unaltered stationary owl models in protecting several garden plots in New Haven County from crow damage (Figure 2). Gardens with the unaltered owl model sustained as much crow damage as unprotected gardens. In contrast, the new "attacking owl" model reduced damage to both tomatoes and cantalopes by over 80%.

These experiments suggest that predator models, especially those with movement and that appear to be catching prey, can reduce bird damage without harming the birds.

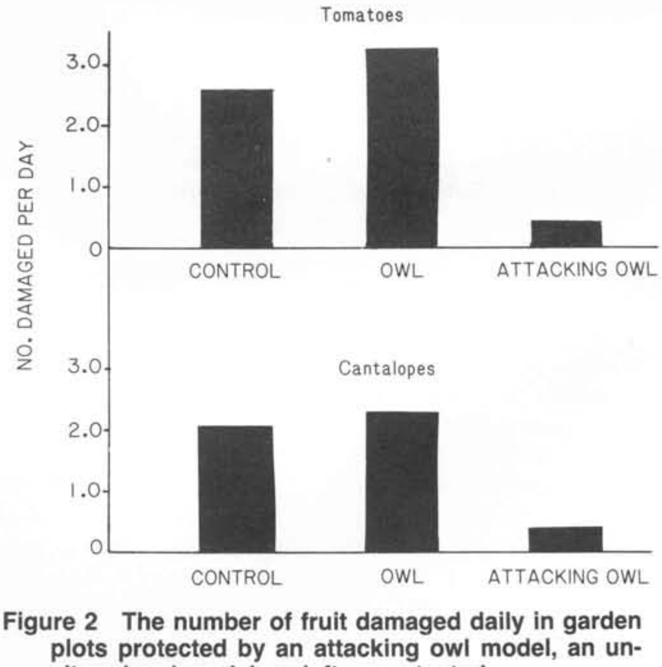

Figure 2 The number of fruit damaged daily in garden plots protected by an attacking owl model, an unaltered owl model, or left unprotected.

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