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SYSTEMIC INSECTICIDE CONTROL OF SOME PESTS OF TREES AND SHRUBS — A PRELIMINARY REPORT

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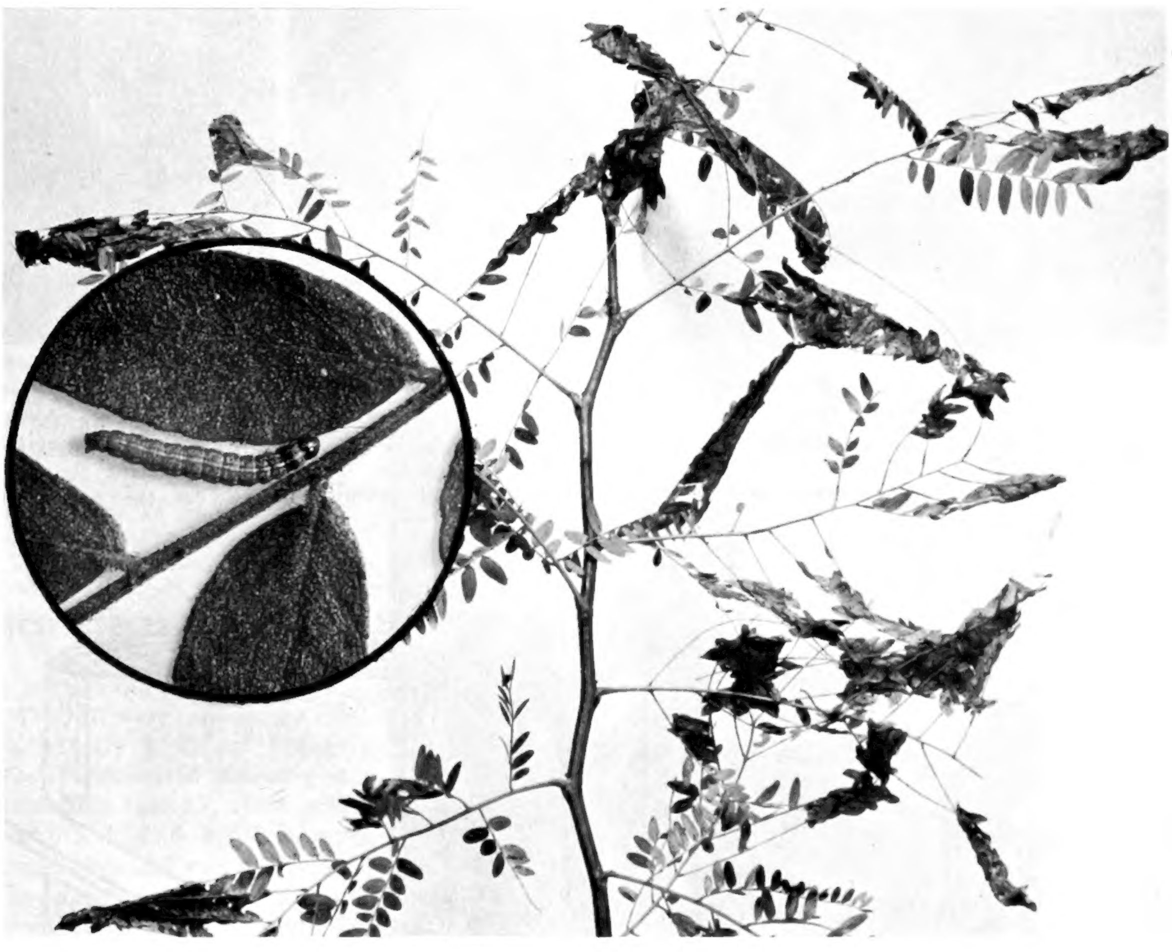

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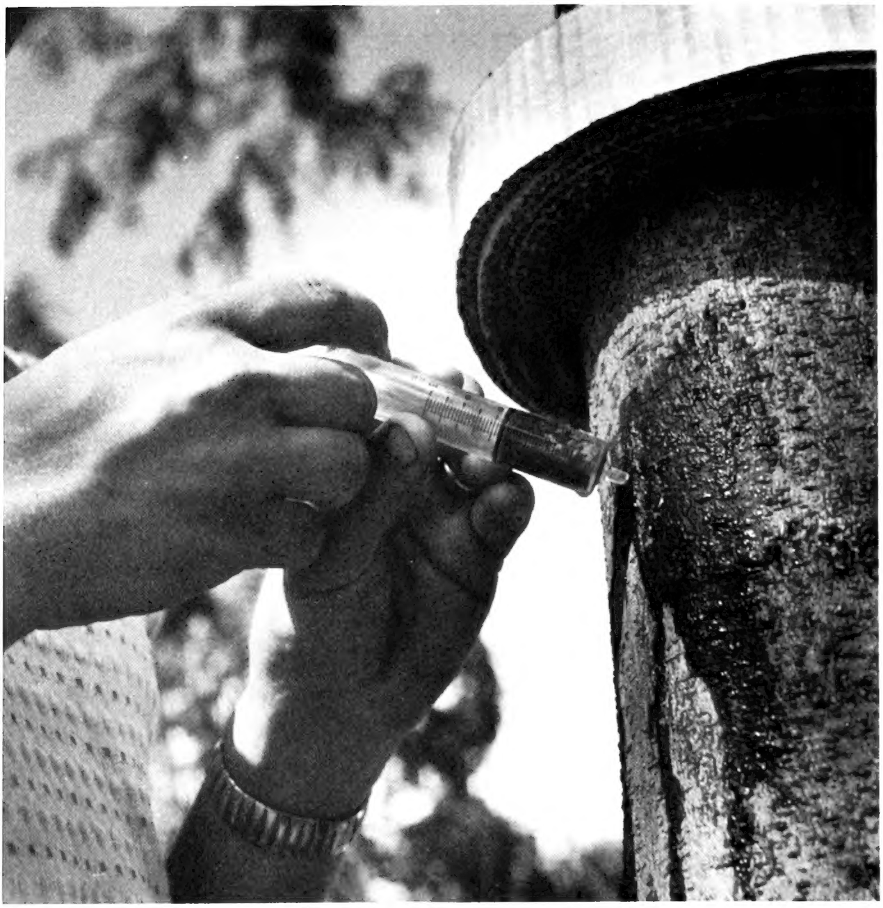

Fig. 1. – Application of SD-3562 to the uninjured bark of a honey locust tree. A measured dosage of the chemical is applied with a syringe.

Cover photograph shows mimosa webworm on honey locust.

Fig. 2. – Injection of SD-3562 into the soil. A bucket pump and wand are used to inject diluted SD-3562 into the soil around a plant. The plastic bag covering the piston is a safety device to protect the pump operator from the chemical.

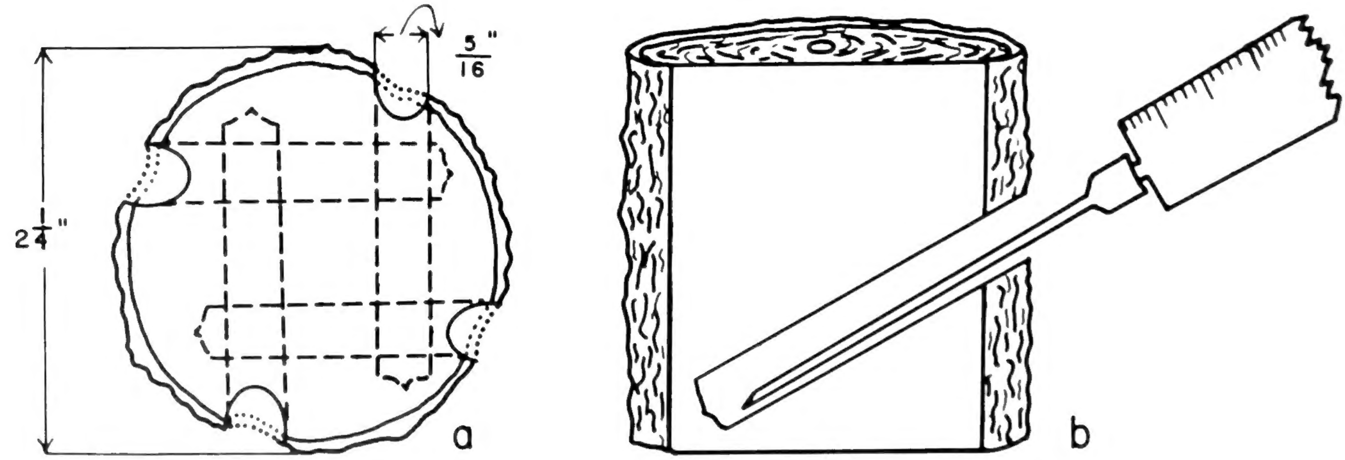

Fig. 3. – Method of injecting SD-3562 into drilled holes in tree. Cross section *a* shows arrangement of drilled holes. Diagrammatic presentation *b* shows approximate downward tilt of a drilled hole in a tree and position of syringe at time of injection of SD-3562.

SYSTEMIC INSECTICIDE CONTROL OF SOME PESTS OF TREES AND SHRUBS – A PRELIMINARY REPORT

L. L. ENGLISH AND WALTER HARTSTIRN*

Information supplied by entomologists of the Shell Development Company of Modesto, California, in the spring of 1959, indicated the possibility of controlling the smaller European elm bark beetle, *Scolytus multistriatus* (Marsham), on elms by injecting a new chemical, SD-3562, into the trees, fig. 3. The beetle is well known as the principal vector of the Dutch elm disease. Later developments suggested the possibility of controlling other pests of trees and shrubs with bark or soil applications of SD-3562, figs. 1 and 2. This chemical, an organic compound, 3-(dimethoxyphosphinyloxy)-N,N-dimethyl-cis-crotonamide, is a systemic insecticide. When taken up by a plant, it is translocated to the stems and leaves, making the plant poisonous to insects that feed on it.

Technical grade SD-3562, used in the experiments reported in this paper, is a brown liquid with a mild odor. It is water soluble and is highly toxic to warm-blooded animals as well as insects. In the research reported here, the chemical was used undiluted except when placed in the soil around trees or shrubs.

The insecticidal activity of technical SD-3562 is proportional to the amount of alpha isomer (actual SD-3562) in the solution. Early preparations, with only 30 to 50 per cent alpha isomer, were used in our experiments of 1959 and 1960. Improved manufacturing processes made possible an increase in the alpha isomer to 75 per cent. The preparation with the higher concentration of alpha isomer was used in the experiments we performed in 1961. At the time of publication of this paper, SD-3562 is not available for use by the public.

PHYTOTOXICITY TESTS

Before tests were undertaken with insects, phytotoxicity tests with SD-3562 were conducted on American elm trees in a nursery plot at Urbana-Champaign. The trees, about 3 inches in diameter at breast height (dbh), were treated on June 19, 1959, with technical SD-3562 at rates of 0.5, 1, 2, 4, and 8 ml per inch of tree dbh. The undiluted chemical was measured with a syringe and placed in holes three-eighths inch in diameter bored at a downward angle into the trunk of each tree at about 3 feet above the ground, fig. 3. In the following pages, this method of treating trees will be designated as injection.

There was no foliar injury to the trees at dosages of 0.5 and 1 ml per inch of tree dbh. At a dosage of 2 ml there was slight injury to the foliage, and at dosages of 4 and 8 ml there was severe damage, resulting in complete defoliation.

TESTS WITH BARK BEETLES ON NURSERY TREES

Early May is believed to be the proper time for treating American elm trees with a systemic insecticide to prevent the first brood of elm bark beetles from infecting the trees with Dutch elm disease. In 1959, the

Fig. 4. – Cylindrical sleeve cage for confining insects on branch of a honey locust tree.

*L. L. English is Entomologist and Walter Hartstirn is Assistant Plant Pathologist, Illinois Natural History Survey. Robert Snetsinger, Robert Kukla, and Clifford Scherer assisted with the work reported here. Howard W. Fox, Forester of Sinnissippi Forest, and Noel B. Wysong, Chief Forester, Forest Preserve District of Cook County, co-operated in the field tests. Wilmer Zehr took the photographs. Mrs. Anne R. Dreyfuss and James S. Ayars edited the manuscript. This paper is printed by authority of the State of Illinois, Ch. 127, IRS, Par. 58.22.

first year of our experiments with SD-3562, the chemical was not available to us until after June 15.

On July 6, 1959, following the tests for phytotoxicity, three lots of American elm trees in a nursery, each lot consisting of three trees 3 to 4 inches dbh, were treated by injection with technical SD-3562 at dosage rates of 0.25, 0.5, and 1 ml per inch of tree dbh, fig. 3. To serve as controls, three other trees were similarly treated, except that distilled water was substituted for SD-3562.

On July 20, three additional trees were treated at a dosage rate of 2 ml technical SD-3562 per inch of tree dbh. As in the previous test, three trees were used as controls.

An ample supply of bark beetles was obtained throughout the period of the tests from infested wood confined in drums fitted with emergence cages. Only freshly emerged and active beetles were used.

Cylindrical cages were used to confine the beetles on selected branches of the elm trees. Each cage, constructed of 40-mesh copper wire screening, was about 6 inches in diameter and 18 inches long, with two 15-inch-long muslin sleeves firmly attached to the ends of the copper wire cylinder, fig. 4. A cage was slipped over the end of a branch which had 25 to 30 undamaged crotches and was tied in place with twine around one of the sleeves. About 25 beetles were counted into a pint carton and transferred promptly to the copper wire cylinder through the open muslin sleeve, which was then tied securely.

Cages were placed on trees at intervals of 2, 4, 8, and 16 days after the trees had received treatment; the purpose of this procedure was to determine the effective period of the chemical. Each cage, with beetles in it, was left on a branch for 7 days; the branch was then clipped and brought to the laboratory, where the number of beetle penetrations in the crotches was recorded. (A feeding scar, caused by a beetle eating into the xylem, was recorded as a penetration by a beetle.)

There was little, if any, reduction in beetle penetrations on trees treated at dosage rates of 0.25, 0.5, and 1 ml per inch of tree dbh, but there was a definite reduction in the number of penetrations at a dosage rate of 2 ml per inch, table 1. Norris (1959:60) reported the prevention of feeding niches longer than 2 mm on trees treated by injection with 20 grams of technical SD-3562 per tree (2 inches dbh); the period of protection lasted for about 21 days after treatment. Later, Norris (1960:1035) reported a significant reduction in feeding niches with a dosage of 18 grams of the chemical per 3-inch tree. This second dosage, which approximates 5.0 ml per inch of tree dbh, is the

Table 1. — Average number of penetrations per beetle in crotches of small elm branches on which bark beetles were confined in cages. The cages, with approximately 25 beetles each, were placed on the branches 2, 4, 8, and 16 days after four lots of three trees each had been treated in July, 1959, with SD-3562 (30-50 per cent alpha isomer) by injection at various dosage rates and left for 7 days; two lots of trees were treated by injection with distilled water only.

Dosage Rate, Ml Per Inch of Tree DBH	Penetrations Per Beetle Caged on Branch on Indicated Day After Tree Treatment			
	2nd	4th	8th	16th
0.0	0.25	0.27	0.64	0.55
0.25	0.38	0.53	0.41	0.79
0.5	0.26	0.22	0.46	0.78
1.0	0.30	0.23	0.35	0.45
0.0	0.55	0.82	1.15	1.29
2.0	0.41	0.25	0.53	0.44

Table 2. — The survival time (number of days) of bark beetles placed in jars with twigs from elm trees 2, 4, 8, 16, and 32 days after treatment of trees in July, 1959. Four lots of twigs were from 12 trees treated by injection with SD-3562 (30-50 per cent alpha isomer) at various dosage rates. Two lots of twigs were from 6 trees treated by injection with distilled water only.

Dosage Rate, Ml Per Inch of Tree DBH	Survival Time (Days) of Beetles Exposed to Elm Twigs on Indicated Day After Tree Treatment					
	2nd	4th	8th	16th	32nd	2 - 32*
0.0	5	7	6	7	9	6.8
0.25	4	6	4	2	9	5.0
0.5	2	3	3	2	4	2.8
1.0	3	7	3	4	2	3.8
0.0	7	7	3	9	...	6.5
2.0	2	2	2	6	...	3.0

*Average survival time for beetles placed in jars with twigs 2, 4, 8, 16, and 32 days after trees had been treated.

dosage necessary to protect elms from infection with Dutch elm disease for the 30 days necessary in Wisconsin, Norris concluded.

We originally planned to place a series of cages on the trees 32 days after treatment, but by that time the crotches in the twigs were so badly damaged by the natural infestation of bark beetles that this procedure proved impractical. However, enough undamaged crotches were found 32 days after treatment to run tests with beetles in jars containing twigs from the treated trees, table 2. These tests showed that the life span of bark beetles placed in jars with twigs from trees treated with 0.5, 1, and 2 ml of technical SD-3562 per inch of tree dbh was about half the normal life span, table 2. Apparently, some of the beetles were killed when exposed to twigs from trees given dosages lower than those required to materially reduce the number of penetrations, while others survived long enough, even on branches from trees given the 2 ml dosage, to produce penetrations in the crotches of twigs.

TESTS WITH SD-3562 INJECTED INTO ELMS FOR CONTROL OF DUTCH ELM DISEASE

The preliminary tests with SD-3562 as a systemic insecticide produced several interesting findings. After injection into American elm trees, SD-3562 was translocated throughout the trees and was toxic to bark beetles feeding in the crotches of twigs, where infection with the Dutch elm disease fungus, *Ceratocystis ulmi* (Buisman) C. Moreau, takes place. The chemical was toxic to the bark beetles for about a month after the trees had been treated at dosages of 0.5 ml per inch of tree dbh. At a dosage of 2 ml per inch of tree dbh, the number of penetrations to the xylem of the twigs was definitely reduced. This dosage, however, caused slight injury to the foliage of elms. There seemed to be little margin between the dosage level required to reduce the number of beetle penetrations and the dosage causing injury to elm trees.

An important question to answer was whether SD-3562 at nonphytotoxic dosages could provide sufficient protection from the bark beetle to control Dutch elm disease. Only comprehensive field experiments could answer this question.

Experiment on Elms at Sinnissippi Forest. — A field experiment to test the effectiveness of SD-3562 for reducing the incidence of Dutch elm disease was started in 1960 at Sinnissippi Forest, near the village of Oregon. The test area contained 162 American elm trees that ranged in size from 1.5 to 12.3 inches dbh. On May 13, just after the buds had broken dormancy, half of the trees (81) were treated by injection with SD-3562. Half were left as controls. (No holes were bored and no distilled water was injected into the trees set aside as controls.) The treated and untreated trees were chosen at random throughout the block. Undiluted technical SD-3562 (30-50 per cent alpha isomer) was injected into four holes, three-eighths inch in diameter, in each test tree at the rate of 2 ml per inch of tree dbh.

Table 3. — Number of elm trees at Sinnissippi Forest showing each of several degrees of chemical damage following treatment of 81 trees with SD-3562 on May 13, 1960 (30-50 per cent alpha isomer), and on May 1, 1961 (75 per cent alpha isomer). SD-3562 was used at the rate of 2 ml per inch of trunk dbh in 1960 and 1.5 ml in 1961.

	Number of Trees	
Damage*	1960	1961
None	3	31
Slight	35	12
Moderate	24	18
Severe	17	17
Complete (tree killed)	2	1

*Slight, some cupping of leaves but no dead areas; moderate, cupping of leaves over the greater portion of the tree, accompanied by some marginal leaf burn; severe, cupping and burning of leaves extensive, between the veins as well as marginal, in some cases one or more branches killed.

On May 1, 1961, the same trees were again treated, this time with the improved technical SD-3562 (75 per cent alpha isomer) at the rate of 1.5 ml per inch of tree dbh; the holes drilled were five-sixteenths inch in diameter. This dosage of the improved chemical was presumed to have more insecticidal activity than 2 ml of the older product. At seasonal intervals after being treated, the trees were examined for disease symptoms and signs of chemical injury.

The observations on phytotoxicity for both years are summarized in table 3. None of the untreated trees showed any signs of injury. Two trees treated with the chemical died in 1960 and one in 1961. Seventeen showed severe injury in each year. Although only 3 trees were free of injury in 1960, 31 were without injury in 1961. The significance of these figures is a matter of conjecture at this stage of the experiment.

There was no evidence of Dutch elm disease in the entire block of trees in 1960. In 1961, however, eight of the untreated trees and one of the treated trees died of the disease, as verified by laboratory tests. The 1961 losses from Dutch elm disease amounted to 1.2 per cent of the treated trees and 9.9 per cent of the control trees. The difference between these percentages is encouraging, but its significance can be determined only by continuing the experiment for several years.

Experiment on Elms in Cook County. — In 1961, a block of 500 American elm trees ranging in size from 1.0 to 7.4 inches dbh was made available in the Forest Preserve District of Cook County for tests with the improved technical SD-3562 product. Three lots of 100 trees each, randomized throughout the entire block, were treated with the chemical at dosages of 1, 1½, and 2 ml per inch of tree dbh, respectively. Treatment

Table 4. – Number of trees in the Forest Preserve District of Cook County showing each of several degrees of chemical damage following treatment of 400 trees with improved SD-3562, each lot of 100 trees at a dosage of 1, 1.5, 2, or 1+1 ml per inch of trunk dbh, May, 1961. Observations were made in June and September of the same year.

	Number of Trees Showing Damage at Indicated Dosage							
	1 Ml		1.5 Ml		2 Ml		1 + 1 Ml	
Damage*	June	Sept.	June	Sept.	June	Sept.	June	Sept.
None	11	37	5	28	5	23	1	15
Slight	16	30	7	30	3	26	7	32
Moderate	23	9	16	11	15	12	13	13
Severe	44	11	61	11	62	10	68	15
Complete (tree killed)	6	13	11	20	15	29	11	25

*Damage classifications the same as under table 3.

was by the injection method on May 5, when the buds of the trees were swollen. A fourth randomized lot was treated with a split dosage--1 ml per inch of tree dbh on May 5 followed in 2 weeks with 1 ml per inch. A fifth randomized lot of 100 trees was left untreated as a control.

No Dutch elm disease was evident in either the treated or control lots in 1961. However, considerable chemical injury was noted in the treated trees. A summary of the observations, table 4, shows that there was injury at all dosage levels. By mid-September the trees killed ranged from 13 per 100 at a dosage of 1 ml to 29 per 100 at a dosage of 2 ml per inch of tree dbh. The observations indicate the ability of many trees to overcome the toxicity of the chemical when the damage is slight or even severe. Trees of 3 inches dbh or smaller appeared to be more easily killed by the chemical than larger trees. The larger trees recovered more readily from nonfatal injury than the small ones. Chemical injury in the Forest Preserve District of Cook County was much more severe than at Sinnissippi Forest or in the Wisconsin areas included in some tests by Norris (1960:1035), who reported only 0 to 5 per cent injury following a dosage, applied in May, of 6 grams per 3-inch tree (equivalent to 5 ml per 3-inch tree or 1 2/3 ml per inch of tree dbh).

TESTS AGAINST OTHER PESTS WITH SD-3562 APPLIED TO TREES BY SEVERAL METHODS

Sixteen honey locust trees were divided into four groups of four trees each, the groups were designated A, B, C, and D, and the trees were designated as in table 5. One tree in each group was set aside as a control. On June 14, 1961, three trees in each group were treated with improved technical SD-3562 at dosages of 1, 2, or 3 ml per inch of trunk dbh by one of the four methods described below; methods A, B, C, and D were used on groups A, B, C, and D, respectively.

A. The chemical was injected into four holes, each five-sixteenths inch in diameter, drilled in the trunk of a tree, fig. 3. The holes were then plugged with dowels.

B. The chemical was applied with a syringe to the surface of the bark entirely around the trunk about 3 feet above the ground and allowed to run down, fig. 1. This method of application was similar to methods employed by Jeppson *et al.* (1952:669).

C. The chemical was applied to the bark as in method B. It was then loosely covered with thin plastic to reduce weathering.

D. The chemical was applied as in method B to bark that had been striated with a razor blade at intervals of about one-fourth inch to a depth of one-eighth inch.

Some yellowing and dropping of leaflets was noted on trees treated with dosages of 2 and 3 ml by method A and with a dosage of 3 ml by method D. The damage was not severe. No damage was noted in 1961 on trees treated by methods B or C.

Bagworm on Honey Locust. – In the second week after treatments by methods A, B, C, and D described above, about 25 larvae of the bagworm, *Thyridopteryx ephemeraeformis* (Haworth), were confined in sleeve cages, fig. 4, one cage on each of the four trees that had previously been treated with a dosage of 3 ml of SD-3562, and one cage on the control tree in group A, table 5. Extent of the kill showed that the chemical had been translocated to the foliage in all but one of the trees in sufficient quantity to be highly toxic to the bagworms.

Each week, from the third week through the ninth week after application of the chemical, a cage with about 25 bagworm larvae was placed over a branch of each of the 16 trees. After a period of 1 week, each caged branch was clipped from the tree, and branch and cage were taken to the laboratory for examination. A new group of bagworms was caged on another branch of each tree for the following week.

The chemical applied by each of the four methods of treatment and at each of the three dosages was highly toxic to the bagworms, table 5. The most consistent and persistent effect was obtained by method A, that is, with the chemical injected into holes in the trees. Here, with one exception, a complete kill of bagworms was obtained at each of the three dosages through the ninth week after treatment. Method D, with the chemical placed on striated bark, gave the next best results. This method gave high, although not always complete, kills through the ninth week. When

Table 5. — Per cent of caged bagworms found dead in each of several weeks on each of 16 honey locust trees. Twelve trees were treated with improved SD-3562 on June 14, 1961. Each lot of caged bagworms was left on a tree for 7 days. The methods of application are indicated by letters in the tree numbers and are discussed in the text.

Tree No.	Dosage Rate, Ml Per Inch of Tree DBH	Per Cent of Bagworms Dead in Indicated Week After Tree Treatment							
		2nd	3rd	4th	5th	6th	7th	8th	9th
A-1	0	40.7	16.0	8.0	0.0	28.1	14.3	30.0	21.9
A-2	1	...	100.0	100.0	100.0	100.0	100.0	100.0	100.0
A-3	2	...	100.0	100.0	100.0	91.6	100.0	100.0	100.0
A-4	3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
B-1	0	...	21.0	15.4	3.3	22.2	21.1	39.3	37.8
B-2	1	...	100.0	96.0	100.0	87.8	100.0	100.0	72.4
B-3	2	...	100.0	100.0	97.0	100.0	91.4	90.0	84.0
B-4	3	30.4	100.0	100.0	100.0	100.0	97.0	97.4	93.8
C-1	0	...	15.0	9.1	0.0	16.7	22.2	3.6	42.4
C-2	1	...	100.0	100.0	70.3	90.6	81.2	96.9	73.4
C-3	2	...	100.0	89.0	64.5	93.0	90.2	94.7	67.8
C-4	3	91.8	100.0	100.0	100.0	100.0	100.0	97.0	89.2
D-1	0	...	0.0	8.0	6.2	23.7	25.0	73.5	62.1
D-2	1	...	100.0	100.0	100.0	100.0	100.0	97.1	97.0
D-3	2	...	100.0	100.0	100.0	100.0	97.5	90.9	87.0
D-4	3	100.0	100.0	100.0	100.0	100.0	100.0	94.1	100.0
Approximate length of bagworms, inches		1/4	1/2	3/8-1/2	1/2	1/2-3/4	3/4	3/4-1	...*

*No record.

Table 6. — Per cent of mimosa webworms found dead in cages on each of 16 honey locust trees at various times. On 12 of these trees, improved SD-3562 had been applied on June 14, 1961 (same trees as in table 5). Each lot of caged mimosa webworms was left on a tree for 7 days during the sixth and tenth weeks after treatment and for 14 days during the eleventh and twelfth weeks and the thirteenth and fourteenth weeks. The methods of application are indicated by letters in the tree numbers and are discussed in the text.

Tree No.	Dosage Rate, Ml Per Inch of Tree DBH	Per Cent of Webworms Dead in Indicated Week or Weeks After Tree Treatment			
		6th	10th	11th-12th	13th-14th
A-1	0	0	0	1.8	0
A-2	1	100.0	66.6	100.0	100.0
A-3	2	100.0	29.4	100.0	100.0
A-4	3	100.0	100.0	100.0	100.0
B-1	0	0	...*	0	3.3
B-2	1	100.0	100.0	100.0	100.0
B-3	2	100.0	100.0	100.0	100.0
B-4	3	100.0	100.0	100.0	100.0
C-1	0	0	0	0	0
C-2	1	100.0	100.0	100.0	100.0
C-3	2	100.0	...*	88.8	100.0
C-4	3	100.0	66.6	100.0	100.0
D-1	0	0	0	3.3	Discontinued on account of leaf sampling
D-2	1	100.0	0	100.0	
D-3	2	100.0	...*	100.0	
D-4	3	...*	100.0	50.0?	

*Observations incomplete.

the chemical was placed on the bark of a tree (method B), high kills were maintained through the eighth week. The bark application covered with plastic (method C) was no more effective than the uncovered application (method B), table 5.

Bagworms introduced into the cages in any week after the first were larger than those used the previous week. Exposing the bagworms to the chemical for more than 1 week probably would have resulted in higher kills than those shown in the table.

Mimosa Webworm on Honey Locust. – At irregular intervals after application of SD-3562 to honey locust trees in groups A, B, C, and D, table 6, nests containing larvae of the mimosa webworm, *Homadaula albizziae* Clarke, were confined in cages on the trees. In the first two tests, in the sixth and tenth weeks after the trees were treated, each caged branch was clipped from the tree at the end of 7 days, and branch and bag were taken to the laboratory for examination. Although the number of larvae recovered in cages on treated trees was low (small dead larvae are very difficult to find in leaf debris), the results showed rather conclusively that SD-3562 applied by each of the four methods was highly effective during the sixth week after treatment, table 6. A drop in kill during the tenth week was noted on some of the trees; subsequently the cages were left on the trees for 2-week periods. The longer exposure resulted in complete kills of larvae on most trees through the period of the experiment, table 6. On trees treated by method B, bark application, complete kills were recorded for all periods of observation.

Mite on Honey Locust. – On August 4, 8 weeks after the application of SD-3562 to honey locust trees in the experiment for control of bagworms, table 5, honey locust leaves infested with the honey locust mite, *Eotetranychus multidigituli* (Ewing), were taped to leaves on the trees in group A. Counts made 2 weeks later indicated a complete kill of mites on all the treated trees in this group.

Fall Webworm and Walnut Caterpillar on Honey Locust. – Larvae of the fall webworm, *Hyphantria cunea* (Drury), and the walnut caterpillar, *Datana integerrima* Grote & Robinson, were caged on honey locust trees in group A during the tenth week after the application of SD-3562. The chemical was highly effective against the larvae of the fall webworm. Results of the test involving the walnut caterpillar were inconclusive.

ADDITIONAL TESTS FOR CONTROL OF MIMOSA WEBWORM

SD-3562 was applied on July 25, 1961, to the uninjured bark of a honey locust tree, 30 feet tall and 6 inches dbh, at the rate of 2 ml per inch of trunk dbh, fig. 1. After treatment, the treated area was covered with a hardware cloth cylinder and heavy kraft paper as a safety measure and to reduce weathering, figs. 5 and 6. The application of SD-3562 was effective within a week after treatment and provided excellent protection for about 5 weeks. The tree was treated again on September 6, when some of its new growth was found to be infested. This tree was virtually free of any sign of webworm damage at the end of the growing season.

Fig. 5 (left). – Hardware cloth around the trunk of a honey locust tree treated with SD-3562. This is a safety measure used on trees in residential areas to keep human beings and pets from coming in contact with the chemical. The hardware cloth was removed 2 weeks after the tree had been treated.

Fig. 6 (right). – The tree shown in fig. 5. Paper covering has been added over the hardware cloth to give further protection to human beings and pets and to reduce weathering of the chemical. The paper was removed 1 week after the tree had been treated.

Webworm infestations on three other honey locust trees were quickly brought under control with applications of technical SD-3562 to uninjured bark at the rate of 3 ml per inch of trunk dbh.

Results of the tests with these four trees were evaluated at weekly intervals by examining the larvae in nests clipped from the treated trees and from nearby untreated trees. No sign of phytotoxicity was observed during 1961 in any of the treated trees.

TESTS WITH FALL WEBWORM ON OAKS

Five small oak trees, red, pin, and bur, 1 to 2½ inches dbh, were treated on July 31, 1961, with improved technical SD-3562 injected into the soil, fig. 2, at dosages ranging from 5 to 40 ml per inch of trunk dbh. Each dosage was diluted with 8 gallons of water. One tree was left untreated as a control. At weekly intervals, beginning 2 weeks after treatment and ending with the fifth week, larvae of the fall webworm were confined in cages, one cage on a limb of each of the six trees. Larvae were exposed for 1 week. The results were inconclusive.

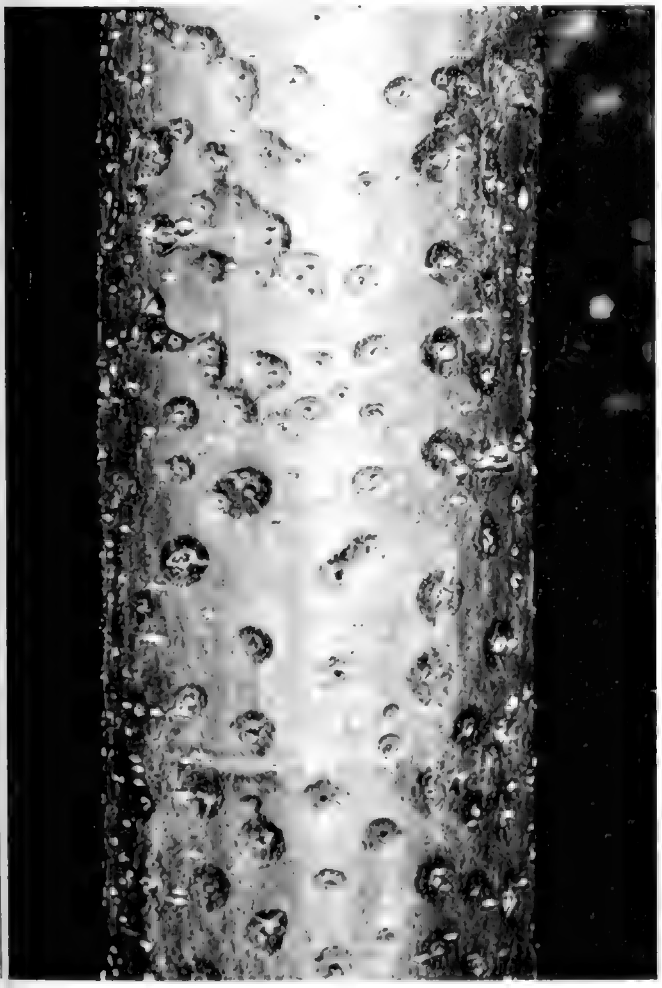

Fig. 7. — Trunk of a pin oak tree 17 days after the bark had been stippled with an ice pick and SD-3562 had been applied to the surface. Circular areas are depressed as a result of tissue damage caused by the chemical.

Applications of technical SD-3562 to the uninjured bark of red oak trees, 1½ to 3 inches dbh, at dosages of 1 to 4 ml per inch of trunk dbh also gave inconclusive results.

In a series of tests on pin oaks, 2 to 3 inches dbh, a dosage of 3 ml per inch of trunk dbh was applied on August 29 by three methods: on uninjured bark, on bark stippled with an ice pick, and into holes drilled in the trunk, one tree for each method and one as a control. One lot of fall webworms was caged on each tree 2 weeks after treatment and another 3 weeks after treatment. Application of SD-3562 to uninjured bark was not appreciably effective against the fall webworm larvae. The chemical apparently did not penetrate uninjured oak bark as readily as uninjured honey locust bark. However, applications of the chemical by the two other methods were highly effective against the larvae. SD-3562 when applied to stippled bark appeared to be taken up by the tree as quickly as when applied in drilled holes. Chemical injury to bark but not to foliage was observed on the treated oak that had been stippled with an ice pick, fig. 7, as well as on the tree drilled with holes. No chemical injury to either bark or foliage was seen in 1961 or 1962 on the tree treated on uninjured bark.

TESTS WITH SD-3562 INJECTED INTO SOIL

In 1961, diluted SD-3562 injected into soil was tested against certain pests of arborvitae, Canaert red cedar or juniper, and honey locust.

Bagworm on Arborvitae. — Six arborvitae plants about 4 feet high were treated July 11, 1961, with improved technical SD-3562 at dosages of 0, 5, 10, 20, 40, and 80 ml per plant, respectively. Each dosage, diluted with water to make 1 gallon, was injected with a pump and wand, fig. 2, into the soil in eight places around the plant and at a distance of about 10 inches from the stem. The wand was slanted under the plant at an angle of about 45 degrees; the holes made were 6 to 10 inches deep. At the time of treatment, the soil was wet. At about weekly intervals, 30 to 50 bagworms were placed on each plant by hand and left there for 7 or 8 days before being removed and examined.

Effectiveness of the chemical was evident within 7 days after treatment at all dosage levels; within this period, complete kills were obtained at dosages of 40 and 80 ml per plant, table 7. Complete kills were obtained 15 days after treatment with dosages of 10, 20, 40, and 80 ml; the kill was only partial with the 5-ml dosage. Forty-three days after treatment, the 80-ml dosage gave a 100 per cent kill of bagworms with bags up to 1 inch long. The treatments resulted in no apparent phytotoxic injury to arborvitae.

Midge on Canaert Red Cedar. — Canaert red cedar plants in a local nursery provided an opportunity for tests against a midge, *Oligotrophus* sp., whose larvae damage the tips of the plants. The red cedars, about 3½ feet high, were heavily infested with the pest. One plant was used for each of the following dosages of improved technical SD-3562: 2½, 5, 10, and 20 ml, each diluted with water to make 1 gallon. On July 11, 1961, the diluted chemical was injected into the soil in the same manner as in the experiment described for control of bagworm on arborvitae. One untreated plant was used as a control.

Within 15 days after treatment, very substantial kills of larvae and pupae were obtained, even at the lowest dosage of 2½ ml per plant. Twenty-two days after treatment, the kill was 100 per cent at dosages of 5, 10, and 20 ml per plant. All dosages provided practical control for the season, table 8. The chemical produced no apparent injury to the red cedars.

Mimosa Webworm on Honey Locust. – On July 24, 1961, a honey locust tree with a trunk 4 inches dbh was treated with 80 ml of technical SD-3562 in 8 gallons of water. One quart of the dilute chemical was injected into the soil in each of 32 places in a regular pattern around the tree beginning 1 foot from the trunk and extending approximately to the periphery of the branch spread. This treatment failed to control the larvae of the mimosa webworm.

Three additional trees ranging in size from 3½ to 4½ inches dbh were treated on July 26, at rates of 5, 10, and 20 ml per inch with technical SD-3562 in the same manner as above. When control of the mimosa webworm was not evident within 3 weeks, the treatment was repeated, but with each dosage in 4 gallons of water injected into eight places in the soil 1 foot from the trunk of the tree. These two soil treatments on each of the three trees failed to control larvae of the mimosa webworm.

DAMAGE TO BARK AND TISSUE

The application of technical SD-3562 to small honey locust trees by injection killed a considerable area of the bark and tissue around each injection hole, fig. 8. Serious injury was caused when the chemical was applied over striated bark, fig. 9. The bark of a pin oak stippled with an ice pick before being treated with SD-3562 was noticeably injured within 17 days after treatment, and by May, 1962, the injured areas had greatly enlarged.

On honey locust trees, the uninjured trunk areas treated with SD-3562 in 1961 became delineated with a slightly darker color of the bark, but no evidence of actual bark injury was observed until the following spring. When examined in May, 1962, some trees showed no signs of bark injury. Others showed various degrees of injury in the form of cracks or checks in in the bark, fig. 10. Injury appeared to be confined to the outer phloem (bark). Additional research will be

Table 7. – Per cent of bagworms found dead on each of several days on each of six arborvitae shrubs, about 4 feet high, five of which had been given soil treatments with improved SD-3562, July 11, 1961. Each lot of bagworms was placed on a shrub, left there for 7 or 8 days, and removed, examined, and counted on the day indicated.

Dosage Rate, Ml Per Plant	Per Cent of Bagworms Dead on Indicated Day After Plant Treatment					
	7th	15th	22nd	29th	36th	43rd
0	8.8	0	19.2	3.2	24.1	8.7
5	41.0	47.6	59.4	20.0	22.2	15.0
10	87.0	100.0	100.0	96.5	91.5	50.0
20	91.5	100.0	100.0	100.0	92.9	77.7
40	100.0	100.0	100.0	100.0	91.3	95.1
80	100.0	100.0	100.0	100.0	100.0	100.0
Approximate length of bagworms, inches	3/8	1/2	1/2-3/4	5/8-3/4	3/4	3/4-1

Table 8. – Per cent of midge population (*Oligotrophus* sp.) found dead on each of several days on each of five Canaert red cedar plants, four of which had been given soil treatments with improved SD-3562, July 11, 1961. The per cent of the midge population dead was determined by counts made on 100 red cedar buds each day indicated.

Dosage Rate, Ml Per Plant	Per Cent of Midge Population Dead on Indicated Day After Plant Treatment							
	7th	15th	22nd	27th	36th	40th	54th	70th
0	20.8	8.1	23.5	0	2.3	4.0	0	0
2½	18.3	80.0	82.7	91.5	100.0	...	...	...
5	23.1	95.6	100.0	100.0	...	...	...	...
10	20.7	100.0	100.0	100.0	...	...	...	...
20	26.7	96.3	100.0	100.0	...	...	...	...

Fig. 8. — Scar in the trunk of a honey locust tree 3 months after treatment with SD-3562. A hole had been drilled, SD-3562 injected, and the hole plugged with a dowel.

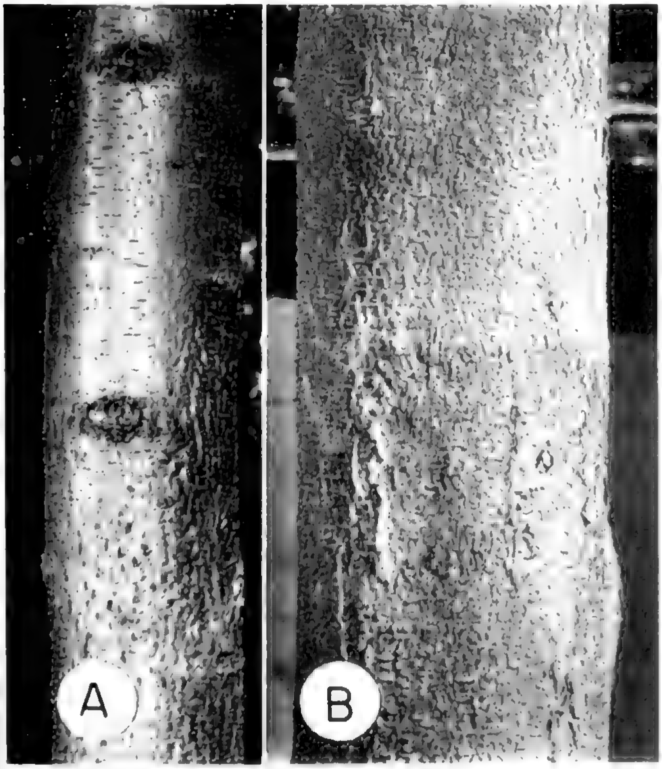

Fig. 10. — Bark of honey locust trees in May, 1962, approximately a year after being treated with technical SD-3562. *A.* Small tree in nursery: bark in upper part of picture was not treated; bark in lower part shows chemical injury. *B.* Tree of medium size along street: treated bark in lower part of picture shows injury; untreated bark above does not.

Fig. 9. — Trunk of a honey locust tree 3 months after the bark had been striated with a razor blade and SD-3562 had been applied to the wounded surface.

required to establish the significance of this injury and to develop methods for avoiding it.

When observed in May, 1962, none of the honey locust or oak trees treated with SD-3562 in 1961 showed foliar damage.

DISCUSSION

Systemic insecticides, such as SD-3562, open up interesting possibilities for the control of tree and shrub pests for which there is now no practical control. In addition, they offer possibilities for the development of improved and more effective means of controlling pests for which controls are now known.

SD-3562 is toxic to the smaller European elm bark beetle, a vector of Dutch elm disease, and may have possibilities for reducing the incidence of this disease. It is effective against the mimosa webworm on honey locust trees when a small quantity of the chemical is applied to the uninjured bark of the tree at the proper time. It shows possibilities for providing a control measure for the midge *Oligotrophus* sp., a troublesome pest of ornamental junipers or red cedars, for which there has been no satisfactory control. Experiments indicate that SD-3562 is toxic to the bagworm and mimosa webworm at lower dosages and over a much longer period of time than it is to the European elm bark beetle.

One of the problems in the use of a systemic insecticide is the selection of the proper method of application. There are three general methods: the chemical can be sprayed on the leaves of the plant, it can be placed in the soil, or it can be placed in or on the trunk of the plant. The first method, foliar spraying, seems to offer the least advantage over methods that use nonsystemic insecticides. Soil applications offer practical possibilities but, with such variables as soil type and moisture, effective dosage levels are difficult to establish. Then, too, a great deal of the chemical is wasted in soil applications. At this time, the introduction of the chemical through the trunk into the sap stream of a tree commands a great deal of interest because of the possibility of obtaining quick, positive results with a small quantity of chemical.

Methods of treating trees with SD-3562 by means of holes drilled into the trunk, or by other means that make wounds in the trees, appear to be fundamentally unsound. Small, thin-barked trees, such as honey locust, react rather violently to wounds, especially when the wounds are laved with the chemical, figs. 8 and 9. Accidental wounds or wounds made in the bark by insects may be the foci of chemical injury. Such injury is unacceptable if yearly treatments are necessary, as, no doubt, they would be for control of most tree pests.

Although the method involving chemical application to uninjured bark may not be effective on all kinds of trees, such applications seem to be on a sounder footing than methods requiring damage to the bark.

Coupled with its advantages, SD-3562 has some drawbacks. Since the chemical is very poisonous and since it is phytotoxic at some dosage levels, details of handling, usage, and application, as well as dosage levels for both pests and plants, must be worked out. On the basis of our work, it appears that further research is needed before we can recommend SD-3562 for use by the public.

ABSTRACT

Tests with technical grade SD-3562 injected into elm trees in a nursery showed that this systemic chemical, although effective at some dosages against the smaller European elm bark beetle, the principal vector of Dutch elm disease, presented the problem of little margin between effective dosage to control beetle penetrations and chemical injury to the trees.

Field tests with SD-3562 injected into elms to control Dutch elm disease, although encouraging, were inconclusive and should be continued. Small elm trees seemed more vulnerable to injury by the chemical than large ones.

Experiments with honey locust trees showed that, after application of the chemical to the uninjured bark, the trees were toxic to the bagworm, the mimosa webworm, the honey locust mite, and the fall webworm.

SD-3562 was effective against the fall webworm on oaks only when applied to injured bark or through holes in the trunk; injury to the bark resulted. The chemical apparently did not penetrate uninjured oak bark as readily as uninjured honey locust bark.

Diluted SD-3562 injected into soil around arborvitae and Canaert red cedars provided excellent control of bagworms and midges, respectively. Injected into the soil around honey locusts, it failed to control mimosa webworms on the trees.

The basic problems in using a systemic insecticide were found to be (a) development of methods of application and dosages that will not injure plants but will provide control of pests and (b) development of safe methods for handling a highly poisonous chemical.

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