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Collection

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Contents

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Highlights Of The Study

Damage to pines in Oklahoma by the Nantucket pine tip moth is present each year but varies greatly by years, location and site, age of trees, and pine species. Damage results from the larvae feeding on and tunneling in buds and shoots, causing discoloration and dying back of these parts and malformation of the tree. Height growth may be retarded.

In this study heavy infestation and damage were more common to trees 2-12 feet in height, particularly if they were in plantations removed from pine forests. The shortleaf pine, the common species in the state, received the heaviest damage of six species observed in the study. Young loblolly pines were also heavily damaged but in a 27-year-old planting they suffered much less than shortleaf pines. Ponderosa pines in this older group were almost free of damage. In a 3-year-old plantation, slash and cluster pines had much lower infestations than shortleaf and loblolly.

Four generations of the pine tip moth occurred in 1964 and 1965 and the beginning dates of moth emergence and oviposition were: overwintering populations, late March; first generation, late May; second, early July; and third, last half of August.

A single application of certain systemic insecticides appears to be comparable in current season effectiveness and cost to three or four foliar spray applications of a contact residual insecticide, such as DDT, which must be applied during the hatching period of each generation of the pest. Critical timing of the systemic treatment was not required and, generally, tip moth infestations were measurably reduced for one or more years after treatment. This method is feasible for ornamental plantings, post-transplant nursery stock, and perhaps for excessively heavy infestations on young trees in moderate sized plantations.

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Good to excellent control during the first season after application was obtained with phorate (Thimet) and disulfoton (Di-Syston), and similar results were obtained in more limited tests with Baygon, Thiocron, Furaday, and Dasanit. An effective rate per tree for phorate or disulfoton is 0.3 oz. of actual toxicant or 3.0 oz. of a 10 percent formulation for each inch of trunk diameter.

Band and broadcast soil treatments applied within the dripline were equally effective. Both granular formulations and drenches, made from liquid concentrates, were effective, but the latter treatments usually gave quicker and shorter controls. Granules were safer and easier to handle and gave extended control. Applying chemicals to the soil surface or mixing them into the soil gave approximately equal results. It was found desirable to thoroughly wet down soil applications, particularly those on the surface.

October and November appeared to be the best time to make granular applications for control during the succeeding growing season. Soil treatments made during the growing season usually became effective within 25 to 60 days after application. It is probable that fall or winter application of soil drenches would also be desirable.

Foliar sprays of systemics at moderate volumes, when applied early in the generation, gave quick and good control of the current generation but had little effect on later generations. Sprays applied in greater volume, to produce marked run-off and moderate drenching of the soil, gave relatively quick and also extended control.

Increased height growth over untreated averaged 16.5 inches per tree per year. The maximum increase in height over untreated trees was a treatment mean of 54 inches during a 3-year period after application of 10 percent granules.

Applications at intervals of one to two years would be satisfactory for use on ornamental plantings and may be feasible in larger plantations where tip moth seriously limits growth. The greatest benefits can be obtained in pines under 10-12 feet in height and by beginning control on transplants during the third season. This method, however, appears to be too expensive to be used in commercial forests.

Introduction

The Nantucket Pine Tip Moth, (Lepidoptera, Olethreutidae) *Rhyacionia frustrana* (Comstock), is present each year in Oklahoma; but population and damage levels vary greatly by year and location. Generally, the highest infestations occur in young trees and in plantations well removed from pine forests. The shortleaf pine (*Pinus echinata*), the common species in Oklahoma, is highly susceptible to attack by this pest.

Damage is caused by the tip moth larvae feeding on and tunneling in the buds and shoots of the pine (Fig. 1). Initial feeding by the young larvae causes oleoresins to seep through the wounds and form small dried deposits on the base of needles and on the surface of buds and shoots. These dried, light-colored deposits may be detected if new growth is examined carefully. Continued larval feeding and tunneling cause the shoots to discolor and "die back" from the tips for distances up to several inches, depending on the number of larvae per shoot and the pine species involved. Such damaged shoots are conspicuous.

Damage by the tip moth to susceptible pines consists of unsightly discoloration and disfiguration of the plant and height growth retardation caused by "die back" of the terminals.

Life History: Yates (1960) described the life history of the pine tip moth. The elliptical eggs are laid singly in the axils of leaves, either on the needle or the stem. The eggs are opaque or light in color when laid but become pinkish or yellow after a few days of development and then turn gray prior to hatching. The time required for incubation varies from one to four weeks depending on weather conditions. The first instar larvae are pinkish-red to cream colored with dark heads and thoracic shields. The newly hatched larvae chew their way through the chorion and begin searching for food. Generally, the first instar larvae burrow into the needle sheath and feed on the needles and may then burrow into the stem or migrate to a new location. A protective covering of oleoresin and webbing is constructed about the individual larvae while they feed on the surface of the stem or around the base of needles.

The mature larvae, about 1/3 inch long and light brown to orange in color, are generally found boring through the heart of the tip or stem where pupation occurs. The pupae are light brown at formation but become darker as they mature. They are approximately 1/4 inch in length and prior to emergence work themselves part-way out of the stem where the adults can emerge uninjured. The moths are quite inconspicuous when at rest on foliage because of their small size. The wing span is 3/8 to 5/8 inch and the body length about 1/2 inch. The wings appear to be a drab color at first glance but they are actually quite colorful when examined closely. The body color is gray with brick-red patches.
that spray applications of DDT gave excellent control at 0.48 percent concentration. They indicated that timing was important and that two

Control: The use of DDT was the first significant program in chemical control of the pine tip moth. Fenton and Afanasiev (1946) reported to four treatments per season were necessary to give protection, depending on the area and the number of insect generations. When various other organic insecticides and chlorinated hydrocarbons were tested,

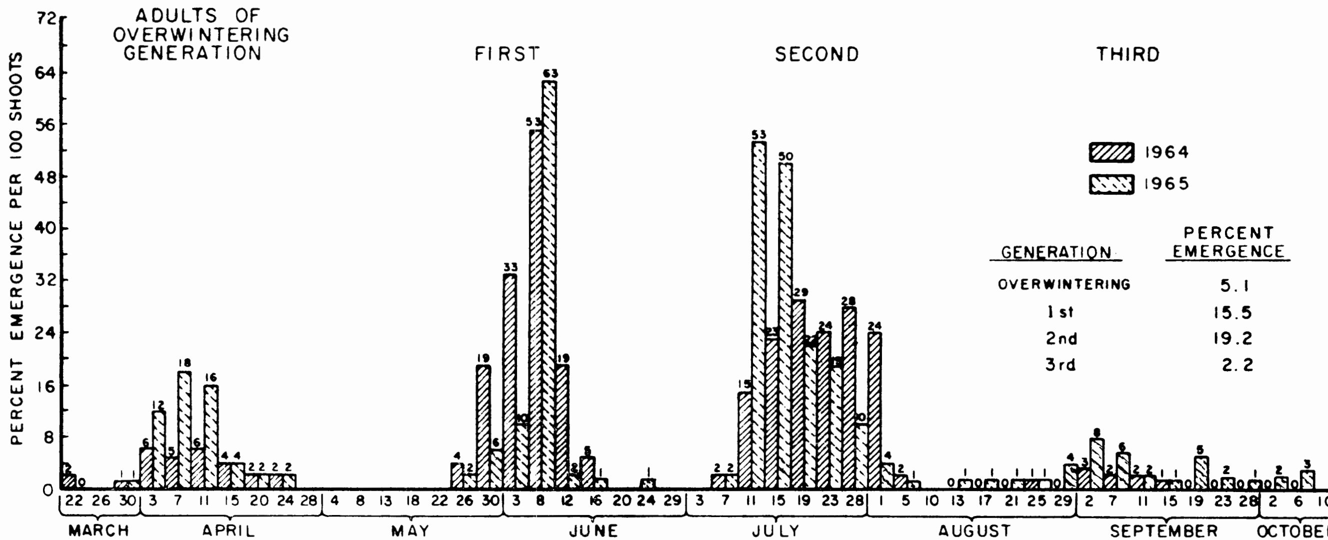

Figure 1. Adult emergency of the Nantucket pine tip moth, **Rhyacionia frustrana** (Comstock), Stillwater, Oklahoma.

similar effects as described for DDT resulted. Bennett (1955) reported that control of the insect by the above method was impractical, under forest conditions, but that it might be practical in plantations where the value of clean, damage-free trees would justify the cost.

Treece and Matthysee (1959) have shown that it is possible to control the pine tip moth with systemic insecticides. They applied 5 and 10 pounds per acre of actual phorate and disulfoton in July to Japanese black pines, *P. thumbergii* Parl. The results were erratic for disulfoton, but phorate gave 88 percent reduction in damaged shoots per plant. Butcher and Haynes (1960) effectively applied dimethoate as a foliar spray to pines for control of the European pine shoot moth, *R. buloiana* (Schiff). Schuder (1960) reduced the number of infested pines from 18 to 5 for the systemic insecticide phorate and to 1 and 0 for phosphamidon and dimethoate, respectively. The applications were made at one pound per 100 gallons of water. Kulman and Dorsey (1962) were able to produce effective control with granular formations of disulfoton and phorate. Beal (1967) has shown that shortleaf and loblolly pines protected from the pine tip moth significantly out grew infested pines during the first six years after planting. Warren (1968) reported that pines treated for three successive years with disulfoton granules averaged up to 5.6 feet greater height than untreated trees. Barras, *et al.* (1967) reported, on work conducted in Louisiana, that loblolly pines were protected from the pine tip moth during the 1960 and early 1961 growing season by granular formulations of phorate and disulfoton. They also obtained appreciable reduction of infestation with a foliar spray of dimethoate. Trunk applications showed that Bidrin was readily absorbed through the bark and translocated by 2-year-old plants.

The study reported in this bulletin was condutced at Stillwater, Oklahoma, during the period August, 1962, to November, 1965. The principal area of investigation was the control of the pine tip moth by various plant systemic insecticides, applied by various methods and schedules. Supplementary information was obtained on the seasonal development of the insect and the effects of pine species and age of trees on infestations and damage.

General Methods, Materials and Conditions

These studies were conducted, in pine plantations on Oklahoma State University property, nine miles west of Stillwater, Oklahoma, and from one-fourth to one mile south of the main body of water of Lake Carl Blackwell during the 1962-1965 period. The terrain was generally classified as rolling tall grass prairie (dominantly *Andropogon* sp. and *Sorghastrum* sp.). Wooded areas sectioned the terrain and were dominantly *Quercus stellata and Q. merilandica*. Annual precipitation one mile northeast of the test area was well below normal with departures of 6.6, 5.5, and 7.8 inches in 1963, 1964, and 1965, respectively (Table 1). The mean air temperatures at Stillwater (U.S. Department of Commerce 1963-1965) were 61.2, 61.1, and 61.1 F, respectively, and were slightly above normal.

Test Areas. The test areas for this study consisted of four different aged blocks of pines, ranging from 1-year-old transplants to 27-year-old trees.

The major test areas was a 5-acre block contaning trees that were reportedly 3 years old in 1962 when the initial systemic insecticide applications were made. Loblolly pines (*P. taeda*) were planted in one-half of the block and the remaining one-half planted in shortleaf pines. The trees were spaced at 8 x 6 ft. intervals on grassland (Norge loam) having a 1-3 percent slope.

The second test area was a mixed planting of 7-year-old shortleaf and loblolly pines. Studies in this area were initiated in 1963. Trees were spaced at 9 x 6 ft intervals on grassland (Norge loam) with a surface slope of 3-5 percent.

A mixed planting of older pines was used as the third test area. The initial treatments were made in 1963 at which time the pines were estimated to be approximately 25 years old. Tree heights ranged from: 30-34 feet for loblolly; 14-18 feet for shortleaf; and 10-15 feet for ponderosa, *P. ponderosa*. The soil was Zaneis loam and the slope 3-5 percent.

Table 1: Precipitation[1] records and mean air temperatures[2], 1963-1965, Lake Carl Blackwell and Stillwater, Oklahoma, respectively.

	1963			1964			1965		
	Precip.	Temp.F		Precip.	Temp. F		Precip.	Temp. F	
Months	(inches)	Max	Min	(inches)	Max	Min	(inches)	Max	Min
January	0.39	45	16	0.58	57	26	0.91	54	27
February	0.04	58	25	1.84	52	27	0.79	55	26
March	3.19	69	39	1.12	64	32	0.74	54	27
April	3.30	77	54	2.43	77	52	1.53	80	53
May	2.76	81	59	4.30	82	61	4.63	82	59
June	2.04	90	76	0.95	89	66	4.07	88	65
July	3.90	96	71	0.24	99	71	1.11	96	70
August	2.73	95	69	8.60	94	69	3.59	95	67
September	4.14	88	62	2.32	84	62	4.97	87	61
October	1.96	86	53	0.55	76	45	0.34	76	46
November	1.94	65	37	3.74	63	43	0.02	68	42
December	0.29	46	20	0.87	51	27	2.59	59	35
Departure	—6.64	0.4		—5.53	0.3		—7.81	0.3	

[1] Precipitation data from the U.S. Department of Agriculture of the Stillwater Outdoor Hydraulic Laboratory, Agricultural Research Service, located 8.5 miles west of Stillwater, Oklahoma.

[2] Temperature records from the U.S. Department of Commerce. Climatological Data; Oklahoma. Vol. 72-74.

The fourth test area was developed in 1964 in an area approximately 0.5 mile north of the major test area. Four species of pines were transplanted on heavily terraced grassland (Norge loam) with a 3-5 percent slope. The area was covered with grass 12-15 inches tall, but one week prior to the planting date approximately one-half of the assigned area was accidently burned off.

Chemicals and Materials Tested. A tabulation of materials and methods tested are presented in Table 2.

Seasonal Development. Moth emergence records and larval-pupal counts from dissections were taken during 1964 and 1965 to study the seasonal development of the Nantucket pine tip moth. The emergence chamber used for the 1964 study was a sheet metal Berlese funnel (4 x 2 ft diameter), with heat source omitted, resting on its side, with a heavy black cloth sleeve closing the large open end and a pint jar screwed into place at the smaller end. One hundred randomly selected infested shoots were cut each week, throughout the activity season, and placed within the emergence chamber. The shoots were placed upright in open ½ pint paper cartons which were partially filled with moist sand. Shoots were held in the funnel for a 5-week period. Moths that emerged from the shoots were attracted to the light and flew into the jar where they were collected every four days. During the emergence the chamber was located on a stand, 3 ft from the ground and under a shed 8 ft in height and open on all sides.

The emergence apparatus used in 1965 permitted the determination of individual shoot records. Each shoot was placed in a standng 150 x 25 mm test tube with the tip pointing toward the mouth. Each test tube was stoppered by a cotton plug and located on a table beneath the previously described shed. Fifty infested shoots were cut weekly and placed in test tubes for periods of 4 weeks.

Results

Seasonal Development

Four generations (overwintering, first, second, and third) were present in Oklahoma during both 1964 and 1965 (Fig. 2). Moth emergence period for the overwintering generation was March 22 to April 24 in 1964 and from March 30 to April 30 in 1965. Peak emergence reached plateaus about April 11, 1964, and on April 7, 1965. Moths of the first generation in 1964 and 1965 began emergence around May 26 and both years reached their peak on June 8. The second generation in both years began emergence around July 7 and continued until August 5. The 1965 third generation began August 13, which was 16 or 17 days earlier

Table 2. A summary of materials used in control tests of the Nantucket pine tip moth 1962-1965.

Formulation		Methods	Years Observed	Comparative Effectiveness
Azodrin[7] (SD9129)	3E	Spray	2	Fair[4]
Dasanit[7] (Bay 25141)	6E	Spray	1	Excellent
″	10G	Broadcast	3	Good
″	5G	Broadcast	1	Good
Baygon[7]	2E	Spray	1	Good
″	5G	Broadcast	1	Good[4]
Bidrin[7]	2E	Spray	2	No Control
″	6E	Injection	2	No Control
Disulfoton	6E	Spray	2	Poor
″	6E	Spray	3	Good
″	6E	Soil Drench	2	Excellent
″	6E	Injection	2	No Control
″	6E	Bored Hole	2	No Control
″	6E	Paint-on	2	No Control
″	6E	Broadcast	4	Excellent
Dimethoate	4E	Spray	2	No Control
″	4E	Spray	3	Fair[4]
″	4E	Soil Drench	4	Good[4]
E I 47031[1]	3E	Spray	2	No Control
″	3E	Spray	3	Poor
″	10G	Broadcast	1	Poor
G C 6506[2]	4E	Spray	1	No Control
G C 9879	4E	Spray	2	Poor
G S 13005[3]	4E	Spray	2	Poor
Methyl demeton	2E	Spray	2	No Control
″	2E	Spray	3	No Control
″	2E	Broadcast	4	No Control
Furadan[7]				
(Nia. 10242)	80WP	Spray	1	Excellent
″	80WP	Broadcast	1	Good
Phorate	10G	Broadcast	4	Excellent
Phosphamidon	4E	Spray	2	No Control
″	4E	Spray	3	No Control
″	4E	Soil Drench	3	Poor
″	8E	Spray	1	Poor
S D 4072[5]	2E	Spray	2	Poor
″	2E	Spray	3	Poor
Temik[7]	10G	Broadcast	3	Fair
Thiocron[7]	3E	Spray	1	Good
″	5G	Broadcast	1	Good
Toxaphene, DMSO[6]		Injection	2	No Control
″ Soltrol		Injection	2	No Control
Dieldrin, DMSO		Injection	2	No Control
DDT, DMSO		Injection	2	No Control
Thuricide (90T) *(Bacillus thuringiensis)*		Spray	2	No Control

[1] 2-(diethoxyphosphinylimine) 1-3 dithiolane
[2] dimethyl p-(methylthio) phenlyphospha.e
[3] phosphorodithioic acid, O,O-dimethyl S- [(2-methoxy-5-oxo-2-1,3,4-thiodiazoly-4-yl) methyl] ester
[4] various degrees of foliage "burning" produced.
[5] 2-chloro-1 (2,4-dichlorophenyl) vinyl ethyl phosphate
[6] DMSO=dimethyl sulfoxide
[7] I

Figure 2. Pine tip moth damage: the left terminal is undamaged, the middle one shows moderate damage and the shoot on the right demonstrates heavy damage with the tunnel slit open to reveal a tip moth larva.

than in 1964, and continued until October 6, 24 days beyond the 1964 records for the final emergence dates; the peak emergence level was reached September 2 in both 1964 and 1965.

The heaviest moth emergence occurred during the second generation but this was reached early in the generation period and fell off rapidly, resulting in an average of 15.5 percent for this generation. Moth emergence during the second generation occurred over a longer period and at a higher level.

Additional information concerning seasonal development was obtained from the percentage of shoots damaged on untreated pines (Table 3). Larval damage was heaviest on new shoots during the last half of June. This occurred after the mid-June records and before the early July records were taken. The percentage of shoots damaged on untreated trees in 1965 was generally lower than in 1963 and 1964.

Table 3. Percentage of shoots on untreated pines damaged by pine tip month larvae[1].

Years	Mid June	Early July	Early August	Late October
1964	37	76	69	26
1965	48	70	58	55

[1] Based on all untreated check trees in study.

Soil Treatments

Soil Treatment Test No. 1: In a preliminary test on August 18, 1962, four systemic insecticides were applied to the soil around 3-year-old loblolly pines. The soil within a 5-foot diameter circle, centered about each tree, was cultivated to a depth of 4-6 inches by means of a powered Rototiller[7]. Granular formulations were applied by using a "shaker jar" made from a quart fruit jar with a screen wire lid. Dimethoate 4E in two gallons of water per tree was applied with a sprinkler can. After application, the soil was again rototilled. Soil moisture at application, and for several weeks thereafter, was well below normal.

The results (Table 4) indicate that phorate and disulfoton gave a high level of protection during the entire pine tip moth activity season of 1963. They also provided moderate protection into the early part of 1964, with phorate protecting at a slightly higher level than disulfoton. Dimethoate soil-drench gave a high level of protection throughout 1963 and into 1964. Dimethoate, however, produced severe foliage "burning" which resulted in the mortality of one tree and extensive needle shedding on others. Meta-Systox-R, in the granular form was ineffective. None of the treatments reduced infestation in 1965.

Soil Treatment Test No. 2: Six systemic compounds were applied at various rates to the soil surface within the dripline of 4-year-old loblolly pines on June 12, 1963. A band six inches wide and three inches deep was dug within the dripline around each tree to receive the insecticide. The formulations were applied by the same methods used in Soil Treatment Test No. 1. Eight gallons of water was applied to the band about each tree.

By July 10, 1963, 28 days following application, granular materials had exerted limited control at best, but dimethoate liquid formulation demonstrated moderate protection (Table 5). By August 12, approximately two months after application, excellent control was exhibited by the higher rates of phorate, disulfoton, and dimethoate. Dasanit gave good to excellent control at the 4- and 6-oz rates, but only the 6 oz rates of E.I. 47031 and Temik[7] gave such high levels of protection for the two higher rates.

During the 1964 activity season, phorate produced good to moderate protecton at all rates of application and disulfoton and Dasanit gave moderate to fair protection throughout the season, but E.I. 47031 and Temik gave poor to no protection at the 6-oz rate. Moderate to fair portection was produced by Dansanit, phorate, and disulfoton at the 6-oz rate in 1965. Dimethoate resulted in fair to poor protection.

Soil Treatment Test No. 3: Ten soil application methods were compared using disulfoton emulsifiable and granular formations applied

Table 4. Soil Treatment Test No. 1: applied in soil, 8-18-62, against the pine tip moth on 3-year-old loblolly pines.

		Percent of Shoots Damaged[1]								
	Ounces Actual	1963		1964			1965			
Treatment	Toxicant/Tree	9-6	10-20	5-27	7-17	10-31	6-2	7-1	8-11	12-20
Disulfoton 10G	0.6	2	8	44	50	20	10	63	44	55
Phorate 10G	0.6	0	3	36	44	14	7	66	23	52
Meta-Systox-R 5G	0.6	84	63	47	59	--	12	76	34	45
Dimethoate 4E	0.8	11	25	57	69	16	13	65	26	50
Untreated ---	---	84	69	53	78	14	10	73	26	62

[1] Based on four trees per treatment.

Table 5. Soil Treatment Test No. 2: applied on the soil 6-12-63 against the pine tip moth on 5-year-old loblolly pines.

			Percent of Shoots Damaged[1]										
		Ounces Toxicant	1963			1964				1965			
Treatment		per tree	7-10	8-12	10-6	5-26	7-17	8-10	11-14	5-28	6-25	8-10	11-31
Disulfoton	10G	0.6	96	1	2	34	22	34	6	16	38	22	37
"	"	0.4	91	3	5	27	33	41	12	18	40	32	40
"	"	0.2	98	3	7	51	46	39	7	18	42	38	39
Phorate	10G	0.6	94	0	0	4	21	25	2	9	33	13	30
"	"	0.4	85	0	0	9	17	30	2	14	29	15	30
"	"	0.2	95	0	0	13	43	47	1	21	42	34	44
Dasanit	10G	0.6	91	2	8	31	55	35	2	14	31	13	29
"	"	0.4	84	6	2	39	44	42	7	11	45	26	36
"	"	0.2	84	20	46	52	73	64	13	23	29	40	46
EI 47031	10G	0.6	59	0	40	52	74	66	19	20	48	42	41
"	"	0.4	60	25	88	71	87	82	17	23	49	45	52
"	"	0.2	77	32	87	65	95	76	32	32	69	61	57
Temik	10G	0.6	58	0	35	43	82	77	20	26	50	52	42
"	"	0.4	68	37	77	55	80	82	12	15	46	42	37
"	"	0.2	71	81	85	62	81	79	11	11	45	49	41
Dimethoate	4E	2.7	43	0	0	61	34	41	13	15	45	27	39
"	"	5.3	34	0	0	37	66	38	14	20	46	36	40
"	"	0.8	29	1	78	55	76	75	21	19	53	26	56
Untreated	--	--	99	94	73	64	80	79	20	25	60	50	41

[1] Based on six trees per treatment.

June 28, 1963. The broadcast-on-soil method involved the uniform distribution of insecticides on the soil surface around the tree from trunk to dripline. The broadcast-in-soil method involved the same procedure plus the mixing of the insecticides into the soil to a depth of 2-3 inches. In the band-on-soil method, insecticides were applied in a circular band four inches in width, centered about the tree and within the dripline. In the band-in-soil treatment, insecticides were distributed in a trench four inches wide and 2-3 inches deep and then covered with soil. Insecticides were also placed in two or four holes, 8-inch diameter and 4-inch depth, spaced at uniform intervals within the dripline about the tree. Disulfoton 6E concentrate was mixed in water and applied to the treated area.

All methods except two gave good to excellent control by August 17, 1963 (Table 6). None of the later records for the liquid formulations showed effectiveness. On the basis of the October 8 records, granular treatments achieved excellent control in 1963 in all methods except where applied in holes. In 1964 and 1965 the level of protection was good to moderate for broadcast and band methods.

Soil Treatment Test No. 4: On July 17, 1963 dimethoate 4E was applied as a soil drench to two sizes of 7-year-old shortleaf pines having trunk circumferences that averaged approximately 5 to 12 inches per group. Application was made to a 4 x 4-inch trench about the tree using 2 gallons of water.

On the smaller trees all treatment rates gave excellent protection through August, 1963, but by October the level of control decreased with the dosage (Table 7). In 1964 only the 4-oz rate measurably reduced damage. On the larger trees the 2- and 4-oz rates gave good to excellent protection through 1963 but no definite benefits were evident in 1964 or later. Phytotoxicity, recorded August 24, was correlated with the dosage rates and tree size but no symptoms of this were noticeable in 1964.

Data recorded June 6, 1964, indicate that a high level of protection was obtained only in the 4-oz rate applied to small trees. Later records showed only limited effectiveness.

Soil Treatment No. 5: Soil applications were made to 25-year-old shortleaf pines on July 25, 1963, using dimethoate 4E and phosphamidon 4E. Various amounts of the concentrates were mixed with two gallons of water and applied in a 4-inch band of tilled soil centered around each tree and within its dripline. After treatment an additional 8 gallons of water was added to each tree.

The 1963 records (Table 8) indicate that 4 or 8 oz of dimethoate or 8 oz of phosphamidon gave appreciable protection to the trees. The 8-oz rates may have had limited effects on infestations in 1964 and 1965.

Table 6. Soil Treatment Test No. 3: disulfoton applied to the soil by various methods, 6-28-63, against the pine tip moth on 4-year-old loblolly pines.

Application Method[1]	Percent of Shoots Damaged[2] 1963 8-17	1963 10-8	1964 6-3	1964 7-9	1964 7-17	1964 8-4	1964 8-17	1965 6-2	1965 6-25	1965 12-30
Disulfoton 6-E, 1.2 oz. in 0.5 Gallon Water Per Tree										
Broadcast-on-soil	6	79	64	79	85	74	74	9	60	37
Broadcast-in-soil	2	74	70	94	91	71	74	14	67	46
Band-in-soil	2	79	70	92	87	69	71	16	73	37
Band-on-soil	7	80	66	93	87	71	71	14	65	48
In-4-holes (dry)	0	64	59	92	90	79	79	12	66	48
In-2-holes (dry)	1	59	61	91	90	77	77	13	73	49
Disulfoton 10% Granules, 6 oz. Per Tree										
Broadcast-on-soil	7	2	22	19	21	31	30	11	62	40
Broadcast-on-soil (dry)	17	4	18	13	10	15	15	12	40	56
Broadcast-in-soil	0	0	14	14	14	16	16	6	45	34
Broadcast-in-soil (dry)	0	0	15	16	9	9	9	8	31	43
Band-on-soil	21	0	24	20	15	25	25	8	31	43
Band-on-soil (dry)	12	0	26	19	12	24	19	9	48	33
Band-in-soil	8	8	21	31	10	15	16	5	45	22
Band-in-soil (dry)	7	1	24	23	14	20	20	9	32	45
In-4-holes (dry)	79	50	56	64	56	51	51	8	41	22
In-2-holes (dry)	89	54	47	67	51	37	58	8	57	50
Check										
Untreated	97	74	55	90	95	75	75	12	64	50

[1] Eight gallons of water added to all treatments not designated as (dry).
[2] Based on six trees per treatment.

Table 7. Soil Treatment Test No. 4: dimethoate 4E, applied in the soil, 7-17-63, to two sizes of shortleaf pines against the pine tip moth.

Ounces Toxicant Per Tree	Average Phytotoxicity Rating[1]	Percent of Shoots Damaged[2] 1963 8-24	1963 10-12	1964 6-3	1964 8-10	1965 6-7
	Trees with Trunk Circumference of 3.5 - 6 inches[3]					
0.25	0.5	7	57	32	--	--
0.50	0.5	1	51	29	--	--
1.00	1.6	0	28	34	--	--
2.00	2.1	0	00	29	63	23
4.00	3.3	0	00	5	32	22
Untreated	---	87	61	37	68	26
	Trees with Trunk Circumference of 10 - 15 inches[3]					
0.25	0	31	41	31	--	--
0.50	0	8	40	22	--	--
1.00	0	2	32	32	--	--
2.00	0	1	15	24	53	32
4.00	2.3	0	2	39	46	43
Untreated	--	84	59	42	53	40

[1] Ratings: 0—No discoloring or burning effect; 1—very light, 2—light, 3—moderate, 4—heavy, 5—very heavy; recorded 8/24.

[2] Based on eight trees per treatment.

[3] Measurements taken ten inches above the soil.

Table 8. Soil Treatment Test No. 5: dimethoate 4E and phosphamidon 4E applied at various rates in the soil, 7-25-63, against the pine tip moth on 25-year-old shortleaf pines.

Ounces Toxicant Per Tree	Percent of Shoots Damaged[1] October 1963	August 1964	October 1965
	Dimethoate		
0.12	54	37	48
0.25	53	50	60
0.50	69	43	58
1.00	52	42	49
2.00	14	49	52
4.00	7	40	26
	Phosphamidon		
1.00	46	46	49
2.00	41	47	50
4.00	16	41	40
	Check		
Untreated	65	58	52

[1] Based on six trees per treatment.

Soil Treatment Test No. 6: Disulfoton 6E was applied at two rates, 0.3 and 0.6 oz actual, to the soil around 4-year-old shortleaf pines on August 17, 1964. Debris and vegetation were removed from the area within the dripline before application and then spread over the area after treatment. The results (Table 9) indicate good control for both treatment rates on September 20, 1964, 35 days after application. Good to excellent control throughout the 1965 activity season was also obtained ,with the 0.6-oz rate showing slightly less damage than the 0.3-oz rate.

Soil Tratment Tests No. 7: Four systemic insecticides were applied to the soil and one systemic insecticide was applied as a spray-drench to 5- to 6-year-old loblolly pines during the June 26-28, 1965, period. Six trees in a block were treated by removing all the debris and vegetation from beneath the tree and the systemic insecticide applied directly to the soil. Four gallons of water was applied to each tree and the debris and vegetation pushed back into place. The spray-drench application was made with a 50-gallon John Bean sprayer and a spray gun equipped with an open nozzle at the rate of 1.06 gallons per minute and 100 psi. Each tree was drenched 10-30 seconds depending on size. The applications were made between the first and second generations of the pine tip moth, when moth emergence was at its lowest.

Disulfoton gave almost complete protection during the entire first season of the test (Table 10). Thiocron produced good protection 11 days after treatment at both the 1.2-oz and the 0.6-oz treatment. By August 12 all treatments were producing excellent protection when compared to untreated checks. The results recorded for November 24 showed all materials except Thiocron to be producing excellent protection. Severe foliar "burning" was observed on all trees treated with Baygon.

Soil Treatment Test No. 8: Preliminary tests were conducted using soil applications of disulfoton granules at the rate of 0.6 ounces actual toxicant per tree, to determine the most effetcive date of application. Blocks of 4-year-old shortleaf pines consisting of 12 trees each were selected and treated at various dates, starting February 4, 1964 and ex-

Table 9. Soil Treatment Test No. 6: two rates of disulfoton 6E applied as a soil-drench 8-17-64, against the pine tip moth on 5-year-old shortleaf pines.

Ounces Toxicant Per Tree[1]	Percent of Shoots Damaged[2]					
	1964			1965		
	8-19	9-20	11-4	7-5	8-12	11-24
0.3	45	24	4	7	9	9
0.6	49	19	3	4	5	4
Untreated	52	54	29	49	57	60

[1] Four gallons of water added to all treatments.
[2] Based on 18 trees per treatment.

Table 10. Soil Treatment Test No. 7: applied to the soil 7-26-65, against the pine tip moth on 6-year-old loblolly pines.

Treatment[1]		Ounces Toxicant/Tree	Percent of Shoots Damaged[2] 7-7	8-12	11-24
Dasanit	5G	1.2	46	2	5
Baygon	5G	1.2	27	2	1
Thiocron	5G	1.2	17	1	17
Thiocron	5G	0.6	11	1	17
Furadan	10G	0.6	37	1	5
Disulfoton	6E	0.6	2	6	0
Untreated	--	--	60	50	41

[1] Treated June 26-28, 1965. Four gallons of water added to all treatments.
[2] Based on six trees per treatment with exception of disulfoton and untreated check trees which were based on 12 trees per treatment.

tending through August 23, 1965. All debris and vegetation was removed from the soil surface beneath the trees, the systemic insecticide was applied, and the debris and vegetation pushed back into place. Four gallons of water was added to each tree at time of treatment.

The results (Table 11) indicate that applications made at the end of the growing season (October and November, 1964) produced good to excellent control during the entire following activity season. Applications made on all other dates resulted in partial protection during the latter part of the activity season (May, 1965) or slight to moderate protection over the entire activity season (February '65, April '64, May '64, January '65, and June '65).

Table 11. Soil Treatment Test No. 8: disulfoton 10G applied on different dates to the soil, at 6 ounces per tree against the pine tip moth.

Application Date[1]	Percent of Shoots Damaged[2] 1964 6-1	7-2	8-12	11-25	1965 6-25	7-3	8-13	11-24
1964								
February 4	39	51	40	13	9	50	29	35
April 10	51	49	42	18	14	33	14	25
May 25	42	61	62	23	12	39	15	12
October 3				10	7	1	1	6
November 25				19	19	12	2	6
1965								
January 22					18	39	11	17
March 4					18	47	22	17
May 24					35	47	7	12
June 28						72	45	32
August 23								46
Untreated	59	70	73	18	30	74	49	64

[1] Applied in 4 gal. water per tree.
[2] Based on 12 trees per treatment.

Foliar Spray Treatments

Foliar Spray Test No. 1: Seven systemics at four rates and DDT at one rate were applied as foliar sprays to 4-year-old loblolly pines on July 23, 1963. The trees were sprayed at 100 psi until beginning of run-off by use of a boom equipped with two No. 9 gal. cone nozzles. Application was made at peak moth emergence.

All treatments and rates gave moderate to excellent protection from the larvae of the next generation through August 20 (Table 12). By October 9, however, none demonstrated effectiveness against the late generation larvae. The short duration of protetcion is not surprising considering the very light rates of application, the highest of which (disulfoton 6E) delivered only about 0.10 ounce of toxicant per tree.

Foliar Spray Test No. 2: A series of four applications were made at weekly intervals to determine the effect of larval age and feeding site

Table 12. Foliar Spray Test No. 1: systemic insecticides and DDT applied 7-23-63, against the pine tip moth on 4-year-old loblolly pines.

Treatment		Percent Spray Conc.	Percent of Shoot Damage	
			August 20	October 9
Meta-systox-R	2E	0.06	8	82
		0.12	13	81
		0.18	6	83
		0.25	4	74
Shell 4072	2E	0.06	7	72
		0.12	5	76
		0.18	2	79
		0.25	2	66
E.I. 47031	3E	0.06	4	78
		0.12	6	76
		0.18	11	82
		0.25	3	75
Phosphamidon	4E	0.06	10	80
		0.12	9	81
		0.18	13	68
		0.25	4	79
Dimethoate	4E	0.06	12	80
		0.12	14	83
		0.18	14	78
		0.25	7	80
Bidrin	2E	0.06	13	86
		0.12	3	78
		0.18	3	77
		0.25	6	76
DDT	2E	0.12	19	79
Untreated		----	96	73

[1] Based on ten trees per treatment.

on control obtained by a systemic compound used in a foliar spray. The first application was made to 4-year-old loblolly pines on July 23, 1963, at approximately the peak of moth emergence from the second generation. Dimethoate 0.12 spray was applied by the methods used in Foliar Spray Test No. 1. A different group of 12 trees was sprayed on each of the application dates.

On the basis of percentage of shoots damaged, the first application was the most effective and control from the other applications decreased as the date of application was delayed (Table 13). However, the data, exaggerates the importance of the earlier applications, since it does not reflect reduction in degree of damage to shoots effected by later applications. In the case of applications made after larvae had entered and damaged shoots, considerable numbers of them were killed by the treatment thereby reducing further damage to the shoot. However, initial damage, if serious enough to kill the growing tip, would be most important.

Foliar Spray Test No. 3: Seven systemic compounds and DDT were applied to 3-year-old loblolly pines on June 18, 1963. Application was made with a power sprayer, equipped with a spray gun and No. 5 disk nozzle, which delivered 0.66 gallon of spray per minute at 100 psi. The majority of larvae of the second generation were within the shoots when treatment was made.

By July 10, twenty-two days after application, shoots damaged in none of the treatments differed greatly from untreated checks (Table 14). However, the degree of shoot injury in some of the treatments was definitely lower than on untreated trees. Disulfoton gave complete control of the third and fourth generation larvae. Dimethoate produced moderate control by August 13 but was ineffective later. Further studies were made on the disulfoton-treated block in 1964, and 1965. One-half

Table 13. Foliar Spray Test No. 2: applied at different dates against larvae of third generation pine tip moths on 4-year-old loblolly pines.

Date of Application	Percent of Shoots Damaged[1] August 26
July 23	14
July 30	22
August 9	88
August 15	95

[1] The July 23 treatment based on ten, the remainder based on 12 trees per treatment.

Table 14. Foliar Spray Test No. 3: applied 6-18-63 against the pine tip moth of 4-year-old loblolly pines.

Treatment		Percent Spray Conc.	Ounces Toxicant Per Tree	Percent of Shoots Damaged[2]							
				1963			1964			1965	
				7-10	8-13	10-6	7-8	8-31	10-31	6-1	11-24
Disulfoton	6E	0.6	0.25	75	0	C	45	18	4	10	16
Repeated 6-19-64		0.6	0.25	75	0	0	34	12	0	5	3
Untreated		--	---	90	91	73	90	75	30	24	50
E.I. 47031	3E	0.6	0.25	62	58						
Dimethoate	4E	1.2	0.50	68	26	74					
Phosphamidon	4E	1.2	0.50	68	74						
SD 4072	2E	0.6	0.25	72	61						
Metasystoxr	2E	0.6	0 25	71	85						
Bidrin	2E	0.6	0.25	71	90						
DDT	2E	0.2	0.09	82	96						

[1] Based on 12-15 trees per treatment.

of the block was treated again on June 19, 1964, using the same method employed in 1963. The 1963 treatment gave measurable reduction in damage during 1964 and 1965. The 1964 application, increased the level of control in both 1964 and 1965.

Test No. 4, Spray vs. Soil Application. On June 17, 1964, five systemic insecticides were applied to 5-year-old shortleaf pines as sprays and as soil treatments. In soil application, debris and undergrowth were removed, insecticides applied in a broadcast pattern, and the debris and undergrowth pushed back into place. Four gallons of water was applied to each treated tree and the assigned checks.

The results (Table 15) indicate that disulfoton 6E at 0.6 oz actual per tree gave the most consistent control. It shows a relatively early uptake by the tree and indicates that a long term residual was in effect by November 31, 1965. At the lower rate (0.3 oz actual per tree), disulfoton 6E presented a pattern of effectiveness similar to the higher rate except for the presence of a slightly higher percentage of damaged shoots.

The granular formulations tested (disulfoton, phorate, and Dasanit) did not exhibit protection of trees until late in the 1964 activity season. The protection throughout the 1965 activity season was good to excellent, disulfoton and phorate produced about the same degree of protection followed by Dasanit.

The data indicate that disulfoton 6E applied as a spray-drench at 0.25 oz and 0.13 oz actual per tree achieved good to moderate control approximately one and one-half months after application. Good control by the higher rate was in effect at the end of the 1964 activity season. By the beginning of the 1965 activity season moderate control was in effect for both rates of disulfoton 6E spray-drench, but this did not extend throughout the season.

Data recorded for G C 9879 and Azodrin, applied as a spray-drench at 0.25 oz actual per tree, indicate that moderate control was in effect one and one-half months following application, but with only slight control for the remainder of the 1964 activity season. The 1965 activity season records show G C 9879 and Azodrin to have approximately the same percentage of shoots damaged as the untreated checks. Azodrin produced moderate foliage "borning" throughout the 1964 activity season.

Spray Tests: Four spray tests comparing disulfoton with several other systemic compounds were made in 1965, beginning in April, May, June, and July (Table 16).

In test No. 5, application was made when first generation larvae were feeding. Both disulfoton 6E and Furadan 80W gave excellent control of succeeding generations of the tip moth.

Table 15. Test No. 4: Spray Vs. Soil Applications applied 6-17-64 against the pine tip moth on 5-year-old shortleaf pines.

Treatment[1]		Ounces Toxicant Per Tree	Percent of Shoots Damaged[2]							
			1964					1965		
			7-16	8-12	8-24	10-29	5-27	6-24	8-16	11-31
					Soil Application					
Disulfoton	10G	0.6	80	45	40	1	4	9	2	6
"	6E	0.3	67	29	32	1	7	14	–	6
"	6E	0.6	46	18	26	1	2	11	1	3
Phorate	10G	0.6	63	36	37	0	2	8	4	10
Dasanit	10G	0.6	60	30	31	5	9	26	20	17
					Spray Application					
Disulfoton	6E	0.25	30	23	24	6	11	49	49	60
Disulfoton[3]	6E	0.13	33	21	22	17	18	42	56	63
G C 9879	4E	0.25	47	26	31	16	19	49	58	65
Azodrin	3E	0.25	29	24	23	19	14	42	52	60
							Check			
Untreated	--	---	84	48	45	29	19	49	57	59

[1] Applied in 4 gal. water per tree.
[2] Based on 24 trees per treatment.
[3] Treatment received ¼ gallon of mixed spray, all other spray treatments received ½ gallon per tree.

Table 16. Spray Tests in 1965: aaginst the pine tip moth on 6-year-old pines.

Formulation		Percent Spray Concentrate	Ounces Toxicant Per Tree	Percent of Shoots Damaged[1] July 7	Aug. 12	Nov. 24
			Test No. 5 Treated April 20			
Disulfoton	6E	0.50	0.25	9	5	1
Furadan	80W	0.50	0.25	1	1	6
Untreated		---	---	82	63	61
			Test No. 6 Treated May 25			
Disulfoton	6E	0.50	0.25	16	4	2
"	6E	0.25	0.25	12	26	9
"	6E	0.25	0.13	15	16	11
Phosphamidon	8E	0.50	0.50	59	61	66
Untreated		---	---	81	67	68
			Test No. 7 Treated June 10			
Disulfoton	6E	0.50	0.25	9	2	1
Dasanit	6E	0.50	0.25	3	0	0
Baygon	2E	0.30	0.25	1	7	25
Furadan	80W	0.50	0.25	17	0	0
Thiocron	3E	0.50	0.25	13	10	14
Untreated		---	---	59	50	41
			Test No. 8 Treated July 10			
Disulfoton	6E	0.50	0.25	--	0	15
G C 6506	4E	0.50	0.25	--	54	31
G S 13005	4E	0.50	0.25	--	16	56
Azodrin[3]	3E	0.50	0.25	--	55	23
Untreated		---	---	--	49	51

[1] Based on 6-12 trees per treatment.

In test No. 6, applied May 25, disulfoton 6E 0.25 spray applied at 0.25 and 0.13 oz of actual toxicant per tree gave moderate to good protection, while disulfoton 6E 0.50 percent spray applied at .50 oz gave good to excellent protection for the remainder of the season. Phosphamidon 8E 0.50 percent spray at 0.50 ounce per tree was comparatively ineffective.

In test No. 7, applied June 10 immediately after first generation peak moth emergence, five compounds gave excellent to moderate control. The best results were obtained from Dasanit 6E and disulfoton 6E. Furadan was slower in action but gave complete control in summer and fall. Baygon 2E gave excellent control of the second and third generations but was less effective against later larvae.

Test No. 8 was applied July 10 near the beginning of second generation moth emergence. Only disulfoton 6E gave good control in this test.

Other Treatment Methods

Other treatment methods were tested in preliminary trials, but none were effective. These methods included injections of insecticides into tree trunks, painting of liquid formulations on pine shoots, and the application of *Bacillus thuringiensis* (Berliner) as a foliar spray.

The materials and amounts per tree used in injection tests were: Bidrin 6E, 6 ml; disulfoton 6E, 6 ml; Azodrin 3E, 20 ml; toxaphene (1 g in 1.5 ml dimethyl sulfoxide), 6 ml; dieldrin (1 g in 5 ml dimethyl sulfoxide), 6 ml; and DDT (1 g in 5 ml dimethyl sulfoxide), 6 ml.

None of the injection treatments appeared to affect the pest. Dieldren in dimethyl sulfoxide caused marked "burning" and shedding of needles and all other treatments containing this solvent caused slight degrees of these phenomena.

In two tests, liquid formulations were painted in a thin film over the surface of the top 10 inches of 7-year-old shortleaf pines. The insecticides and their concentrations were: disulfoton 6E, toxaphene 1 g in 5 ml Soltrol, toxaphene 1 g in 5 ml dimethyl sulfoxide, DDT 1 g in 5 ml dimethyl sulfoxide, and aldrin 1 g in 5 ml dimethyl sulfoxide. None of these treatments were effective nor caused phytotoxic symptoms.

Bacillus thuringiensis (Berliner) (Thuricide 90T, 30 billion viable spores per gram) was applied as a foliar spray to 6-year-old shortleaf pines. Three applications of a 0.5 spray were made at weekly intervals, beginning during second generation moth emergence. Damage by pine tip moth on these pines did not differ from that on untreated pines.

Pine Species and Tree Age in Relation to Damage

Limited information was obtained on compaartive tip moth damage occurring on various pine species. The data are presented in Table 17 and are arranged according to age of the pines.

On the basis of trees from 2 to 27 years of age, shortleaf pines sustained the greatest damage. Loblolly pines were equally heavily attacked within the 2-6 year range. Damage on 25- to 27-year-old pines of this species, however, was light. Ponderosa pines of the older group sustained even less damage than loblolly. In a comparison of 3-year-old trees, slash pines (*P. elliottii*) demonstrated significant resistance and cluster pines (*P. pinaster*) showed a very high degree of resistance.

The data indicate that damage level is markedly affected by certain tree ages. In this connection it should be stated that the data of various age groups are not directly comparable because two or more of them were up to one-half mile apart. One- and two-year-old trees suffered little or no damage from the top moth. Tree ages within 3 to 6 years appeared to be most favorable for the pest. Trees 25 years of age or older

Table 17. Effects of pine species and tree age on pine tip moth damage.

Tree Age	Pine Species	Percent of Shoots Damaged[1]		
		1963	1964	1965
1,2 years	Shortleaf	--	0	1
	Loblolly	--	0	1
	Ponderosa	--	0	1
	Austrian	--	0	0
3 years	Shortleaf	90	--	--
	Loblolly	91	--	--
	Slash	26	--	--
	Cluster	5	--	--
4,5 and 6 years	Shortleaf	89	72	69
	Loblolly	92	80	62
25,26 and 27 years	Shortleaf	74	32	29
	Loblolly	3	7	11
	Ponderosa	5	2	0

[1] Based on a minimum of 20 trees per record.

suffered significantly less damage than the last mentioned age bracket. The decrease for loblolly and ponderosa species in this older group was striking.

Height Growth of Treated Pines

Measurements were taken for comparison of height growth increases for treated and untreated pines in 1963, 1964, and 1965. All trees used in the Soil Treatment Test No. 2 (Table 5) and Test No. 4 (Table 15) were measured and recorded for this study. Measurements were taken on the date of application and again in December of each year. Tree height was measured as the distance from the soil surface to the tip of the tallest shoot.

Height growth data (Table 18) for Soil Treatment Test No. 4 show that increase in height per treatment over untreated trees in 1963 ranged from 1.8 to 12.8 inches, with an average increase of 7.9 inches. Dimethoate 4E at the two higher rates produced 12.0 and 12.8 inches of height growth increase over untreated checks. The 1964 records show, generally, that the highest rate of toxicants produced the largest amount of growth, however, this would be expected since the higher rates generally gave superior protection. The average increase of 5.3 inches was 2.6 inches less than for 1963. In 1965 height increase over checks was, generally, less than in the former years. The total increase over checks for the various treatments shows a range from —7.0 to 38.3 inches with an average gain of 16.5 inches.

Table 19 shows the average increase in height over checks in 1964 to be 2.5 inches for soil applications compared to 2.1 inches for spray-

Table 18. Height growth of 4-year-old loblolly pines in Soil Treatment Test No. 4, applied June 13, 1963.

Treatment		Ounces Tox./Tree	Height Growth, Inches[1] 1963	1964	1965	Total	Increase Over Check, Inches[1] 1963	1964	1965	Total
Disulfoton	10G	0.6	6.9	21.4	30.6	58.9	5.6	5.7	8.4	19.7
"	"	0.4	8.5	18.2	21.6	48.3	7.3	2.4	—0.6	9.1
"	"	0.2	3.2	16.3	22.2	41.7	2.0	0.5	0.0	2.5
Phorate	10G	0.6	6.3	23.2	22.5	52.0	5.1	7.4	0.3	12.8
"	"	0.4	11.1	35.8	29.3	76.2	9.9	20.0	7.1	37.0
"	"	0.2	7.2	23.3	23.7	54.2	6.0	7.5	1.5	15.0
Dasanit	10G	0.6	8.6	26.0	32.1	66.7	7.4	10.2	9.9	27.5
"	"	0.4	9.7	24.5	30.0	60.0	6.0	7.0	7.8	20.8
E I 47031	10G	0.6	11.8	19.4	21.2	52.4	10.6	3.6	—1.0	13.2
"	"	0.4	8.3	16.7	25.8	49.8	7.1	0.9	2.6	10.6
"	"	0.2	3.0	11.2	18.0	32.2	1.8	—4.6	—4.2	—7.0
Temik	10G	0.6	13.3	21.2	23.1	57.6	12.1	5.4	0.9	18.4
"	"	0.4	10.5	16.7	26.0	53.2	0.3	0.9	3.8	14.0
"	"	0.2	6.0	15.6	31.2	52.8	4.8	—0.2	9.3	13.6
Dimethoate	4E	4.0	13.2	29.1	35.2	77.5	12.0	13.3	13.0	38.3
"	"	2.7	14.0	18.4	28.9	61.3	12.8	2.6	6.7	22.1
"	"	1.4	7.3	19.9	15.3	42.5	6.1	4.1	—6.9	3.2
Untreated Check			1.2	15.8	22.2	39.2	---	---	---	---
Combined Average			---	---	---	---	7.9	5.3	4.0	16.5

[1] Based on six trees per treatment.

Table 19. Height growth for shortleaf pines in Test No. 4, Spray vs. Soil Application.

Treatment		Ounces Toxicant Per Tree	Inches[1] Height Growth 1964	1965	Total	Increase Over Check 1964	1965	Total
			Soil Application					
Disulfoton	10G	0.6	11.5	28.9	40.4	3.3	10.8	14.1
"	6E	0.3	9.5	27.6	37.1	1.3	9.5	10.8
"	6E	0.6	10.2	30.6	40.8	2.0	12.5	14.5
Phorate	10G	0.6	10.7	29.9	40.6	2.5	11.8	14.3
Dasanit	10G	0.6	11.8	27.6	39.4	3.6	9.5	13.1
			Spray Application					
Disulfoton	6E	0.25	10.6	17.0	27.6	2.4	—1.1	1.3
"	6E	0.50	11.5	19.8	31.3	3.3	1.7	5.0
G C 9379	4E	0.50	9.4	19.1	28.5	1.2	1.0	2.2
Azodrin	3E	0.50	9.8	17.7	27.5	1.6	—0.4	1.2
			Check					
Untreated		---	8.2	18.1	26.3	--	--	--

[1] Based on 24 trees per treatment.

drench applications. The same comparison in 1965 shows a 10.8 inch increase in height above untreated trees for soil applications and no appreciable difference between spray-drench and untreated check trees. The total increase during the entire test period was an average of 13.1-inches over checks for soil applications compared to a 2.4 inch increase for spray-drench tests. This too would be expected since, in general, soil application gave extended control compared to sprays.

A comparison of height growth increase over checks was made for the various rates of disulfoton applied to the soil in 1963 and 1964. The data (Table 20) show little difference between 0.6- and 0.4-oz rates applied in 1963. The 1964 data showed all rates to have a similar in-

Table 20. Average height growth from all tests of pines treated with disulfoton 10G at various application rates.

Ounces Tox./Tree	Increase Over Checks, Inches[1] 1963	1964	1965	Total
0.6	7.0	16.8	30.2	54.0
0.4	8.5	18.2	21.6	48.3
0.2	3.2	16.3	22.2	41.7

[1] Based on six trees per treatment in 1963 and 18 trees per treatment for the six-ounce rate and six trees per treatment ofr the four- and two-ounce rates in 1964 and 1965.

crease in height growth over checks. In 1965 the 0.6-oz rate produced an approximate eight-inch increase above the 0.4- and 0.2-oz rates. The total increase over checks during the three years was correlated with the rate of application: The 0.2-, 0.4- and 0.6-oz rates produced increases of 42, 48, and 54 inches, respectively.

Control of the Pine Tip Moth During Spring, Summer and Fall

Fig. 3 shows the percentage of control for a single application plotted by spring, summer, and fall periods for all tests where moderate to high levels of control were secured for the initial season and where data were obtained for the second and third years. The toxicants and formulations were not the same for all of the nine tests, but all involved systemic insecticides.

The relationship of control levels to periods of the growing season, and the trends in control were generally the same for each year of observation. Where a treatment was observed for two or three years, the level of control was lower in the second and third years. In addition to this trend, control levels in the spring and fall were lower than in the summer in both second and third years.

Zanher (1962) has shown that there were periods of increased growth in pines in early spring and late fall which might have some bearing on spring and fall levels of control. According to Gibbs (1957), the water content of white pines during early spring and late fall was low. Gibbs also indicated that the water content rises during the summer, which follows the trend established by systemic insecticide levels of protection. Translocation rates are influenced by factors affecting transpiration such as the presence or absence of leaves, presence or absence and intensity of sunlight, concentration of soil solutions, temperature, air humidity, wind velocity, soil temperature, soil aeration, and possibly other factors (Johnson and Rediske 1965). Since the translocation of systemics is influenced by moisture present within the tree and soil, the water content, and possibly other factors, in early spring and late fall unfavorably affected tip moth control.

Discussion

The Nantucket pine tip moth is present regularly from year to year over its range. The results of this study, on the effective duration of systemic pesticides in control of the pine tip moth, show that populations may be significantly reduced by use of systemic pesticides. The use of systemics to control this insect is feasible for ornamental plantings, 3-

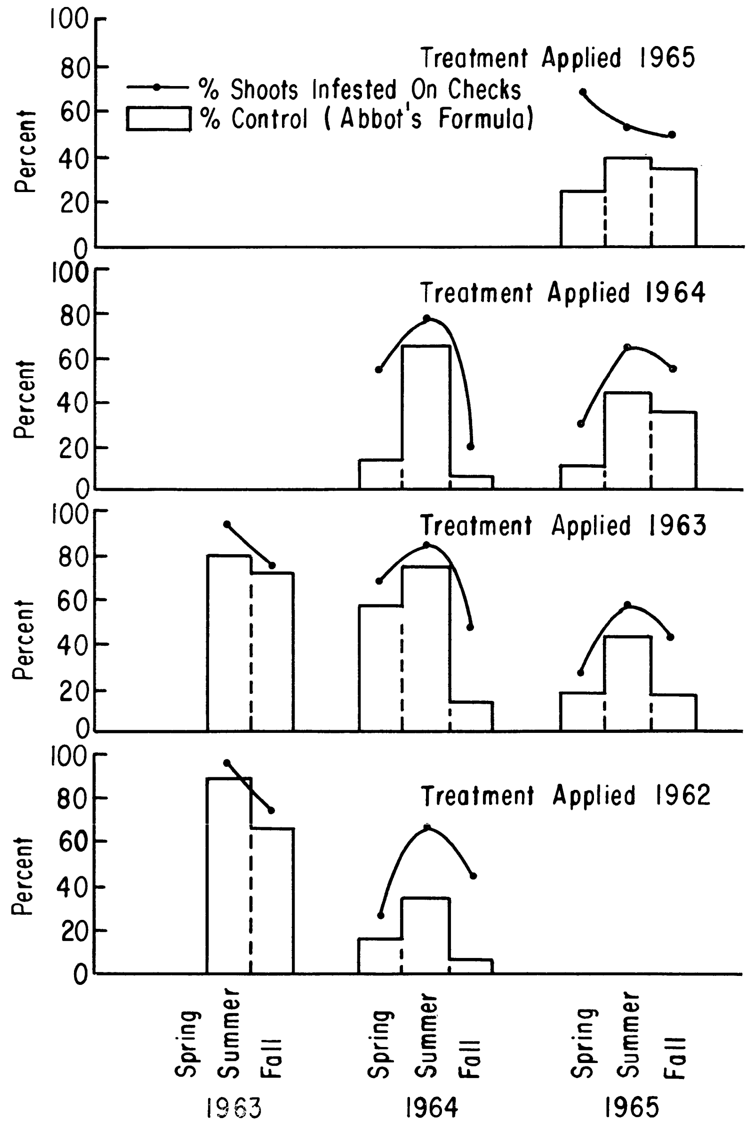

Figure 3. Percentage control of the pine tip moth by systemic insecticides during spring, summer and fall.

year-old and older nursery stock, and perhaps for heavy infestations on young trees in moderate-sized plantations. The commonly recommended method for a season's control of the tip moth involves three or more applications of the contact insecticide DDT timed to kill the larvae of each generation before they enter the shoots. By contrast, a single application of certain systemic pesticides in this study gave protection for more than one year. Costs for the two methods do not differ greatly but the systemic method is better since it involves only one application which requires no critical timing and usually provides moderate protection beyond one year.

Good to excellent control was produced by phorate, and disulfoton, and very promising results were obtained with Baygon, Thiocron, Furadan and Dasanit during the first activity season following application. Phytotoxicity following use of dimethoate and Baygon was evident in that very light needle tip "burning" to heavy "burning" and needle shedding were observed. Table 6 indicates the relative phytotoxi effects of dimethoate at various rates of application. Azodrin also produced moderate foliage "burning." Fair to good control was produced by phosphamidon, Azodrin, and Temik. Thuricide, a microbial insecticide, applied under field plot conditions was ineffective in pine tip moth control.

Both granular and liquid formulations were generally effective as soil treatments. Drenches made from liquid concentrates produced control faster than granular treatments but usually for shorter duration. Generally 28-32 days were required for liquid treatments to produce substantial control, compared to 46-56 days for granular formations. Control effectiveness of granular treatments was generally at reduced levels during the second growing season but still exhibited some degree of protection during the third season in a few of the tests. Effectiveness of liquid concentrate treatments usually terminated during the latter part of the second season, but both rates of disulfoton drench-treatments remained effective to the end of the second season after application. Granules were safer and easier to apply than liquid concentrate treatments.

Where granules were placed in the soil, as opposed to placing the material on the soil, initial control was better but there was no consistent difference in the longterm results (Table 6). Similarly, applications of granules in a band around the trees were equally as effective as broadcast applications. The importance of completely encircling trees with the chemicals was emphasized by the poor results obtained when granules were placed in two or four holes near the pines. Water added at the time of treatment (Table 6) generally did not affect control immediately, nor did it influence the long term results. In this connection, however, it should be emphasized that the amount of water used was limited as compared to amounts ordinarily applied to ornamentals and lawns.

Spray applications applied on the foliage to the point of saturation, but without "run-off," produced immediate protection to the trees. Treatments made in July 1963 gave good to excellent control within a few days after treatment for the current generation, but the percent of shoots damaged was equal to untreated check trees by the end of the 1963 growing season.

In 1964 and 1965 sprays were applied in greater volume until trees were saturated and "run-off" had continued producing a moderate drench effect. Protection by the "spray-drench" method was immediate, because the insects were sprayed or came in contact with treated foliage. The extended period of effectiveness by this method was caused by translocation of the chemical absorbed through foliage or from the soil. Typically, protection was quickly established and remained excellent throughout the latter part of the first growing season. Usually partial protection resulted during the first generation of pine tip moths in the second activity season following treatment.

The effectiveness of "spray-drench applications at equal rates but at intervals of one and two-year periods differed little and gave good to excellent protection of terminal shoots through the two-year test period (Table 14).

Preliminary tests of trunk injections showed no control. There was some indication that DMSO solutions were moved into the translocation stream of the xylem because of the needle "burning" present on treated trees. Dieldrin in DMSO produced the most phytoxic effects of all non-systemic solutions used. Bidrin[7] and disulfoton injected with the Mauget injector apparatus produced localized phytotoxic effects on the foliage within the immediate area of the injection.

The "paint-on" applications, using non-systemic solutions and disulfoton, described in the discussion on injections, produced no protection during 1964 and 1965. There was some indication of bark peeling where dieldrin in DMSO was used, but there was no evidence of foliage "burning" about the terminal area.

The duration of effectiveness of systemic insecticides was affected by tree size (Table 7). Approximately twice the amount of toxicant was needed to maintain effectiveness on trees having diameters of about 4 inches as required on trees averaging about 1.5 inches.

A comparison of granular applications made at various dates during 1964 and 1965 showed that October and November applications were the only ones that gave good to excellent protection throughout the succeeding activity season (Table 11). March, April, and May applications indicated good protection, but not before first generation larvae had inflicted damage to the shoots. A relationship between application date and water content level within the tree may explain the above observed reactions. Gibbs (1957) in Canada found that water content in white pines was low during October, reached a peak during December, decreased steadily until May, rose to a peak during September, and decreased to a low in October. The pine species and climatic factors differ from those in this study, but such fluctuation in water content is associated with systemic insecticide translocation and accumulation.

Soil moisture is important as the intermediate carrier of systemics from the soil into the trees. Where soil moisture is low, absorption and translocation of systemics within the tree would likely be poor.

The amount of damage on untreated trees in spring and fall was quite low compared with that in summer. However, percent control, calculated by Abbott's formula was generally lower in spring and fall. This trend may be related to rates of transpiration and water movement in pines. Gibbs (1957) showed that the water content of white pines had yearly minimum levels in spring and fall and higher levels in summer. Transpiration rate has an important effect on on water movement in plants (Greenidge 1958, Johnson and Rediske 1965). The transpiration rate in turn, varies directly with light intensity and temperature and inversely with humidity (Johnson and Rediske 1965). Generally, light intensity and temperature are reduced and humidity elevated in spring and fall as compared with summer. It would appear, therefore, that reduced movement of water upward was an important cause of reduction in control during spring and fall.

During 1964 and 1965 four generations of the pine tip moth were observed in emergence chamber studies. Percent moth emergence per 100 shoots (Fig. 2) gave an indication of population levels present during each generation. The overall moth emergence for the overwintering and third generations was 5.1 and 2.2 percent, respectively, but for the first and second generation it was 15.5 and 19.2 percent. The second generation had the largest moth populaion, and the first generation population was slightly smaller. The third generation appeared to be smaller than the overwintering generation.

Trends for both years were generally the same for all periods of emergence, except the third generation. The extended period of emergence in the third generation for 1965 may be credited to use of more efficient techniques for measuring emergence or a partial fourth generation period of emergence was in existence. The overlapping of generations was not observed in 1964 or 1965. However, over-lapping might have occurred between the second and third generations, since there was only a 12-day interval of no emergence.

Pine transplants of all species tested had negligible infestation during the first two years the small trees were in the field. Infestations toward the end of the second year were .01 percent on transplants under grass cover and .03 percent on those in an area where grass was burned off prior to transplanting dates. The application of granular systemic insecticides at planting time produced a high rate of tree mortality by the procedures used in this study. Considering the hazard of chemical phytotoxicity and the low incidence of tip moth attack, insecticidal treatment was not justified for protection during the first two years. However, observaions and records in other phases of this study show that young trees are moderately to heavily attacked during the third season after transplanting. Therefore, it is desirable that they be protected from the stunting effects of pine tip moth injury to permit normal growth. Such protection can be obtained by systemic insecticide treatments applied in the fall of the second year or early in the third season. Treatment for this age of tree is particularly justified because of the importance of good growth in young trees and the fact that they are more economical to treat.

Population levels of pine tip moth on untreated 3- to 6-year-old shortleaf and loblolly pines were approximately equal, but on 27-year-old trees the infestation on loblolly pines was much less. Results of studies by Yates (1966) indicate similarly that damage is approximately equal in young shortleaf and loblolly pines. Ponderosa pines of the same age and location were almost free from infestation. The effective duration of systemic pesticides was greater in the 5-year-old pines than in 25- to 27-year-old pines, but this may have been due to inadequate dosage rates for the older and larger trees. The experiment involving various dosage rates of dimethoate as a soil drench for two-size-classes of 7-year-old trees (Table 12) indicated that the duration of protection decreased as the tree size increased.

On the basis of the percent of shoots damaged, the pine tip moth indicated a host preference for shortleaf pines. Loblolly pines were also preferred over most of the other pine species observed in the study. Ponderosa was fed on by pine tip moth, but generally damage was light. Slash and cluster pines present in limited numbers in the test area were not heavily damaged.

Height growth, generally, was increased where systemic insecticides were applied. In 1963 a seasonal maximum increase over checks of 12.8 inches was observed, and the average increase was 7.9 inches. In 1964 the average increase over check trees was 5.3 inches, and the 1965 readings were generally less than the 1964 measurements. A relationship was observed between rates of application and height growth. The 2-, 4-, and 6-oz rates of disulfoton granules produced total increases during three seasons of 41.7, 48.3, and 54.0 inches, respectively. Soil applications generally produced more height growth than was produced by spray-drench treatments.

The duration of various systemic insecticides may be observed in

Tables 2 and 4. Three years of study show that it is possible to achieve long-term effects through use of systemic insecticdes. As would be expected, however, the level of control gradually decreased with time as the toxicant is exhausted in the soil by absorption, evaporation, or deterioration. Heavy rains probably help to leach away or dilute systemic materials in the soil.

This study has shown that a single application of phorate or disulfoton to the soil will reduce tip moth damage for two years or more. This method is more convenient, less expensive, and less involved than the presently recommended practice of applying a contact insecticide in multiple applications which require critical timing.

Applications at intervals of one to two years would be satisfactory for use or ornamental plantings and may be feasible in larger plantations where tip moth seriously limits growth. The greatest benefits can be obtained in pines under 10-12 feet in height and by beginning control on third season transplants. This method, however, appears to be too expensive to be used in commercial forests.

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