THE EFFECTS OF SYSTEMIC INSECTICIDES AND ECOLOGICAL FACTORS ON INFESTATIONS OF THE NANTUCKET PINE TIP MOTH, *Rhyacionia frustrana* (Comstock)

By

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PREFACE

This author, while assisting Dr. R. R. Walton in his research programs during the summer of 1962, conducted a preliminary test on several pines to determine the effectiveness of systemic insecticides against the Nantucket pine tip moth. The treatments were quite successful in controlling the pest which brought about extensive improvement in the appearance of the trees. These results created an intense interest and led to the development of this thesis program. Plans were made to study other chemicals and their methods of application as well as some biological aspects of the pest in this area.

I am deeply grateful to Dr. R. R. Walton, my major advisor, for his encouragement, guidance and assistance in all phases of the program and in the preparation of this manuscript. I wish to extend my gratitude to Dr. D. E. Bryan, Dr. W. A. Drew and Dr. W. G. Carter for their advice and their aid in the preparation of this paper. I am also grateful to the entire Department of Entomology at Oklahoma State University for its co-operation and monetary assistance.

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INTRODUCTION

The Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock), is a common pest of pines over most of the eastern and southeastern United States. However, some controversy is involved as to whether or not the damage inflicted to pines is of a temporary nature. Most published material contends that it is not but has permanent consequences. Even so, there appears to be no practical method at the present time for the control of this pest on a large scale. Where pines are grown in nurseries and ornamental plantings, transplants and trees free of infestation are greatly desired. Under these conditions, involving relatively small areas, the cost of control can be borne.

LITERATURE REVIEW

Life History

The Nantucket pine tip moth is a small lepidopterous insect of the family Olethreutidae. After overwintering as a pupa in the damaged terminals the adult emerges during the warm days of early spring. The colorful moth has a wing span of about 9-15 mm. The elliptical egg (approximately 0.85 by 0.55 mm) is laid singly on a stem or needle of the growing pine terminal. The color of the egg changes from white or opaque when laid to yellow to orange within several days and then to gray before hatching. The incubation period can vary from one to four weeks depending on weather conditions. The first instar larva is approximately 1.5 mm long and is cream colored with a black head and thoracic shield. After chewing its way through the chorion, it wanders about searching for a suitable feeding area. Generally, the larva burrows into the needle sheath and feeds on the needle. The larva may then burrow into the stem or migrate to a new location. Generally, when feeding on the exterior of the stem, a protective covering of resin and webbing is constructed. Eventually the tip or stem is penetrated and the larva tunnels the heart of the tip or stem or both. It grows to about 8 mm in length in the last instar and is light brown to orange in color. The exact number of instars is not known but three or more seem to occur. Pupation occurs in the stem or tip. The light brown pupa is approximately 6 mm in length and becomes darker as it matures. Shortly before emergence the pupa works itself part way out of the stem where the adult can emerge uninjured. From one to four generations a year occur depending on the geographical location. Usually three generations and a partial fourth occur in Oklahoma. Hosts of this insect include all species of the genus *Pinus* except two, *P. strobus* and *P. palustris*. This generalized life history and the descriptions follow Yates (1960).

Damage

Since the buds or growing terminals of the pines are infested, the damage inflicted by this small pest can be very serious. Normally one to two larvae are common but as many as 17 were found in one dissected shoot in this study. In such cases of heavy damage the shoot is killed back for several inches. When the terminal is damaged a new shoot developes from a bud below the damaged area. Repeated heavy damage to a tree results in a bushy, dwarfed appearance (Beal 1952). Wakeley (1954) reported that damage over the years may cause crooking or forking of the main stem. Retardation in height growth (Wakeley 1954, Neel 1959, Foil et al. 1961) can also occur and a reduction in cone crops can exist (Zak 1956). Also, tree mortality can result when heavy infestations are combined with other unfavorable factors (Yates 1960).

History of Control

This pest was first discovered in 1876 on Nantucket Island, Massachusetts, by Scudder (1879). He suggested that bonfires be built at night to attract and kill the adults and to pick and burn all infested tips. His final suggestion was to destroy all the pines on the island to eliminate the pest's food source. Of course these suggestions are not practiced now but there are more recent silvicultural practices that are recommended or suggested for use today. These practices include;

planting under hardwood cover, planting on a closely spaced planting plan, using more resistant species such as slash and longleaf pines, confining the more susceptible ones to favorable sites and the mixing of resistant species with the susceptible ones (Wakeley 1935, Huckenpahlen 1953, Yates 1960).

Early chemicals suggested for control were nicotine oleate, lead arsenate and Volck (Wakeley 1935, Mortimer 1941). However, with the introduction of organic insecticides, particularly DDT, new and better measures of control were available (Fenton and Afanasiev 1946). DDT is still recommended and used in the control of this pest. However, even with critical timing, two or four applications of a contact insecticide per season are required for satisfactory control. When complete freedom of the pest is desired, as in research programs or nurseries, a weekly to bimonthly spray program is used (Foil 1961).

In the past, the majority of insecticides screened against the Nantucket pine tip moth have been non-systemic in action. However, with the introduction of new systemic insecticides, a new method of control for this and related pests exists. Treece and Matthysse (1959) showed that the tip moth could be controlled by using systemic insecticides. Their results with granular applications of Di-Syston and phorate were erratic but phorate granules reduced the number of damaged shoots by 88%. Their results with foliar sprays of phorate and American Cyanamid 12008 (O,O-diethyl S-isopropylthiomethyl phosphorodithioate) gave a substantial reduction of infested shoots. Butcher and Haynes (1960) showed dimethoate, when applied as a foliar spray, to be effective against the European pine shoot moth, Rhyacionia buoliana (Schiff). Kulman and Dorsey (1962) found that phorate and Di-Syston (O,O-diethyl

S-/2-(ethylthio)ethyl/phosphorodithioate) in granular form were effective in controlling this pest and that phorate was superior to Di-Syston in all tests.

GENERAL METHODS AND CONDITIONS

All tests were conducted in an area 0.5 mile in radius, 9 miles west of Stillwater, Oklahoma, and immediately south of Lake Carl Blackwell. The terrain was rolling tall-grass prairie (dominantly Andropogon sp. and Sorghastrum sp.) sectioned by wooded areas (dominantly Quercus stellata and Q. marilandica). Total precipitation, measured 1 mile northeast of the test area, for January - October, 1963, was 24.45 inches. The mean temperature, measured in Stillwater, was 64 °F.

Pine Plantings .

Three plantings or blocks of trees, each a different age, were used for these tests.

The principle test area was a 5.4-acre block of 3-year-old trees, one-half which was planted to loblolly pines (Pinus taeda) and the remainder to shortleaf pines (P. echinata). The trees were spaced at 8 X 6 ft. intervals on grassland with 1-3% slope and Norge loam soil.

A mixed planting of 7-year-old shortleaf and loblolly pines, spaced at approximately 9 X 6 ft. on Norge loam on a 3-5% slope was also used. A great variation in size of trees suggested that some were replacements of a younger age.

The third test area was a planting of 25-year-old pines composed of three species, with no symmetrical planting plan, on 3-5% slope of Zaneis loam. The approximate heights were : loblolly, 34 ft.; shortleaf, 14-16 ft.; and ponderosa (P. ponderosa), 10-12 ft.

Several species of pines, from which data were taken, were located in another area and were spaced at 6 X 6 ft. in 66 ft. square blocks. The approximate heights of the species used were: cluster pines (P. pinaster), 18 to 24 inches; slash pines (P. elliottii), 24 to 36 inches; loblolly and shortleaf pines, 36 to 48 inches. The grass height was approximately 12 inches.

Infestation counts were made on shortleaf pines under hardwood cover. These trees were planted in 1960 through postoak and blackjack timber. No symmetrical planting plan was used. Some were under complete cover while others were planted in the small openings common in such wooded areas. The height of the pines ranged from 18 to 36 inches.

The test for toxic effects of systemic insecticides to common bermuda grass (Cynodon dactylon) was conducted on the campus of Oklahoma State University. The test area was level and the grass had been cut at medium height by reel type lawn mower. The bermuda grass was interspersed occasionally with crab grass (Digitaria sp.).

Measurements

Counts of damaged and undamaged shoots were the common index used to record damage levels of tip moth larvae on each tree. At less frequent intervals, shoots were dissected to determine the percent of population represented by larvae, pupae, and empty pupal cases. Phytotoxicity to the pines was recorded by a visual rating of the extent of foliage "burning". The five ratings with numerical values were: no noticeable effects, 0; very slight "tip burn", 1; light, 2; moderate, 3; heavy, 4; and heavy burn with marked shedding of needles, 5.

Tree height was measured as the distance from the soil surface to the tallest shoot. The length of terminal shoot kill-back by larval damage was in all cases taken from the tallest shoot on the tree. The measurement for shoot kill-back was the distance from the tip of the shoot to the uppermost living needle fascicle on a shoot. The kill-back for uninfested shoots was recorded as 0.

RESULTS

Soil Application Test No. 1

On August 18, 1962, four systemic insecticides were applied to the soil around 3-year-old loblolly pines. The soil within a 5-ft. diameter circle about the tree was pulverized to a depth of 4-6 inches by means of a gasoline-engine driven Rototiller. Granular formulations were applied by using a "shaker jar" made from a quart jar and a screen wire lid. An emulsifiable concentrate was applied with a sprinkler can. After application, the soil was rototilled. Soil moisture at application, and for several weeks thereafter was well below normal.

The results are given in table 1. Phorate and Di-Syston gave a high level of protection during the entire pine tip moth activity season of 1963, a period of approximately 15 months after treatment application. Dimethoate applied as a drench to the soil produced severe foliage "burning" and in combination with other stress factors, caused mortality of one tree.

Soil Application Test No. 2

Six systemic compounds were applied at various rates to the soil surface within the dripline of 3-year-old loblolly pines on June 12, 1963. A band 6 inches wide and 2-3 inches deep was dug within the dripline around each tree to receive the insecticide. Granules were applied with a "shaker jar" and the emulsifiable concentrate, mixed with 2 gallons of water, was applied using a sprinkler can. Eight gallons of

Table 1.--Effectiveness of systemic insecticides, applied in the soil, in the control of the Nantucket pine tip moth on loblolly pines, 1962-1963, Stillwater, Oklahoma.

Treatment[a]		June 6, 1963 Number Damaged Shoots per Tree	Sept. 6, 1963 Per Cent of Shoots Damaged	Oct. 20, 1963 Per Cent of Shoots Damaged
Di-Syston 10% Granules	6 oz	1.5	2.0	7.7
Phorate 10% Granules	6 oz	7.8	0.4	3.2
Dimethoate 4E	8 oz	5.7	10.5	25.2
Meta-Systox-R 5% Granules[b]	12 oz	61.0	83.8	62.8
Untreated	-	52.0	83.5	68.8

[a]Four trees per treatment treated August 18, 1962.
[b]S-2-(ethylsulfinyl)ethyl O,O-dimethyl phosphorothioate.

water were applied to the band of each tree except those receiving dry treatments.

Insect damage records made July 10, 28 days following application, showed granular materials had exerted limited control at best (table 2). Dimethoate liquid formulation demonstrated moderate protection by this date. Data recorded August 12, approximately 2 months following application, showed excellent control by the higher rates of all treatments and by all rates of phorate, Di-Syston, and dimethoate. Bayer 25141 (O,O-diethyl O-p-(methylsulfinyl)phenyl phosphorothioate) gave good to excellent control at the 4- and 6-ounce rates, but only the 6-ounce rates of E.I. 47031 and U.C. 21149 gave such high levels of protection. By October 6, phorate and Di-Syston maintained excellent and good control, respectively, at all application rates. Dimethoate demonstrated complete control at the two higher rates but showed no control at the 2.70-ounce level. Records on Bayer 25141 indicate good to excellent protection for the two higher rates.

Table 2.--Effectiveness of systemic insecticides, applied on the soil, in the control of the Nantucket pine tip moth on loblolly pines, 1963, Stillwater, Oklahoma.

Treatment[a]		Per Cent of Shoots Damaged[b]		
		July 10	Aug. 15	Oct. 6
Di-Syston 10% Granules	6 oz	96.4	2.2	3.2
" " "	6 oz (Dry)	94.3	0.0	1.2
" " "	4 oz	90.9	2.6	4.9
" " "	2 oz	97.7	2.9	6.8
Phorate 10% Granules	6 oz	92.4	0.0	0.0
" " "	6 oz (Dry)	96.3	0.0	0.0
" " "	4 oz	85.1	0.0	0.0
" " "	2 oz	95.1	0.0	0.0
Bayer 25141 10% Granules	6 oz	85.7	0.0	0.0
" " " "	6 oz (Dry)	96.3	4.0	15.5
" " " "	4 oz	83.6	6.0	1.7
" " " "	2 oz	83.6	20.2	45.8
E.I. 47031 10% Granules	6 oz	59.3	0.3	39.5
" " " "	4 oz	60.2	24.5	87.8
" " " "	2 oz	77.4	32.3	87.1
U.C. 21149 10% Granules	6 oz	57.6	0.0	35.4
" " " "	4 oz	67.5	36.7	76.8
" " " "	2 oz	71.7	81.4	85.0
Dimethoate 4E	8 oz	34.8	0.0	0.0
"	8 oz (Dry)	50.8	0.0	0.0
"	5.3 oz	34.0	0.0	0.0
"	2.7 oz	28.9	0.8	77.6
Untreated	-- (Dry)	98.5	93.6	73.0

[a]Treated June 12, 1963. Eight gallons of water added to all treatments not designated as (Dry).
[b]Based on six trees per treatment.

Methods of Application Test

Ten soil application methods, using Di-Syston emulsifiable and granular formulations, were compared in a test initiated June 28-29, 1963, on 3-year-old loblolly pines (table 3). Broadcast treatments involved the distribution of insecticides on the soil surface around the tree from trunk to dripline. The broadcast-in-soil treatment involved

Table 3.--Effectiveness of Di-Syston emulsifiable and granular formulations, applied by different methods to the soil, in the control of the Nantucket pine tip moth, 1963, Stillwater, Oklahoma.

Application Method[a]	Per Cent of Shoots Damaged[b] August 17	October 8
Di-Syston 6E, 1.2 oz in 0.5 Gallon Water Per Tree		
Broadcast-on-soil	5.9	78.6
Broadcast-in-soil	2.0	74.3
Band-in-soil	31.0	79.1
Band-on-soil	6.8	80.2
In 4 holes (Dry)	0.0	64.0
In 2 holes (Dry)	0.7	58.5
Di-Syston 10% Granules, 6 oz Per Tree		
Broadcast-on-soil	6.7	2.0
Broadcast-on-soil (Dry)	16.5	3.8
Broadcast-in-soil	0.1	0.0
Broadcast-in-soil (Dry)	0.0	0.0
Band-on-soil	20.5	0.0
Band-on-soil (Dry)	11.6	0.0
Band-in-soil	8.2	8.1
Band-in-soil (Dry)	6.8	0.6
In 4 holes (Dry)	79.3	49.6
In 2 holes (Dry)	89.2	53.8
Dimethoate 4E, 2 oz Per Tree		
Foliar Spray	3.1	74.2
Check		
Untreated	96.6	73.8

[a]Treated June 28-29, 1963. Eight gallons of water added to all treatments not designated as (Dry).
[b]Based on six trees per treatment.

a second procedure of mixing the insecticide into the soil to a depth of 2-3 inches by use of a hoe. In the band-on-soil treatment, insecticides were applied to the soil surface in a 24-inch circular band, 4 inches in width and centered about the tree. In the band-in-soil treatment, insecticides were placed in a 24-inch circular trench, 4 inches wide and

2-3 inches deep, centered about the tree. Insecticides were also placed in two or four holes, dug with a round-point shovel to a depth of 3-4 inches, that were spaced at uniform intervals in a 24-inch circle centered about the tree. Di-Syston 6E concentrate was mixed in 0.5 gallon of water per tree. All except the dry treatments were wet down with 8 gallons of water per tree, applied to the treated area.

Damage records made August 17 showed liquid Di-Syston gave good to excellent control by all methods except one (table 3). The band-in-soil treatment showed average damage of 31% but included two trees out of six with 2% or less damage. However, records taken on October 8 followed the succeeding generation and showed that the liquid concentrate had lost its effectiveness.

Where Di-Syston granules were applied, the hole method gave no substantial reduction in infestation. Within the other treatments at 50 days after application, several trees were heavily damaged but each had from two to four trees showing 100% control. The data recorded on October 8 showed all but the hole methods giving excellent control.

The foliar spray application of dimethoate 4E gave excellent immediate control but failed completely against subsequent generations.

Dimethoate Soil Test No. 1.

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 and 12 inches per group. Each of the five dosage rates was mixed with 2 gallons of water and applied with a sprinkler can to a 4-inch-wide band, 3-4 inches deep, centered about the tree in a 24-inch circle. Trees in the two groups received identical dosages.

The data recorded on August 24 (table 4) indicated that 2 ounces were required for satisfactory control on the larger trees; whereas, only 1 ounce was needed for excellent control on the smaller size. By October 12, however, a high level of control was maintained by only the 8-ounce rate on large trees and the 4- and 8-ounce treatments on small trees. These higher dosage rates produced phytotoxic effects as can be seen in the table.

Table 4.--Effectiveness of dimethoate 4E, applied in the soil to two sizes of shortleaf pines, in the control of the Nantucket pine moth, 1963, Stillwater, Oklahoma.

Amount of Formulation Per Tree[a]	Phytotoxicity Rating[b]	Per Cent of Shoots Damaged[c] August 24	Per Cent of Shoots Damaged[c] October 12
	Trees with Trunk Circumference of 3.5-6 inches[d]		
0.5 oz	0.5	7.4	56.9
1.0 oz	0.5	0.6	51.0
2.0 oz	1.6	0.0	28.2
4.0 oz	2.1	0.0	0.0
8.0 oz	3.3	0.0	0.0
Untreated	-	86.7	60.8
	Trees with Trunk Circumference of 10-15 inches[d]		
0.5 oz	0.0	31.2	40.6
1.0 oz	0.0	8.5	39.5
2.0 oz	0.0	1.7	31.7
4.0 oz	0.0	0.5	14.8
8.0 oz	2.3	0.0	2.4
Untreated	-	83.7	58.6

[a]Treated July 17, 1963.
[b]Ratings; 0-No phytotoxic effect, 1-Very light, 2-Light, 3-Moderate, 4-Heavy, 5-Very heavy.
[c]Based on eight trees per treatment.
[d]Measurements taken ten inches above the soil.

Dimethoate Soil Test No. 2

Dimethoate 4E and phosphamidon 4E were applied to the soil around 25-year-old shortleaf pines on July 25, 1963. Each treatment was mixed with 2 gallons of water and applied to a 4-inch-wide band of loosened soil centered around the tree at 4 to 5 feet from the trunk. Eight gallons of water were added to each treatment for a total of 10 gallons per tree.

Data recorded at 53 days after application (table 5) indicate that 4 ounces of dimethoate or 8 ounces of phosphamidon were needed for an appreciable reduction of infestation. Because of slow growth of new shoots it was impossible to accurately measure treatment effects on the first generation following treatment.

Table 5.--Effectiveness of dimethoate and phosphamidon, applied at different rates in the soil, in the control of the Nantucket pine tip moth on older shortleaf pines,[a] 1963, Stillwater, Oklahoma.

Amount of Formulation Per Tree[b]	Per Cent of Damaged Shoots[c]
Dimethoate 4E	
0.25 oz	53.9
0.50 oz	53.0
1.00 oz	68.5
2.00 oz	52.2
4.00 oz	13.9
8.00 oz	7.1
Phosphamidon 4E	
2.00 oz	45.6
4.00 oz	40.7
8.00 oz	16.4
Check	
Untreated	65.1

[a]Twenty-five-year-old pines.
[b]Treated July 25, 1963. Damage recorded October 12, 1963.
[c]Based on six trees per treatment.

Foliar Spray Test No. 1

This preliminary foliar spray test was applied to 3-year-old loblolly pines on June 18-19, 1963. Seven of the eight chemicals used were systemic in action. The spray was applied with a 50-gallon John Bean sprayer and a spray-gun equipped with No. 5 disc, at 100 p.s.i. at the rate of 0.66 gallons per minute. A block of 12 pines was sprayed for each treatment. Each tree was sprayed for 10-30 seconds depending on size.

The sprays were applied somewhat late in the life cycle and very little control could be seen by July 10 (table 6). The damage records of August 13 showed that Di-Syston gave excellent control and dimethoate gave substantial reduction in infestation. By October 6, dimethoate had lost its effectiveness but Di-Syston continued to give excellent control.

Foliar Spray Test No. 2

Seven systemics at four rates, plus DDT at the standard rate, were applied as foliar sprays to 3-year-old loblolly pines on July 23, 1963. Ten trees in a block were treated using a 50-gallon John Bean sprayer and a hand boom with two nozzles fitted with No. 9G discs. Each tree was sprayed to saturation using 100 p.s.i.

In contrast to the previous test, these treatments were applied at peak moth emergence. The damage recorded a month following treatment (table 7) shows that good to excellent control resulted from all materials at all rates tested. The following check of October 9, however shows that all treatments had lost their effectiveness.

Table 6.--Effectiveness of systemic insecticides and DDT, applied as foliar sprays, in the control of the Nantucket pine tip moth on loblolly pines, 1963, Stillwater, Oklahoma.

Treatment[a]		Spray Concentration Per Cent[b]	Per Cent of Shoots Damaged[c] July 10	August 13	October 6
Meta-Systox-R	2E	0.6	71.1	84.9	----
E.I. 47031	3E	0.6	62.1	57.9	----
Dimethoate	4E	1.2	68.3	25.5	83.6
Phosphamidon	4E	1.2	68.4	73.7	----
Di-Syston	6E	0.6	74.5	0.0	0.0
Bidrin[d]	2E	0.6	70.5	89.8	----
Shell 4072	2E	0.6	71.9	60.8	----
DDT	2E	0.2	81.9	95.5	----
Untreated		----	89.7	91.2	73.0

[a]Treated June 18-19, 1963.
[b]Applied with power sprayer and gun with No. 5 discs at 100 p.s.i.
[c]Based on twelve trees per treatment.
[d]3-hydroxy-N,N-dimethyl-cis-croton-amide dimethyl phosphate.

Weekly Spray Tests

Each week following the previous test an additional 12 trees were sprayed with a single application of dimethoate at the recommended dosage to determine the effect on control level of application date in relation to moth emergence. The application procedure used in the above test was followed.

The first application, applied at peak moth emergence, shows an effective reduction in damaged tips (table 8). The following application gave somewhat less control and the remaining two applications showed no control.

Table 7.--Effectiveness of systemic insecticides and DDT applied as foliar sprays at different rates, in the control of the Nantucket pine tip moth, 1963, Stillwater, Oklahoma.

Treatment[a]		Spray Concentrations Per Cent	Per Cent of Damaged Shoots[b] August 20	October 9
Meta-Systox-R	2E	0.06	7.6	82.3
		0.12	13.1	80.7
		0.18	5.8	82.8
		0.25	3.8	73.6
Shell 4072	2E	0.06	6.6	71.6
		0.12	4.5	76.0
		0.18	2.4	79.1
		0.25	1.9	66.2
E.I. 47031	3E	0.06	4.0	78.2
		0.12	6.3	76.3
		0.18	10.6	81.8
		0.25	2.7	75.3
Phosphamidon	4E	0.16	9.7	79.7
		0.12	9.2	81.2
		0.18	13.1	68.1
		0.25	4.4	78.7
Dimethoate	4E	0.06	11.5	80.4
		0.12	13.7	83.3
		0.18	14.4	77.8
		0.25	6.9	79.5
Di-Syston	6E	0.06	12.2	79.3
		0.12	7.5	80.0
		0.18	11.0	69.6
		0.25	9.0	71.0
Bidrin	2E	0.06	12.9	86.3
		0.12	3.0	77.7
		0.18	3.3	77.0
		0.25	6.3	75.9
DDT	2E	0.12	18.5	79.1
Untreated		-	95.8	53.4 ?

[a]Treated July 23, 1963.
[b]Based on ten trees per treatment.

Table 8.--Effectiveness of a single application of dimethoate 0.12% spray, applied at different dates, in the control of the Nantucket pine tip moth, 1963, Stillwater, Oklahoma.

Date of Application	Per Cent of Shoots Damaged August 26[a]
July 23	13.7
July 30	21.7
August 9	88.3
August 15	95.4

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

Grass Toxicity Test

On August 8, 1963, ten systemic insecticides were applied at three rates to common bermuda grass to determine their phytotoxicity. Each treatment was applied to a 3-ft. square plot with adjacent 6-ft. square untreated plots. Each treatment was replicated three times in randomized blocks. One gallon of water was added following application of the granular formulations with the "shaker jar". The liquid concentrates were mixed with 1 gallon of water and applied with a sprinkler can.

The results (table 9) indicate that all the granular materials were virtually non-toxic to bermuda grass at these rates. Only phorate produced as much as very light burn. Except for Bidrin 2E, all emulsifiable concentrates tested proved phytotoxic to some extent. The burning effect of some materials became more intensified with time, whereas, others less toxic. Dimethoate produced the heaviest burn and phosphamidon the lightest.

Table 9.--Toxicity of systemic insecticides to a common bermuda grass lawn, 1963, Stillwater, Oklahoma

Treatment[a]		Amount of Formulation	Phytotoxicity Rating[b]-August 10	Phytotoxicity Rating[b]-August 15
Phorate 10% Granules		6 oz	0.3	1.2
" " "		4 oz	0.5	1.2
" " "		2 oz	0.3	0.0
U.C. 21149 10% Granules		6 oz	0.0	0.0
" " "		4 oz	0.0	0.0
" " "		2 oz	0.0	0.0
Bayer 25141 10% Granules		6 oz	0.0	0.0
" " "		4 oz	0.0	0.0
" " "		2 oz	0.0	0.0
Di-Syston 10% Granules		6 oz	0.0	0.0
" " "		4 oz	0.0	0.0
" " "		2 oz	0.0	0.0
DiSyston	6E	0.80 oz	2.0	3.0
"	"	0.53 oz	0.8	2.2
"	"	0.27 oz	0.0	0.8
Dimethoate	4E	2.00 oz	4.6	5.0
"	"	1.33 oz	4.0	4.5
"	"	0.67 oz	3.2	4.0
Phosphamidon	4E	2.00 oz	1.3	0.3
"	"	1.33 oz	1.0	0.0
"	"	0.67 oz	0.0	0.0
Meta-Systox-R	2E	4.00 oz	3.3	2.2
"	"	2.67 oz	2.0	0.8
"	"	1.33 oz	1.2	0.0
E.I. 47031	3E	1.60 oz	1.6	0.6
"	"	1.07	1.0	0.0
"	"	0.53 oz	0.0	0.0
Bidrin	2E	0.60 oz	0.0	0.0
"	"	0.40 oz	0.0	0.0
"	"	0.20 oz	0.0	0.0
Shell 4072	2E	2.40 oz	3.6	2.6
"	"	1.60 oz	3.5	2.5
"	"	0.80 oz	2.2	2.2

[a]Treated on August 8.

[b]The phytotoxicity rating used was as follows: 0-No phytotoxic effect, 1-Very light burning, 2-Light burning, 3-Moderate burning, 4-Heavy burning, 5-Completely killed.

Height Growth

Measurements were taken for comparison of growth in height of treated and untreated pines in Soil Test No. 2 and the Dimethoate Soil Test No. 1. The results may be found in tables 10 and 11, respectively.

Table 10.-- Gain in height for loblolly pines treated with systemic insecticides applied to the soil in the control of the Nantucket pine tip moth, 1963, Stillwater Oklahoma.[a]

Treatment[b]		Average Gain (Inches)
Di-Syston 10% Granules	6 oz	8.3
" " "	6 oz (Dry)	5.8
" " "	4 oz	8.5
" " "	2 oz	3.2
Phorate 10% Granules	6 oz	6.3
" " "	6 oz (Dry)	6.3
" " "	4 oz	11.1
" " "	2 oz	7.2
Bayer 25141 10% Granules	6 oz	11.8
" " "	6 oz (Dry)	5.5
" " "	4 oz	9.7
" " "	2 oz	7.2
E.I. 47031 10% Granules	6 oz	11.8
" " "	4 oz	8.3
" " "	2 oz	3.0
U.C. 21149 10% Granules	6 oz	13.6
" " "	4 oz	10.5
" " "	2 oz	6.0
Dimethoate 4E	8 oz	13.1
" "	8 oz (Dry)	13.3
" "	5.3 oz	14.0
" "	2.7 oz	7.3
Untreated	--- (Dry)	1.2

[a]Based on six trees per treatment. Measurements taken October 25, 1963. Eight gallons of water added to all treatments not designated as (Dry).

[b]Treated June 12, 1963.

Table 11.--Gain in height of pines treated with Dimethoate 4E, applied in the soil to two sizes of shortleaf pines, in the control of the Nantucket pine tip moth, 1963, Stillwater, Oklahoma.[a]

Amount of Formulation Per Tree[b]	Average Gain
Trees with Trunk Circumference of 3.5-6 Inches[c]	
0.5 oz	12.9
1.0 oz	10.2
2.0 oz	14.3
4.0 oz	12.8
8.0 oz	14.2
Untreated	8.1
Trees with Trunk Circumference of 10-15 Inches[c]	
0.5 oz	16.5
1.0 oz	14.1
2.0 oz	13.7
4.0 oz	15.1
8.0 oz	15.1
Untreated	12.3

[a]Based on eight trees per treatment. Measurements taken November 8, 1963.
[b]Treated July 17, 1963.
[c]Measurements taken ten inches above the soil.

Table 10 shows that the difference in average gain in height between treated and untreated pines ranged from 1.8 to 12.8 inches within treatments. The average gain in height for all the treated pines was 7.5 inches greater than the untreated. Table 11 shows the range in difference between treated and untreated in this test to be 2.1 to 6.2 inches for the smaller pines and 1.4 to 4.2 inches for the larger pines.

For both sizes, the combined average difference between treated and untreated was 3.7 inches.

Damage to Untreated Older Trees

Three species of 25-year-old pines were sampled on July 10, 1963, to compare infestation levels. A 12-ft. pruning hook was used to cut three branches, 12 to 15 inches long, from the upper area and three from the lateral area of the pines. The samples were taken to the laboratory where each shoot was examined for damage.

The upper portion of the shortleaf and loblolly pines received more damage than the lateral portions (table 12). The ponderosa pines show an opposite trend. However, the differences between upper and lateral portions of all species was not great. The combined damage was intensive for the shortleaf pines and only minor for the other two species.

Different Species and Damage

Damage records were taken on several species of 2-year-old pines on September 23-24, 1963. All shoots on each tree were recorded as damaged or undamaged (table 13). The cluster pines showed the lowest percentage of damaged shoots with 5.1% followed by the slash pines at 26.1%. The remaining types showed intensive damage.

Effects of Hardwood Cover

To show the effects of hardwood cover on the incidence of the tip moth, damage records from shortleaf pines in this particular habitat were compared with those taken on shortleaf pines in the open planted experimental growth plots. Though the ages varied slightly, the size and average number of tips corresponded more closely.

Table 12.--Damage by the Nantucket pine tip moth on three untreated species of 25-year-old pines, July 10, 1963, Stillwater, Oklahoma.[a]

Species	Per Cent of Shoots Damaged: Side of Tree	Top of Tree	All Shoots
Shortleaf	61.6	86.8	73.9
Ponderosa	7.6	2.9	5.4
Loblolly	2.6	9.3	5.6

[a]Based on three samples from sides and three from tops taken from thirteen shortleaf, seven ponderosa and six loblolly pines.

Table 13.--Damage by the Nantucket pine tip moth on 2-year-old pines of different species, September 23-24, 1963, Stillwater, Oklahoma.

	Slash Pine	Loblolly Pine, Texas Variety	Shortleaf Pine	Cluster Pine	Loblolly Pine
Per Cent of Shoots Damaged	26.1	88.8	90.0	5.1	93.1

[a]Based on 20-40 trees per species.

A high damage rate of 90.0% occurred on open planted pines, which is not uncommon for this immediate area, contrasted with only 12.1% for those pines planted in hardwoods.

DISCUSSION

Considering the cost of chemicals, labor and the periods of protection obtained in this program, the use of systemic pesticides to control tip moth is certainly practicable on pines in ornamental plantings or in nurseries. This method of control has certain advantages over the use of a contact poison such as DDT which is currently recommended for this pest. The successful use of a contact insecticide requires a minimum of three or four spray applications per season in this area. Planning, observation and judgement are involved in properly timing the application since each must be made early in the oviposition period in each of the tip moth generations. Results from this study show that the problem of timing can be essentially eliminated by making a single application of a systemic compound during the latter part of the growing season which will give protection for the entire succeeding year. On the basis of current chemical and labor prices the costs for the two methods do not differ greatly and the systemic method is much more convenient.

Currently, the lumber and pulp industries cannot be assured that control of the tip moth is economically feasible. Until this fact is determined, work will include a search for cheaper chemicals and methods that more efficiently utilize chemicals in an effort to reduce the cost of treatment.

All toxicants tested resulted in an appreciable reduction of infestation although the period of protection in certain cases was of short duration. Phorate and Di-Syston were the most effective, giving almost complete protection for well over one year. In the two tests with phorate, 100% control resulted. Dimethoate gave a high level of control but for somewhat shorter periods at the low dosage rates. Other promising materials were Bayer 25141, U.C. 21149, E.I. 47031, phosphamidon and Bidrin.

Granular formulations applied to the soil generally gave longer periods of protection than liquid formulations applied as drenches to the soil or as foliar sprays. Broadcast applications in the soil of Di-Syston in granular and emulsifiable formulations showed excellent control 49 days following treatment. At the end of an additional period of 52 days, granular-treated trees had no infested shoots but drench-treated trees had infestations equal to untreated trees.

Long residual action can be obtained by soil application of granular systemics but control is not immediate. Granular formulations of five toxicants applied to the soil showed moderate to no control at 28 days and excellent control by 64 days following application (table 2). In a second test Di-Syston granules established excellent control within 48 days following treatment. Dissections made at this test, 25 days after application, showed several dead larvae on and in shoots indicating that concentrations of systemics in the trees had reached toxic levels by that time.

The incorporation of the granules into the soil, as opposed to placing the material on the soil, increased the immediate effects of Di-Syston somewhat but had no significance in the long-term results. The addition of water to the treatments caused little increase in immediate action, nor did it affect the long-term results.

It appears that no difference exists between the methods of applying granules in a band around the pines or broadcasting them about the trees. Spot application by the hole method, however, was quite unsuccessful which demonstrates the importance of good distribution.

Drenches of liquid systemic concentrates added to the soil appeared to become systemically active sooner than granular materials. Drenches of dimethoate 4E gave quicker action than granular formulations of other toxicants (table 2). Dissections of shoots from six treatments of liquid Di-Syston had an average of 13 dead larvae and 10.5 living pupae 25 days following application. In the same test and at the same time, similar averages for ten treatments of granular Di-Syston were 7.7 dead larvae and 17.5 living pupae. Although more rapid results were achieved with liquid formulations, the effective period of Di-Syston 6E and low dosage rates of dimethoate 4E were quite short.

The application of systemic insecticides as foliar sprays was quite successful in immediate control of the tip moth larvae when applied at the time of peak moth emergence. Little difference existed between the compounds tested when applied during this period. It is possible that applying the systemics as foliar sprays after the entrance of the larvae into the shoots was also effective but such results are not practical since the damage was already inflicted. The foliar sprays, except where high concentrations of Di-Syston and dimethoate were used, were short-lived which eliminated the possibility of controlling the succeeding generation, even when applied between moth emergences. Di-Syston, at this high concentration, showed excellent control of the subsequent two generations and was still effective at the end of the season. Dimethoate showed only limited effectiveness against the next generation.

DDT, applied at the standard rate, was reasonably effective when applied at peak moth emergence but it appeared that, generally, better control was received with the foliar spray applications of systemic insecticides.

Dimethoate 4E was tested as a soil treatment to determine if effective dosage rates were correlated with tree size (table 4). The averages for the two size groups of pines indicate the effective rates were roughly proportional to the trunk circumference; that is, a two-fold increase in circumference required a two-fold increase in dosage (table 4). The same trend appeared to apply to 25-year-old trees (table 5).

The duration of effectiveness was also affected by tree size. Again, approximately twice the amount of toxicant was needed to maintain effectiveness on the large shortleaf pines as on the smaller ones.

Dimethoate was the only systemic insecticide tested that showed definite toxic effects on pines. Various degrees of "burning" occurred, varying from slight needle "tip burn" to heavy needle burn in cases where high dosage rates were used, resulting in heavy needle shed. When the dosage rate was reduced to prevent phytotoxicity, the result was a reduction in the length of the effective control period. The phytotoxicity was primarily confined to the treatments applied to the soil.

The toxicity of systemic insecticides to bermuda grass lawns should be considered when treating ornamental pines. Discretion is particularly needed where liquid formulations are used. Tests indicate that all liquid materials included in this program, with the exception of Bidrin 2E, were toxic to common bermuda grass to some degree. Conversely, [illegible] among the granular materials included, only phorate gave as much as very light burn.

The variation in height growth between treated and untreated 3-year-old loblolly pines was quite significant. On the other hand, the difference for 7-year-old shortleaf pines was small. The infestation level was only slightly less for the 7-year-old trees, indicating that the smaller difference between treated and untreated cannot be attributed to this factor alone.

The overall infestation levels for the 25-year-old shortleaf pines were very heavy but were light or negligible on loblolly and ponderosa pines of the same age. However, shortleaf and loblolly pines 2-3 years old showed high infestations that were approximately equal. This indicates that age and height has little effect on the incidence of the tip moth on shortleaf pines. Where loblolly pines are concerned however, age and height appear to affect either the resistance of the trees to the pest or the preference of the pest for the trees.

Certain species of pines, it is known, are more resistant to damage by tip moth than others. The actual reason for this resistance is not clear but the fact that it does exist is an incentive to select such a species for planting. However, other factors must be considered also. Cluster pine has shown a high degree of resistance to tip moth in these counts. However, not much is known about growth rate in this immediate area. As compared to shortleaf and loblolly it is a slow starter. The seed source for this tree is a low rainfall area of Spain. Slash pine, also somewhat resistant, is a native of the extreme southern United States where high rainfall is common. It is considered as a fast grower and does very well in this area. The main disadvantage, it seems, is its susceptibility to ice damage. Ponderosa pine shows high resistance to the tip moth in this region but is a slow grower.

It has been shown by several workers that planting of pines under hardwood cover creates an inhibiting factor for the tip moth. The damage recorded for the pines in this situation was much lower than that for those planted in open areas. Though cover does reduce the incidence of this insect, it appears that competition with the oaks may create other limiting factors for growing pines in this manner.

SUMMARY

The investigation included the evaluation of several systemic insecticides for control of the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock), and to determine their effective rates, methods of application and phytotoxicity. The investigation also included height growth of treated and untreated pines, damage to older untreated pines, effects of planting under hardwood cover and variation in damage due to pine species.

All toxicants tested resulted in an appreciable reduction of infestation although the periods of protection in certain cases was of short duration. Granular formulations of phorate and Di-Syston were the most effective, giving almost complete protection for well over one year. Phorate was slightly superior to Di-Syston. Dimethoate gave a high level of control but for somewhat shorter periods at the low dosage rates.

Granular formulations, applied to the soil, generally gave longer periods of protection than liquid formulations applied as drenches to the soil or as foliar sprays. The liquid formulations usually gave more immediate control than the granules. The addition of water to treatments had little effect. Spot application was unsuccessful which demonstrated the importance of good distribution of toxicants.

Application of systemics as foliar sprays was quite successful in immediate control when applied at peak moth emergence but exhibited, in

most cases, short effective periods. Standard applications of DDT, though reasonably effective when applied at peak moth emergence, were generally not as successful as foliar application of systemics.

Residual periods and effective dosage rates of dimethoate as soil treatments appeared to be roughly proportional to trunk circumference. Dimethoate was the only systemic insecticide that showed definite phytotoxic effects to pines. All liquid materials tested in this program, with the exception of Bidrin 2E, were toxic to common bermuda grass. Conversely, among the granules tested, only phorate gave as much as very light effects.

The variation in height growth between treated and untreated 3-year-old pines was quite significant but the difference was small for 7-year-old pines. Infestation levels for 25-year-old shortleaf pines were very heavy but light or negligible for loblolly and ponderosa of the same age. Little difference existed between 2- to 3-year-old shortleaf and loblolly pines. Cluster pines showed the highest degree of natural resistance to the pest and slash pines were also somewhat resistant. The damage recorded for pines planted under hardwood cover was much lower than for those planted in open areas.

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