EFFECTIVE DURATION OF SYSTEMIC INSECTICIDES

APPLIED BY VARIOUS METHODS ON THE

NANTUCKET PINE TIP MOTH,

Rhyacionia frustrana

(Comstock)

By

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PREFACE

Systemic insecticides were tested by various methods for control of the Nantucket pine tip moth in 1962 and 1963 by R. R. Walton and Robert L. Burton. Further work was needed to determine the effectiveness and duration of materials applied in 1962 and 1963. Also, it was deemed advisable to conduct tests with some of the newer systemics and investigate newer application methods. Seasonal development of the tip moth and pine transplant tests were also brought into the study. Tests by injection of non-systemic solutions into trees and foliar sprays of thuricide, a microbial insecticide, were also performed.

The author wishes to express his sincere graditude to Dr. R. R. Walton, his major adviser, for his leadership, thoughtful guidance and advice throughout the course of this study and in preparation of this manuscript. Grateful acknowledgement is expressed to other members of the committee, Dr. Harvey L. Chada, Professor and Research Entomologist, Entomology Research Division, U.S.D.A., and Dr. Ralph S. Matlock, Professor of Agronomy, for their constructive criticism of the thesis. I am grateful also to the entire Department of Entomology at Oklahoma State University for its co-operation throughout this study.

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INTRODUCTION

The Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock), a common pest of pines, is present each year in the eastern and southeastern United States. DDT is the presently recommended insecticide for control of this pest. However, with the introduction of new systemic insecticides, a potential new method of control for this pest became available.

Observations and tests were conducted over a two-year period following studies made in 1963 by R. R. Walton and Robert L. Burton. The objectives of the investigation reported in this thesis were to provide more information on the effectiveness and duration of systemics applied by various methods to pines in control of the pine tip moth.

Some controversy is involved as to whether or not the damage inflicted to pines by the pine tip moth is of a temporary nature. However, most published material contends this damage is not temporary but has permanent consequences. There appears to be no practical method at this time for control of this pest on a large scale. Where relatively small areas are involved, such as small ornamental plantings or nurseries, trees free of infestation are greatly desired. Under these circumstances the costs of control by systemic insecticides may be borne.

REVIEW OF LITERATURE

Distribution: The distribution of the important species of the genus Rhyacionia was given by Yates in 1960. The range of the Nantucket pine tip moth, R. frustrana (Comstock), is an area covering the east-southeast portions of the United States. The northern boundary is along a line running through the middle of the state of New York, eastward to the Atlantic Coast. The southern boundary is the Gulf Coast with the exception of an area on the tip of Florida. The western most point of development is in Oklahoma with the boundary line running northeast through Missouri, Illinois, Ohio, and Indiana, and southeast through Texas to the Gulf Coast. A variety of the pine tip moth, R. frustrana var. bushnelli (Busck), has been reported in Montana, Michigan, North Dakota, South Dakota, Nebraska, New Mexico and Arizona. It is larger than R. frustrana, and the larva, prior to pupation in the fall, drops to the ground and pupates in the litter; the Nantucket pine tip moth overwinters as a pupa in the young shoots on the host tree. According to Heinrich (1923), R. frustrana var. bushnelli is the result of R. frustrana developing, over a number of generations, on a local host plant, Pinus ponderosa var. ponderosa. The European pine shoot moth, R. buoliana (Schiff), is an introduced species found in the northern range of R. frustrana and is commonly found in the southeastern portion of Canada. Presently, ten species of Rhyacionia are known to exist in the United States, five of them within the Nantucket pine tip moth's range. The remaining five species, including R. frustrana var.

bushnelli (Busck), are found in the western and midwestern parts of the United States. All have the same general habits and inflict injury by boring into buds and young stems of various pines (Yates 1960).

Biology: Craighead (1950) reported the insect as having only one generation per year in the northern portions of its range, but that two generations were present in Pennsylvania. Stearns (1953) reported that two generations were present, also, in southern New York and northern Virginia, and that the first activity period in this area started in mid-April and continued to mid-May. The second and shorter generation began in late June and ended in early July. Polivka (1936) reported that two generations occurred in southern Ohio, and that "the 1935 first-generation adults of the Nantucket pine tip moth began to emerge in April and those of the second generation in July. The overwintering pupae were found as early as August."

Three generations were found in southern Tennessee, Virginia, North Carolina, and South Carolina, with a possible fourth generation developing in South Carolina (Mortimer, 1941; Underhill, 1943; Beal, 1952 and Flory et al. 1955).

Afanasiev and Fenton (1947) working in Oklahoma observed that three complete generations and a partial fourth generation occurred. The remaining pupa became lodged within the tips where they remained until the following spring.

Bennett (1955), while working in east Texas, reported that four generations were observed. Craighead (1950) indicated that four generations were also present in Louisiana. Yates (1960) suggests that more than four generations may occur in the southern portions of the Gulf States.

Life History: The elliptical eggs are laid singly in the axles 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 before 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. First instar larvae feed around the base of the needles and 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 are from 8.0 to 8.5 mm in length and are light brown to orange in color. They are generally found boring through the heart of the tip or stem of both, where pupation occurs. The pupae are light brown when first developed but turn darker as they mature. They are approximately six mm in length. As the pupa develops it works itself part-way out of the stem where the adult can escape uninjured. The genus *Pinus* is the prefered host of this insect, and all species are attacked except two: eastern white pine, *P. strobus* L. and longleaf pine, *P. palustris* Mill. (Underhill 1943, and Yates 1960).

Damage: Reports have been made concerning damage caused by infestations of the Nantucket pine tip moth since 1879, when Scudder reported that every new shoot of the trees examined on Nantucket Island, Mass. had been killed by its attack. Damage to the pines is directed to the new buds and terminal shoots where it can produce serious effects to the tree (Yates 1960).

In the southern ranges heavy infestations and conspicuous injury to loblolly, _P. taeda_, and shortleaf, _P. echinata_ (Mill.) pines, were observed. Retardation in height growth had been reported by Wakely (1954), who also concluded, "the insects seldom kill a tree, and, in general, visible evidence of injury practically disappears before the trees reach minimum pulpwood size." Beal (1952) reported that a "dwarfted bushy appearance" resulted from the insects attack. Yates (1960) indicates that tree mortality can result due to a combination of heavy infestation and other unfavorable factors.

Control: The original control recommendations for the Nantucket pine tip moth involved building bonfires at night to attract and kill the adults and picking and burning all infested tips (Scudder 1879). Since that time many control procedures have been used to curb the attack of this pest. The development of DDT was the first real break-through in chemical control of the pine tip moth. Fenton and Afanasiev (1946) reported that spray applications of DDT gave excellent control at the 0.48 per cent concentration. They indicated that timing was important and that two to four treatments per season, depending on the area to be treated, were necessary to give protection. When various other organic insecticides and chlorinated hydrocarbons were tested, similar results 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 may be practical in plantations where the value of the trees and the damage justify the cost.

The measure for determining effectiveness of the various control treatments was in terms of larvae killed or in the number of buds infested or uninfested. About 1955 workers realized that measurement of height growth was needed to fully evaluate their tests. Kramer (1943) reported that "height growth is determined by the interaction of hereditary potentialities and environmental factors." This may explain why Foil et al. (1961) reported that foresters had suggested, that damage to small trees merely slows height growth temporarily, and that this disadvantage is overcome by more rapid height growth once the trees are tall enough to escape severe damage. In laboratory studies Kramer (1957) was able to demonstrate effects of thermoperiodism in trees. The behavior of two-year-old seedling loblolly pines showed that an increase in day temperature was accompanied by increase in shoot growth, but an increase in night temperature was accompanied by decrease in shoot growth. The most growth was made with the greatest difference between day and night temperatures. This would indicate two periods of growth during one season, early spring and late fall. Zanher (1962) demonstrated, under simulated field conditions, that an early spring and late fall period of growth were present in pines.

The development of systemic insecticides has opened a new field of plant protection. Bennett (1957), after reviewing the literature concerning plant physiological mechanisms connected with the use of systemics, indicated that physiological and biochemical processes of the plant governs the insecticidal efficiency of the systemic insecticides.

A thorough understanding of how systemic insecticides, applied to the soil, are transported through the system of a tree has not been reported in the literature. Harris (1961) demonstrated water-conduction in the stems of pines by using aqueous solutions of acid fuchsin, reduced basic fuchsin, and safranin dyes. Trees grown in the laboratory were placed in nutrient solutions containing one of the dyes and left from one to five days. Dissection of the tissue revealed that water conduction was restricted to the early wood. He stated, "Continuity between the transpiring leaves and the roots is only possible along those growth-layers penetrated by the traces of the living needle." Kozlowski et al. (1965) reported in a similar study that the medullary rays were heavily stained with dye. This suggests an efficient radial conduction of water across the late wood of the outmost annual ring into the phloem ray cells. Kozlowski et al. (1965) and Harris (1961) both reported dyes to be present throughout the water conducting systems. Kozlowski et al. (1965) indicated that higher intensity of staining in the xylem of the lower parts of the pines was an indication of greater velocity of the flow through the lower branches. He believed this was due to the large number of needles on lower whorls. Scholander (1957) reported that upward water movement in trees follows the path of least resistance, in the early wood in the case of pines. Mirov (1957) suggests that oleoresin is the end product of tree metabolism, which is heavily supported by the water-conduction system within the tree.

The water content level of the eastern white pine, _P. strobus_ L., was found by Gibbs (1957) to vary considerably during the season. The water content decreased from 124 to 80 per cent of dry-weight between January and early May. The May low of 80 increased to 132 per cent by the first week of June, where a plateau was observed until early July. From July there was a moderate increase from 132 to 146 per cent with the maximum being reached in late September. A steady decrease from 146 to 120 per cent followed into early November with a small increase from 120 to 127 per cent by the middle of December. This was followed by a decrease into January of the following year.

The literature on the use of systemics for control of forest insects is limited. Truce and Matthysee (1955) showed 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. thunbergii Parl. The results were erratic for disulfoton, but phorate gave an 88 per cent reduction in damaged shoots per plant. Butcher and Haynes (1960) applied dimethoate as a foliar spray to pines for control of the European pine shoot moth, R. buoliana (Schiff). A spring application was effective in controlling the larvae in three locations in Michigan. 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 formulations of disulfoton and phorate, but control with phorate was superior to disulfoton. The period of effectiveness was not determined for these studies.

Rudinsky (1959) reported that demeton, Dimefox, and phorate introduced through a hole bored in the trees were effective and fast in controlling larvae of the balsam gall midge on balsam fir. Larvae of the red-headed pine sawfly on red pines were controlled with similar success, but Dimetox was phytotoxic. Coppel and Norris (1960) obtained good control of the introduced pine sawfly on white pines by injections of systemic insecticides into trees. Phorate, demeton, and Chipman-R-6199 gave good control of the first generation at the rate of eight grams of technical systemic per tree. Injections with dimethyl sulfoxide (DMSO) in solution with various non-systemic insecticides were carried out by Harries (1965) on fruit trees. He reported observing noticeable burning of leaf margins and lesions on the leaf surfaces at all concentrations tested.

Johnson and Rediske (1965), in a review of the literature and of their own work on systemic insecticides in woody plants, stated that the transpiration rate of plants affects the rate of translocation of chemicals and that knowledge was needed in nine specific areas concerning systemics.

GENERAL METHODS, MATERIALS, AND CONDITIONS

These studies were conducted, in pine plantations on Oklahoma State University property, 9 miles west of Stillwater, Oklahoma, and from 1/4 to 1 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. marilandica*. Annual precipitation 1 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 I). 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 one-year-old transplants to 27-year-old trees.

The major test area was a 5.4-acre block of trees that was reportedly two-years old in 1962 when the initial systemic insecticide applications were made. Loblolly pines 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 having a 1-3 per cent slope. The soil was a Norge loam.

The second group of trees, a mixed planting of seven-year-old shortleaf and loblolly pines, were those used in 1963. The spacing

TABLE I

PRECIPITATION[a] RECORDS AND MEAN AIR TEMPERATURES[b], 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	

[a]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

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

between trees was six feet within the rows and nine feet between the rows, and the soil was Norge loam with a surface slope of 3-5 per cent.

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 per cent.

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, and the systemics were applied, on Norge loam with a 3-5 per cent slope. The entire area was heavily terraced. One week prior to the planting date approximately one-half of the assigned area was accidentally burned off, and the remaining one-half had 12-15 inches of grass above the ground surface.

<u>Measurements</u>: Seasonal development was recorded during 1964 and 1965 to extend the observations of Fenton and Afanasiev (1946). The major indexes used were moth emergence records made throughout the season and, to some extent field infestation records.

Counts were made of damaged and undamaged shoots on each tree to determine the effectiveness and duration of the systemic insecticides applied. The per cent of damaged shoots compared to the data from untreated trees, showed the effectiveness of the systemic insecticide applied. The duration of a treatment was determined when these records were established over a period of time. Phytotoxicity to pines was recorded by a visual rating of the extent of foliage "burning." The five ratings with numeral values were: no noticeable effects, 0;

very slight, "tip burning," 1; light, 2; moderate, 3; heavy, 4; and heavy burn with marked shedding of needles, 5.

Data on the chemicals tested and methods of application, along with one test using Bacillus thuringiensis (Berliner) are presented in Table II.

Seasonal Development: Emergence records were taken during 1964 and 1965 to study the seasonal development of the Nantucket pine tip moth. The purpose was to determine by generations the (1) number of generations, (2) length of emergence periods, (3) peak emergence for each generation, (4) population intensity and, (5) the possibility of any overlapping of generations.

The emergence chamber used for the 1964 study was a Berlese funnel (4 ft x 2 ft diameter) placed on its side, with a heavy black cloth sleeve closing the large open end and a pint jar screwed into place at the smaller "funnel shaped" end. One hundred damaged shoots were cut each week, throughout the activity season, and placed within the emergence chamber. The shoots were placed upright in labeled open 1/2 pint ice cream cartons which were partially filled with moist sand to retard dessication of the shoots and larvae and pupae that were within the shoots. The shoots were held in the funnel for a five-week period after cutting and then discarded. Moths that emerged from the shoots were attracted to the light and flew into the jar where they were collected every four days. The emergence chamber was located on a stand, three feet from the ground and under a shed to protect it from direct sunlight. The shed was eight feet high and open on all sides to permit good air circulation.

The emergence apparatus designed for the 1965 seasonal development

TABLE II

A SUMMARY OF MATERIALS USED IN CONTROL TESTS OF THE NANTUCKET PINE TIP MOTH 1962-1965, STILLWATER, OKLAHOMA

Formulation		Chemical Definition	Methods	Years Observed	Comparative Effectiveness
Bayer 25141	6E	0,0 diethyl 0-p-(methylsulfinyl) phenyl phosphorothioate	Spray-drench	1	Excellent
"	10G		Broadcast	3	Good
"	5G		Broadcast	1	Good
Baygon	2E	o-isopropoxyphenyl methylcarbamate	Spray-drench	1	Good
"	5G		Broadcast	1	Good[a]
Bidrin	2E	3-hydroxy-N,N-dimethyl-cis-crotonamide dimethyl phosphate	Foliar Spray	2	No Control
"	6E		Injection	2	No Control
disulfoton	6E		Foliar Spray	2	Poor
"	"		Spray-drench	3	Good
"	"		Soil Drench	2	Excellent
"	"		Injection	2	No Control
"	"		Bored Hole	2	No Control
"	"		Painton	2	No Control
"	"		Broadcast	4	Excellent
dimethoate	4E		Foliar Spray	2	No Control
"	"		Spray-drench	3	Fair[a]
"	"		Soil Drench	4	Good[a]
E I 47031	3E	2-(diethyoxyphosphinylimine) 1-3-dithiolane	Foliar Spray	2	No Control
"	"		Spray-drench	3	Poor
"	10G		Broadcast	1	Poor

Table II (Continued)

Formulation		Chemical Definition	Methods	Years Observed	Comparative Effectiveness
G C 6506	4E	dimethyl p-(methylthio) phenyl phosphate	Spray-drench	1	No Control
G C 9879	4E		Spray-drench	2	Poor
G S 13005	4E	phosphorodithioic acid 0,0-dimethyl S-[(2-methoxy-5-oxo-Δ^2-1,3,4-thiodiazoly-4-yl) methyl]-ester	Spray-drench	2	Poor
methyl demeton	2E		Foliar Spray	2	No Control
" "	"		Spray-drench	3	No Control
" "	5G		Broadcast	4	No Control
Niagara 10242	8W	2,3-dihydro-2,2-diethyl-7-benzofuranyl methylcarbamate	Spray-drench	1	Excellent
" "	10G		Broadcast	1	Good
phorate	10G		Broadcast	4	Excellent
phosphamidon	4E		Foliar Spray	2	No Control
"	"		Spray-drench	3	No Control
"	"		Soil Drench	3	Poor
"	8E		Spray-drench	1	Poor
Shell S D 4072	2E	2-chloro-1(2,4-dichlorophenyl) vinyl ethyl phosphate	Foliar Spray	2	Poor
"	"		Spray-drench	3	Poor
Shell S D 9129	3E	3-hydroxy-N-methylcrotonamide dimethyl phosphate (an analogue to Bidrin)	Spray-drench	2	Fair[a]

Table II (Continued)

Formulation		Chemical Definition	Methods	Years Observed	Comparative Effectiveness
Thiocron	3E	0,0-dimethyl-S(2-methoxyethyl-carbamoyl-methyl)-dithiophosphate	Spray-drench	1	Good
"	5G		Broadcast	1	Good
U C 21149	10G	2-methyl-2-(methylthio) propionaldehyde, 0-(methylcarbamoyl) oxime	Broadcast	3	Fair
Toxaphene,	DMSO[b]		Injection	2	No Control
"	Soltrol		"	"	" "
Dieldrin,	DMSO		"	"	" "
DDT,	DMSO		"	"	" "
Thuricide (90 T)[c]		*Bacillus thuringiensis* (Berliner)	Foliar Spray	2	No Control

[a]Various degrees of foliage "burning" produced.
[b]DMSO, Dimethyl Sulfoxide
[c]Active ingredient of 30 billion spores per gram.

study, was based on individual shoot records. Each shoot was placed upright in a labeled test tube (150 mm x 25 mm) which was stoppered by a cotton ball. Test tubes were held upright by placing their bottoms in one-inch depth holes in a two-inch thick board. Fifty damaged shoots were cut weekly and placed in test tubes for periods of four weeks. Location of test tubes was the same as that of the Berlese funnel and the moth collection period was the same used in 1964.

Transplants Tests: In March 1964 transplants of four pine species were planted in a three-acre block to determine susceptibility of one- and two-year-old pines to pine tip moth attack and to injury from systemic insecticides. The pine transplants were from seedings grown by the Oklahoma Forest Service. The species of pines included loblolly, *Pinus taeda* L.; shortleaf, *P. echinata* Mill.; ponderosa, *P. ponderosa* Douglas, and Austrian, *P. nigra* Arnold.

The transplant block was bordered on the west by several rows of three-year-old trees which were heavily infested during 1964 and 1965. A larger block of infested trees was located approximately 1/4 mile to the east.

Phorate and disulfoton 10 per cent granular formulations were applied at rates of 0.5, 1.0, 2.0, and 4.0 ounces per tree to loblolly pines. Both insecticides were applied at the two-ounce rate per tree to shortleaf, ponderosa, and Austrian pines. Untreated checks were included for each species of tree. A plot consisted of three rows of four trees each with nine feet between rows and six feet spacing between trees. Plots were separated by unplanted border zones 12 feet wide. Treatments were randomized within the three-acre block and were replicated four times on loblolly and three times on other species.

A transplanting tool or "dibble bar" was used to make an hourglass shaped hole with a depth of 6-7 inches. A weighed dosage of the granular insecticide was placed in the bottom of the hole. The transplant was placed in the hole and the soil was pressed tightly about the roots and stem by use of the dibble bar.

Injection Tests: Preliminary injection tests were conducted during 1964, to determine the effectiveness and duration of solutions of non-systemic toxicants and systemic emulsifiable concentrates, injected into the lower trunk area of five to seven-year-old shortleaf pines. The solutions of non-systemic toxicants were prepared by dissolving one gram technical of a non-systemic pesticide in five milliliters of a solvent. The solvents used were: dimethyl sulfoxide (DMSO), and Soltrol 130. Technical grades of toxaphene, DDT, and dieldrin were dissolved in DMSO, but only toxaphene was dissolved in Soltrol 130. Dieldrin and DDT were slightly soluble in Soltrol 130 but would not dissolve to the desired concentration under the conditions present for this study. Toxaphene was also dissolved in turpentine to study any effect it might produce when injected into pines. The systemic emulsifiable concentrates were injected in the trees at the (actual) concentrations for each.

The Mauget injector apparatus was used for the injection of Bidrin 6E and disulfoton 6E. One injector containing three milliliters of systemic insecticide was used on each of six trees per treatment. Solutions of non-systemic toxicants and systemic emulsifiable concentrates, disulfoton 6E, disulfoton 5E and Shell S D 9129 3E, were fed directly into the transpiration stream of the xylem, through a 1/4-inch hole, bored into the trunk at a 45° angle. Two holes were bored on opposite sides and at different levels on each of six trees per treatment. The holes were sealed with a plastic-base putty to prevent the entrance of disease and secondary decay causing organisms.

Paint-on Tests: Preliminary tests were conducted to determine the effectiveness of "paint-on" applications of disulfoton and solutions of non-systemic insecticides, applied to the terminal area of the individual shortleaf pine trees. Solutions of non-systemic insecticides were prepared by dissolving one gram technical of a non-systemic pesticide in five milliliters of a solvent. The solvents used were: dimethyl sulfoxide (DMSO) and Soltrol 130. Technical grades of toxaphene, DDT, and dieldrin were dissolved in DMSO, but only toxaphene was dissolved in Soltrol 130. Dieldrin and DDT were slightly soluble in Soltrol 130 but would not dissolve to the desired concentration under the conditions present for this study. The application area involved the top ten inches of terminal growth. A two-inch brush was used to apply a thin film of test material to the designated area. Each treatment was composed of a block of six trees. Applications were made June 16, 1964, for disulfoton and July 30, 1964, for all solutions of non-systemic insecticides.

RESULTS

Seasonal Development: The results from the study (Figure 1) show that four generations were present in Oklahoma during both 1964 and 1965. They were designated by Fenton and Afanasiev (1946) as: overwintering, first, second, and third. The moth emergence period for the overwintering generation started March 22 in 1964 and terminated April 24. In 1965 the first record of emergence was taken March 30, eight days later than for 1964, and it also was terminated on April 24. The peak emergence level for 1964 overwintering generation moths reached a plateau around April 11, and in 1965 it was reached on April 7. Moths of the first generation in both 1964 and 1965 began emergence around May 26. Emergence continued until June 24 in 1964 but was terminated June 16 in 1965. Peak emergence for first generation moths was June 8 for both years.

The second generation in both years began emergence around July 7 and continued until August 5. Peak emergence in 1965 occurred on July 11, eight days earlier than for 1964. The emergence records for the third generation indicate that the 1965 third generation began 16 or 17 days earlier 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 for the 1964 and 1965 study of seasonal development.

The heaviest moth emergence occurred during the second generation in both 1964 and 1965 when it was 19.2 per cent per 100 shoots. The highest individual peak emergence level was recorded in the first

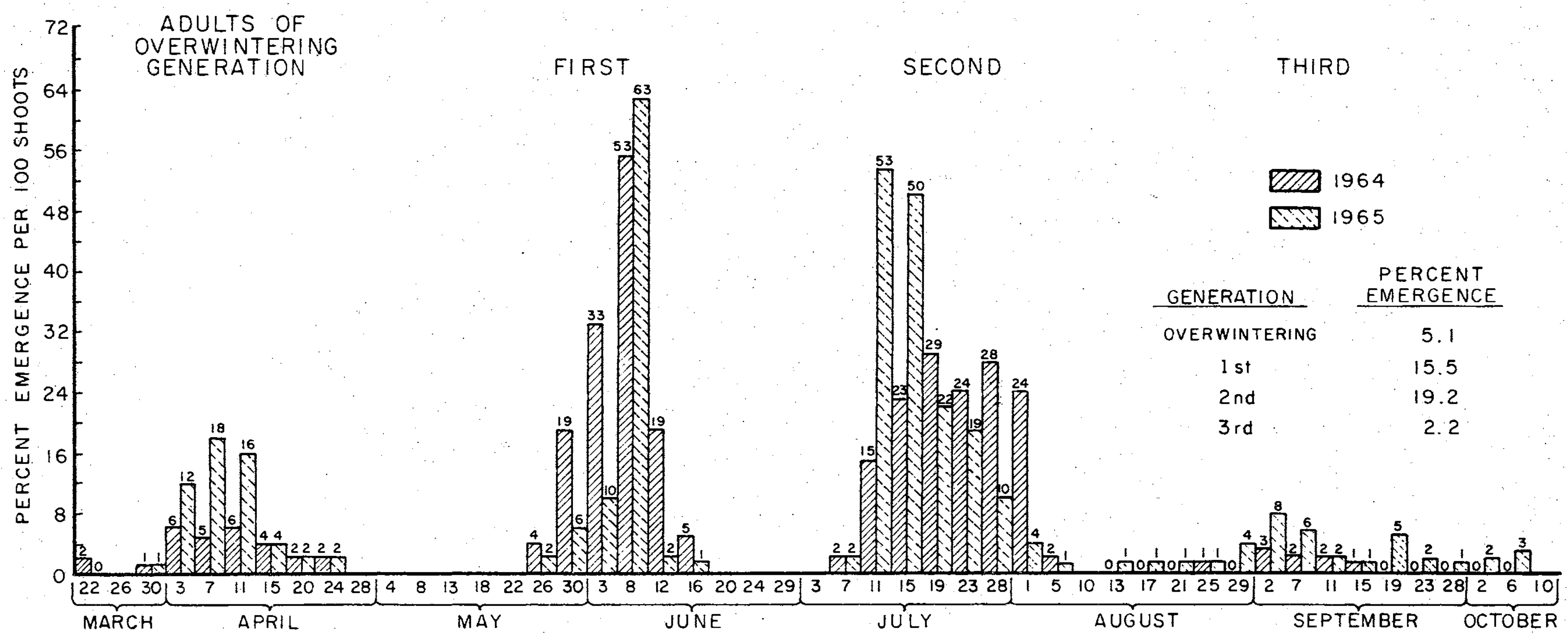

Figure 1. Adult Emergence of the Nantucket Pine Tip Moth, Rhyacionia frustrana (Comstock), Stillwater, Oklahoma

generation, but, this was reached early in the generation period and fell off rapidly, resulting in an average of 15.5 per cent for this generation. Moth emergence during the second generation occurred over a longer period and at higher levels.

The overlapping of generations was studied in 1964 and 1965. The data for 1964 indicate that there was no overlapping between periods of emergence for any generations throughout the season. There were clear breaks between periods of emergence for all generations, except between the second and third in 1965. The occurrence of only a 12-day break in emergence between these generations suggests a possibility of overlapping.

Additional information concerning seasonal development was obtained from the per cent of shoots damaged on untreated pines. The results (Table III) show that damage from larvae feeding and boring was heaviest on new shoots after the mid-June records and before the early July records were taken. The per cent of shoots damaged in 1965 was generally lower than in 1963 and 1964 (Tables IV, V, VI).

TABLE III

DAMAGE TO UNTREATED PINES, AN INDICATION OF LARVAL INFESTATION LEVELS, FOR THE GENERATIONS OF THE NANTUCKET PINE TIP MOTH, STILLWATER, OKLAHOMA

	Per Cent of Shoots Damaged[a]			
Years	Mid June	Early July	Early August	Late October
1964	37	76	69	26
1965	48	70	58	55

[a]Based on all untreated check trees used in this study.

<u>Soil Application Test No. I</u>: In a preliminary test on August 18, 1962, four systemic insecticides were applied to the soil around three-year-old loblolly pines. The soil within a five-foot diameter circle centered about the trees was cultivated to a depth of 4-6 inches by means of a gasoline-engine Rototiller. Granular formulations were applied by using a "shaker jar" made from a quart fruit jar with a screen wire lid. An emulsifiable concentrate 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 IV) indicate that phorate and disulfoton gave a high level of protection during the entire pine tip moth activity season of 1963. They also carried some protection into the early part of 1964, with phorate protecting at a slightly higher level than disulfoton. The results of dimethoate applied as a drench to the soil indicate a high level of protection throughout 1963 and into 1964. Dimethoate, however, produced severe foliage "burning" which resulted in the mortality of one tree. Meta-Systox-R, in the granular form was ineffective. None of the treatments reduced infestation in 1965.

<u>Soil Application Test No. II</u>: Six systemic compounds were applied at various rates to the soil surface within the dripline of three-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. Granules were applied with a "shaker jar" and the emulsifiable concentrate, mixed with two gallons of water, was applied using a sprinkler can. Eight gallons of water were applied to the band about each tree.

TABLE IV

EFFECTIVENESS OF SYSTEMIC INSECTICIDES, APPLIED IN THE SOIL, AUGUST, 1962, IN CONTROL OF THE NANTUCKET PINE TIP MOTH ON LOBLOLLY PINES, 1962-1965, STILLWATER, OKLAHOMA

Treatment[a]		Ounces Per Tree	Per Cent of Shoots Damaged 1963 9/6	1963 10/20	1964 5/27	1964 7/17	1964 10/31	1965 6/2	1965 7/1	1965 8/11	1965 12/20
Disulfoton	10G	6 oz	2	8	44	50	20	10	63	44	55
Phorate	10G	6 oz	0	3	36	44	14	7	66	23	52
Dimethoate	4E	8 oz	11	25	57	69	16	13	65	26	50
Meta-Systox-R	5G	12 oz	84	63	47	59	--	12	76	34	45
Untreated	--	--	84	67	53	78	14	10	73	26	62

[a]Four trees per treatment treated August 18, 1962.

Insect damage records made July 10, 1963, 28 days following application, showed granular materials had exerted limited control at best (Table V). Dimethoate liquid formulation demonstrated moderate protection by this date. Data recorded August 12, approximately two months after application, showed excellent control by the higher rates of phorate, disulfoton and dimethoate. Bayer 25141 gave good to excellent control at the four- and six-ounce rates, but only the six-ounce rates of E. I. 47031 and U. C. 21149 gave such high levels of protection. By October 6, phorate and disulfoton 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 2.7-ounce level. Records on Bayer 25141 indicate good to excellent protection for the two higher rates.

In a continued study of this test, it was observed that some systemic activity was evident in 1964 and to a lesser degree in 1965. During the 1964 activity season, phorate produced good to moderate protection at all rates of application and disulfoton and Bayer 25141 gave moderate protection at the four- and six-ounce rates. Dimethoate resulted in fair protection throughout the season, but E. I. 47031 and U. C. 21149 gave poor to no protection at the six-ounce rate. The long-term effect of the various systemic insecticides was indicated by infestation counts taken in 1965 throughout the third activity season following application. The results (Table V) show that moderate to fair protection was produced by Bayer 25141, phorate, and disulfoton at the six-ounce rate. Dimethoate resulted in fair to poor protection.

Methods of Application: Ten soil application methods were compared using disulfoton emulsifiable and granular formulations as the

TABLE V

EFFECTIVENESS OF SYSTEMIC INSECTICIDES, APPLIED ON THE SOIL, JUNE 12, 1963, IN CONTROL OF THE NANTUCKET PINE TIP MOTH ON LOBLOLLY PINES, 1963-1965, STILLWATER, OKLAHOMA

Treatment[a]		Ounces Per Tree	Per Cent of Shoots Damaged 1963 7/10	1963 8/12	1963 10/6	1964 5/26	1964 7/17	1964 8/10	1964 11/14	1965 5/28	1965 6/25	1965 8/10	1965 11/31
Disulfoton	10G	6	96	1	2	34	22	34	6	16	38	22	37
"	"	4	91	3	5	27	33	41	12	18	40	32	40
"	"	2	98	3	7	51	46	39	7	18	42	38	39
Phorate	10G	6	94	0	0	4	21	25	2	9	33	13	30
"	"	4	85	0	0	9	17	30	2	14	29	15	30
"	"	2	95	0	0	13	43	47	1	21	42	34	44
Bayer 25141	10G	6	91	2	8	31	55	35	2	14	31	13	29
"	"	4	84	6	2	39	44	42	7	11	45	26	36
"	"	2	84	2	46	52	73	64	13	23	29	40	46
E I 47031	10G	6	59	0	40	52	74	66	19	20	48	42	41
"	"	4	60	25	88	71	87	82	17	23	49	45	52
"	"	2	77	32	87	65	95	76	32	32	69	61	57
U C 21149	10G	6	58	0	35	43	82	77	20	26	50	52	42
"	"	4	68	37	77	55	80	82	12	15	46	42	37
"	"	2	71	81	85	62	81	79	11	11	45	49	41
Dimethoate	4E	8	43	0	0	61	34	41	13	15	45	27	39
"	"	5.3	34	0	0	37	66	38	14	20	46	36	40
"	"	2.7	29	1	78	55	76	75	21	19	53	26	56
Untreated		--	99	94	73	64	80	79	20	25	60	50	41

[a]Based on six trees per treatment

insecticide. The test was initiated June 28-29, 1963, on three-year-old loblolly pines (Table VI). 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 by use of a hoe. 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 that encircled the tree. After application, the trench was refilled with the soil that was previously removed. 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 within the dripline and arranged about the tree.

Disulfoton 6E concentrate was mixed in water and applied at the rate of 0.5 gallon per tree. All treatments not designated as dry received eight gallons of water per tree applied to the treated area. The data (Table VI) recorded on August 17, 1963, show by all methods except two, that disulfoton gave good to excellent control. The 31 per cent damage recorded for the band-in-soil method was the average damage for six trees treated by this method and involved two trees of the six that had two per cent or less damage. All data recorded from October 8, 1963, to December 20, 1965, showed that the liquid concentration had lost its effectiveness.

Where disulfoton granules were applied, 100 per cent control was achieved in 1963 on from 2-4 trees in each method tested, with the exception of the hole method. In 1964 and 1965 the level of protection

TABLE VI

EFFECTIVENESS OF DISULFOTON EMULSIFIABLE AND GRANULAR FORMULATIONS, APPLIED TO THE SOIL BY VARIOUS METHODS, JUNE 28, 1963, IN CONTROL OF THE NANTUCKET PINE TIP MOTH, STILLWATER OKLAHOMA

	Per Cent of Shoots Damaged									
	1963		1964					1965		
Application Method[a]	8/17	10/8	6/3	7/9	7/17	8/4	8/17	6/2	6/25	12/30
	Disulfoton 6E, 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	31	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)	78	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

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

was good to moderate, respectively, for all broadcast and band methods tested.

Dimethoate Soil Test No. I: On July 17, 1963, dimethoate 4E was applied as a soil drench to two sizes of seven-year-old shortleaf pines having trunk circumferences that averaged approximately 5 and 12 inches per group. Identical dosages were applied to the trees in the two groups. Application was made with a sprinkler can to a four-inch-wide trench, 3-4 inches deep, and centered about the tree within the dripline. Each of the five insecticide dosage rates was mixed with two gallons of water.

The data recorded on August 24, 1963, (Table VII) indicated that two ounces were required for satisfactory control on the larger trees; whereas only one ounce was needed for excellent control on the smaller size. By October 12, however, a high level of control was maintained by only the eight-ounce treatment on small trees. The table also indicates the relative phytotoxicity associated with the various dosage rates and tree sizes for 1963. There was no phytotoxic effects, indicated by foliage "burning," present on the trees in 1964 or 1965.

The June 3, 1964, data indicate that a high level of protection was obtained only in the eight-ounce rate applied to small trees. By August 10, 1964, the results at the eight-ounce rate on small trees provided only moderate protection, and by June, 1965, no protection was present when compared to untreated control trees.

Dimethoate Soil Test No. II: Soil applications were made to 25-year-old shortleaf pines on July 25, 1963, using dimethoate 4E and phosphamidon 4E. The application to each tree consisted of two gallons of water mixed with each treatment and applied in a band to a four-

TABLE VII

EFFECTIVENESS OF DIMETHOATE 4E, APPLIED IN THE SOIL, JULY 17, 1963, TO TWO SIZES OF SHORTLEAF PINES, IN THE CONTROL OF THE NANTUCKET PINE TIP MOTH, STILLWATER, OKLAHOMA

Amount of Formulation Per Tree	Phyto-toxicity Rating[a]	Per Cent of Shoots Damaged[b]				
		1963		1964		1965
		8/24	10/12	6/3	8/10	6/7
Trees with Trunk Circumference of 3.5-6 inches[c]						
0.5 oz	0.5	7	57	32	--	--
1.0 oz	0.5	1	51	29	--	--
2.0 oz	1.6	0	28	34	--	--
4.0 oz	2.1	0	0	29	63	23
8.0 oz	3.3	0	0	5	32	22
Untreated	- -	87	61	37	68	26
Trees with Trunk Circumference of 10-15 inches[c]						
0.5 oz	0	31	41	31	--	--
1.0 oz	0	8	40	22	--	--
2.0 oz	0	2	32	32	--	--
4.0 oz	0	1	15	24	53	32
8.0 oz	2.3	0	2	39	46	43
Untreated	- -	84	59	42	53	40

[a]Ratings: 0-No discoloring or burning effect; 1-Very light; 2-Light; 3-Moderate; 4-Heavy; 5-Very heavy.
[b]Based on eight trees per treatment.
[c]Measurements taken ten inches above the soil.

inch-wide area of tiled soil centered around the tree inside the drip-line. An additional eight gallons of water were added to each treated tree for a total of 10 gallons of water per tree.

Data from the 1963 records (Table VIII) indicate that four ounces of dimethoate or eight ounces of phosphamidon were needed for appreciable protection to the trees. The 1964 records show that fair to moderate protection was produced by the eight-ounce rate of dimethoate and phosphamidon. In 1965, dimethoate at the eight-ounce rate produced moderate protection, and the eight-ounce rate of phosphamidon resulted in poor protection when compared to untreated check trees.

TABLE VIII

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], STILLWATER, OKLAHOMA

Amount of Formulation Per Tree[b]	Per Cent of Shoots Damaged[c] 1963	1964	1965
	Dimethoate 4E		
0.25 oz	53.9	36.8	47.6
0.50 oz	53.0	49.7	60.0
1.00 oz	68.5	43.2	58.4
2.00 oz	52.2	41.5	48.9
4.00 oz	13.9	49.4	52.2
8.00 oz	7.1	39.5	25.6
	Phosphamidon 4E		
2.00 oz	45.6	46.2	49.3
4.00 oz	40.7	47.3	50.1
8.00 oz	16.4	41.2	39.8
	Check		
Untreated	65.1	57.5	51.9

[a]Twenty-five-year-old pines (1963).
[b]Treated July 25, 1963. Damage recorded October 12, 1963, August 17, 1964, and October 19, 1965.
[c]Based on six trees per treatment.

Spray-Drench Test: This preliminary spray-drench test was applied to three-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 by means of a spray-gun equipped with a No. 5 disk, at the rate of 0.66 gallon per minute and pressured at 100 p.s.i. A block of 30 pines were sprayed for each treatment. Each tree was sprayed from 10-30 seconds depending on size.

The sprays were applied somewhat late in the life cycle and the data indicate that very little control was obtained by July 10, 1963, (Table IX). The damage records of August 13, 1963, showed that disulfoton gave excellent control and dimethoate gave substantial reduction in infestation. By October 6, 1963, dimethoate had lost its effectiveness, but disulfoton continued to give excellent control.

Further studies were made on the 1964 and 1965 disulfoton-treated block. A modification was made in that one-half of the block was retreated on June 19, 1964, using the same method as previously described for the original spray-drench tests.

The results (Table X) show an increase in protection in the yearly application when compared to the treatment receiving only one application of disulfoton applied as a spray-drench over a two-year period. The 1965 records for this study show the yearly application to be protecting substantially better than the single application applied to protect a two-year period. However, when a comparison of average height growth for the two treatments was made (Table XI) there was no difference in the average height growth for the 1964 season. In 1965 an average height growth increase of 1.1 inches was recorded for the yearly application over the single application for two years of protection. In all cases height growth was excellent when compared to untreated trees.

<u>Damage to Untreated Older Pines</u>: Three species of 25-year-old pines, shortleaf, loblolly, and ponderosa, were sampled on July 10, 1963, June 9, 1964, and July 20, 1965, for a comparison of infestation levels. A 12-foot pruning hook was used to cut three branches each from the upper and lateral areas of each tree examined. The same procedure was

TABLE IX

EFFECTIVENESS OF SYSTEMIC INSECTICIDES AND DDT, APPLIED AS SPRAY-DRENCHES, 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]		
			7/10	8/13	10/6
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	--
Disulfoton	6E	0.6	74.5	0.0	0.0
Bidrin	2E	0.6	70.5	89.8	--
S D 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 psi.
[c]Based on 12 trees per treatment.

followed each year. The records in Table XII show that shortleaf pine is the favored host for the Nantucket pine tip moth in this area. The table indicates also that loblolly is favored only slightly, as a host, when compared to ponderosa over a three-year period in an area where all three species of pines were equally accessible.

Susceptibility of Pine Transplants to Tip Moth Attack and to Damage from Systemic Insecticides: The results of the transplant test are given in Tables XIII, XIV, and XV. Weather conditions were very unfavorable for transplant survival both at planting time, when soil moisture was unusually low, and during the remainder of 1964 which was

TABLE X

EFFECTIVENESS OF DISULFOTON 6E, APPLIED AS A SPRAY-DRENCH AT ONE-YEAR AND TWO-YEAR INTERVALS, IN CONTROL OF THE NANTUCKET PINE TIP MOTH ON LOBLOLLY PINES, STILLWATER, OKLAHOMA

Date Applied[a]	Per Cent of Shoots Damaged[b]									
	1963			1964				1965		
	7/10	8/13	10/6	7/8	8/4	8/31	10/31	6/1	7/30	11/24
6-18-63[c]	75	0	0	45	60	18	4	10	53	16
6-18-63[c] & 6-19-64[c]	--	--	--	34	48	12	0	5	29	3
Untreated	90	91	73	90	80	75	30	24	72	50

[a]Applied with Bean power sprayer and gun with No. 5 disc, at 100 psi.
[b]Based on 15 trees per treatment.
[c]Actual systemic applied was 0.25 oz per tree per treatment.

TABLE XI

GAIN IN HEIGHT FOR LOBLOLLY PINES TREATED WITH DISULFOTON 6E AS A SPRAY-DRENCH, IN CONTROL OF THE NANTUCKET PINE TIP MOTH, STILLWATER, OKLAHOMA

Date Applied[a]	Average Gain in Height (Inches)[b] 1964	1965
6-18-63[c]	28.6	30.9
6-18-63[c] & 6-19-64[c]	28.2	32.2
Untreated	16.0	22.0

[a]Applied with Bean power sprayer and gun with No. 5 disc, at 100 psi.
[b]Based on 15 trees per treatment.
[c]Actual systemic applied was 0.25 oz per tree per treatment.

TABLE XII

DAMAGE BY THE NANTUCKET PINE TIP MOTH ON THREE UNTREATED SPECIES OF 25-YEAR-OLD PINES, STILLWATER, OKLAHOMA

	Per Cent of Shoots Damaged		
Species	7/10/63	6/9/64	7/20/65
Shortleaf	73.9	21.6	29.3
Ponderosa	5.4	1.6	0.0
Loblolly	2.6	6.9	11.1

[a]Based on thirteen shortleaf, seven ponderosa and six loblolly pines.

characterized by above normal summer temperature and on annual precipitation that was 5.53 inches below normal. The resulting high mortality levels in untreated trees tended to obscure the phytotoxic effects of the chemicals on young pines. The per cent of tree mortality in untreated checks was not great until August 7, 1964, (Table XIII).

Despite the high natural mortality in the test, the records taken in May, June and August, 1964, (Table XIV) indicate that all rates of the two compounds were injurious to the young trees, and that level of injury increased with increased rate of application. Tree mortality in 1964 and 1965 due to the phytotoxic effects of the systemic insecticides, was approximately 17.7 per cent and 18.5 per cent greater, respectively, than in the untreated control trees. Under the conditions of the test, no differences were indicated between the compounds or among the pine species.

No tip moth infested or damaged shoots were found in any of the untreated or treated pines in either grass-covered or burned-off areas growing during the first season after transplanting (Table XV). In 1965, the second season, only .03 per cent of shoots on untreated

TABLE XIII

PER CENT TREE MORTALITY OF FOUR SPECIES OF PINE TRANSPLANTS[a], TREATED WITH VARIOUS RATES OF SYSTEMIC INSECTICIDES, ON VARIOUS DATES IN 1964, STILLWATER, OKLAHOMA

Treatment	Rate Per Tree (oz)	1964					1965	
		5/8	5/25	6/30	8/7	11/24	6/19	12/21
				Loblolly[b]				
Disulfoton	0.5	20	30	42	63	73	71	81
"	1.0	0	12	14	64	72	75	75
"	2.0	44	69	73	78	81	81	81
"	4.0	86	86	86	92	94	97	97
Phorate	0.5	14	25	33	67	72	92	92
"	1.0	3	18	31	86	89	89	89
"	2.0	46	71	75	78	88	88	88
"	4.0	50	75	81	92	97	97	100
Untreated	- -	3	7	7	34	47	52	53
				Shortleaf[c]				
Disulfoton	2.0	17	31	39	72	82	89	89
Phorate	2.0	25	35	50	85	90	94	94
Untreated	- -	8	13	17	38	63	63	63
				Ponderosa[c]				
Disulfoton	2.0	0	21	71	100	--	--	--
Phorate	2.0	6	42	58	75	97	97	97
Untreated	- -	3	6	14	56	81	81	81
				Austrian[c]				
Disulfoton	2.0	3	31	67	97	100	--	--
Phorate	2.0	22	47	64	67	100	--	--
Untreated	- -	8	11	17	64	94	100	--

[a]Transplanted and treated, with 10 per cent granules in March, 1964.
[b]Based on four replicates of 12 trees per treatment.
[c]Based on three replicates of 12 trees per treatment.

TABLE XIV

COMBINED TREE MORTALITY, IN FOUR SPECIES OF PINE TRANSPLANTS, STILLWATER, OKLAHOMA

Condition[a]	Total Per Cent Tree Mortality 1964	1965
Disulfoton	86.2	88.9
Phorate	90.4	94.1
Untreated	69.7	72.3

[a]Transplanted and treated, with 10 per cent granules, in March, 1964.

TABLE XV

PER CENT OF SHOOTS DAMAGED BY PINE TIP MOTHS, ON FOUR SPECIES OF PINE TRANSPLANTS, UNDER GRASS COVER AND BURNED-OFF SURFACE CONDITIONS, STILLWATER, OKLAHOMA

Treatment Condition[a]	Per Cent of Shoots Damaged 1964	1965
Treated		
Grass Cover	0.0	0.0
Burned-off	0.0	0.0
Untreated		
Grass Cover	0.0	0.01
Burned-off	0.0	0.03

[a]Transplanted and treated, with 10 per cent granules, in March, 1964.

plants were infested in the burned-off area and .01 per cent in the area with grass cover.

Injection Tests: The results (Table XVI) indicate that all injection methods used had virtually no effect on the pine tip moth. The only indication of materials being translocated was observed in the systemic solution treatments where DMSO was used as a solvent. All DMSO treatments produced slight needle "burning" during the first activity season following treatment. Dieldrin in DMSO resulted in severe foliage "burning" and heavy needle shedding.

TABLE XVI

TESTS OF TRUNK INJECTION OF VARIOUS LIQUID CONCENTRATES IN SHORTLEAF PINES IN CONTROL OF THE NANTUCKET PINE TIP MOTH, STILLWATER, OKLAHOMA

			Per Cent of Shoots Damaged[a]						
		Rate Per	1964				1965		
Toxicant		Tree (ml)	6/30	8/4	11/25	5/28	7/6	8/13	12/24
			Injected by Mauget Injector						
Bidrin	6E[b]	3	63	76	34	30	59	57	57
Disulfoton	6E[b]	3	62	84	30	38	63	58	49
			Injected by Boring into Trunk						
Disulfoton	6E[b]	5	70	79	23	17	60	41	61
"	5E[b]	6	73	71	21	15	58	39	68
S D 9129	3E[b]	10	60	66	25	20	53	38	48
Toxaphene in Turpentine[c]		5	66	78	27	16	63	34	60
Toxaphene in Soltrol[c]		3	--	53	47	36	92	88	56
Toxaphene in DMSO[c]		3	--	52	42	28	90	86	56
Dieldrin in DMSO[c]		3	--	55	34	28	87	81	57
DDT in DMSO[c]		3	--	58	31	26	90	75	54
			Check						
Untreated		-	63	85	29	22	62	59	50

[a]Based on six trees per treatment.
[b]Systemics applied June 16, 1964.
[c]Non-systemics applied July 30, 1964. The concentration of Toxaphene in turpentine was, 1 gram technical in 1.5 milliliters of solvent, all others were mixed at 1 gram technical in 5 milliliters of solvent.

Paint-on Application Tests: Table XVII gives the per cent of shoots damaged by larvae on shortleaf pines on which various insecticide concentrates were painted on terminals. The data shows that no protection was given to the terminal areas by any of the materials tested.

TABLE XVII

TESTS OF VARIOUS LIQUID CONCENTRATES, PAINTED ON THE TERMINAL OF SHORTLEAF PINES, FOR CONTROL OF THE NANTUCKET PINE TIP MOTH, STILLWATER, OKLAHOMA

	Per Cent of Shoots Damaged[b]						
	1964				1965		
Treatment[a]	6/30	8/4	11/24	5/28	7/6	8/13	12/24
Disulfoton 6E	76	65	25	19	63	31	58
Toxaphene in DMSO	--	43	48	26	81	79	59
Toxaphene in Soltrol	--	61	35	37	88	78	61
DDT in DMSO	--	55	36	20	89	77	64
Dieldrin in DMSO	--	49	45	27	88	84	61
Untreated	71	54	32	22	69	77	59

[a]Disulfoton applied June 16, 1964, others applied July 30, 1964. All non-systemics prepared from 1 gram technical in 5 milliliters of the appropriate solvent.
[b]Infestation counts made on the terminal area of six trees per treatment.

1964 Methods Test: On June 17, 1964, five systemic insecticides were applied to the soil and as a spray-drench to five-year-old shortleaf pines. In preparation for soil application of the systemic insecticide, all debris and undergrowth was removed from beneath the assigned trees. The systemic insecticides were applied in a broadcast pattern directly to the soil and the debris and undergrowth pushed back into place. Four gallons of water were applied to each treated tree and the assigned checks. The spray-drench method of application was designed to produce a runoff from the foliage to the soil surface. Applications were applied 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 a pressured 100 p.s.i. Each tree was sprayed 10-30 seconds, depending on size. The results (Table XVIII) indicate that disulfoton 6E at the 6 oz rate gave the most consistent control. It shows a relatively early up take by the tree and indicates that a long term residual was in effect by November 31, 1965. At the lower rate (3 oz), disulfoton 6E presented a pattern of effectiveness similar to the higher rate except for the presence of a slightly higher per cent of damaged shoots.

The granular formulations tested, disulfoton, phorate, and Bayer 25141, did not start protecting the trees until late in the 1964 activity season. The protection throughout the 1965 activity season was good to excellent, with disulfoton and phorate producing about the same degree of protection and being followed by Bayer 25141.

The data indicate that disulfoton 6E applied as a spray-drench at .25 oz and at .125 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. The records indicate that 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 S D 9129, applied as a spray-drench at .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

TABLE XVIII

EFFECTIVENESS OF SYSTEMIC INSECTICIDES, APPLIED ON THE SOIL AND AS A SPRAY-DRENCH, IN THE CONTROL OF THE NANTUCKET PINE TIP MOTH ON SHORTLEAF PINES, STILLWATER, OKLAHOMA

Treatment[a]		Rate Per Tree	Per Cent of Shoots Damaged[b] 1964 7/16	8/12	8/24	10/29	1965 5/27	6/24	8/16	11/31
			Soil Application							
Disulfoton	10G	6oz	80	45	40	1	4	9	2	6
"	6E	3oz	67	29	32	1	7	14	--	6
"	6E	6oz	46	18	26	1	2	11	1	3
Phorate	10G	6oz	63	36	37	0	2	8	4	10
Bayer 25141	10G	6oz	60	30	31	5	9	26	20	17
			Spray-Drench Application							
Disulfoton	6E	.5%	30	23	24	6	11	49	49	60
"	6E	.5%	33	21	22	17	18	42	56	63
G C 9879	4E	.5%	47	26	31	16	19	49	58	65
S D 9129	3E	.5%	29	24	23	19	14	42	52	60
			Check							
Untreated	--	--	84	48	45	29	19	49	57	59

[a]Treated June 17, 1964. Four gallons of water added to all treatments.
[b]Based on 24 trees per treatment.
[c]Treatment received 1/4 gallon of mixed spray, all other spray drench treatments received 1/2 gallon per tree.

activity season records show G C 9879 and S D 9129 to have approximately the same per cent of shoots damaged as the untreated checks. S D 9129 produced moderate foliage "burning" throughout the 1964 activity season.

Thuricide Foliar Spray Test: Thuricide 90T, *Bacillus thuringiensis* Berliner, with an active ingredient level based on 30 billion viable spores per gram, was applied as a foliar spray to five-year-old shortleaf pines. Three applications were made at weekly intervals, starting

July 20, 1964, using a 0.5 per cent concentration of the insecticide in a three gallon Hudson back-pack sprayer equipped with a standard nozzle and a pressure gage. Each tree received approximately .2 gallons of the .5 per cent solution at a pressure of 30 p.s.i.

Damage records indicate that under field plot conditions the microbial insecticide is not effective as a control of the pine tip moth (Table XIX).

TABLE XIX
TESTS OF *Bacillus thuringiensis* (Berliner), AS A FOLIAR SPRAY, APPLIED ON DIFFERENT DATES, IN CONTROL OF THE NANTUCKET PINE TIP MOTH ON SHORTLEAF PINES, 1964, STILLWATER, OKLAHOMA

Date of Application[a]	Per Cent of Shoots Damaged[b]	
	8/4	11/14
July 20	55.0	24.4
July 27	53.4	26.0
August 3	52.7	17.5
Untreated	54.9	19.0

[a]Spray concentration of 0.5% used on all treatments.
[b]Based on 12 trees per treatment.

Disulfoton 6E Soil Application Test: The systemic insecticide, disulfoton 6E, was applied at two rates, .3 oz and .6 oz actual, to the soil around four-year-old shortleaf pines on August 17, 1964. Eighteen trees in a block were treated after removing the debris and vegetation from beneath the assigned trees and applying the systemic insecticide directly to the soil. After treatment all debris and vegetation was pushed back into place and each tree received four gallons of water.

The results (Table XX) indicate good control for both treatment rates on September 20, 1964, 35 days after application. Good to excellent control throughout the the 1965 activity season was also obtained with the .6 oz rate showing slightly less damage than the .3 oz rate.

TABLE XX

EFFECTIVENESS OF TWO RATES OF DISULFOTON 6E SYSTEMIC INSECTICIDE APPLIED AS A LIQUID SOIL DRENCH, IN CONTROL OF THE NANTUCKET PINE TIP MOTH ON SHORTLEAF PINES, STILLWATER, OKLAHOMA

Actual Toxicant Per Tree[a]	Per Cent of Shoots Damaged[b]					
	1964			1965		
	8/19	9/20	11/4	7/5	8/12	11/24
0.3 oz	44.7	23.6	3.8	6.7	9.0	8.7
0.6 oz	48.7	19.0	2.6	3.6	4.7	3.9
Untreated	51.6	53.9	29.4	49.4	57.4	59.5

[a]Treated August 17, 1964. Four gallons of water added to all treatments.
[b]Based on 18 trees per treatment.

Niagara 10242 Spray-Drench Test: The systemic insecticides Niagara 10242 80W and disulfoton 6E were applied as a spray-drench to five-year-old shortleaf pines on April 20, 1965. Six trees in a block were treated using 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 a pressure of 100 p.s.i. Each tree was spray-drenched from 15-35 seconds, depending on size, with a 0.5 per cent concentration of the systemic insecticide.

The spray-drenches were applied between the emergence periods for overwintering and first generation pupae, and were producing excellent control for both treatments when emergence for the second and heaviest generation was in effect, around July 12.

Niagara 10242 (Table XXI) produced protection at a higher level than disulfoton earlier in the activity season, but the November 24 records show that protection during the late part of the season was slightly better with disulfoton. Both treatments were excellent when compared to untreated check trees.

TABLE XXI

EFFECTIVENESS OF SYSTEMIC INSECTICIDES, APPLIED AS A SPRAY-DRENCH[a], IN CONTROL OF THE NANTUCKET PINE TIP MOTH ON SHORTLEAF PINES, 1965, STILLWATER, OKLAHOMA

Treatment[b]	Per Cent of Shoots Damaged[c]		
	7/5	8/12	11/24
Disulfoton 6E	8.6	5.1	1.4
Niagara 10242	0.5	0.7	6.3
Untreated	82.3	62.5	61.3

[a]Spray concentration used was 0.5 per cent. Each tree received approximately 0.25 oz actual toxicant per tree.
[b]Treated April 20, 1965.
[c]Based on six trees per treatment.

<u>Spray-Drench 1965 Test No. I</u>: Two systemic insecticides, disulfoton and phosphamidon, were applied May 26, 1965, at various rates as spray-drenches to five-year-old shortleaf pines. Six trees in a block were treated using 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 a pressured 100 p.s.i. Each tree was drenched 10-30 seconds depending on size.

The results (Table XXII) indicate that disulfoton at all rates tested was given good protection around July 7. The 0.5 per cent spray concentration, with 0.25 oz actual systemic insecticide applied to a given tree, gave the best protection throughout the remainder of the activity season. The 0.25 per cent spray concentration, with 0.125 oz actual toxicant applied, gave about the same degree of protection as the 0.25 per cent spray, with 0.25 oz actual toxicant, applied per treated tree. All three rates of disulfoton were exceptionally better than phosphamidon, which gave only a slight indication of systemic activity around July 7.

TABLE XXII

EFFECTIVENESS OF VARIOUS RATES OF THE SYSTEMIC INSECTICIDES DISULFOTON 6E AND PHOSPHAMIDON 8E, APPLIED AS A SPRAY-DRENCH, IN CONTROL OF THE NANTUCKET PINE TIP MOTH, ON SHORTLEAF PINES, 1965, STILLWATER, OKLAHOMA

Treatment[a]	Spray Concentration %	Ounces Actual Toxicant / Tree	Per Cent of Shoots Damaged[b] 7/7	8/12	11/24
Disulfoton	0.50	0.25	15.8	3.6	1.6
"	0.25	0.25	12.1	25.5	9.0
"	0.25	0.125	14.9	16.4	11.0
Phosphamidon	0.50	0.50	59.4	61.1	65.9
Untreated	- -	- -	81.2	67.3	68.1

[a]Treated May 25-26, 1965.
[b]Based on six trees per treatment for disulfoton and 12 trees per treatment for phosphamidon and untreated control trees.

Spray-Drench 1965 Test No. II: Five systemic insecticides were applied as spray-drenches to five-year-old loblolly pines on June 10, 1965. Six trees in a block were treated using 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 a pressured 100 p.s.i. Each tree was drenched for 10-30 seconds, depending on size, with a 0.5 per cent concentration of the systemic insecticide. This treatment was applied three days after peak moth emergence.

The damage recorded for July 7 (Table XXIII) indicates that good to excellent control resulted for all treatments. The following checks of August 12 and November 24, show that Niagara 10242 and Bayer 25141 gave almost perfect protection which lasted for the remainder of the activity season. Disulfoton was producing excellent protection by August 12 and Thiocron gave good control throughout the season. Baygon showed a gradual reduction in systemic activity throughout the activity season and produced a slight foliage "burning" starting about 28 days after treatment.

TABLE XXIII

EFFECTIVENESS OF SYSTEMIC INSECTICIDES, APPLIED AS A SPRAY-DRENCH[a], IN CONTROL OF THE NANTUCKET PINE TIP MOTH, ON LOBLOLLY PINES, 1965, STILLWATER, OKLAHOMA

Treatment[b]		Per Cent of Shoots Damaged[c]		
		7/7	8/12	11/24
Bayer 25141	6E	3.1	0.0	0.0
Baygon	2E	1.3	6.8	25.0
Disulfoton	6E	19.2	1.9	0.4
Niagara 10242	80W	17.4	0.0	0.24
Thiocron	3E	13.2	10.3	13.7
Untreated		59.4	50.3	41.2

[a]Spray concentration used was 0.5 per cent for all treatments.
[b]Each tree received approximately 0.25 oz actual toxicant.
[c]Based on six trees per treatment.

<u>Spray-Drench 1965 Test No. III</u>: Three experimental systemic compounds and disulfoton were applied as spray-drenches to five-year-old shortleaf pines on July 10, 1965. Six trees in a block were treated using a 50-gallon John Bean sprayer and a spray-gun equipped with an open nozzle at 1.06 gallons per minute, and a pressured 100 p.s.i. Each tree was drenched for 10-30 seconds, depending on size, with a 0.5 per cent concentration of the systemic insecticides. The application was made during the peak emergence period for the second generation of pine tip moths.

Results indicate (Table XXIV) that by August 12, G S 13005 and disulfoton were giving good to excellent protection. G C 6506 and S D 9129 treatments showed no systemic activity at that time. By November 24, disulfoton was giving good to excellent control and G S 13005 indicated no systemic activity. G C 6506 and S D 9129 showed an indication of some systemic action. S D 9129 produced moderate foliage "burning."

<u>Soil Application 1965 Test</u>: Four systemic insecticides were applied to the soil and one systemic insecticide was applied as a spray-drench to five-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 applied in the same manner as described in the spray-drench 1965 tests I, II, and III. The applications were made between the first and second generations of the pine tip moth, when moth emergence was at its lowest.

Disulfoton resulted in almost perfect protection during the entire

TABLE XXIV

EFFECTIVENESS OF SYSTEMIC INSECTICIDES, APPLIED AS A SPRAY-DRENCH[a], ON SHORTLEAF PINES, IN CONTROL OF THE NANTUCKET PINE TIP MOTH, 1965, STILLWATER, OKLAHOMA

Treatment[b]		Actual Toxicant / Tree	Per Cent of Shoots Damaged[c] 8/12	11/24
Disulfoton	6E	.25 oz	0.0	15.1
G C 6506	4E	.25 oz	53.8	30.6
G S 13005	4E	.25 oz	16.0	55.9
S D 9129	3E	.25 oz	55.4	23.4
Untreated	--	--	49.4	50.8

[a]Spray concentration was 0.5 per cent.
[b]Treated July 10, 1965.
[c]Based on six trees per treatment.

first season of the test (Table XXV). Thiocron produced good protection 11 days after treatment at both the 1.2 oz and the 0.6 oz actual rates tested. All remaining treatments indicated some protection but to a lesser degree. By August 12 all treatments were producing excellent protection when compared to untreated checks. The results recorded for November 24 showed disulfoton, Baygon, Bayer 25141, and Niagara 10242 to be producing excellent protection. Thiocron at both rates was giving good protection. Baygon, although producing a high level of protection, also produced severe foliage "burning" to all trees tested.

<u>Date of Application Tests</u>: Preliminary tests were conducted using soil applications of disulfoton granules at the rate of 0.6 oz actual toxicant per tree, to determine a date of application that would give protection for the entire following year. Blocks of four-year-old shortleaf pines consisting of 12 trees each were selected and treated

TABLE XXV

EFFECTIVENESS OF SYSTEMIC INSECTICIDES, APPLIED TO THE SOIL, IN CONTROL OF THE NANTUCKET PINE TIP MOTH ON LOBLOLLY PINES, 1965, STILLWATER, OKLAHOMA

Treatment[a]		Ounces Actual Toxicant/Tree	Per Cent of Shoots Damaged[b] 7/7	8/12	11/24
Bayer 25141	5G	1.2	46.0	2.3	4.7
Baygon	5G	1.2	26.6	2.3	0.5
Thiocron	5G	1.2	16.6	1.1	16.7
"	5G	.6	10.9	1.0	16.7
Niagara 10242	10G	.6	36.9	1.0	5.3
Disulfoton	6E	.6	2.0	6.0	0.0
Untreated	--	--	59.9	50.3	41.2

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

at various dates starting February 4, 1964, and extending through August 23, 1965. In preparation for application, 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 were added to each tree at time of treatment.

The results (Table XXVI) 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 64, April 64, May 64, January 65, March 65, and June 65).

TABLE XXVI

EFFECTIVENESS OF DISULFOTON 10G, APPLIED AT THE RATE OF SIX OUNCES PER TREE, ON DIFFERENT DATES TO THE SOIL, IN CONTROL OF THE NANTUCKET PINE TIP MOTH, STILLWATER, OKLAHOMA

Application Date		Per Cent of Shoots Damaged[b] 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	65	32
August	23								46
Untreated		59	70	73	18	30	74	49	64

[a]Four gallons of water added to all treatments at time of treatment.
[b]Based on 12 trees per treatment.

Height Growth: 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 Application Test No. II and Methods 1964 were measured and recorded for this study. Measurements were taken following treatment 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 tallest shoot. Results may be found in Tables XXVII and XVIII.

TABLE XXVII

HEIGHT GROWTH OF LOBLOLLY PINES TREATED WITH SYSTEMIC INSECTICIDES, APPLIED JUNE 12, 1963, TO THE SOIL FOR CONTROL OF THE NANTUCKET PINE TIP MOTH, STILLWATER, OKLAHOMA

Treatment		Ounces Per Tree	Height Growth, Inches[a] 1963	1964	1965	Total	Increase over Check, Inches[a] 1963	1964	1965	Total
Disulfoton	10G	6	6.9	21.4	30.6	58.9	5.6	5.7	8.4	19.7
"	"	4	8.5	18.2	21.6	48.3	7.3	2.4	-0.6	9.1
"	"	2	3.2	16.3	22.2	41.7	2.0	0.5	0.0	2.5
Phorate	10G	6	6.3	23.2	22.5	52.0	5.1	7.4	0.3	12.8
"	"	4	11.1	35.8	29.3	76.2	9.9	20.0	7.1	37.0
"	"	2	7.2	23.3	23.7	54.2	6.0	7.5	1.5	15.0
Bayer 25141	10G	6	8.6	26.0	32.1	66.7	7.4	10.2	9.9	27.5
"	"	4	9.7	24.5	30.0	60.0	6.0	7.0	7.8	20.8
E I 47031	10G	6	11.8	19.4	21.2	52.4	10.6	3.6	-1.0	13.2
"	"	4	8.3	16.7	24.8	49.8	7.1	0.9	2.6	10.6
"	"	2	3.0	11.2	18.0	32.2	1.8	-4.6	-4.2	-7.0
U C 21149	10G	6	13.3	21.2	23.1	57.6	12.1	5.4	0.9	18.4
"	"	4	10.5	16.7	26.0	53.2	0.3	0.9	3.8	14.0
"	"	2	6.0	15.6	31.2	52.8	4.8	-0.2	9.8	13.6
Dimethoate	4E	8	13.2	29.1	35.2	77.5	12.0	13.3	13.0	38.3
"	"	5.3	14.0	18.4	28.9	61.3	12.8	2.6	6.7	22.1
"	"	2.7	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

[a]Based on six trees per treatment.

TABLE XXVIII

HEIGHT GROWTH FOR SHORTLEAF PINES TREATED WITH SYSTEMIC INSECTICIDES APPLIED JUNE 17, 1964, TO THE SOIL OR AS A SPRAY-DRENCH IN CONTROL OF THE NANTUCKET PINE TIP MOTH, STILLWATER, OKLAHOMA

Treatment		Actual Toxicant Per Tree	Height Growth			Increase over Check		
			1964	1965	Total	1964	1965	Total
			Soil Application					
Disulfoton	10G	.6oz	11.5	28.9	40.4	3.3	10.8	14.1
"	6E	.3oz	9.5	27.6	37.1	1.3	9.5	10.8
"	"	.6oz	10.2	30.6	40.8	2.0	12.5	14.5
Phorate	10G	.6oz	10.7	29.9	40.6	2.5	11.8	14.3
Bayer 25141	10G	.6oz	11.8	27.6	39.4	3.6	9.5	13.1
Combined Average			--	--	--	2.5	10.8	13.4
			Spray-Drench Application					
Disulfoton	6E	.25oz	10.6	17.0	27.6	2.4	-1.1	1.3
"	"	.50oz	11.5	19.8	31.3	3.3	1.7	5.0
G C 9879	4E	.50oz	9.4	19.1	28.5	1.2	1.0	2.2
S D 9129	3E	.50oz	9.8	17.7	27.5	1.6	-0.4	1.2
Combined Average			--	--	--	2.1	0.3	2.4
			Check					
Untreated			8.2	18.1	26.3	--	--	--

[a]All measurements expressed in inches and based on 24 trees per treatment.

Height growth data for Soil Application Test No. II (Table XXVII) 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, 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 XXVIII 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-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.

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 XXIX) show little difference between six-ounce and four-ounce rates applied in 1963. The 1964 data showed all rates to have a similar increase in height growth over checks. In 1965 the six-ounce rate produced an approximate eight-inch increase above the four- and two-ounce rates. The total increase over checks during the three years was correlated with the rate of application: the two-, four-, and six-ounce rates produced increases of 41.7, 48.3, and 54.0 inches, respectively.

TABLE XXIX

AVERAGE HEIGHT GROWTH FROM ALL TESTS OF PINES TREATED WITH DISULFOTON 10G AT VARIOUS APPLICATION RATES, STILLWATER, OKLAHOMA

Ounces Per Tree	Increase over Checks, Inches[a]			
	1963	1964	1965	Total
6	7.0	16.8	30.2	54.0
4	8.5	18.2	21.6	48.3
2	3.2	16.3	22.2	41.7

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

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. Considering the cost of the chemicals, labor, and the periods of protection obtained from this program, the use of systemics to control the pine tip moth is feasible in ornamental pine plantings and on nursery stock. 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. On the basis of the current chemical and labor prices, costs for the two methods for one year do not differ greatly but the systemic method is much more convenient and feasible, since it involves only one application which requires no critical timing. Another important advantage of this method is that protection, at moderate levels, is extended beyond one year.

The study showed that several systemic insecticides gave promise for control of the Nantucket pine tip moth. Good to excellent control was produced by phorate, disulfoton, Baygon, Thiocron, Niagara 10242, Bayer 25141, and dimethoate during the first activity season following application. However, 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 VII indicates the relative phytotoxic effects of dimethoate at various rates of application. Fair to good control was produced by Phosphamidon, Shell S D 9129, and U C 21149. Shell S D 9129 produced moderate foliage "burning". None to poor control resulted from tests using Shell S D 4072, methyl demeton, E I 47031, G C 6506, G S 13005, and Bidrin. The non-systemic toxicants, toxaphene, dieldrin, and DDT, were ineffective when injected or applied as "paint-on" treatments to shoots. Thuricide, a microbial insecticide, applied under field plot conditions was ineffective in pine tip moth control. A further study of applications in isolated areas would be of value in determining Thuricide's potential as a microbial insecticide in control of the Nantucket pine tip moth.

Granular and liquid formulations were applied as soil treatments throughout the study. Both were generally effective in producing substantial control of the pine tip moth. Drenches made from liquid concentrates produced control faster than granular treatments but generally for a shorter duration. Generally 28-32 days were required for liquid treatments to produce substantial control, compared to 46-56 days for granular formulations. Control effectiveness of granular treatments was generally at reduced levels during the second growing season but exhibited some degree of protection during the third season in a few of the tests. Effectiveness of liquid concentrate treatments generally 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 to handle and easier to apply than liquid concentrate treatments.

Where granules were placed in the soil, as opposed to placing the material on the soil, there was an initial increase in effectiveness. However, there was no consistent difference between the two methods in the long-term results (Table VI). Similarly, applications of granules in a band on or in the soil around the trees was 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 VI) generally did not affect control immediately, nor did it influence the long-term results.

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, but the per cent of shoots damaged was equal to untreated check trees by the end of the 1963 growing season. Control produced by systemics was better than that produced by DDT. Records were not continued into the 1964 activity season.

Spray-drench methods of application were used instead of the foliar spray methods during the 1964 and 1965 study. The spray-drench method was derived from comparisons of foliar spray and liquid soil drench methods of application used in the 1963 study. The purpose was to establish two means of control with one application. Spray was applied until trees were saturated and "run-off" had continued to produce moderate drench effects. Protection by the spray-drench method was immediate, because the insects were sprayed or made contact with treated foliage. The extended period of effectiveness by this method was caused by translocation of chemical absorbed through foliage or from the soil by the roots. Protection was excellent throughout the latter part of the first growing season. Generally, 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 X).

Preliminary tests conducted to study the effectiveness and duration of trunk injection applications of pesticides showed that no control of the pine tip moth was obtained under the conditions present for this study. The Mauget-injector method of application required that a good seal between tree and aluminum sleeve was necessary to keep the apparatus from leaking. The pine trees available for this study ranged from 2.4 to 3.1 inches in diameter and had a bark thickness of from 1/4 to 3/8 inch. The specified depth of the aluminum sleeve into the tree was 1/4 inch inside the bark layer. The thickness of the bark plus the added 1/4 inch to achieve the depth required was not enough to make a proper seal and leakage was common. Where more depth into the trunk was used the systemic insecticide was not absorbed into the tree tissue within the given time. When 1/4 inch holes were bored into the trunk a reservoir was created to hold the systemic emulsifiable concentrates and non-systemic solutions. The insecticides were in contact with the tree for a longer period of time than by the Mauget injection system; however, results did not indicate protection to the tree at any time after treatment. 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 phytotoxic effects of all non-systemic solutions used. Bidrin 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 the bark peeling off 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 VII). Approximately twice the amount of toxicant was needed to maintain effectiveness on the larger shortleaf pines then was needed on the smaller trees.

A comparison of granular applications made at various dates during 1964 and 1965 was designed to determine the best period of the year to apply treatments to secure maximum control. The results (Table XXVI) showed that October and November applications were the only ones that gave good to excellent protection throughout the succeeding activity season. 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) was able to determine the approximate water content level of white pines at any given time throughout the year. He indicated that water content was low during October but began to rise in November and reached a peak during December. A steady decrease in the level was present until May, at which time an upward trend developed reaching a peak during September. A steady decrease into October followed, which completed the cycle. Water content levels in pines would not be the same in the Stillwater, Oklahoma, area as it would be in Montreal, Canada, where Gibbs conducted his study, but pine species would have a similar fluctuation in water content. There is the possibility that systemic insecticide accumulation and effective application periods are associated with the fluctuation in water content levels within the trees.

Soil moisture is important as the intermediate carrier of systemics from the soil into the trees. Where soil moisture is low, pick up and translocation of systemics within the tree is poor.

It was observed that the level of control resulting from systemic treatments often varied considerably during the growing season. In most cases the per cent of control, calculated by Abbott's Formula, was at a maximum in July and August and at lower levels in the spring and fall. This variation during the initial season of the early experiments was not surprising to the investigator. The increase in effectiveness from spring to late summer was interpreted as the result of progressive accumulation of the toxicant in pine shoots following applications made in the spring or early summer. A decrease in control during the fall was thought possibly to be a result of deterioration and dissipation of the toxicant in the soil or in the plant.

When the trend occurred in most tests during the second year after application, it was evident that the explanations suggested above were not valid for these control fluctuations in later seasons. Accordingly, it was decided to study control results in relation to period of growing season, particularly with reference to data taken in years after the season of application.

Figure 2 shows the per cent control 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 since all involved systemic insecticides it is believed that the results show the relationship of control levels to periods of the growing season.

The trends in control were generally the same for each year of observation. Where a treatment was observed for two or three years, a progressive decrease in the per cent control occurred. All trends were generally the same with a lower per cent control in the spring and fall than in the summer. Zanher (1962) showed 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. Since the translocation of systemics is influenced by moisture present within the tree and the surrounding soil, the water content in early spring and late fall may also influence levels of control. 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).

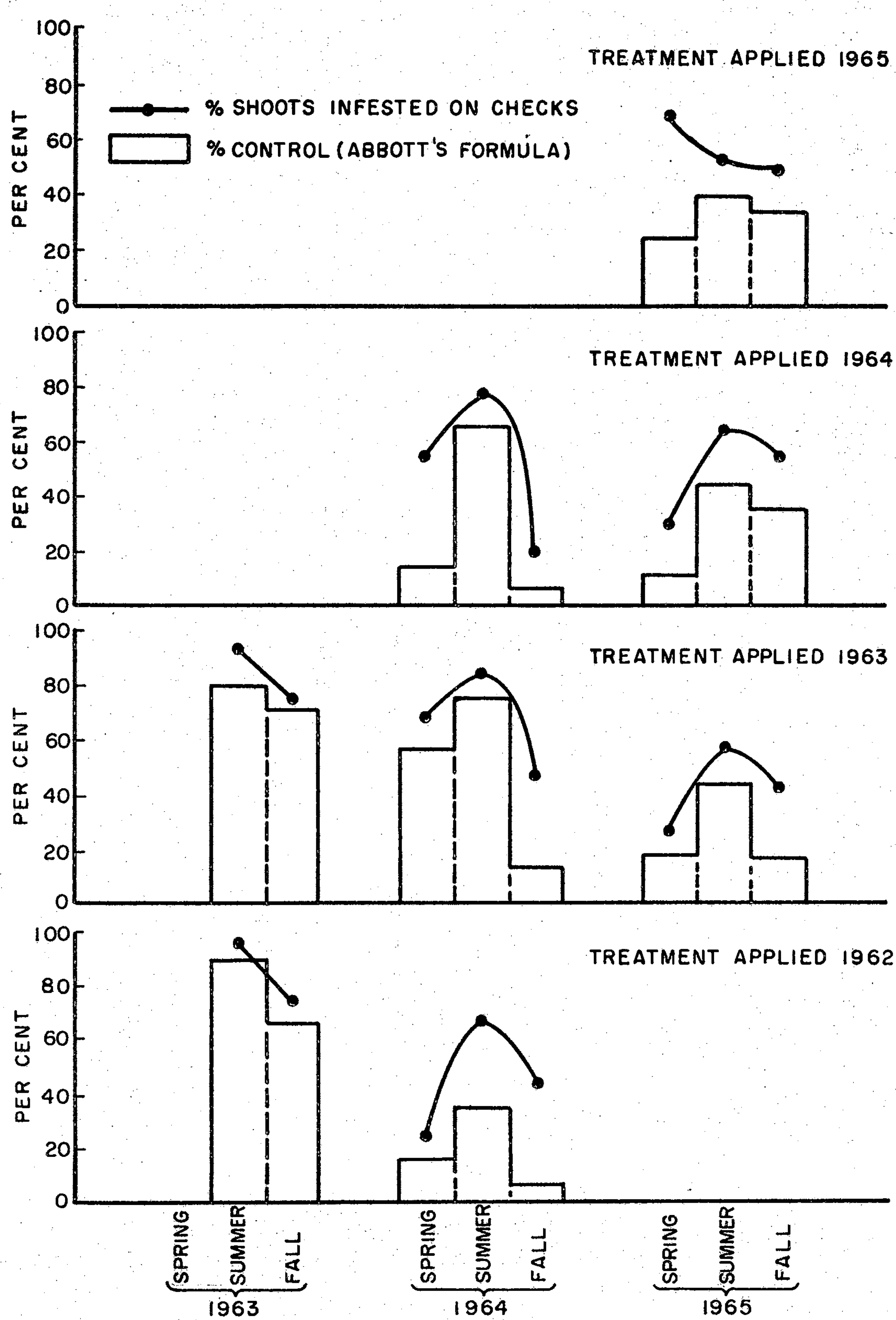

Figure 2. Per cent control of the Nantucket pine tip moth by insecticides at three periods during the growing season, Stillwater, Oklahoma.

The lower levels of control during the spring and fall may have been caused largely by the lower transpiration rates of the trees during these periods.

Increased levels of control in the spring may be produced by a spray-drench application when moth emergence for the overwintering generation is at its peak. The larvae produced by surviving moths would be controlled by contact with the poison on the tree or by systemic action of the poison as it is picked up and translocated throughout the tree. Good protection throughout the remainder of the season would be produced due to the accumulation of systemics within the trees.

During 1964 and 1965 four generations of the pine tip moth were observed in emergence chamber studies. Per cent moth emergence per 100 shoots (Figure 1) gave an indication as to the population levels present during each generation. The overall moth emergence for the overwintering and third generations was 5.1 and 2.2 per cent, respectively, but for the first and second generation it was 15.5 and 19.2 per cent. The second generation had the largest population, and the first generation population was slightly smaller. The third generation was observed 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 or a partial fourth generation period of emergence was in existence. The over-lapping of generations was not observed in 1964 or 1965. However, over-lapping might possibly occur between the second and third generations, since there was only a 12-day break between them.

Pine transplants of all species tested had negligible infestation during the first two years the small trees were in the field. Infestation toward the end of the second year reached the .01 per cent level on untreated pine transplants under grass cover and .03 per cent level on untreated pine transplants in an area where grass was burned off prior to transplanting dates. The application of granular systemic insecticides at time of treatment 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 is not justified for protection during the first two years. However, observations and records made on 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 tip moth injury to permit normal growth. Such protection can be obtained by systemic treatment 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 also since the amount of chemical required would be less than for larger trees.

Population levels of pine tip moth on untreated five-year-old shortleaf and loblolly pines were approximately equal. However, the overall infestation level for 27-year-old shortleaf pines was heavy, compared to very light infestations on loblolly pines of approximately the same age. Twenty-five-year-old ponderosa pines were almost free from pine tip moth infestation. The effective duration of systemic pesticides was greater in the five-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 seven-year-old trees (Table VIII) showed, as would be expected, that the duration of protection decreased as the tree size increased.

On the basis of the per cent 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 present in this area. 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, which was less than that recorded for 1963, and the 1965 reading were generally less than the 1964 measurements. A relationship was observed between rates of application and height growth. The two-, four-, and six-ounce 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 Table V. Three years of study show that it is possible to achieve long-term control effects through use of systemic insecticides. As would be expected however, the level of control gradually decreases 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 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 years of age and by beginning control on third season transplants. The cost of this method, however, makes it too expensive to be used over large scale forested areas.

SUMMARY

The investigation made in 1964 and 1965 included evaluation of several systemic insecticides for control of the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock), and determination of effective rates, duration, and methods of application. Studies were made on insect seasonal development, and differential damage on pines of various ages and species.

All systemic toxicants tested resulted in population reduction, but protection in certain cases was of short duration. Granular formulations of phorate and disulfoton and the emulsifiable concentrate of disulfoton were most effective, giving a high degree of protection for over one year as well as moderate control throughout the second year. Niagara 10242 and Bayer 25141 gave almost complete protection throughout the first activity season of 1965. Baygon, thiocron, and dimethoate also produced a high level of control.

Granular formulations applied to the soil generally gave longer periods of protection than liquid formulations but were slower in action. The importance of good distribution of toxicants in or on the soil was demonstrated. Spray-drenches produced immediate protection and excellent control throughout the first season. Dimethoate, Baygon, and Shell S D 9129 caused phytotoxic effects. Injections and paint-on applications of systemic and non-systemic insecticides were ineffective. Thuricide, a microbial insecticide, also was generally ineffective.

Fall soil applications produced the best overall protection throughout the succeeding activity season. The per cent control, determined by Abbott's Formula, was at a maximum in summer and lower in spring and fall. Height growth of systemically treated pines was consistently greater than that of untreated trees. Infestation levels for 25- to 27-year-old trees were very heavy on shortleaf pines but light to negligible on loblolly and ponderosa pines. Infestation levels on five-year-old shortleaf and loblolly pines were approximately equal. Pine transplants received little or no infestation during the first two years in the field. Four generations of the pine tip moth were present in this area.

LITERATURE CITED

Afanasiev, M., and F. A. Fenton. 1947. Pine tip moth and its control in Oklahoma. J. Forest. 45(2):127-128.

Beal, J. A. 1952. Forest insects of the southeast: with special reference to species occurring in the Piedmont Plateau of North Carolina. Duke Univ., Forest. Bul. 14. p. 36-38.

Bennett, S. H. 1957. The behavior of systemic insecticides applied to plants. Ann. Rev. Entomol. 2:279-296.

Bennett, W. H. 1955. Pine tip moth: Rhyacionia frustrana (Comstock). Texas Forest Service Circ. 46. 2p.

Burton, R. L. 1963. The effects of systemic insecticides and ecological factors on infestations of the Nantucket pine tip moth, Rhyacionia frustrana (Comstock). M.S. Thesis. Oklahoma State Univ. Stillwater, Oklahoma. 34p.

Butcher, J. W., and D. L. Haynes. 1960. Influence of timing and insect biology on the effectiveness of insecticides applied for control of European pine shoot moth, Rhyacionia frustrana. J. Econ. Entomol. 53(3):349-354.

Coppel, H. C., and D. M. Norris. 1960. Systemic insecticides for control of the introduced pine sawfly, Diprion similis, with notes on parasitic survival. J. Econ. Entomol. 53(4):648-650.

Craighead, F. C. 1950. Insect enemies of eastern forests. U. S. Dep. Agr. Misc. Pub. 657:467-468.

Fenton, F. A., and M. Afanasiev. 1946. Seasonal cycle and control of the pine tip moth. J. Econ. Entomol. 39(6):818.

Flory, C. H., W. C. Nettles, and W. J. Barker. 1955. Forest insects and diseases of South Carolina trees. South Carolina State Forest. Comm. and Clemson Col. Ext. Service Bul. 116. 40p.

Foil, C. H., R. G. Merrifield, and T. Hansbrough. 1961. Tip moth control on loblolly pine. Louisiana Agr. Exp. Sta. North La. Hill Farm Exp. Sta. Hill Farm Facts, Forest.-II. 5p.

Gibbs, D. R. 1957. Patterns in the seasonal water content of trees, p. 43-69. In K. V. Thiman (ed) The physiology of trees. Ronald Press Co. New York.

Harries, E. H. 1965. Control of insects and mites on fruit trees by trunk injections. J. Econ. Entomol. 58(4):631-634.

Harris, J. M. 1961. Water-conduction in the stems of certain conifers. Nature. 189(4765):678.

Johnson, N. E., and J. H. Rediske. 1965. Systemic pesticides in woody plants: translocation. Bul. Entomol. Soc. Amer. 11(3):190-195.

Kramer, P. J. 1943. Amount and duration of growth of various species of tree seedlings. Pl. Physiol. 18(1):239-251.

____________ 1957. Thermoperiodism in trees, p. 573-580. In K. Y. Thiman (ed) The physiology of trees. Ronald Press Co., New York.

Kozlowski, T. T., L. Leyton, and J. E. Hughes. 1965. Pathways of water movement in young conifers. Nature. 205(4973):830.

Kulman, H. M., and C. K. Dorsey. 1962. Granular application of systemics for control of European pine shoot moth. J. Econ. Entomol. 55(3):304-305.

Mirov, N. T. 1957. Distribution of turpentine components among species of the genus *Pinus*, p. 251-268. In K. V. Thiman (ed) The physiology of trees. Ronald Press Co., New York.

Mortimer, M. F. 1941. The life history and control of the pine tip moth, *Rhyacionia frustrana* (Comstock), (Family: Tortricidae), at Nashville, Tennessee. Tennessee Acad. Sci. J. 16(2):190-206.

Neel, W. W. 1959. Tip moth control on young pines. Mississippi Farm Res. Mississippi Agr. Exp. Sta. 22:1.

Polivka, J. B., and J. S. Houser. 1936. Pine tip moth of southern Ohio. J. Econ. Entomol. 29(3):494-497.

Rudinsky, J. A. 1959. Systemics in the control of forest insects. J. Forest. 57(4):284-286.

Scholander, P. F. 1957. The rise of sap in Lianas, p. 3-17. In K. V. Thiman (ed) The physiology of trees. Ronald Press Co., New York.

Schuder, D. L. 1960. The Zimmerman pine moth, *Dioryctria zimmermani* (Grote). Purdue Univ., Agr. Exp. Sta., Res. Bul. 698.

Scudder, S. H. 1879. Meeting of the Entomological Club of the American Association for the Advancement of Science. Can. Entomol. 11(9):176.

Stearns, A. 1953. The biology and control of the Nantucket pine moth and the European pine shoot moth. J. Econ. Entomol. 46(4):690-692.

Treece, R. E., and J. C. Matthysse. 1959. Use of systemic insecticides on woody ornamental plants. Cornell Univ. Exp. Sta. Bul. 945.

Underhill, G. W. 1943. Some insect pests of ornamental plants. Virginia Agr. Exp. Sta. Bul. 349. 38p.

U. S. Department of Commerce. 1963. Climatological data; Oklahoma. 72(1-12).

______________________________ 1964. Climatological data; Oklahoma. 73(1-12).

______________________________ 1965. Climatological data; Oklahoma. 74(1-12).

Wakely, P. C. 1954. Planting the southern pines. U. S. Dep. Agr. Forest Service. U. S. Dep. Agr. Monogr. 18:154-155.

Yates, O. H., III. 1960. The Nantucket pine moth; a literature review. U. S. Dep. Agr. Forest Service. Southeastern Forest Exp. Sta. Paper, 115. 19p.

Zanher, R. 1962. Terminal growth and wood formation by juvenile loblolly pine, <u>Pinus taeda</u>, under two moisture regimes. Forest Sci. 8(4):345-352.

VITA

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