

NANTUCKET PINE TIP MOTH INFESTATIONS IN RELATION TO STAND TYPE

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I. INTRODUCTION

The Nantucket pine tip moth, Rhyacionia frustrana (Comstock) is a common pest of young pines. In the eastern United States all species of yellow pines are attacked to some degree except longleaf pine, Pinus palustris Mill. (Yates 1960).

Chemical control of the tip moth has been demonstrated to be effective, but it generally has been considered to be too expensive since the evidence was only inconclusive as to any permanent additional height growth of pines resulting from complete control. There has been considerable speculation about silvicultural control and a number of methods have been suggested by various workers. Many of these methods, however, have not been backed by quantitative data. Some of the suggested silvicultural controls are mixing susceptible species with resistant species, starting trees under an overstory, using close spacing, and starting trees in brush. To date, there have been no detailed investigations of silvicultural control for the tip moth.

This study was designed to determine if stands of loblolly pine, Pinus taeda L., growing under various conditions show any differences in rate of attack by the tip moth that might, in the future, be a basis for silvicultural or integrated control.

II. LITERATURE REVIEW

The Nantucket pine tip moth, Rhyacionia frustrana (Comstock), (Lepidoptera: Olethreutidae) was first reported damaging pines on Nantucket Island in Massachusetts, in 1879 (Comstock 1880). A more detailed account of the insect was published by Scudder in 1883. Since that time the tip moth has received considerable attention due to the habit of its larvae mining the shoots of pines. In the genus Pinus in eastern United States, only eastern white pine, Pinus strobus L. and longleaf pine, Pinus palustris Mill. appear to be completely immune to attack (Yates 1960). Loblolly pine, Pinus taeda L. and shortleaf pine, Pinus echinata Mill. are the favored hosts in the South. According to Yates (1960), the tip moth may have from two to five generations depending on the geographic area. It overwinters as a pupa within the damaged shoot. A western variety, Rhyacionia frustrana var. bushnelli, drops to the ground and pupates in the litter.

The tip moth can be controlled with chemical insecticides, (Mason 1958, Neel 1959, Donley 1960, Foil et al. 1961, Somes & McIntyre 1963, Warren 1964), but it is generally considered to be of limited practicability due to high cost, necessity of controlling up to five generations, and the doubtful value of any additional height growth resulting from control.

Mason (1958) showed that height growth could be significantly improved by chemical control of the tip moth, but during the following year more control operations did not produce a significant difference between treatment and control trees. Neel (1949) showed a significant height increase for one year with complete control of the tip moth. Warren (1964) also found a significant growth increase resulting from control, but questioned the economic justification of such control. Somes and McIntyre (1964) could not detect an increase in height growth with control of the two generations of tip moth in eastern Maryland. Wenger (1955) reported that two and four-year-old infested seedlings made significantly more height growth than non-infested seedlings and Thor and Beavers (1964) reported that infested seedlings produced more height than non-infested seedlings.

In the absence of any proof that the tip moth causes enough permanent damage to warrant chemical control, there has been a profusion of speculations on assumed less expensive silvicultural approaches to tip moth control. In many cases these were based on long years of field experience by the writers and apparently not the results of quantitative studies. In cases where quantitative data were not presented in the following three paragraphs, it will be specifically indicated.

Wakeley (1928) suggested the following silvicultural control measures: (1) mixing susceptible species with

resistant species, (2) starting trees in brush, (3) starting trees under an overstory, and (4) using close spacing. Wakeley also suggested the breeding of resistant strains. Some researchers have suggested that grasses and brush may act as a mechanical barrier to the tip moth, (Graham and Baumhofer 1927, Beal et al. 1952, Foil et al. 1962, Warren 1963).

Wakeley (1935) states: "There is definite evidence that growing the trees in dense stands minimizes the damage." He failed, however, to supply supporting data. Bronson (1941) advocates seeding to produce a dense stand to control the tip moth, but also did not give supporting data. Beal et al. (1952) states that plantations are more severely affected by the tip moth than areas of natural reproduction but does not indicate a reference to supporting studies. Hansbrough (1956) reported tip moth attack to be more intense at wide spacings in loblolly pine plantations, but did not refer to any quantitative data.

Seedlings growing under an overstory have been reported to be infested at a lower rate than exposed trees, and release brought about an increase in infestation (Huckenpahler 1951, Huckenpahler 1953, Wenger 1955b, Williston and Huckenpahler 1958). Harrington (1955), however, working in Texas, reported that tip moth incidence on loblolly pine was not significantly related to shading. He also failed to present supporting data.

Some workers have looked into the possibility of resistant strains of susceptible species. Graham and Baumhofer (1930) working in Nebraska with western yellow pine, Pinus ponderosa and other species stated: "The variation in ability of different trees to grow in spite of tip moth does not, in the light of present information, appear to be correlated with any environmental factor, but is the result of differences between individual trees." A Louisiana study on loblolly pine from four different seed sources showed no significant difference in susceptibility to tip moth attack (Crow 1956, Crow 1958). Henry and Hepting (1957) reported that loblolly pine from 15 seed sources in 13 plantations did not indicate any difference in susceptibility. Some strains of loblolly pine have been found in Texas that are apparently resistant to the tip moth (Texas Forest Service, 1960). Holst (1963), in a review of resistance to Rhyacionia in pines, states: "It is not likely that tip-moth-resistant strains can be found in loblolly pine, but individual selection and hybridization may yield results."

In another species of the genus, Rhyacionia buoliana (Schiff.), Kulman (1965) has shown that the rate of parasitism varies in different levels of red pine trees. If a similar relationship occurs in loblolly pine with the Nantucket pine tip moth, it may affect the distribution of damaged shoots.

III. METHODS AND MATERIALS

Stands selected for study were in Brunswick County, which is within the natural range of loblolly pine in the Piedmont Plateau of Virginia. The stands were on private, company, and state-owned land. The Seward Forest at Triplet, Virginia, was the headquarters for the study.

Selection of Stands

In the spring of 1963, six types of loblolly pine stands were selected for study (see Page 11 for description). Ten replications of 25 trees each were taken in each stand type. An analysis of variance after the first season showed that 5 trees per stand was sufficient. Therefore, in the spring of 1964, fifteen replications of 5 trees each were used for each stand type. All trees selected for study were from 5.5 to 6.5 feet tall at the beginning of the growing season. The trees were marked with plastic ribbons, a yellow paint spot, and a metal tag bearing the number of the tree. Infested and non-infested shoots were counted using hand tallies in each of three levels of each tree. A shoot was considered to be infested if it was killed; no data was recorded on initiated but unsuccessful attack. The points at which the shoot growth originated were designated as clusters of new shoots as defined by Kulman and Hodson (1962), and were also counted in each level of the trees. Data were collected in this manner for

each of the three generations in 1963 and 1964. The levels within the trees were designated as:

(1) Top -- This area included any shoots which were dominant, or in the opinion of the observer, capable of becoming dominant if one or more of the leaders were killed. In a typical tree, the terminal and most of the shoots in the first whorl would be included in the top level.

(2) Next two feet -- This area was measured with a two-foot stick from the top cluster of new shoots downward. If more than one cluster was present in the top of a tree that was not at the same height, the stick was placed in such a way that the distance was divided so that some shoots on the lower edge of the clusters would not be included in the top level.

(3) Bottom -- This area included any shoots below the next two feet level. Clusters of new shoots originating in the bottom with most shoots extending up into the next two feet section were counted as being in the latter.

Stand types selected for study were as follows:

Description of Stand Categories

1. Plantations - Planted stands on old fields with an average spacing of 7 x 7 feet to 8 x 8 feet.
2. Old fields - Naturally seeded old fields with an average spacing of 7 x 7 feet to 8 x 8 feet. Measurements were made with a long pole graduated in feet. All trees here were nearly the same height.

3. Old fields - 15 feet - Naturally seeded old fields with average spacing 7 x 7 feet to 8 x 8 feet, but with 30 to 50 percent of the trees averaging 15 feet in height.
4. Dense - Seeded areas with an average spacing of 3 x 3 feet or less.
5. Light overstory - Stands growing under a light pine overstory and receiving direct sunlight for only short periods during the day, with variable spacing.
6. Hardwood competition - Plantations with severe hardwood competition. This competition usually came from sprouts of stumps in recently cutover areas. This stand type was added in the spring of 1964.

The data were expressed as percentage of shoots infested at each level of the tree. The analysis was made using standard analysis of variance. The data were transformed to the arc sine. Stand categories were compared using Duncan's multiple range test. The same analysis was run on the average number of shoots per cluster of new shoots.

Removal of Overstory

During the winter of 1963-1964, the overstory on one of the light overstory stands was removed in a regular cutting operation, exposing the trees to direct sunlight. Data were taken again on 10 of the original 25 trees to determine the effect of the removal on the incidence of attack by the tip moth.

Vegetation as a Mechanical Barrier to the Tip Moth

Seven pairs of trees were selected in the area with heavy ground cover. A 6 x 6 foot square of black polyethylene was placed at the base of one member of each pair to kill the vegetation. This cover was removed prior to the emergence of the second generation adults after the grasses had been killed. Data on the infestation rate was taken for the third generation on these trees and the 7 control trees.

IV. RESULTS

Rate of Infestation in Relation to Stand Categories

As shown in Figure 1, in each generation for both 1963 and 1964, plantations had the highest rate of infestation and light overstory stands always had the lowest rate. Hardwood competition stands, on which data were collected only for 1964, were generally higher than old field and dense stands. The old field and dense categories fluctuated in relation to each other. The old-field-15' stands usually showed the second lowest infestation rate.

Within levels in the trees, the top level always exhibited the highest rate of infestation, followed by the next-two-feet and bottom levels (Fig. 1).

In the analyses of the data on percentage of shoots infested (Appendix A), there was a highly significant difference between stand types and usually a highly significant difference between replications within each stand type.

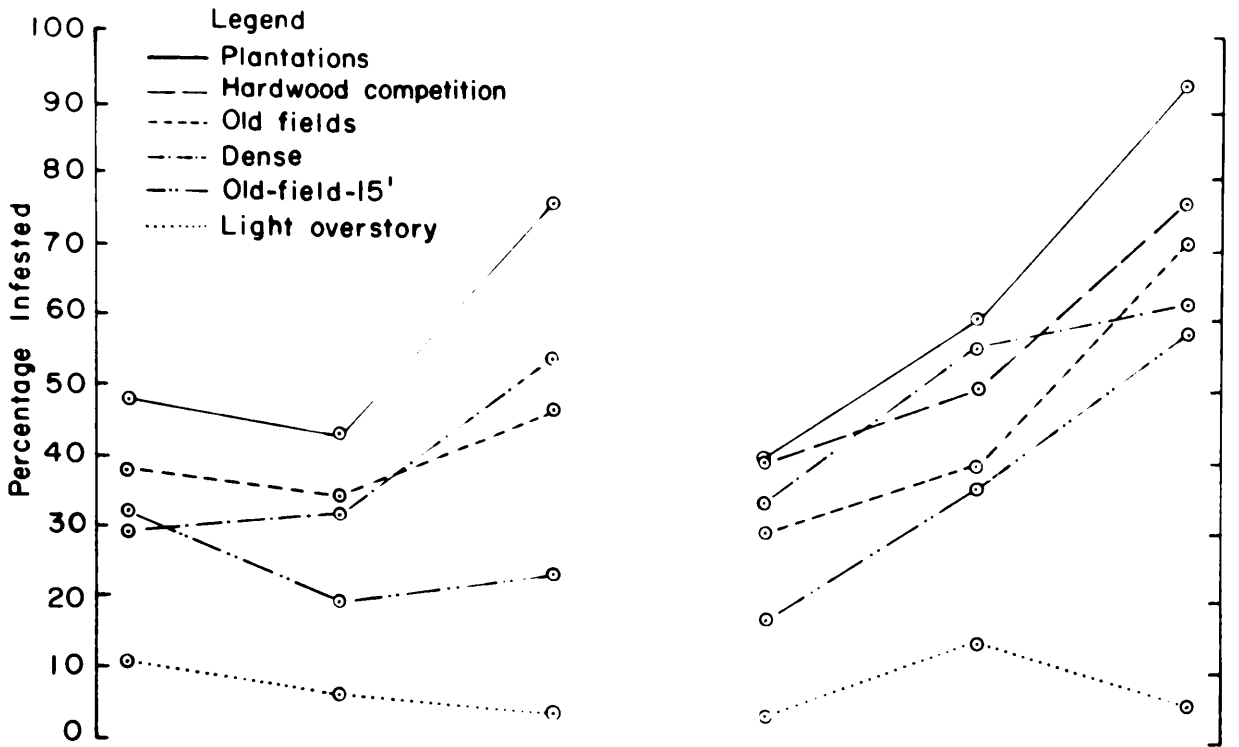
Differences between individual stand types were determined with Duncan's new multiple range test as shown in Tables 1 to 6.

In 1963, infestations in plantations were always significantly higher than all other types of stands. The light overstory type was significantly lower than all others except for the bottom for the third generation where it did

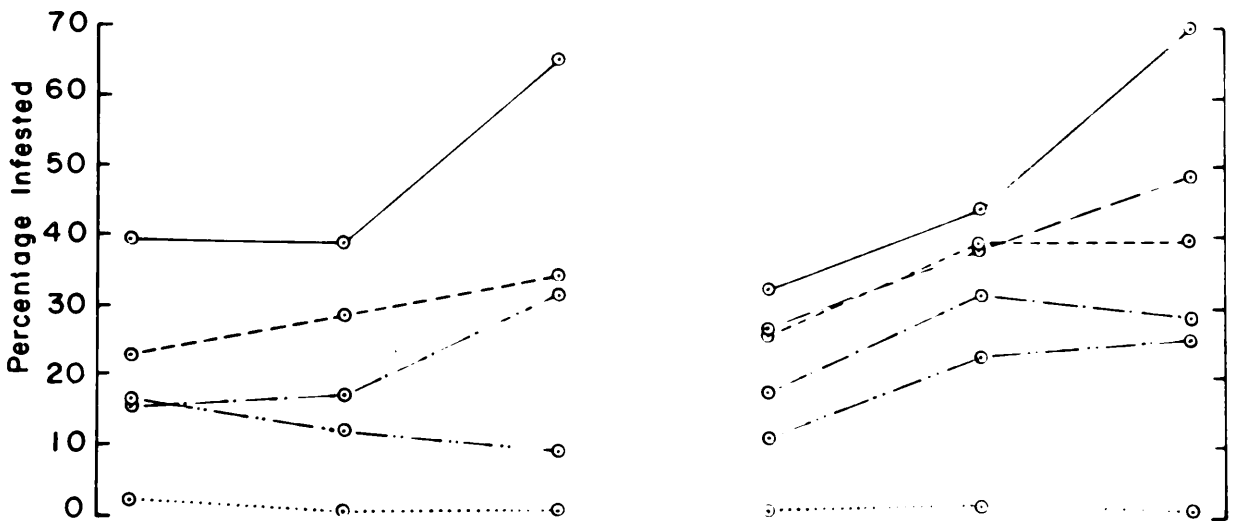
not differ from old field 15'. The old field category was significantly higher than old field 15' except in the bottom for the first generation. The old field type was generally infested at a higher rate than dense, being higher 7 of the 9 possible times, and of these, significantly higher 6 times. The dense category was significantly higher than the old field type only twice; in the top for the third generation and the bottom for the first generation.

In 1964, the infestation rate of plantations was significantly higher than light overstory and old field 15' categories for each generation and in each of the within-tree levels. Plantations also were significantly higher than dense stands in every case except the top for the second generation. Old field stands were significantly higher than light overstory and old field 15' in every case except the top level for the first generation where they were not significantly different from the old field 15' type. The old field, hardwood competition, and dense categories did not show any consistent significant relationships although the dense stands were generally infested at a lower rate than the other two. Old field stands were always significantly lower than plantations in the top level. No consistent relationship between old fields and plantations occurred in the next-two-feet and bottom levels.

TOP



NEXT TWO FEET



BOTTOM

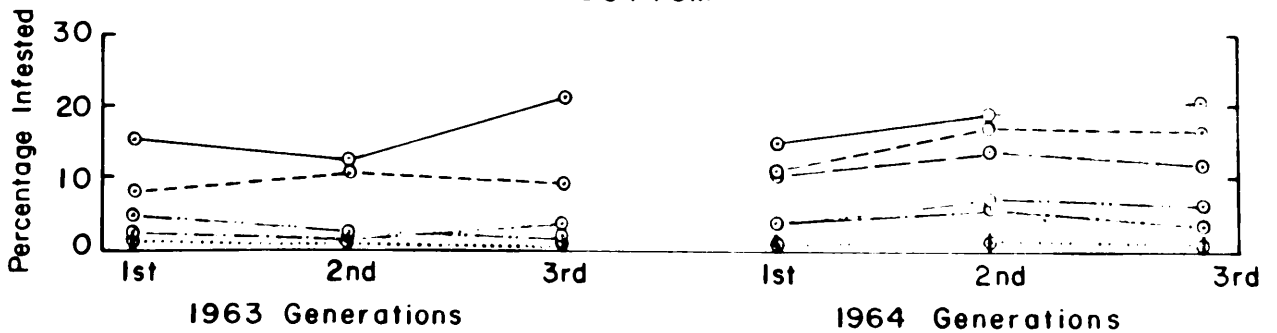


Table 1. Results of Duncan's Multiple Range Test on Stand Categories

First Generation - 1963

Top

Lt. overst	Dense	Old fld.15'	Old fld.	Plantations
23.00	34.12	34.19	37.03	46.21

Next two feet

Lt. overst	Old fld.15'	Dense	Old fld.	Plantations
9.76	21.77	21.79	27.04	36.03

Bottom

Lt. overst	Old fld.	Old fld.15'	Dense	Plantations
11.18	14.28	14.32	17.90	21.36

Table 2. Results of Duncan's Multiple Range Test on Stand Categories

Second Generation - 1963

Top

Lt. overst	Old fld.15'	Dense	Old fld.	Plantations
23.01	28.29	37.06	38.60	44.50

Next two feet

Lt. overst	Old fld.15'	Dense	Old fld.	Plantations
8.31	19.60	23.63	32.57	39.34

Bottom

Lt. overst	Old fld.15'	Dense	Old fld.	Plantations
7.85	8.92	10.60	13.82	18.87

Table 3. Results of Duncan's Multiple Range Test on Stand Categories

Third Generation - 1963

Top

Lt. overst	Old fld.15'	Old fld.	Dense	Plantations
19.66	31.16	44.96	51.82	<u>66.79</u>

Next two feet

Lt. overst	Old fld.15'	Dense	Old fld.	Plantations
7.95	17.45	32.16	36.12	<u>56.48</u>

Bottom

Lt. overst	Old fld. 15'	Dense	Old fld.	Plantations
8.60	8.66	11.12	16.53	<u>27.07</u>

Table 4. Results of Duncan's Multiple Range Test on Stand Categories

First Generation - 1964

Top

Lt. overst	Old fld.15'	Old fld.	Dense	Hdwd.comp.	Plantations
16.70	28.16	35.02	35.60	40.74	43.53

Next two feet

Lt. overst	Old fld.15'	Dense	Old fld.	Hdwd.comp.	Plantations
8.43	18.25	24.89	30.07	32.34	35.17

Bottom

Lt. overst	Old fld.15'	Dense	Hdwd.comp.	Old fld.	Plantations
8.70	11.45	12.09	17.45	18.17	22.26

Table 5. Results of Duncan's Multiple Range Test on Stand Categories

Second Generation - 1964

Top

Lt. overst	Old fld.15'	Old fld.	Hdwd.comp.	Dense	Plantations
23.68	34.26	40.76	47.90	50.59	54.97

Next two feet

Lt. overst	Old fld.15'	Dense	Old fld.	Hdwd.comp.	Plantations
9.50	26.87	33.38	38.45	39.97	43.84

Bottom

Lt. overst	Old fld.15'	Dense	Hdwd.comp.	Old fld.	Plantations
7.62	13.92	16.92	20.48	22.70	24.50

Table 6. Results of Duncan's Multiple Range Test on Stand Categories

Third Generation - 1964

Top

Lt. overst	Old fld.15'	Dense	Old fld.	Hdwd.comp.	Plantations
21.26	51.99	56.62	61.54	66.26	81.25

Next two feet

Lt. overst	Old fld.15'	Dense	Hdwd.comp.	Old fld.	Plantations
8.51	28.05	31.43	44.94	46.22	59.05

Bottom

Lt. overst	Old fld.15'	Dense	Hdwd.comp.	Old fld.	Plantations
7.91	12.59	14.24	18.12	23.31	26.68

In 1963, the rate of infestation decreased in the second generation and increased in the third generation (Fig. 1). The infestation rate decreased sharply between the third generation for 1963 and the first generation for 1964. A large number of infested tips were torn open during the pupal stages of the third generation both in 1963 and 1964, apparently by birds. The author did not actually see the apparent bird predation taking place. A number of the infested tips also appeared to have been broken during the winter by wind whipping the branches together. In 1964 the infestation was higher in each successive generation except in the light overstory stands. It reached a level in the third generation that was considerably higher than the infestation rate in 1963. The first generation infestation levels were nearly the same in 1963 and 1964 (Fig. 1).

The average number of shoots per cluster of new shoots, with the exception of the first generation for 1963, showed few significant differences or consistent relationships (Table 7).

For the average number of shoots per cluster in the first generation of 1963 (Table 7), plantations were significantly higher than dense and light overstory stands in all 3 levels, and significantly higher than old field 15' in the top and next-two-feet levels. Light overstory stands

were significantly lower than all others in the top and next-two-feet levels. The old field 15' category was significantly higher than dense and light overstory stands.

Removal of Overstory

Removal of the overstory from a light overstory stand resulted in an increase in the rate of tip moth infestation in the top and next-two-feet sections of the trees (Fig. 2). The bottoms were not attacked, either before or after the removal of the overstory. Although there was an increase, the rate of infestation was much lower than the infestation in stands that had always been exposed to full sunlight. A high degree of initiated but unsuccessful attack was noted in the first generation after overstory removal.

Table 7. Average number of shoots per cluster of new shoots 1963-1964

1963

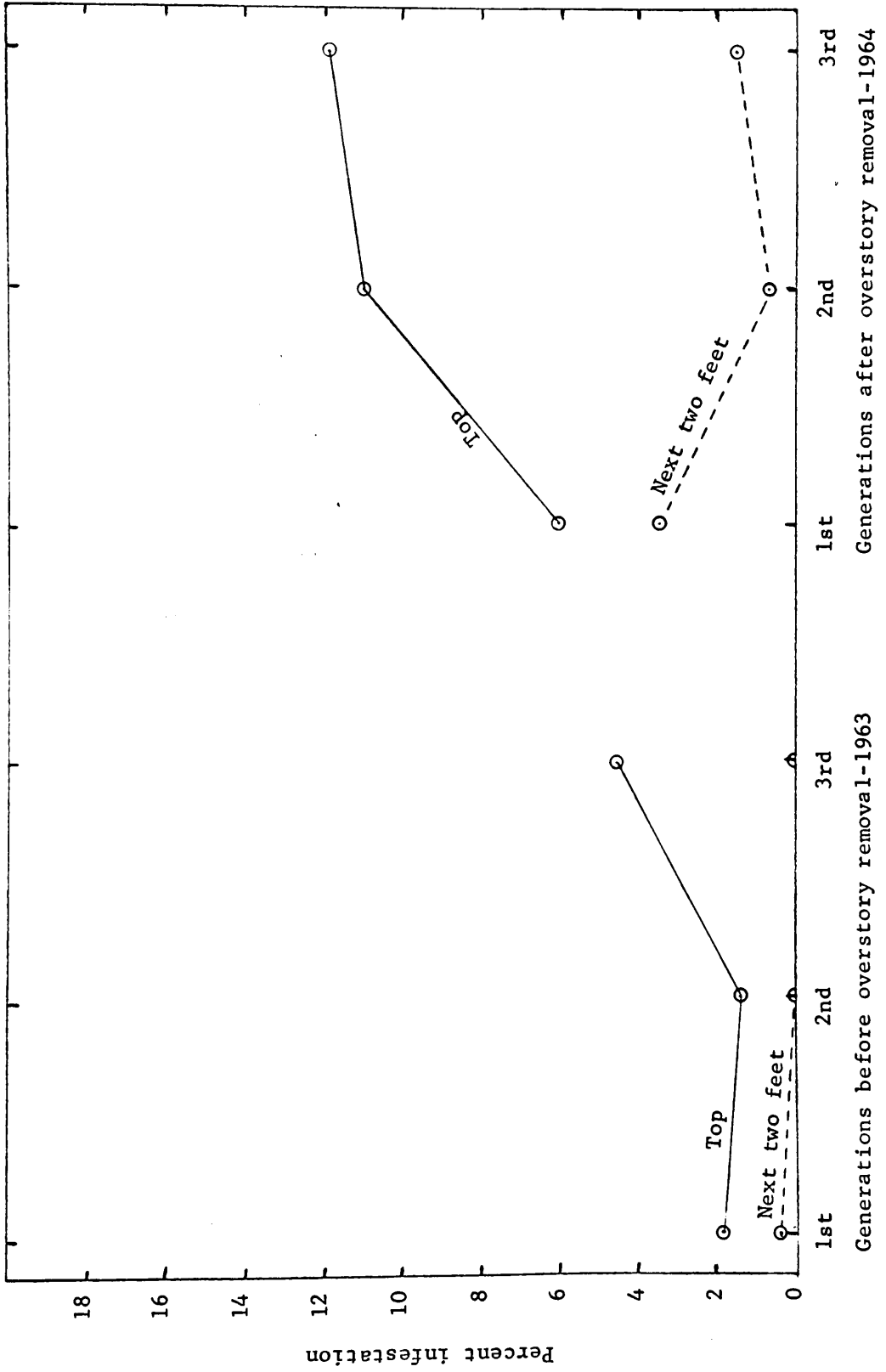
Stand Type	First Generation		Second Generation		Third Generation							
	Top	Next 2 ft. Bottom Total	Top	Next 2 ft. Bottom Total	Top	Next 2 ft. Bottom Total						
Plantations	4.25	2.65	1.95	2.42	3.04	2.26	1.98	2.16	2.25	2.04	2.13	2.12
Old fields	4.58	2.60	1.88	2.41	3.10	2.26	2.28	2.34	2.29	1.86	2.32	2.18
Old fields 15'	3.82	2.29	1.79	2.23	3.12	2.16	2.34	2.34	2.62	1.94	2.16	2.12
Dense	3.55	2.07	1.62	2.11	3.18	2.07	2.12	2.22	2.07	1.61	2.03	1.87
Light overstory	3.02	1.83	1.59	1.81	2.18	2.00	1.98	2.00	2.18	1.93	1.94	1.95

1964

Plantations	3.50	2.13	1.91	2.07	2.43	1.80	1.75	1.84	1.63	1.53	1.49	1.52
Old fields	3.61	2.16	1.85	2.08	2.19	1.92	1.79	1.88	1.99	1.82	1.86	1.86
Old fields 15'	3.64	2.09	1.78	2.02	2.19	1.66	1.58	1.65	2.41	1.72	1.60	1.72
Dense	3.19	1.94	1.68	1.94	1.79	1.76	1.59	1.70	1.80	1.65	1.75	1.72
Light overstory	2.86	1.72	1.71	1.82	1.84	1.60	1.64	1.64	1.92	1.75	1.73	1.76
*Hardwood competition	3.47	1.70	1.67	1.81	2.08	1.65	1.66	1.71	1.98	1.68	1.76	1.76

*Data taken for 1964 only

Figure 2. Effect of removal of overstory on tip moth infestation.



Vegetation as a Mechanical Barrier to the Tip Moth

The results from this small sample show that with the level of infestation present at the time of the study, there is little difference between the rate of infestation on trees with heavy ground cover around them and those without ground cover (Table 8).

Table 8. Effect of ground cover on infestation rate between second and third generations - 1964, percent infestation.

<u>Treatment</u>				
<u>Level in Tree</u>				
<u>Generation</u>	<u>Top</u>	<u>Next-two-feet</u>	<u>Bottom</u>	<u>Total</u>
	<u>%</u>	<u>%</u>	<u>%</u>	<u>%</u>
<u>Second</u>	51.52	39.16	13.46	28.86
<u>Third</u>	95.71	70.81	20.00	49.89
<u>Check</u>				
<u>Second</u>	46.03	52.03	18.81	33.17
<u>Third</u>	95.16	69.89	26.14	51.15

V. DISCUSSION

Data obtained in this study show that wider spacings and more exposed trees are attacked at generally higher rates than those receiving some degree of influence, probably shade, from an overstory or associated vegetation. The highly significant differences among replications within individual categories of stands, however, indicates the presence of factors other than spacing and shading affecting tip moth population levels.

Since considerable effort was made to have replications within stand categories similar in every respect, it was surprising that there were significant differences within the stand categories. Although these differences probably obscured some of the relationships between stand categories, it widened the applicability of the study, in that it showed that the differences between stand categories were sufficiently large to be evident even in the presence of large variations within the categories.

Trees with wider spacings do not necessarily sustain the heaviest damage even though they sustain a higher rate of tip moth attack. There appears to be other factors, probably site, which greatly affect the amount of damage inflicted by the tip moth at a given level of infestation. Some stands exhibited the ability to make excellent growth in spite of heavy tip moth attack, while others of the same

category made poor growth and suffered heavy damage from the same rate of infestation. Those stands which appeared to suffer the heaviest damage were probably growing on the poorer sites, since they were frequently in areas supporting shortleaf pine as well as loblolly pine. Shortleaf pine is usually confined to the drier sites which are generally poorer for loblolly pine. On sites such as these, shortleaf pine might be superior to loblolly in resistance to tip moth damage.

The hardwood competition stands were infested at a lower rate than the plantations which were identical in spacing, but lacked the competition from hardwood sprouts. This lower infestation rate cannot be entirely attributed to shade since the tops of pines in the hardwood competition stands were completely exposed as were the tops of pines in the plantation stands. However, the lower tree levels in hardwood competition stands would receive more shade than plantation trees. The difference in the infestation in tops of trees between the two types of stands may be due to a change in the microclimate effected by the hardwood competition. Furthermore, parasites, predators, and disease may have been influenced by microclimate changes and by the wider range of alternate hosts provided by the associated hardwoods.

At present, no readily apparent reasons have been found to account for the differences between old fields and plantations. The average spacing is similar for both types of stands and the sites appear to be about the same. Both types are on old fields. Ground cover and associated species appear to be generally the same although the more irregular arrangement of trees in the old field categories might create some subtle adverse conditions for the tip moth. The old fields are apparently seeded from trees growing in the immediate area and the plantations are from stock of unknown origin. The old field stock may have an adaptation to the site that gives it some degree of natural resistance to the tip moth not possessed by the planted stock. However, Crow (1956, 1958) could detect no difference in tip moth susceptibility for 4 seed sources in Louisiana 20 to 180 miles from the planting site. The plantations and old field stands appear to be making about the same rate of growth. The hardwood competition stands appeared to be making about the same height growth as plantations and old fields, but generally had better form, possibly the result of protection from tip moth attack when the trees were smaller.

Data obtained in this study do not support the contention of Wakeley (1935) and Bronson (1941), that growing trees in dense stands reduces tip moth damage. As shown in

Tables 1 to 6 and Figure 1, the tops of dense stands are frequently infested at rates in the same general range as old fields and hardwood competition and is generally more heavily infested than old-field-15' and light overstory stands. The crowding apparently reduces growth and lowers vigor. This is commonly expressed by the failure of lateral shoots in the tops to establish dominance after the leader has been killed by the tip moth which results in multiple stems. Trees with poor form appear to lose their dominant position more readily in the older stands to those trees with better form, i. e. those less seriously affected by the tip moth.

The old-field-15' stands displayed a low incidence of tip moth attack (Fig. 1), good growth, and excellent form, but the establishment of such a stand with any degree of certainty and at a reasonable cost would be difficult if not impossible. These stands are apparently the result of a lightly stocked stand being established on an old field followed a few years later by another successful seed crop. The taller trees provide some shade for the younger ones but they are always exposed to full sunlight for at least part of the day. This type of stand might be economically established by interplanting a lightly stocked stand, but opportunities of this nature would probably not occur often.

Although the light overstory stands exhibited a very low incidence of tip moth attack, the growth rate was very slow. In many cases the growth rate was only 3 to 4 inches per season. Williston (1959), determined that loblolly pine in Mississippi responded well to release postponed as long as 8 years. Careful stand manipulation might provide some tip moth control by underplanting and later removing the overstory in time to allow the seedlings to respond to release.

It is apparent that shading of trees has an adverse effect on the tip moth. Since the adults are crepuscular or nocturnal the shade does not affect the egg-laying adults directly. A physiological condition of the trees caused by shading might produce unfavorable conditions for the tip moth larvae. The initial rate of attack may be nearly the same on the different types of stands, but the degree of success may be different. This speculation is supported by the numerous unsuccessful attacks observed on released light overstory trees. Early evidence of attack (tiny pitch balls) is easily seen on the shaded light overstory trees because the foliage is sparse. This unsuccessful attack may have occurred in the other types of stands and was overlooked due to dense clumps of needles partially obscuring the buds.

There were fewer significant differences among categories of stands in 1964 than in 1963 in spite of 5 additional

replications. These additional replications theoretically would have increased the possibility of significant differences although the number of trees per replication was reduced from 25 to 5 since analysis showed differences between trees in a replication to be very small. Since there were fewer differences between stand categories in 1964 than in 1963, the reduction in significant differences between categories may be attributed to the increase in infestation rates. The effect of the category of stand was apparently masked at high tip moth population levels. This information could be useful in integrated control programs for determining when to spray certain categories of stands that are not normally attacked at lower tip moth population levels.

A high rate of tip moth mortality during the winter occurs in all the types of stands (Fig. 1). This may be a result of the long exposure of the overwintering third generation pupae to parasites and predators, low winter temperatures, bird predation, and breakage of the infested tips due to whipping by wind which would expose the pupae. If the effect of exposure due to breakage can be shown to be important, the effect might be increased by running a tractor through a plantation with bars extending horizontally that drag across the trees about one foot from the top to break the infested tips. A low first generation tip moth population would be desirable in spite of the ability of the tip

moth to build up quickly in successive generations, because the first generation attacks the first flush of growth which is the longest and probably the most important.

According to the data from the small sample used, ground cover did not afford any protection to the lower levels of the trees at the population levels present at the time of the study. (Table 8). Similar results were obtained in 1962 during a study in Montgomery County, Virginia, on planted loblolly pine. Trees on bare ground were compared to trees growing in high grass (Table 9). Graham and Baumhofer (1927), Beal et al. (1952), Foil et al. (1962), and Warren (1963) suggest, however, that vegetation does protect the lower levels from tip moth attack.

Even in the presence of large differences in the rate of tip moth infestation between types of stands, the number of shoots per cluster of new shoots did not appear to be greatly influenced (Table 7).

Table 9. Percentage of shoots infested by the Nantucket pine tip moth on trees occurring on grassy and bare surfaces. a/

Tree No.	Top half of tree		Bottom half of tree	
	Grass	Bare surface	Grass	Bare surface
1	97	98	64	90
2	97	98	57	51
3	99	91	71	65
4	91	96	79	71
5	96	95	63	88
Total	97	96	68	74

a/ Top half of trees averaged 69 shoots per tree and the bottom half averaged 60 shoots per tree.

VI. SUMMARY

1. It was shown that a significant difference in the rate of tip moth infestation occurred between the 6 categories of stands used in the study.

2. In general, plantations were infested at the highest rate, followed by hardwood competition, then old field and dense stands which fluctuated above and below each other. Old-field-15' stands were the next lowest, followed by light overstory stands.

3. The top level of the trees was infested at the highest rate, followed by the next-two-feet and bottom levels.

4. A sharp decrease in infestation was observed between the overwintering third generation for 1963 and the following first generation for 1964.

5. The average number of shoots per cluster of new shoots, with the exception of the first generation for 1963, showed few significant differences or consistent relationships.

6. Release of the shaded light overstory trees brought about an increase in infestation.

7. Data from this study indicate that heavy ground cover at the base of the trees does not influence the tip moth infestation rate.

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APPENDIX A

Analysis of Data - percentage of shoots infested (transferred
to arc sine)

1963 - FIRST GENERATION

Top

Source	d.f.	SS	MS	F
Between stand types	4	68,844.6237	17,211.1559	9.52**
Between replications within stand types	45	81,383.5104	1,808.5224	8.20**
Between trees within stand types	1200	264,714.9184	220.5958	
Total	1249	414,943.0525		

Next-two-feet

Source	d.f.	SS	MS	F
Between stand types	4	91,010.6824	22,752.6706	19.55**
Between replications within stand types	45	52,376.2454	1,163.9166	19.97**
Between trees within stand types	1200	69,923.8819	58.2699	
Total	1249	213,310.8097		

Bottom

Source	d.f.	SS	MS	F
Between stand types	4	15,277.4392	3819.3598	10.97**
Between replications within stand types	45	15,666.1062	348.1357	5.77
Between trees within stand types	1200	72,436.9147	60.3641	
Total	1249	103,380.4601		

1963 - SECOND GENERATION

Top

Source	d.f.	SS	MS	F
Between stand types	4	73,460.4263	18,365.1066	7.90**
Between replications within stand types	45	104,594.4522	2,324.3212	8.74**
Between trees within stand types	1200	319,244.1329	266.0368	
Total	1249	497,299.0114		

Next-two-feet

Source	d.f.	SS	MS	F
Between stand types	4	143,020.6998	35,755.1750	16.09**
Between replications within stand types	45	99,975.5002	2,221.6778	21.57**
Between trees within stand types	1200	123,586.3990	102.9887	
Total	1249	366,582.5990		

Bottom

Source	d.f.	SS	MS	F
Between stand types	4	19,794.8799	4,948.7200	11.16**
Between replications within stand types	45	19,955.1786	443.4484	13.87**
Between trees within stand types	1200	38,371.9009	31.9766	
Total	1249	78,121.9594		

1963 - THIRD GENERATION

Top

Source	d.f.	SS	MS	F
Between stand types	4	333,222.4436	83,305.6109	42.49**
Between replications within stand types	45	88,219.2429	1,960.4276	5.86**
Between trees within stand types	1200	401,676.6349	334.7305	
Total	1249	823,118.3214		

Next-two-feet

Source	d.f.	SS	MS	F
Between stand types	4	346,777.0663	86,694.2666	42.60**
Between replications within stand types	45	91,584.9286	2,035.2206	11.61**
Between trees within stand types	1200	210,318.3525	175.2653	
Total	1249	648,680.3474		

Bottom

Source	d.f.	SS	MS	F
Between stand types	4	60,619.7098	15,154.9274	29.21**
Between replications within stand types	45	23,345.7398	518.7942	12.54**
Between trees within stand types	1200	49,639.5687	41.3663	
Total	1249	133,605.0183		

1964 - FIRST GENERATION

Top

Source	d.f.	SS	MS	F
Between stand types	5	35,270.8592	7,054.1718	13.54**
Between replications within stand types	84	43,756.9768	520.9164	1.36*
Between trees within stand types	360	137,433.2441	381.7590	
Total	449	216,461.0801		

Next-two-feet

Source	d.f.	SS	MS	F
Between stand types	5	37,700.9475	7,540.1895	27.13**
Between replications within stand types	84	23,348.5370	277.9588	4.80**
Between trees within stand types	364	20,841.5819	57.8933	
Total	449	81,891.0664		

Bottom

Source	d.f.	SS	MS	F
Between stand types	5	9,675.7944	1,935.1589	16.11**
Between replications within stand types	84	10,091.9269	120.1420	4.03**
Between trees within stand types	359	10,706.0473	29.8218	
Total	448	30,473.7686		

1964 - SECOND GENERATION

Top

Source	d.f.	SS	MS	F
Between stand types	5	50,206.3631	10,041.2726	29.19**
Between replications within stand types	84	28,311.4952	337.0416	1.42
Between trees within stand types	359	85,366.7491	237.7904	
Total	448	163,884.6074		

Next-two-feet

Source	d.f.	SS	MS	F
Between stand types	5	58,473.2098	11,694.6420	33.94**
Between replications within stand types	84	28,938.7713	344.5092	2.33**
Between trees within stand types	360	53,187.5364	147.7432	
Total	449	140,599.5175		

Bottom

Source	d.f.	SS	MS	F
Between stand types	5	14,668.0036	2,933.6007	21.52**
Between replications within stand types	84	11,449.2782	136.3009	1.60**
Between trees within stand types	360	30,587.5132	84.9653	
Total	449	56,704.7950		

1964 - THIRD GENERATION

Top

Source	d.f.	SS	MS	F
Between stand types	5	149,721.3074	29,944.2615	55.42**
Between replications within stand types	84	45,390.4545	540.3626	1.78**
Between trees within stand types	360	109,331.9018	303.6997	
Total	449	304,443.6637		

Next-two-feet

Source	d.f.	SS	MS	F
Between stand types	5	116,588.8276	23,317.7655	57.24**
Between replications within stand types	84	34,216.9944	407.3452	3.09**
Between trees within stand types	360	47,452.4203	131.8123	
Total	449	198,258.2423		

Bottom

Source	d.f.	SS	MS	F
Between stand types	5	18,293.6658	3,658.7332	32.48**
Between replications within stand types	84	9,463.1938	112.6571	2.55**
Between trees within stand types	356	15,736.1004	44.2025	
Total	445	43,492.9600		

ABSTRACT

Six categories of stands were examined for the rate of tip moth infestation in each of 6 generations over a two-year period. Data were taken for 3 levels within each tree.

The effect of overstory removal on infestation on shaded trees was determined, and the effect of ground cover at the base of trees on tip moth infestations was determined.

A significant difference between the stand categories was found to exist for all 6 generations. Infestation rates were generally as follows: Plantations, hardwood competition, old fields, dense, old-field-15', and light overstory. Only the dense and old field categories fluctuated in relation to each other.

The 3 levels within trees showed that tops were always infested at the highest rate followed by next-two-feet and bottom respectively.

The various infestation rates appear to be partly the result of various degrees of shading, but significant differences among stands within the various categories suggest the presence of other factors influencing the infestation rates.

Removal of the overstory from the shaded trees brought about an increase in tip moth infestation in light overstory stands.

No difference could be detected between trees with heavy ground cover at the base and those with the ground cover removed.