Damage to a Young Pine Caused by the Shoot Moth

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1. Introduction

In pine woods in the Tokyo University Forest in Aichi Prefecture, there live two species of pine shoot moths. They are; *Evetria cristata* WALSINGHAM and *Rhyacionia duplana simulata* HEINRICH. The third species, *Dioryctria splendidella* HERRICH-SCHÄFFER, which belongs to the family of Pyralidae, lives also on a pine shoot. Larval feeding of these three species usually brings either complete or partial death of a pine shoot. The term "shoot" is used here to indicate the current year's elongation of the bud. Population densities of *R. duplana simulata* and *D. splendidella* are, however, relatively low and the majority of shoot injury is attributable to *E. cristata* in Aichi Prefecture. Fig. 1 indicates the feeding periods of the three species of insects and the resulting death of pine shoots. The majority of shoots are thus killed from June to September. What changes take place on a host tree after the death of its shoots has recently been brought to the interest of many foresters and economic entomologists. It is generally accepted that evil effects of shoot moth infestation upon the host tree can be classified into the following three categories; 1) Death of a tree, 2) Deformation of a tree and 3) Losses in the annual growth. This paper deals with results of a field observation where heavy shoot moth infestation has occurred and also of a field experiment in which the degree of infestation has been replaced artificially by cutting some numbers of shoots on a given tree.

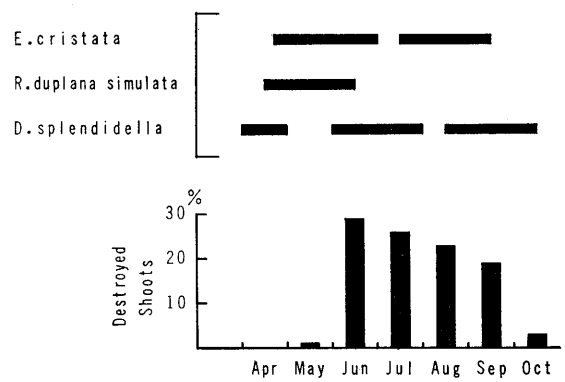

Fig. 1. The feeding periods of insects and the resulting death of pine shoots expressed in percentages, Seto, 1962.

2. Degree of infestation occurring in the field

Field observation in Aichi Prefecture was made in some artificial plantations of *Pinus thunbergii* PARL. of 7–15 years in age. The average height growth of the tree was relatively poor in the studied areas. Table 1 gives a summary of the intensities of pine shoot moth infestation observed in the field. The survey was made in 7 plots in Seto and 4 plots in Inuyama in the years from 1957 to 1961. In Plot C in this table, 5.1% of the total number of shoots or 8.0% of the total length of the shoots were

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Table 1. Various intensities of shoot moth infestation observed in Aichi Prefecture, 1957–1961.

Plot	No. of trees examined	% of shoots destroyed in number	% of shoots destroyed in length	% of trees whose leading shoots were destroyed	Degree of infestation
A*	40	13.1	—	80	very severe
B*	34	8.6	—	56	severe
C*	30	5.1	8.0	33	severe
D*	20	4.6	—	—	moderate
E*	30	3.1	5.0	23	moderate
F	76	2.4	—	21	moderate
G*	30	2.0	2.9	23	moderate
H*	32	1.4	—	13	moderate
I	20	0.5	—	—	light
J	30	0.3	0.4	3	light
K	30	0.1	0.2	3	light

* are in Seto and the rest are in Inuyama.

destroyed by the insect, and 33% of the trees were damaged on their leading shoots. The shoots in the upper part of a tree were always more often attacked by the insect than in the middle or the lower part (KANAMITSU, 1965). The percentage of trees whose leading shoots were killed was therefore remarkably great in comparison with the percentage of shoot injury. Thus, more than 50% of the trees were damaged on their leading shoots when the infestation was as severe as about 8% of the total shoots.

3. Tree mortality

It has never been reported in Japan that trees were killed by the direct effects of shoot moth infestation. The insect population does not usually increase so many as to infest on all the shoots of a host tree. The severest infestation of the shoot moth recorded in Seto has destroyed 15% of the shoots. In Kagoshima, it was reported that 26% of the shoots were destroyed on 6 years old trees (BUNYU, 1965). Even in the latter example, three shoots out of four in the average did escape from being killed. The trees did not die of this severest infestation.

4. Deformation of the tree

Shoot injury occurred in more proportion at the upper part of a tree, and the leading shoot was most often being attacked. This injury on the leading shoot was generally the source for the deformation of a host tree. When the leading shoot was completely killed, one or some neighbouring shoots usually grew to be the main shoot. When injury was not complete, the leading shoot produced some adventitious buds.

At the end of 1960 an examination was made on 100 trees in Plot C in Seto. The past injury on the stem by the insect was identified in a similar manner as described by HEIKKENEN (1960). The trees in this plot was 10 years old, and the average height was 156cm±28cm (S.D.). The intensity of shoot moth infestation was such that

10–50% of the trees had been injured on their leading shoots every year. The following is to show how often various deformations of trees resulted in this plot.

Trees with more or less crooked stems	56
Trees with 2–3 forked stems	7
Trees with the top crowns being bushy	7
Trees of greatly retarded growth	16
Trees of normal growth	14
Total	100

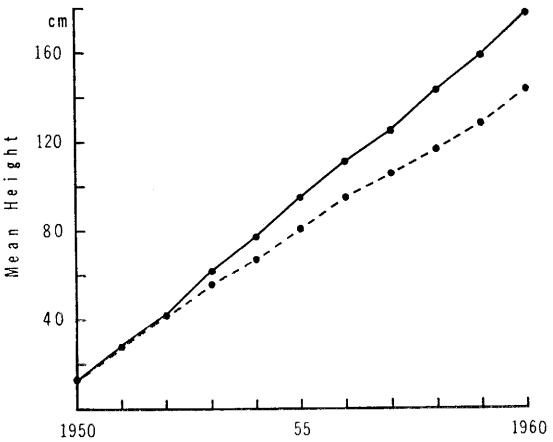
The separation of trees into five categories in this example was done by the investigator's personal judgement, since there were some difficulties in drawing a clearly distinguishable line between the categories. It is now concluded that for the ten years after the plantation, nearly 70% of the trees were more or less deformed through the injury caused by the shoot moth.

5. Losses in the annual growth

It is perhaps most difficult to evaluate the losses in annual growth of a tree caused by the shoot moth attack. Diametric growth on the stem is put out of consideration here, as it looks to have little importance on the culture of such young pines as in the present study. Height growth, on the other hand, is the major concern for the most foresters when the tree is very young. It seems probable that loss in height growth will not usually occur unless the leading shoot or the shoots on the top crown are destroyed, since the death of some proportion of the lateral shoots on the middle or lower crown does not seriously affect a naturally growing tree.

In the same plot referred to in the previous chapter, the internodal length of a stem, which corresponded to the annual height growth of the tree, was measured when and after the trees were injured on their leading shoots. The comparison was then made each year in terms of these internodal distances on injured and uninjured trees. The percentage of injured trees which showed decrease in annual height growth was revealed to be 69% in the year of insect attack, 48% in the next year and 10% in the second year respectively. It is indicated here that about 30% of the injured trees did not suffer any reduction in the point of their height growth even in the year of injury. This explains a possibility that the tree might not lose its height growth when a neighbouring lateral shoot which had escaped from the shoot moth attack replaced the destroyed leading shoot, or in another case, one adventitious bud on the injured leading shoot grew well to make up for the height loss. In the next year after the injury, either the adventitious bud or the lateral shoot grew to be the main stem, and the height growth of about one half of the damaged trees became as good as on the undamaged trees. In the second year the height growth on the majority of the damaged trees showed almost no difference from that on the undamaged trees. Thus, it seems safe to conclude that the most trees recovered their height growth in the second year after the injury on their leading shoots.

In this study plot there were no trees which had been completely immune from the insect attack for the past ten years. This made it considerably difficult to estimate the loss. A compromising method was then taken and the trees that were most often damaged by the insect were compared with the trees that were least damaged. Fig. 2 indicates about 20% loss in height between the trees that were destroyed on their leading shoots more than three times and those that were destroyed not more than once in this ten years' period.



Fig, 2. The mean height of the trees that were frequently (dotted line) and seldom (solid line) damaged on their leading shoots in ten years after plantation, Seto, 1950-1960.

6. A field experiment

The field experiment was designed to help interpretation on the consequence of a tree after it was injured on its shoots. Here, the destruction of shoots by the shoot moth was replaced by the artificial deprival of shoots through a pair of scissors. This experiment was done in Tanashi Experiment Forest in Tokyo, the tree was a three years old *Pinus densiflora* SIEB. et ZUCC.

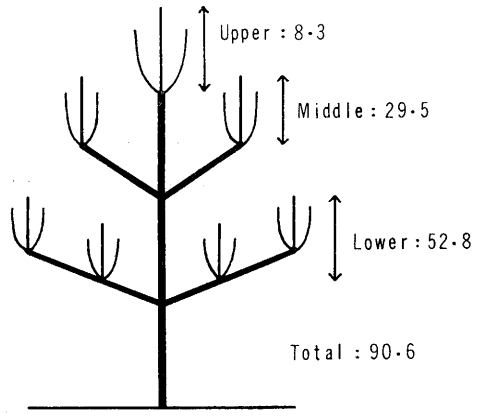


Fig. 3. A diagram of a 3 years old *Pinus densiflora* with the average number of shoots in three crown classes.

a) Methods

The studied plot was 36×20 square meters, and young pine trees were planted in every one meter. Fig. 3 is a diagram to show the average number of shoots in three crown classes of the tree. From the south-west corner of the plot, the eight different sorts of treatments, shown in Table 2, were excuted one by one for the all trees. In order to provide the material for the experiment to be uniform, it was needed to exclude the trees that had already been more or less deformed and the trees of relatively poor growth. Deprival of shoots by scissors was undertaken on the 20th June, 1961, and the subsequent changes on the trees were measured in November in 1962 and 1963. The treatments A and B, where only the leading shoot was cut, were especially aimed to explain the field occurrence of injury on the leading shoot by the shoot moth.

Table 2. Intensities in the artificial deprival of shoots on a three years old *Pinus densiflora*, Tanashi, Tokyo, June, 1961.

Deprival of shoots	No. of trees treated	No. of shoots deprived	% of shoots deprived
A: One half of the leading shoot	53	0.5	—
B: The leading shoot	54	1	—
C: The all shoots on the upper third of the crown	54	8	9
D: The all shoots on the lower third of the crown	53	53	58
E: The all shoots on the upper and middle third of the crown	30	38	42
F: The all shoots on the middle and lower third of the crown	53	82	91
G: The all shoots of a tree	53	91	100
H: No treatment	139	0	0

Table 3. The outcome of artificial shoot deprival which was undertaken in June, 1961.

Treatment	% of trees killed		% of trees with abnormal forms		Tree height		Annual height growth	
	1962	1963	1962	1963	1962	1963	1962	1963
	%	%	%	%	cm	cm	cm	cm
A	4	6	48	44	121*	173*	46*	49
B	0	4	100	67	132*	181*	53	45
C	8	9	85	66	115*	163*	47*	46
D	0	2	4	4	136	188	51*	49
E	10	17	90	67	103*	154*	42*	44
F	6	10	19	15	125*	167*	38*	38*
G	30	42	70	47	74*	111*	23*	34*
H	3	5	2	3	144	195	56	48

* indicates that a statistically significant difference (Pr. <0.05) was calculated in comparison with untreated trees.

b) Results

Table 3 shows the outcome of various treatments. In this table it is noted that many trees, after they lost the leading shoot or the shoots on the upper crown, were deformed but the resulted abnormal form was returning to be normal on the later year. It is also shown that the height growth of the trees, after they lost shoots on the top crown, recovered in the second year after the treatment, though the height of these trees was still lower than that of the untreated trees.

In the treatment A, where one half of the leading shoot was only deprived, all the trees produced some adventitious buds by the end of the year of treatment, and on about 50% of the trees one of these adventitious bud grew much longer than the others, and the tree shape was somehow kept as being normal. In the treatment B, where the whole of the leading shoot was cut off, some neighbouring shoots in the upper crown competed for dominance. Consequently all the trees were topped with crooked

branches. However, in the second year after the treatment one of these crooked branches became straight on some proportion of trees, and the deformation of the tree shape disappeared. In this treatment, the annual height growth of the uppermost shoot did not show much difference from that of the untreated trees. In the treatment D, where the all shoots in the lowest third of the crown were dislodged, the trees were not so greatly affected as in other treatments. The height growth of the leading shoot showed a little decrease in the next year after the treatment. In the second year, both the height and height growth of the trees were as good as of the untreated trees.

In the treatments C, E, F and G, where extremely severe deprival of shoots was undertaken in various parts of the crown, almost all trees were either killed or deformed and also resulted in a great decrease of their height from the ground. Nevertheless, it is noteworthy that in the treatments C and E the length of the uppermost shoot was measured almost as long as of untreated trees in the second year after the treatment. Thus, the trees seemed to have recovered the annual height growth in the second year. Arguments are perhaps of little practical use in the treatments F and G where the trees lost more than 90% of their shoots.

7. Discussions

Both field observation and experiment have shown that the tree, when it was injured on its leading shoot, was able to recover normal height growth by the second year after the injury. However, this does not indicate that the injured tree overtook its height loss and reached as tall as the uninjured tree. The loss in height was compensated in the year of injury by the elongation of an adventitious bud from the injured shoot or by a neighbouring shoot which later developed to be the uppermost main shoot. But this compensation was not always enough and the height of an injured tree was consequently kept lower than the uninjured tree by that difference. This is perhaps what is happening in the field. Whenever the leading shoot is destroyed by the insect, the tree will become lower and lower, even though the later growth would be the same on both the injured and uninjured tree.

The field experiment has shown that there were some trees, though very small in proportion, which were considered to have been killed by the direct effect of the deprival of the all shoots on the top crown (Treatment C). This may indicate a possibility that the shoot moth might be able to kill a host tree when it is very young, though no field observation has yet properly confirmed this.

Deformation in the tree shape caused by the death of the leading shoot is perhaps the most characteristic feature on the damage by the pine shoot moth. When the leading shoot was partially or completely destroyed, about 50% of the trees were made ill-formed even in the second year after the injury. It seems probable, however, that in many cases mild deformation returns gradually to be normal shape in the course of years. Very severe crookedness or a 2–3 forked stem will never come back.

Time factor at the death of pine shoots seems important, as the recovery or the

reaction of the injured tree is different according to whether the injury occurs in June or in August. Young *Pinus thunbergii* in Aichi Prefecture was always able to produce some adventitious buds by the end of the growing season, if the whole of the shoot was not destroyed, but the later development of these adventitious buds was observed quite different when the shoot was injured in different months. Also, when the leading shoot was completely killed, the recovery of the tree shape by some other shoot was generally better when the shoot was killed in the early period of the season such as in May or June. When the main shoot was destroyed at the time of elongation in May, one of the neighbouring shoots grew more often straightly upward than in later months.

It has been emphasized by many authors (GRAHAM and BAUMHOFFER, 1930, HEIKKENEN and MILLER, 1960, YATES, 1960) that the recovery of a pine tree from the shoot moth damage depended on the vigor of the tree itself. It seems evident that the tree attaining better growth rate is not so seriously affected by the insect, since the tree will recover more quickly than the poorly growing tree. In the present observation the trees growing vigorously were, when injured on their leading shoots, able to resume normal height growth in the next year, while on the other less vigorously growing trees the height growth became normal in the second year. Thus, the ability of damaged tree to make a good recovery might reflect physiological differences of an individual tree.

Summary

A field observation was made in Seto, Aichi Prefecture, where heavy shoot moth infestation had occurred. An experiment, in which the degree of shoot moth infestation was replaced by the artificial deprival of pine shoots on young trees, was undertaken in Tanashi, Tokyo. The death of a tree was not observed in natural condition, but the field expriment on three years old seedlings indicated a small possibility for it. In a heavily infested plot in Seto, where 10–50% of the trees were injured annually on their leading shoots for the past ten years after plantation, it was observed that nearly 70% of the trees were more or less deformed. The loss in height growth was estimated to be at least 20% in ten years in the same plot. Both the field observation and the experiment showed that the tree recovered its normal height growth by the second year after the injury on the leading shoot.

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マツ幼令木におこるシンクイムシの被害

金　光　桂　二

和文要旨

東京大学愛知演習林において，シンクイムシ類の食害をうけた若いクロマツの生育状況を調査した。また東京の田無試験地においては，シンクイムシの食害を想定して，アカマツ苗について人為的に摘穂をおこない，その後の2年間の生長を調べた。これらからシンクイムシによる被害を大別し，単木の枯死・奇形・生長量減退の3項目についてそれぞれ検討をおこなった。

一般に，シンクイムシの加害による単木の枯死は野外では全くみられなかったが，3年生苗について摘穂をおこなった実験結果では，その可能性がないとはいえなかった。中心の穂が食害をうけると，しばしば奇形や樹高生長の減退がみられた。植栽後10年間にわたってシンクイムシの食害をうけ，毎年10～50%の木が中心穂の被害をうけていたクロマツ造林地では，植栽木の約70%のものが程度の差はあるが異状樹形となっていた。また同じ林において，シンクイムシの加害をひんぱんにうけた木とほとんどうけなかった木をくらべてみると，樹高生長の減少量は10年間で約20%であった。野外観察と摘穂実験の結果から，マツ幼令木が中心穂に被害をうけたばあい，おそくも翌々年には樹高生長が正常に回復することが判明した。