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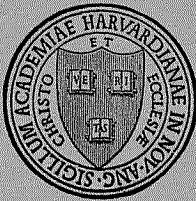
BULLETIN NO. 5

RICHARD T. FISHER, *Director*

CONTROL OF THE WHITE PINE WEEVIL BY FOREST MANAGEMENT

BY

H. B. PEIRSON



HARVARD FOREST, PETERSHAM, MASS.

1922

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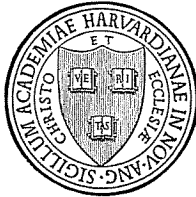
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NOTE

This study was carried out by the Harvard Forest with the coöperation of the Massachusetts Department of Conservation. For the duration of the work Mr. Peirson was appointed Collaborator by the State Forester.

R. T. F.

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SUMMARY OF CONCLUSIONS

I. The white pine weevil can be controlled by proper forest management.

II. The white pine weevil is a native forest pest and even the better stands of second growth pine in central New England have in their earlier years been weeviled.

III. Weevil injury is largely overcome by a density of stand which does not allow for the spreading and forking of the tree.

IV. Healthy, rapidly growing pine, is less susceptible to permanent injury than slow growing trees.

V. Pine occurring in mixture with hardwoods receives a high degree of protection from weevil injury, this protection increasing as the number of pine trees per acre decreases.

VI. Nature, in the way of parasites and composition of the forest, aided somewhat by man, can make the weevil a negligible quantity so far as permanent injury to the tree is concerned.

CONTROL OF THE WHITE PINE WEEVIL BY FOREST MANAGEMENT

INTRODUCTION

THE ease with which the white pine may be managed, together with its rapid growth, high yield and wide range of utility has made this tree of immense value; so that at the present time no other tree is so widely used in plantations in the Northeastern United States. This widespread planting has brought about a condition similar to that found in specialized agriculture in which a large amount of a given food is made available at one time. This condition has had a great effect on the general prevalence of the white pine weevil.

The ravages of this beetle, particularly in plantations, are so very apparent that it has brought forth a great deal of comment as to the advisability of further plantings of white pine. A vast amount of literature has been written about this insect and many control methods have been advised, often without previous experimentation as to their feasibility. Some of the methods of control are satisfactory when applied under certain conditions, but few, — if any — are applicable to economic forest management at the present time. The damage which is so apparent in the young stand is often not so readily seen in a mature stand. It has, therefore, been an open question as to the amount of actual damage resulting in the mature stand. As it is these questions which particularly interest foresters, the problems involved have been studied from the standpoint of forest management.

The present study was started in the Fall of 1919, at which time the large percentage of weeviling in the plantations on the Harvard Forest, and in the vicinity of Petersham, empha-

sized the fact that more definite knowledge as to the damage caused by the white pine weevil was needed. An exhaustive study was made of white pine plantations throughout the state under all conditions of age, height, density, location in regard to altitude and surrounding forest, and exposure. A further study was made to include natural stands up through maturity so that from the data collected it would be possible to foretell conditions at different ages. The study was still further expanded so as to include mixed stands of pine and hardwoods, and also mixed coniferous stands, as it is very apparent that these types will take an important place in the future management of cut-over lands. Particularly is this true of the mixed pine and hardwood type.

It has seemed wise to include in this report a short résumé of the work previously done by entomologists on the life history and control of the weevil. The distribution of the insect is recorded from Hopkins' excellent report on "The Genus *Pissodes*" (1911). The general facts as to the life history were worked out by Fitch (1857), Packard (1890) and Hopkins (1907). These records have been verified and a few new facts added.

Much of the data for this paper was collected on the Harvard Forest in the plantations, in mature stands of pure pine, and in stands of mixed pine and hardwood. An expression of gratitude is due to Professor Fisher for the many helpful suggestions in regard to proper forest management. Thanks are also due to the Massachusetts State Department of Forestry for making it possible to visit their plantations.

HISTORY AND DISTRIBUTION

HISTORY

The white pine weevil (*Pissodes strobi*) is a native of the United States. It was first described in 1817 by W. N. Peck in the "Massachusetts Repository and Journal," under the name *Rhynchaenus strobi*. It was one of the first insects to

receive the attention of economic entomologists. From the time of Harris (1841) entomologists took a more or less keen interest in the weevil and a large amount of literature has been written about the insect.¹ One of the most interesting articles, due to the stand taken by the author, appeared in "The American Entomologist" 1880. This article, written by A. S. Fuller and entitled "A good Word for the White Pine Weevil," takes the attitude that the pine is benefited by having the leader killed, in that it stimulates the growth of the laterals and causes the tree to assume a more symmetrical and stocky form. It is very apparent, however, that few observers take this optimistic view of the damage created by the insect. Amongst the later writers Hopkins, Graham, and Blackman all offer suggestions for controlling the weevil.

DISTRIBUTION

The distribution of the white pine weevil is restricted to the area in which the white pine (*Pinus strobus*) is found growing. From observations made in New England it is very apparent that even within this area the occurrence of the weevil depends largely on the amount of white pine present. Where the pine occurs only scatteringly the weevil may be almost entirely absent.

There is a considerable amount of inconsistency in the data on the botanical distribution of white pine. Some writers restrict the distribution to those areas where it occurs in fairly large natural groves, others extending the area so as to include localities where it occurs naturally, although sparingly. The accompanying map is based on these latter observations. This accounts for the fact that the area infested by the white pine weevil does not extend into Southern

¹ Fitch in his fourth New York report (1857) described the life history of the insect in detail and also gave numerous examples of the damage done by the beetle. Packard (1886) wrote a long account of the ravages of the weevil and enlarged somewhat upon the life history as worked out by Fitch.

Indiana or Ohio although the white pine is found in these localities.

In general the line of distribution for *Pissodes strobi*, in the United States, follows down the Atlantic seaboard to central New Jersey, cutting across the upper part of Delaware, then follows the eastern slope of the Appalachians through



Map showing distribution of White Pine (*Pinus strobus*) and the White Pine weevil (*Pissodes strobi*) in the United States

Virginia, North Carolina, South Carolina into the north-eastern corner of Georgia. The line then follows up the western slope of the range so as to include West Virginia and Pennsylvania. It then turns west, passing through southern Michigan and Wisconsin into Central Minnesota. The beetle is also found throughout Southeastern Canada where it is rated as one of the worst enemies of the white pine.

NATURE OF DAMAGE

New England lumbermen are all familiar with the so-called "cabbage" or "pasture" pine in which the stem becomes much forked and crooked due to the repeated death of the terminal shoot. The death of this shoot causes the first group of laterals below the injury to turn up and strive for supremacy. This results in a forked top. The new leaders may in turn be killed so that at times there may be from twenty to even thirty terminal shoots all contending for dominance.

This destruction of the leader by the larvae of the white pine weevil, the adult of which lays its eggs in the terminal shoots, results in a decided loss from a timber standpoint. In the first place the rotation of the crop is lengthened, oftentimes averaging about five years above the normal fifty to sixty year period. This in itself amounts to a considerable loss of interest on investment and normal return, and to some increase in taxes. In general it can be stated that a tree loses one-half year each time the leader is destroyed. If the damage extends below the first lateral an additional half-year is lost for each interval or space between nodes destroyed. As the side branches grow much more slowly than the leading shoot this loss in height growth is greatly augmented.

In the second place the branching of the tree due to the destruction of the leader results in a more or less pronounced crook which decreases the value of the log, although remark-

ably large amounts of round-edged box boards are sawed from badly weeviled trees. This decrease in value is due to the shortening of the internode and crooked grain in the wood. The length of the board cut is also reduced since oftentimes it is difficult to cut straight logs of more than seven feet in badly infested trees. This again adds to the damage created by the insect.

In the third place weeviling results in large knots due to the branching of the tree. These knots detract greatly from the value of the resulting lumber cut, throwing it into a lower grade.

In general it can be stated that the average stand of second growth pure pine in North Central New England suffers a twenty per cent loss due to weeviling. This figure is based upon thousands of trees examined under a large number of conditions. In very open, exposed stands the damage may reach as much as forty per cent and the stand be absolutely worthless so far as good lumber is concerned. On the other hand the loss may not amount to more than eight per cent in the better stands. The average woodsman does not appreciate the damage until he actually begins to tally it down tree by tree.

FOOD PLANTS

Although the white pine is the favorite food of *Pissodes strobi*, it also attacks several other conifers and at times does considerable damage to plantations of Norway Spruce. In the original primeval forest that at one time covered New England, the weevil is thought by some entomologists to have lived largely in the mature pines boring into the sap wood of dying trees and only occasionally attacking the leaders of young pine springing up under the cover of the mature stand. To some extent it has probably retained this habit of attacking mature pine and spruce, although it has undoubtedly often been confused with *Pissodes approximatus* and *Pissodes affinis*. The latter species is the only

one the writer has seen on the bark of mature trees. The wide extension of white pine both by artificial means in plantations and by natural seeding in abandoned pastures has made available large quantities of tender shoots which are extremely favorable to the rapid development and increase of the weevil. The presence of the weevil may, therefore, be expected wherever there are pine stands and will be found in particular abundance where there are extensive plantations. The following is a list of known food plants.

<i>Pinus Banksiana</i> ¹	Lamb.....	Jack Pine
<i>Pinus sylvestris</i> ²	Lamb.....	Scotch Pine
<i>Pinus densiflora</i> ²	Sieb & Zucc.....	Japanese Pine
<i>Pinus rigida</i> ¹	Mil.....	Pitch Pine
<i>Pinus strobus</i> ²	Lamb.....	White or Weymouth Pine
<i>Cedrus deodara</i> ⁴	Lamb.....	Deodar or Himalayan Cedar
<i>Picea rubra</i> ¹	Dietre.....	Red Spruce
<i>Picea Abies</i> (L) ²	Karsten.....	Norway Spruce
<i>Abies balsamea</i> (L) ³	Mil.....	Balsam Fir
<i>Tsuga canadensis</i> (L) ³	Can.....	Hemlock

WEEVIL INJURY IN NATURAL REPRODUCTION

Natural reproduction of pine occurs in two types. In the first place we have the pure stands of pine which come up on abandoned pastures or, under certain rare conditions, on cut-over areas, and which approximate the pine plantation in degree of weevil injury and possibility of control. In the second place we have the mixed pine and hardwood reproduction which may, either by forest management or by accident, reforest cut-over areas or abandoned fields. It is with this second type that this section deals.

The original forest as found in what is now known as the white pine region contained very few pure blocks of pine, the tree for the most part occurring scattered throughout the forest. It is particularly noticeable how free from weevil

¹ Hopkins (1911).

² Observed or verified by writer.

³ Packard (1890).

⁴ Currie (1905).

injury such trees are. Not only is this true in the few remaining pieces of virgin forest but also in second growth forests where the white pine occurs intermixed with hardwoods. Figures taken in the vicinity of Petersham, Mass. showed as low as two per cent injury in twenty-five year old stands where the pine constituted only ten per cent of the total number of trees in the stand. It was found that the percentage of weeviling increased almost in direct proportion to the percentage of pine in the mixture, providing that the composition of the stand, i. e. species involved, was similar. Broad leafed trees such as the oaks, linden, and maples gave more protection than the smaller leafed trees such as cherry, birch, and poplar.

On cut-over pine lands the stump and seedling sprouts will soon outgrow, even where they do not overtop the young pine. This condition in a small way approaches that found in the original forest in that the young pine reproduction is protected by a canopy of taller trees which to a large extent immunize the pine from weevil attack. In the virgin forest the protection was of course much greater, for the young pine would merely come up in an open space left by the death of a mature tree and were hedged in by a veritable high fence. The explanation of this protection seems to lie in the fact that during the breeding season the beetles in flying over the woods in search of leaders in which to lay their eggs, generally do not come in contact with the young pine which is coming up under the protection of other trees. It is apparent then that the height of the hardwoods above the pine has a decided influence on the percentage of weeviling. Observations in the field have shown that pine out-topped only two feet by the hardwoods may be expected to have twenty per cent less weeviling than pine occurring in the open.

The denser and broader shade, and the swaying of the hardwoods all tend to prevent the growth of more than one leader on an injured pine, to a much more pronounced degree than is the case in pure stands of pine. The general

conical shape of the pine makes a dense shade near the ground whereas the more mushroom shaped form of the hardwood tree brings the maximum shade to a greater height. This results in the earlier killing of the lateral branches of the pine, thus preventing forking in the tree. The superior quality of pine grown in mixture with hardwood is well known.

WEEVIL INJURY IN PLANTATIONS

An extensive study was made of weevil injury in white pine plantations throughout the state, a total of approximately seventy-five plantations having been visited and examined. The plantations studied occurred under a wide variety of conditions from the typical sandy, pitch pine areas of Cape Cod, to the rugged spruce areas in the higher Berkshires, with intermediate conditions as found in the white pine area of northern Worcester County, and the open and hardwood country found in the vicinity of Ashburnham. Notes on the plantations included locations, altitude, site, exposure, shade, soil, drainage, surrounding forest, average height and age of trees in plantation, spacing, total trees in plantation, and percentage of trees weeviled. In plantations that were growing in mixture with hardwoods the height of the hardwoods was taken and the species noted, for these factors have a direct bearing on the amount of shade or protection the white pine receives. In a like manner mixed coniferous plantations were studied, special emphasis being given to species, height growth, and nature of mixture. In comparing the observations made on the various plantations it was surprising to note how many of the above factors actually enter into the resulting amount of weeviling. Those factors which have the most direct bearing on the insect damage include exposure, surrounding forest, rate of height growth, and general type of plantation, that is whether pure stands or in mixture with hardwoods. The points are well worth taking up separately.

Speaking in broad terms, the majority of the weeviling in pure open pine plantations occurs when the pines are between the heights of two and twelve feet. No definite percentages of weeviling can be given for the different heights on account of the outside factors which may affect the weeviling even to a degree of sixty per cent. A graph showing the relation between height of trees and percentage of weeviling appears like a broad leaf, the space between the margins representing the variation in percentage of weeviling due to various factors. For example, plantations occurring in the region where the weevil was most abundant showed a difference in percentage of weeviling at seven feet in height of from twenty-five to eighty per cent.

Weevil injury in plantations does not occur in clumps, but is scattered throughout the entire plantation so that a chart with the weeviled trees put in as black squares and the uninjured trees being left as white squares appears like a checker-board. As a general rule the percentage of trees weeviled each year is approximately the same, although there are of course exceptions. It is a notable fact that the weevils choose, up to a certain height, the trees with the tallest leaders. On the whole this might be considered a favorable factor in spite of the discouragement in seeing the long leaders destroyed, for it tends to keep the trees at a more even height growth, and these large, fast growing leaders stand less chance of being killed as they are less apt to be girdled. In exceptionally fast growing plantations ten per cent or even higher of the weeviled leaders may recover.

Probably the most important factor affecting the percentage of weeviling in plantations is the exposure and particularly the nature of the surrounding forest. Plantations occurring in close proximity to other stands of pine are naturally more apt to be weeviled than those occurring in a locality where white pine is either entirely absent or occurs only scatteringly. One of the most conclusive evidences of this occurs in a section of the state that is typical agricultural

country, very few pine occurring in the locality. Twenty years ago a fairly extensive white pine plantation was set out. This plantation escaped the weevil until it was nearly fifteen years of age. During the last ten years, hundreds of acres of white pine plantations have been set out in this locality, and the weevils have been attracted in large numbers so that in the more recent plantations the weevil injury is as bad as can be found almost anywhere in the state. On the same tract considerable Norway spruce has also been set out in recent years and in these plantations the percentage of weeviling is very high, due to the great amount of surrounding white pine. Plantations of white spruce adjoining badly weeviled Norway spruce and white pine plantations were untouched. Its apparent exemption from weevil injury may be due to several reasons. The twigs appear much tougher and more difficult to get at, on account of the heavy needles, than in the case of the Norway spruce, in spite of the fact that the twigs are glabrous. It is also quite possible that the odor, which gives this tree the common name of cat, or skunk spruce, may affect the exemption of this tree.

A second very important factor in determining the amount of weevil damage is the rate of height growth. It is quite apparent, taking it for granted that the trees are most liable to be attacked by the weevil when between the heights of two and fifteen feet, that the sooner the trees reach this height of fifteen feet, or in some cases twenty feet, the less weeviling there will be, for there is only a single generation of the weevil a year. Furthermore a thrifty fast growing tree more readily overcomes the resulting crook due to the loss of the leader, for the cells in the fast growing tree are far more pliable. As was previously stated, large healthy leaders often recover from the weevils' attack. It is rarely that the larvae go below the previous year's whorl of laterals in a fast growing, long leader, for there is sufficient food in the internode for the complete development. One of the best examples of injury resulting from slow growth was

found in a white pine plantation growing on a shallow sandy soil. The percentage of weeviled trees in this plantation was extremely high for its age, but the most important feature was that in nearly every case the larvae had destroyed from two to four years' growth and even at that, had not covered the length of stem that might be expected in a fast growing leader of a single year's growth. The resulting injury in this plantation is going to be much more severe than if the trees were more thrifty. In the first place several years' growth is lost; secondly, the laterals being naturally of slower growth than the leader produce short internodes; thirdly, the lower branches or laterals having become more firmly fixed in a horizontal position due to several years' growth, are far less likely to assume an erect position.

A great deal has been written in recent years as to the possible good results to be obtained by setting out mixed coniferous plantations. In this study considerable time was given over to this question and it is the belief of the writer that it is useless to set out mixed coniferous plantations merely to check weevil infestation. There must, of course, be some foundation for this belief and it seems probable, from many observations made, that such plantations occurred in regions where the weeviling was not so pronounced and that the trees would have been just as immune if the plantations had been made entirely of white pine. Several suggestions for mixed coniferous plantations have been advanced which deserve attention. The main object is to out-top the white pine by some other conifer planted in alternate rows. Observations made in the field by the writer showed that in order to be effective the pine must be out-topped by at least two feet when below the height of six feet and at least three feet when above this height. In most cases this would require the planting of the alternate tree several years ahead of the time that the white pine is set out which in most cases is impractical. Scotch pine has been suggested, but the benefit gained would hardly be offset by the loss of space taken up by

the Scotch pine, which hardly seems worth planting as long as better trees are available. Furthermore, the cost of planting the Scotch pine could in no case equalize the benefit gained. Another tree suggested is Norway spruce which under ordinary circumstances is a somewhat slower growing tree than white pine and furthermore is itself subject to severe injury. Even red pine, which for some reason was overlooked, is apparently of no benefit when intermixed with white pine.

Some very enlightening figures were obtained from mixed coniferous plantations on the Harvard Forest. In the following case the white pine was planted in double rows with the species named on either side.

Center two Rows	Ht.	Species side A	Ht.	Species side B	Ht.	Per cent weevil- ing in white pine
Pinus strobus	5'	Pseudotsuga taxifolia	4'	Pinus sylvestris	9'	94
"	"	5' Pinus sylvestris	8'	" "	8'	77
"	"	5' Picea excelsa	4'	" "	8'	75
"	"	5' Pseudotsuga taxifolia	7'	" "	5'	81
"	"	5' Picea excelsa	3½'	Picea excelsa	3'	85
"	"	6' Pseudotsuga taxifolia	7'	Pseudotsuga taxifolia	7'	65
"	"	6' " "	7'	" "	7'	70

The only point to be gained from the above table is that the alternate species positively did not check the percentage of weeviling which in this locality was very severe. Yet it is in such a place that observations should be taken since other factors all favor the weevil. In another large plantation with alternate rows of red and white pine the weevil damage was in no way checked.

One point which is of especial value is the decrease in percentage of weeviling found in pine plantations intermixed with natural second growth hardwoods. Such plantations approximate the natural stands of mixed pine and hardwoods except for the usually much higher percentage of pine found on the planted areas. The decrease in percentage of weeviling may amount to as high as twenty per cent if the hard-

wood is of the broad leaved type. There is a large number of this type of plantation throughout Massachusetts and it is doubtful if the owners of such plantations appreciate the value of the hardwoods. It seems to be the custom repeatedly to cut out the hardwoods regardless of their commercial value or their influence in increasing the quality of the pine. True, there is danger of the pine being suppressed or injured by the hardwoods during ice storms, but the danger from these sources can be met without clean cutting the hardwoods. It often happens that the hardwoods occur in clumps through the plantation in which case the variation in percentage of weeviling between those trees occurring among the hardwoods and those occurring in the open is very pronounced.

RESULTING INJURY IN MATURE STANDS OF PURE PINE

In order to obtain exact data on the extent to which early weevil damage is overcome during the growth of the stand, thousands of trees were examined for the purpose of arriving at an accurate and simple classification of the principal kinds of defect due to this cause; and logs were watched as they went through the mill. As near as possible the field data were collected in stands fifty to fifty-five years of age, on quality two sites, it being essential to keep this factor constant. The work was done entirely in regions where weeviling was very prevalent.

Observations soon showed that the amount of ultimate damage depended almost entirely upon the density of the stand so that this factor became the prime variable in the study of a woodlot. Density in itself is such a variable factor that extreme care was necessarily taken to find plots in which the trees were both even aged and evenly distributed or spaced. It is quite possible to find a variation in density of from 200 to 400 trees per acre in the same stand. Several

methods, each having its advantages and disadvantages, were followed in obtaining the density of a stand. Usually a quarter acre circle (having a radius of fifty-nine feet) was found to be the most satisfactory. The outer trees were marked with crayon for accuracy, although in dense stands it was sometimes necessary to mark and tally each individual tree and then recheck. Another method followed was to lay out a square or rectangle using a fence, stone wall, path, or some other prominent boundary for one side. By walking along the opposite boundary the trees were easily tallied and the density per acre figured out by proportion.

After the density, height, and age of a stand were obtained, the trees were classified and recorded according to their lumber value under seven heads decided upon only after careful study. From this classification a stand factor was found which showed the deficiency of the stand as compared with a perfect or uninjured one.

The classification used is as follows:

- | | |
|-------|-----------------------------------------------------------------------------------------------------------------------------------------|
| Class | I. Trees forked five feet or less from the ground. These trees usually have more than one stem and are usually scrubby. 30 % deficient. |
| " | II. Trees forked approximately fifteen feet from ground. Usually at least one straight log. 25 % deficient. |
| " | III. Trees forked twenty-five feet from ground. Seldom seriously damaged. 10 % deficient. |
| " | IV. Trees slightly crooked. Only one leader present. 10 % deficient. |
| " | V. Trees usually with two or more crooks, but with at least one straight log. 25 % deficient. |
| " | VI. Trees badly crooked or forked; generally no straight logs available. 45 % deficient. |
| " | VII. Trees perfect or practically so. |

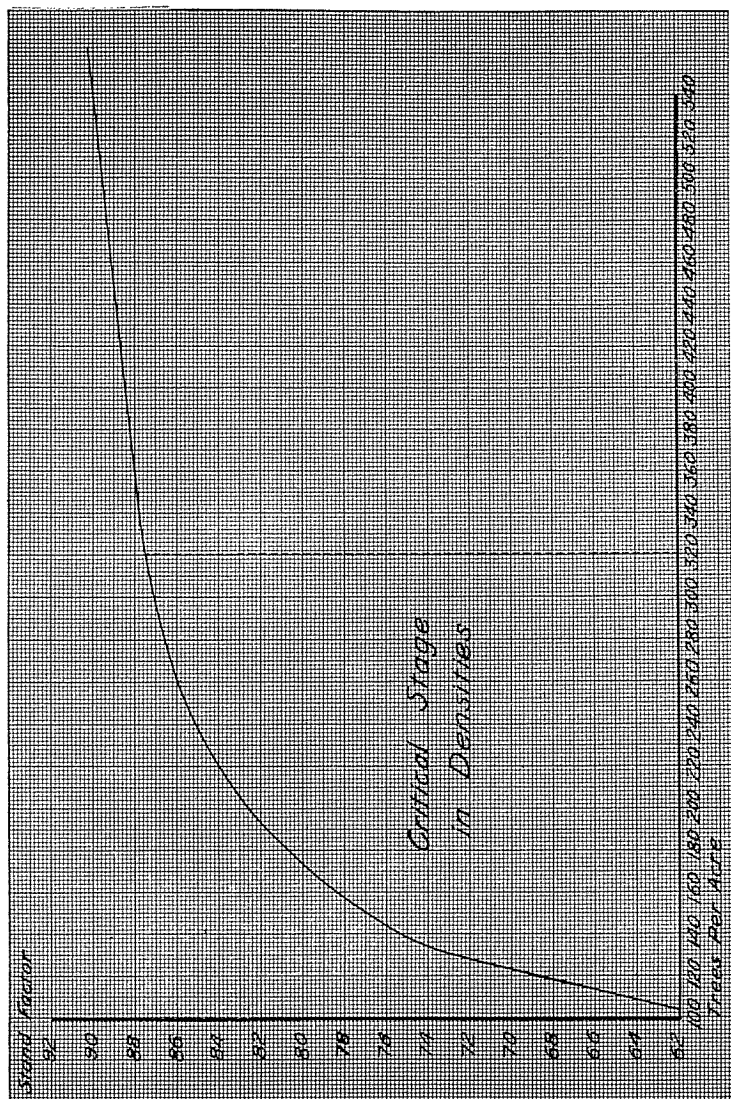
Based on several plots a preliminary curve using density and the stand factor as the two variables, was plotted in order to test out the accuracy of the classification used. Later as more plots were examined and tallied, these were also plotted on the graph and it was rare that a variation of more than one per cent was found from the original curve.

This made plain the fact that the classification used was as accurate as possible considering the many minor factors which are bound to creep in. Example:

I	II	Class Number					Trees in Plot	Per cent deficient	Stand Factor	Number Per Acre	Age	Height
		III	IV	V	VI	VII						
6	5	4	56	15	8	24	118	13.4	86.6	392	40	45'

There being 118 trees in the plot the percentage value of each tree equals .84. Multiplying this factor by 6, or the number of trees in Class I, gives the normal value of the trees in this class. As these are thirty per cent deficient the percentage value is brought down to 3.53. Adding these values for each class gives the stand factor. This is the index to the value of the entire stand, which in this case is 86.6 % perfect, having a total deficiency of 13.4 % for the seven classes.

By reference to the accompanying graph (page 23) it can be seen that there is a great improvement in the quality of the stand as the density increases from 100 trees per acre, which may be considered a maximum open stand, to 260 trees per acre which at fifty years of age appears to be a well stocked stand of reasonably good quality. From this point on the increase in quality rises rather slowly, and gradually the trees begin to lose diameter although increasing in straightness. Stands up to 600 trees per acre at fifty years of age were examined. At this density, which makes a typical large pole stand of small diameter trees, there is a very strong competition going on, so that a large number of trees are being suppressed and killed. Indications point to the fact that a quality two site will rarely support more than 600 trees per acre at fifty years of age. From this point on stands were examined up to a density of 6,000 trees per acre at an age of twenty-five years. This stand proved to be 93 % perfect considering only weevil effects, i. e. forked and crooked trees. Stands of the same age containing 3,000 trees per acre proved to have overcome the weeviling effects



Graph showing that the percentage of defects resulting from weeviling varies inversely with the density of the stand.
Data collected in stands averaging fifty years in age on quality II sites

to the same degree. Densities such as this are not only rare but are of course detrimental to the normal growth of the tree.

The explanation of this overcoming of weeviling effects by increase in density of the stand is not difficult. Taking for granted that an acre of land will hold only 100 typical pasture or cabbage pine, fifty years of age, it is evident that as more trees are crowded into this area some of the side branches are going to intermix and sooner or later natural pruning results, due to lack of sunlight which kills the branches, and rubbing together of limbs which eventually break them off. If the stand starts with a density of between 1200 and 2000 trees per acre the competition for room will be so great at the time that weeviling takes place that the trees will not have the chance to branch out. If several leaders are striving for supremacy the slower growing ones will soon be killed off from overcrowding. Furthermore, it is evident that the sooner the secondary leaders are killed the smaller the resulting knots will be, thus improving the quality of the tree.

In mature, fully stocked stands, it is often very difficult to determine accurately whether certain trees have been weeviled or not without a conception of how the tree overcomes the weeviling effects. In the majority of cases the crook in the tree due to previous loss of leader is not visible from all sides. This necessitates a careful examination of each individual tree in order to obtain accurate results. The chain of evidence, however, proving that weeviling is overcome by increase in density, is so conclusive that there is little room for believing that the correction is due to any other cause. It must be remembered, however, that in certain localities where white pine is not abundant there is also a lack in the prevalence of the weevil so that it is to be supposed that such stands would be of good quality. It has also been found that stands of white pine occurring on small islands some distance from shore appear to be immune from weeviling. This is explained by the fact that the weevils are not strong fliers and unless they have been carried to the island by some means of transportation other than flight it

is probable that they are not to be found. Strong winds which are quite common on reasonably large bodies of water would also tend to blow them from the island into the water during even short flights.

The use of the graph, then, shows the possibilities of overcoming the effects of weeviling by control of density. It does not show what a stand will be like in a weevil-free locality. For example, in some sections of New England stands of 120 trees per acre may be found that have a stand factor of 90 % or over.

SEASONAL HISTORY AND HABITS

The adult beetles emerge from hibernation and become active about the middle of May or earlier if climatic conditions of temperature and moisture are favorable. The adults may feed for a short time on the bark of pine twigs leaving an injury very similar to that of *Hylobius pales* except for the fact that it is always on older trees. The beetles then fly to the leader or topmost shoot of the previous year's growth of the pine and begin excavating holes into which the small pearly white eggs are forced. The female may lay as many as one hundred eggs. These are laid largely in the upper third of the leader. The time required to complete the cavity in which the egg is laid is considerably longer than would be imagined. In several cases observed, the beetle required slightly over an hour to complete the operation even when kept in a glass tube so as not to be disturbed. Oftentimes several females may lay their eggs on a single leader so that it is by no means uncommon to find between thirty and forty punctures on a leader. The exudation of pitch on the terminal shoots where the eggs have been laid is very characteristic of the injury. The eggs require about ten days before hatching. The minute, legless, white larvae feed just beneath the thin bark in the area consisting of the cortex, phloem, and cambium. The larvae work down and as they become older feed to some extent on the outer layers

of the wood parenchyma. The competition for food often becomes very keen so that the final survival is only a fraction of the number of larvae hatching. Some are forced to pupate before going far, others, that are left behind, die from lack of food or disease. The larvae are voracious feeders and require a large amount of food. The food becomes digested in approximately one hour. The larval stage lasts nearly two months, and about the first of August the mature larvae bore into the wood parenchyma forming a deep cell which is lined with excelsior-like chips. In this cell pupation takes place. This change from the larval stage into the pupa and adult is most remarkable to observe. The gradual formation of elytra, legs, and beak, followed later by the appearance of claws, mandibles, antennae, and eyes is an extremely interesting sight. The pupa which is at first pure white gradually assumes a light brown color, the pigmentation occurring first near the tips of the beak, elytra, etc. The transformation from larva to adult requires approximately ten days. The majority of the adults have emerged by the latter part of August although stragglers may be found until into October. It is probable that the adults pass the winter in the ground, although exact observation on this point is lacking.

It is believed by some authorities that the weevils may live for several years depositing eggs for two or even three years in succession. An unsuccessful experiment was carried on in order to verify this belief. Adults were kept under as near normal conditions as possible with food and water, but none survived after the latter part of June. It is also apparent that flight is seldom resorted to. The loss of beetles kept in open trays whose sides had been treated with Tree Tanglefoot was extremely low, even in the one case where food was kept away from the beetles and a fresh pine bow hung over the tray few resorted to flight. The beetles, however, are capable of flight.

As is the case with many insects, climatic conditions, un-

favorable feeding conditions, time of egg deposition, etc., all tend to make a more or less pronounced overlapping of the different stages. The above dates are based largely upon notes made in Massachusetts, particularly in the vicinity of Petersham. Blackman (1919) states that some of the weevils pass the winter either as larvae or young immature adults in the leaders.

Evidence all points to the fact that the beetles usually fly over the plantations before egg laying. Almost invariably the tallest leaders are attacked whereas the shorter trees are fairly immune. It is patent that the weevils in flying low over a plantation would strike the tallest trees. Observations have shown that it is not a matter of shade which immunizes the shorter trees, for in plantations adjacent to mature woods the weeviling is just as prevalent along the outer edges where the young trees are shaded to some extent by the older stand, as it is in the center of the plantation which is not shaded. The decrease in percentage of weeviling when the plantation is out-topped by hardwoods, which will be discussed under control, is explainable only by assuming that the beetles in flying over the plantation strike or sense comparatively few of the pine. In a like manner the fact that it is seldom that the laterals are attacked, although these oftentimes could well support the larvae, strengthens the belief in flight.

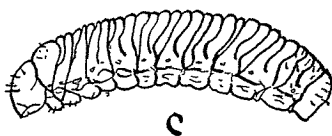
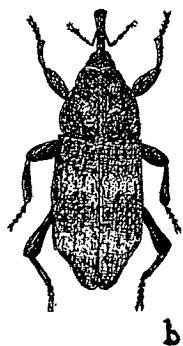
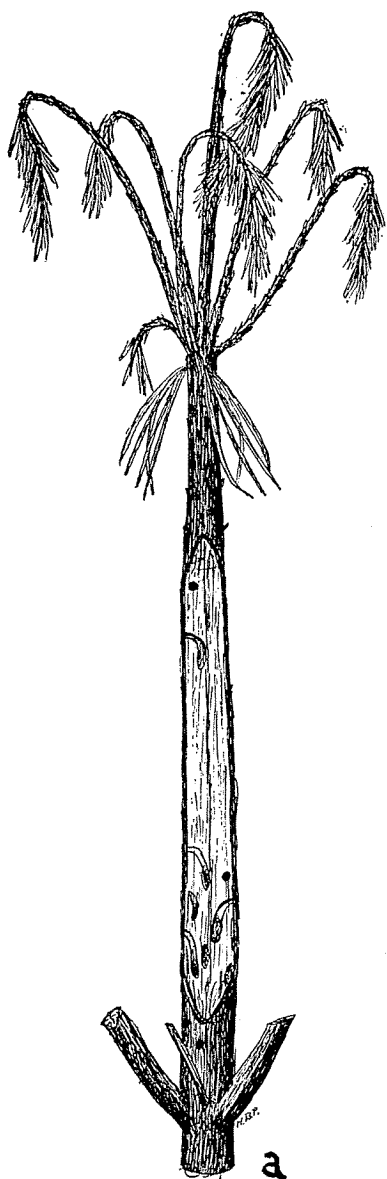
As is the case with many other bark weevils the habit of feigning death is strongly developed. Even when feeding or excavating the egg cavity, in which cases the odor of pitch must be extremely pronounced, the weevils are easily disturbed by the presence of an observer and oftentimes drop to the ground. Slight jarring does not easily disturb them and they do not appear to be strongly aware of movements in front of the eyes. Adults kept in stoppered glass test tubes, with pine twigs, could be moved about without disturbing the process of egg laying, but if the stopper was removed they immediately became conscious of danger.

DESCRIPTION

THE ADULT

- Rhynchaenus strobi* Peck, W. D. 1817. On the Insects which Destroy the Young Branches of the Pear Tree, and the Leading Shoot of the Weymouth Pine. Mass. Agr. Repository and Journal, Vol. 4, No. 3, p. 209, pl. 2. (Original Description.)
- Pissodes strobi* Say, T. 1831. Description of N. A. Curculionidae and an Arrangement of Some of Our Own Species Agreeably to the Method of Schoenherr. P. 14, New Harmony, 3rd.
- Pissodes strobi* Say, T. 1859. The Complete Writings of Thomas Say on the Entomology of North America. Edited by John L. Le Conte, M. D., Vol. 1, p. 277.
- Pissodes strobi* Gemininger, M. and De Harold, E. 1871. Catalogus Coleopterorum, Vol. 8, pp. 2431-2432.
- Pissodes strobi* Le Conte, J. L. & Horn, G. H. 1876. The Rhynchophora of America North of Mexico. Proc. Amer. Phil. Soc., Vol. 15, No. 96, pp. 142-144.
- Pissodes strobi* Hopkins, A. D. 1911. U. S. Dept. Agr. Tech. Ser. No. 20, Part I, p. 48-49.
- Pissodes strobi* Blatchley, W. S. & Leng, C. W. 1916. Rhynchophora or Weevils of North Eastern America, p. 179.

The adult is an oblong, oval, rather slender weevil. Length 4.5 to 6 mm. It is usually of a reddish, chestnut-brown color, ranging from a dark to light brown, marked with irregular spots of brown and white scales on posterior third of wing covers. Head and legs colored similar to body. Small patches of white scales often occur on femora, sides of thorax, and on under side of both thorax and abdomen. Head about one-half width of elytra, beak slender, cylindrical. Antennae inserted on sides near middle of beak. Scutellum distinct. Length of head and thorax together only slightly less than that of wing covers. Elytra slightly broader than thorax, oblong with sides parallel, rounded at apex, covering abdomen and wings. The legs are strong, subequal, tibiae armed at apex with an incurved spine, tarsi short, broad. Tarsal claws simple.



- a. Weeviled leader showing characteristic drooping of current year's growth, and pupal chambers with exit holes.
 b. Adult, *Pissodes strobi*.
 c. Larva, *Pissodes strobi*.
 d. Chip cocoon in which pupal stage is passed.

THE EGG

The eggs are pearly white, slightly oblong, equally rounded at both ends, about 1.5 mm. in diameter.

THE LARVA

The larva is a small, moderately stout, yellowish white to white, footless grub. The body is divided by transverse constrictions into thirteen segments including the head. The head, which is about half the width of the body, is a shiny light brown to a tawny yellow in color, with distinct eye spots. Breathing pores or trachea form a row of small round tawny yellow dots along each side. The full grown larvae are about 7 mm. in length.

THE PUPA

The pupa is creamy white, with eyes and tips of mandibles brown. Later, as the pupa matures, the snout and legs become partially brown and gradually the pupa takes on the adult form and color. The tip of the abdomen is square, with a sharp, slender, curved spine on either side. Length, similar to that of adult.

The pupal cells are usually entirely within the wood and are surrounded by shreds of wood.

SIMILAR SPECIES

The weevils of the family Curculionidae, include some of our most important forest pests. Owing to the general similarity of the beetles in this group a few most likely to be mistaken for the white pine weevil, with characteristics which will differentiate them, are given here.

Hylobius pales Herbst. Adult feeds on the bark of coniferous seedlings. Larvae found in stumps and logs of white pine. May be distinguished from *Pissodes strobi* by noting insertion of antennae which is nearly two-thirds way down the beak, whereas in the white pine weevil the antennae are inserted about midway on the beak. The Pales Weevil is also much larger than the white pine weevil.

Pissodes approximatus Hopk. Occurs in thick bark on trunks of trees and base of saplings. *Pinus strobus* and *Pinus rigida* only hosts in common with the white pine weevil. Distinguished from *Pissodes strobi* by the larger average size, and the fact that the sides of the elytra are usually distinctly narrowed behind.

Pissodes affinis Randall. Occurs in thick bark on stumps of white pine. Easily distinguished from other species of *Pissodes* by the equal width of the elytral interspaces, the third and fifth of which are not elevated.

Several other species of *Pissodes* occur in different localities within the range of *P. Strobi*, but these have not been reported as attacking white pine.

METHODS OF CONTROL

It is the object of this paper to emphasize the possibilities of controlling the white pine weevil by means of proper forest management. Hitherto control methods advised have not been applicable to economic forest conditions. It is *undoubtedly* true that many, if not most of our serious forest insect pests, can be controlled economically by a thorough study of the life history and habits, not only of the insect, but also of forest types concerned.

NATURAL ENEMIES

It has proved a revelation to note the high percentage of parasitism in connection with the white pine weevil. Usually between twenty and thirty eggs are laid in a terminal and it is seldom that more than five and usually even fewer adults emerge from a leader. The fight for survival starts soon after the eggs hatch. Those larvae hatching from eggs farthest down on the leader leave only a trail of wet frass for those that follow to feed upon. These soon die from starvation or disease. It is during the pupation stage that the heaviest percentage of parasitism takes place. It is probable that nearly fifty per cent of the pupae are devoured by parasites. In the fall of 1919 a large number of weeviled tops

were collected in order to rear the over-wintering parasites. These leaders were put in a darkened cage equipped with test tubes into which the parasites went, due to the attraction of light. Mr. C. F. W. Muesebeck of Melrose Highlands very kindly identified the parasitic material. Owing to the fact that the parasites all belong to groups that are very poorly known it is extremely difficult to place specific names even by comparison with types which may be available. The genera represented included *Epirus*, *Eurytoma*, *Microbracon*, and apparently *Paracrias*. Among the parasites listed by other investigators are *Coeloides pissodes* Ashm., *Habrobraconidea bicoloripes* Viereck, *Microbracon nanus* Prov., *Bracon pissodes* Ashm., *Eurytoma pissodes* Girault, *Phopalicus suspensus* Ratz., and *Spathius brachyrus* Ashm.

Hopkins believes that some larvae die from disease and that the larger ones may even feed on the smaller ones. It is his belief that not more than three to five per cent of hatched larvae ever reach maturity. Riley in his report of 1885 states that the young of *Tenebrionidae* have been found feeding on the larvae of *Pissodes strobi*. Woodpeckers often feed on the larvae, pupae, and adults. No fungus disease has been found.

ARTIFICIAL MEANS

For several years the Connecticut Agricultural Experiment Station has carried on spraying experiments in an endeavor to repel or kill the adult weevils before the eggs are laid. This means of combating the weevil if successful would be applicable particularly to ornamental plantings and commercial nurseries.

Lime sulphur used in the proportion of one part in eight parts of water proved very satisfactory as a repellent. The trees were in no way injured by the spray in spite of its concentration. It is essential, however, that the leaders be thoroughly coated with the spray which is best applied with a compressed air pump which is easily carried about. In

several cases the control proved to be one hundred per cent efficient, if applied at the proper time, i. e., when the first of the weevils emerge from winter hibernation.

Arsenate of lead, when applied at the rate of one ounce of paste to a gallon of water, gave a certain degree of protection, in most cases decreasing the number of weeviled tops by one-half. It is essential that the spraying be very thorough for the adult weevil requires only a small space to excavate the egg cavity.

Graham (1916) experimenting at St. Paul, Minnesota, along these lines found arsenicals and lime sulphur to be of little use, whereas carbolineum and creosote when sprayed on the leaders proved very effective in checking the amount of weeviling but did some damage to the trees so that the benefit to be derived is questionable. It is patent that there is still need of more work along this line.

"Whale Oil" or fish oil soap, when applied at the rate of eight ounces to a gallon of water, proved effective and did no injury to the trees.

TREE BANDING MATERIALS

The use of "tanglefoot," in the belief that the beetles crawl up the trees to the leader, has been reported as giving fairly satisfactory results, when tried on a small scale, although the writer was unable to get any conclusive evidence from several plots treated with "tanglefoot" and check plots that were carefully watched. Unless experimented with on an extensive scale the factor of weevil prevalence may make useless any comparisons that are obtained. The use of tanglefoot in a forest plantation is at present of course out of the question.

REMOVAL OF INFESTED LEADERS

Probably the most recommended method of control at the present writing is to collect the infested terminals in early July and place these in a tight barrel or box, one end of which

has been covered with ordinary wire fly screening. This prevents the escape of the adult weevil but does allow the parasites to escape and continue their helpful work. The wire-covered box, or barrel, should be left in the plantation and kept on its side to prevent rains from collecting in it. The wire covering may be removed in early November but the cut leaders should not be destroyed until the following summer owing to the large braconid parasites which pass the winter and part of the spring in the terminals.

Unquestionably there are conditions where the above method of control is worth following. Especially is this true in the case of extremely valuable plantations or in commercial nurseries. In localities where the weevil is not very prevalent, infestations may be checked to a considerable extent by consistent removal of infested leaders. It is worse than useless, however, to go through plantations, cut off the leaders, and merely throw them on the ground — a practice that the writer has observed in some plantations. Some people immediately burn the infested leaders. This destroys the weevils, but also the parasites which might aid greatly in preventing future losses.

In cutting off the leaders care should be taken not to destroy those which are likely to recover. The extreme browning of the needles can usually be taken as a sure sign that the leader has been killed. The epidermal layer turns brown over the burrows of the larvae, thus showing the extent of the damage. Injured leaders are readily spotted in a plantation due to the drooping of the current year's growth.

JARRING

Felt (1916) recommends collecting the weevils from the pine leaders with a net. The net is held close to the base of the leader and the opposite side of the leader is rapped with a stick, thus knocking the weevils present into the net. It was found that four collections in a young plantation could be made at the rate of \$1.28 per acre. Similar experiments

were carried on by Walden and Zappe (1914) in Connecticut with exceptionally good results. A net having a rim diameter of about sixteen inches with a notch about three inches deep on the side to place against the leader was used. Collections were made once a week during May. The damage from weevil injury on treated plots was slightly less than half that occurring in the check plots. The writer carried on similar experiments in two of the plantations at the Harvard Forest, the results proving even more satisfactory than those cited. This was probably due to the fact that it was noticed that many of the weevils hid at the base of the new year's growth and could not always be dislodged by merely jarring, so that care was taken to capture these adults also. It required a little more time, but it is believed that the time was well spent. This method of control is, like those previously mentioned, applicable only in small ornamental plantations.

CONTROL BY FOREST MANAGEMENT

IN PLANTATIONS

The most valuable result obtained from this study of the white pine weevil was the fact that good forest management and freedom from permanent weevil injury are practically synonymous. Keeping in mind the influence of density, rate of growth, and the presence of hardwood on the amount of final damage created by the weevil, a very satisfactory means of control can be evolved.

In the first place a great deal of emphasis should be laid on the choice of site. White pine set out in swamps, on sandy ridges, or under a dense growth of mature trees should not be expected to give satisfactory results. Yet many plantations were found under these very conditions, where the trees at ten years of age would average only between two and three feet in height and where the survival was less than fifty per cent. Nearly all white pine plantations are now set out using a six by six foot rectangular spacing. This results in an

early density of 1210 trees per acre, which is none too high for a quality two site. It is essential that the crowns be kept fairly crowded until the trees reach an age of twenty-five years. This means that extreme care should be taken in selection of stock and planting methods. Few people realize how quickly the extremely sensitive cells in the young roots will dry up and cease to function. It has been very apparent that in many plantations too little attention has been given to proper planting, which has resulted in open stands where the tendency of pine to spread out has been unchecked and accentuated by the weevil injury. Such plantations should be restocked by filling in the gaps, thus keeping up the proper density. If, then, we have a normally rapid growing plantation of the proper density the following results can be expected. First, the length of internode will prevent weevils from going below the first laterals. Second, the rate of growth will shorten the period of susceptibility. Third, the density of the stand will prevent forking of weeviled trees, and will have a strong tendency to keep the trees erect thus overcoming crooks. Such plantations should not, even in badly infested areas, be damaged more than ten per cent, which in reality is an excellent stand.

Mr. Arthur F. Allen in making a study of white pine at the Harvard Forest derived the following table of densities:

OPTIMUM DENSITY FOR BEST QUALITY TIMBER		
Age	Number of trees per acre	
	Site I	Site II
10.....	1630	1800
20.....	1300	1460
30.....	960	1120
40.....	690	820
50.....	490	580
60.....	340	390
70.....	235	270
80.....	190	220

Comparing this table with the graph on page 23 it will be seen that a density of 580 trees per acre at fifty years of age

should be 91 % perfect, for the graph is based on fifty-year old stands on quality two sites in heavily weevil infested areas.

The above table, while based on optimum forest conditions, is not applicable to forest plantations during the early years due to the prohibitive expense of starting with the high densities shown in the table. Nevertheless, a plantation of 1200 trees per acre can be so managed and judiciously thinned that the final results will approximate those in a stand starting at a greater density. Such a plantation should hold nearly this density until twenty-five years of age on a quality II site.

It is well to bear in mind that a plantation set out in close proximity to an older one intensifies the danger of weeviling. Observations made in the seventy-five or more plantations examined throughout the state show that the type of the surrounding forest makes a vast difference in the percentage of weeviling, due to the breeding of the weevils in older trees. Plantations set out in the midst of a white pine or pitch pine area are far more liable to severe injury than those set out in a typically hardwood area.

NUMBER OF TREES REQUIRED TO PLANT AN ACRE, USING RECTANGULAR METHOD OF SPACING ¹

Distance between the rows Feet	Number of trees when distance apart in the row is:				
	4 feet	5 feet	6 feet	7 feet	8 feet
4	2,722
5	2,178	1,742
6	1,815	1,452	1,210
7	1,556	1,244	1,037	888	...
8	1,361	1,089	907	777	680

¹ Table taken from U. S. D. A. Bull. No. 13, p. 55, 1914.

HEIGHT GROWTH OF WHITE PINE SEEDLINGS (BASED ON 1600 IN
NEW ENGLAND)¹

Age Years	Height Inches	Age Years	Height Inches
1	1.0	6	17.0
2	1.5	7	24.0
3	3.5	8	32.0
4	7.0	9	45.0
5	11.0	10	64.0

CONTROL IN PURE STANDS OF PASTURE PINE

All through New England it is common to see abandoned pastures slowly being reforested by white pine. The seeds are blown on to the fields from the older trees and the young seedlings often come up in scattered groups, so far apart that the trees become what is known as "cabbage" or "pasture pine," a condition augmented by the weevil. In the early stages when these trees are three feet or less in height an excellent young forest could be started by merely filling in the gaps so that the stand would approach a six by six spacing. Ordinarily these pasture stands are about one-third or more stocked, depending upon local conditions of soil, seed trees, prevailing wind, etc., so that much of the expense of planting is done away with. Once the proper density is obtained, the trees will be able to overcome weevil injury as have the trees in properly stocked stands. It would seem well worth while if more attention was paid to this type of prospective forest.

CONTROL IN MIXED STANDS ON CUT-OVER AREAS

When dealing with natural factors it is usually wise to let nature decide the plan to be followed. As soon as man upsets the plan of nature, particularly in agriculture, the entire natural balance of insects and parasites, and the helpful influences of the intermixing of species, is interfered with.

¹ Table taken from U. S. D. A. Bull. No. 13, p. 18, 1914.

In the original forest, which at one time covered Central New England, white pine seldom occurred in pure stands, but usually in mixture with other species of trees, particularly hardwoods. That this condition tends to reduce weevil attack has already been shown; and experience on the Harvard Forest indicates that both for silvical and financial reasons it is better to convert the white pine type into mixed hardwood and pine, at least upon the heavier soils. On such sites it is relatively cheap and easy to secure a reproduction of mixed pine and hardwood, either by the shelterwood method of cutting, or by irregular or "spot" planting on the cut-over land. Whichever method is followed, the problem is to maintain a reasonable amount of young pine among the sprouts and advance growth hardwood which start immediately after cutting. For the first ten or fifteen years, competition between the young pine and the hardwoods will be one-sided, and it is necessary to make from one to three weedings or cleanings. The manner of these cleanings may be adapted both to checking the infestation by the weevil and to correcting injury after it occurs. There is an age, usually between the tenth and fifteenth year, when the height growth of white pine first equals or exceeds that of hardwoods of the same age, provided the latter are not stump sprouts. In making the cleanings, therefore, it is desirable first: to leave a fairly large percentage of the better hardwoods in the mixture; second: to remove trees which are overtopping or whipping the pine; and third: to cut back the fast growing stump sprouts always. The general object is to keep a well distributed hardwood stand at a level of one to three feet above the pine tops. If these hardwoods are of seedling or seedling sprout origin, the pines will catch up to them between the tenth and fifteenth year, after which the stand will be in condition to progress at a fairly uniform rate of growth, and mainly free from weevils. It is well to bear in mind that the larger-leaved trees — such as oak, maple, and ash — besides being valuable, afford more

protection than the smaller-leaved trees — such as birch and poplar. The best results should occur when the pine is evenly scattered through the stand and constitutes not more than twenty or twenty-five per cent of the total number of dominant or prospectively dominant trees. A crop so constituted will produce the best quality of lumber obtainable from white pine.

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