BIOLOGY AND CONTROL OF WARREN'S COLLAR WEEVIL, *HYLOBIUS WARRENI* WOOD, IN ALBERTA

by

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TABLE OF CONTENTS

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INTRODUCTION

Warren's collar weevil, *Hylobius warreni* Wood, is a large and robust beetle which attacks pines and spruces throughout Canada (Daviault, 1949; Ross, 1955; Warren, 1956a; Finnegan, 1962; Warren and Parrott, 1965; Grant, 1966). In Alberta, its primary host is lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.), but jack pine (*P. banksiana* Lamb.), white spruce (*Picea glauca* (Moench) Voss) and black spruce (*P. mariana* (Mill.) BSP) are also attacked (Reid, 1952; Stark, 1959; Cerezke, 1969). The larvae of this insect feed in the root collar zone, causing large open wounds and resinosis. Trees may be killed directly from girdling, accumulate growth losses from repeated attacks, or the wounds may serve as entry points for root and stem diseases (Warren, 1956a; Whitney, 1961, 1962).

Intensive studies were initiated in 1961 to examine the abundance and damage relationships of the weevil in a variety of lodgepole pine stands in Alberta. These investigations are now nearing completion. This report reviews the main findings of these studies, and in the light of these, recommends control of the weevil through forest management.

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Accordingly, the report is divided into two main sections: (A) biological and economical appraisal of the weevil and (B) silvicultural recommendations for its control. In addition, a method for assessing the abundance of H. warreni is described in the Appendix.

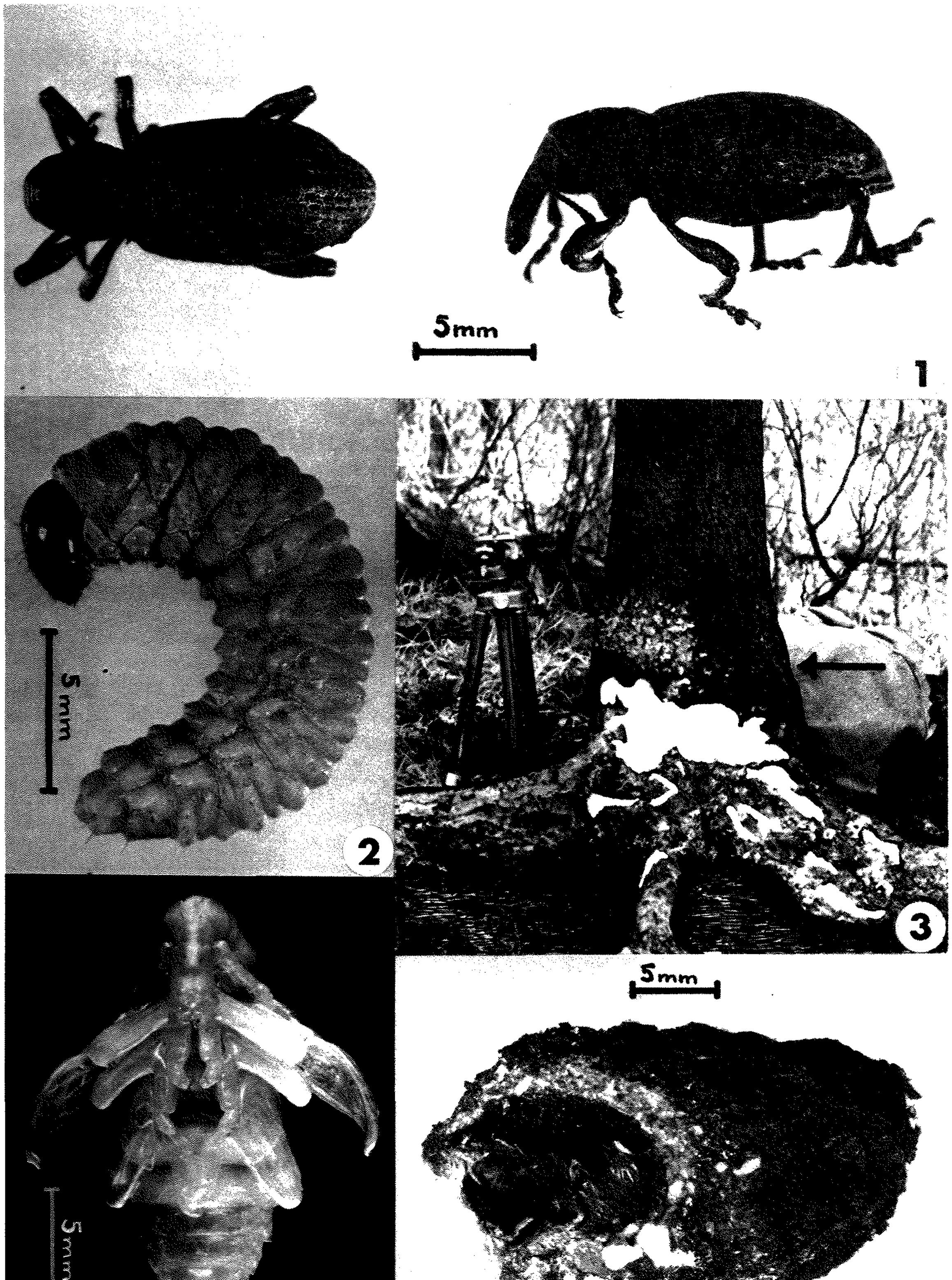
BIOLOGICAL AND ECONOMICAL ASSESSMENT OF H. WARRENI IN ALBERTA

General Biology of H. warreni in Alberta

Warren's collar weevil (Fig. 1) is a primary attacker, requiring no pre-weakening of its host for successful attack. The female lays its eggs in the root-collar zone of the tree, either in small bark niches or in the adjacent soil. Oviposition may extend from May to September, and reaches a peak in early July. After being hatched, the larvae (Fig. 2) feed on the root collar and lateral roots, but confine their feeding between the mineral soil and the upper surface of the forest duff (Fig. 3). Their development is completed on, or in association with, a single host.

Development of the larval stage lasts about two years and after a short pre-pupal stage in June, the larva transforms into a pupa (Fig. 4) and the adult emerges in August or early September. While the time of pupation is relatively constant from year to year, some adults may not emerge until the following spring. The pre-pupal, pupal, and teneral stages are stationary, being spent in a special chamber constructed from a resin-bark fragment matrix (Fig. 5).

The adult is flightless and long-lived; tagged adults were known to survive through four winters in their natural habitat. During its life, the adult is capable of laying eggs at least in the second, third, and fourth summers of adulthood. When reared in the field, females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laid up to 36 eggs each during a season but the average was only 12.2 per female. During daylight hours, adults usually rest in the forest duff; at night, they disperse laterally between trees and up stems to feed on phloem in the crown. Most return to the duff in the early morning. Their feeding damage is considered negligible. Little or no adult activity occurs when temperatures in the field drop below 36-40°F.

Few natural parasites and predators of all stages are known.

Distribution in Alberta

The distribution of _H. warreni_ is shown in Fig. 6. The main forested areas infested include the Lower (B19a) and Upper (B19c) Foothills Sections of the Boreal Forest Region (Rowe, 1959). The former Section includes 54% of the total lodgepole forested area (Smithers, 1962), much of which consists of prime pine pulpwood sites. Little or no incidence of the weevil occurs at altitudes above 5000 ft. Other infestations occur at main valley bottoms in Yoho, Kootenay, and Jasper National Parks, and in outlying areas such as the Cypress Hills and Clear Hills.

Site Requirements

Within lodgepole pine forests of the Alberta foothills, highest levels of weevil abundance have occurred on rich, moist growing sites (Cerezke,1969). These can be defined broadly as having good drainage and corresponding soil profile development, an abundance of ground floral species of mosses, herbs, and shrubs. In general, these sites occur in Productivity Classes I and II defined by Smithers (1962). An abundance

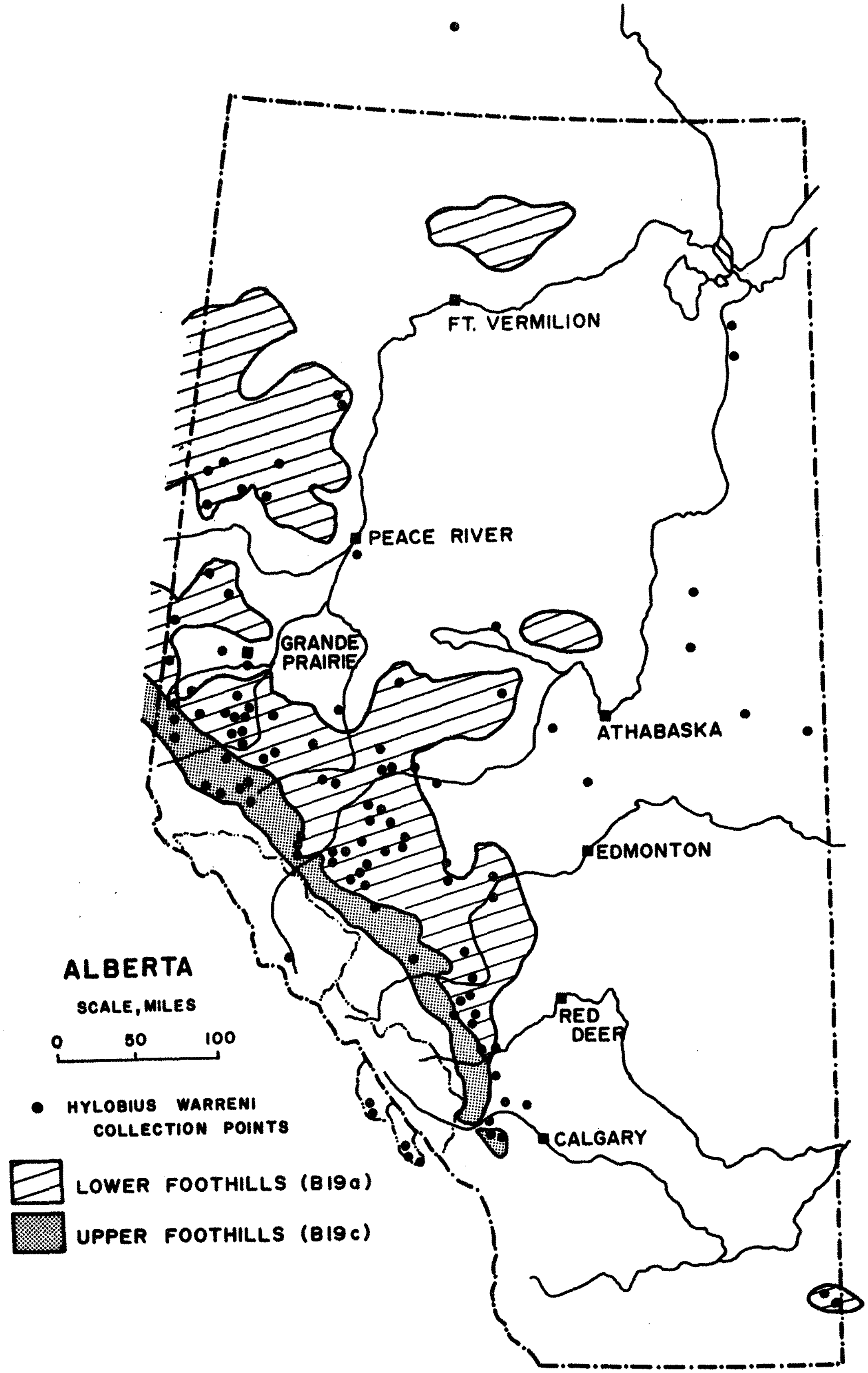

Fig. 6. Distribution map of Hylobius warreni in Alberta, Rocky Mountain National Parks, and Northwest Territories.

of rotting logs lying at the bases of trees is often a characteristic of good weevil sites since they are utilized by mature larvae for pupal cell construction. In addition, moist areas of the root-collar zone, enhanced by the presence of logs, tend to be favored as oviposition sites (Warren, 1956a).

Weevil Distribution within Pine Forests

In essentially even-aged pine stands, trees first become susceptible to attack when they are 6-8 years old and about 4-5 ft high. After their successful immigration, the weevils attack trees in the pattern illustrated in Figs. 7 and 8; dominant and co-dominant trees are usually attacked first. This pattern continues as attacks accumulate through to stand maturity. The net effect is that up to 100% of trees may sustain various degrees of damage as they approach the age of 60 years (Fig. 9). As indicated in the graph, attack incidence accumulates temporally by selection of new hosts and by changes in stand density, the latter being a consequence of natural thinning processes. Figs. 10, 11, and 12 summarize some observed relations between attack incidence, tree size, and stand density for three age classes. Current and old attacks increased directly with tree size at all density levels, but there is evidence that excessively stocked stands constitute poor weevil habitats (Figs. 10 and 11).

The estimates of weevil numbers per acre varied from 100 to 936 in the three stand-age classes (Figs. 10, 11, and 12), which indicates that young and old stands can support similar weevil population densities. Other estimates obtained in a variety of lodgepole pine stands have generally ranged between 200 and 1200 weevils per acre (Cerezke, 1969).

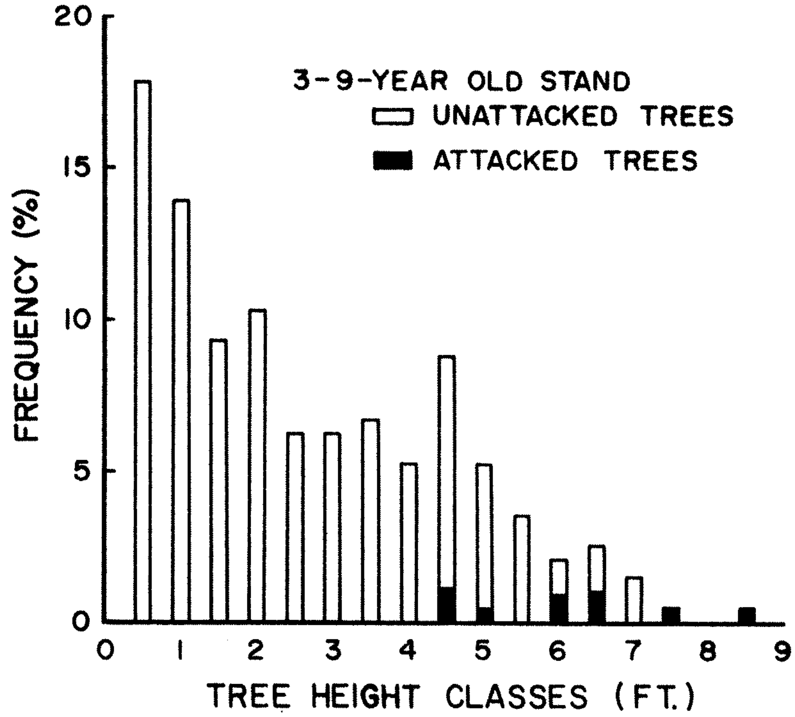

Fig. 7. Frequency distribution of tree-height classes of pine regeneration, 3 to 9 years old, showing the pattern of weevil-attacked trees.

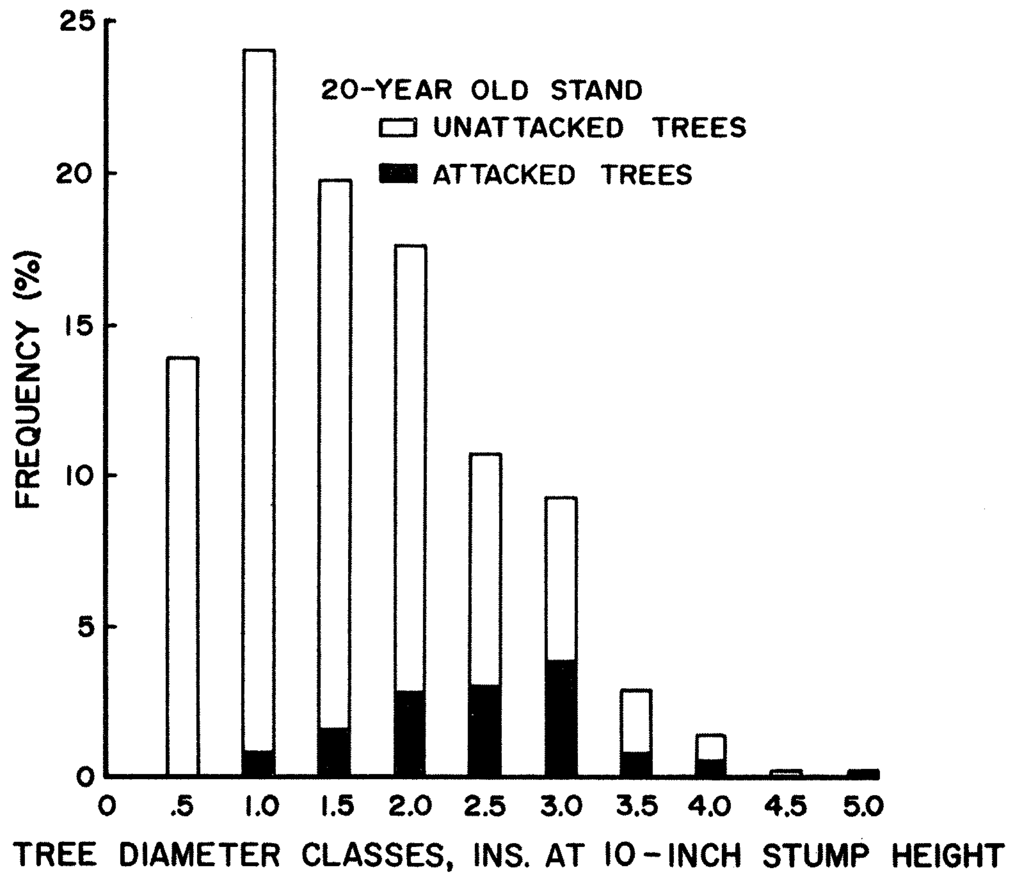

Fig. 8. Frequency distribution of tree diameter classes in a 20-year-old pine stand showing the pattern of weevil attack.

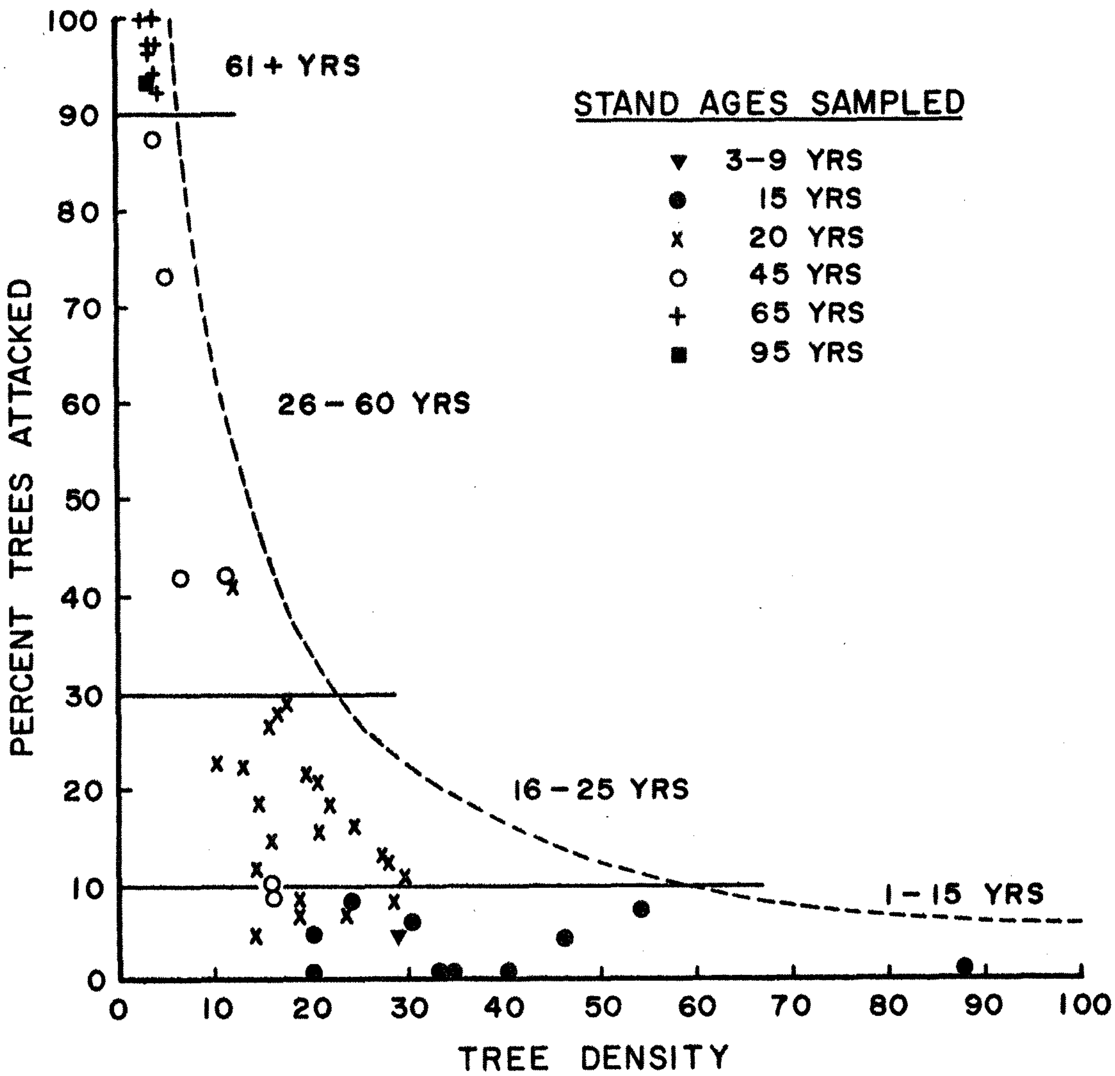

Fig. 9. Progressive weevil-attack pattern in naturally stocked pine stands, ranging in age from a few years old to mature. Age divisions were arbitrarily assigned. All areas sampled were converted to a common unit area equivalent to 10-ft radius circle.

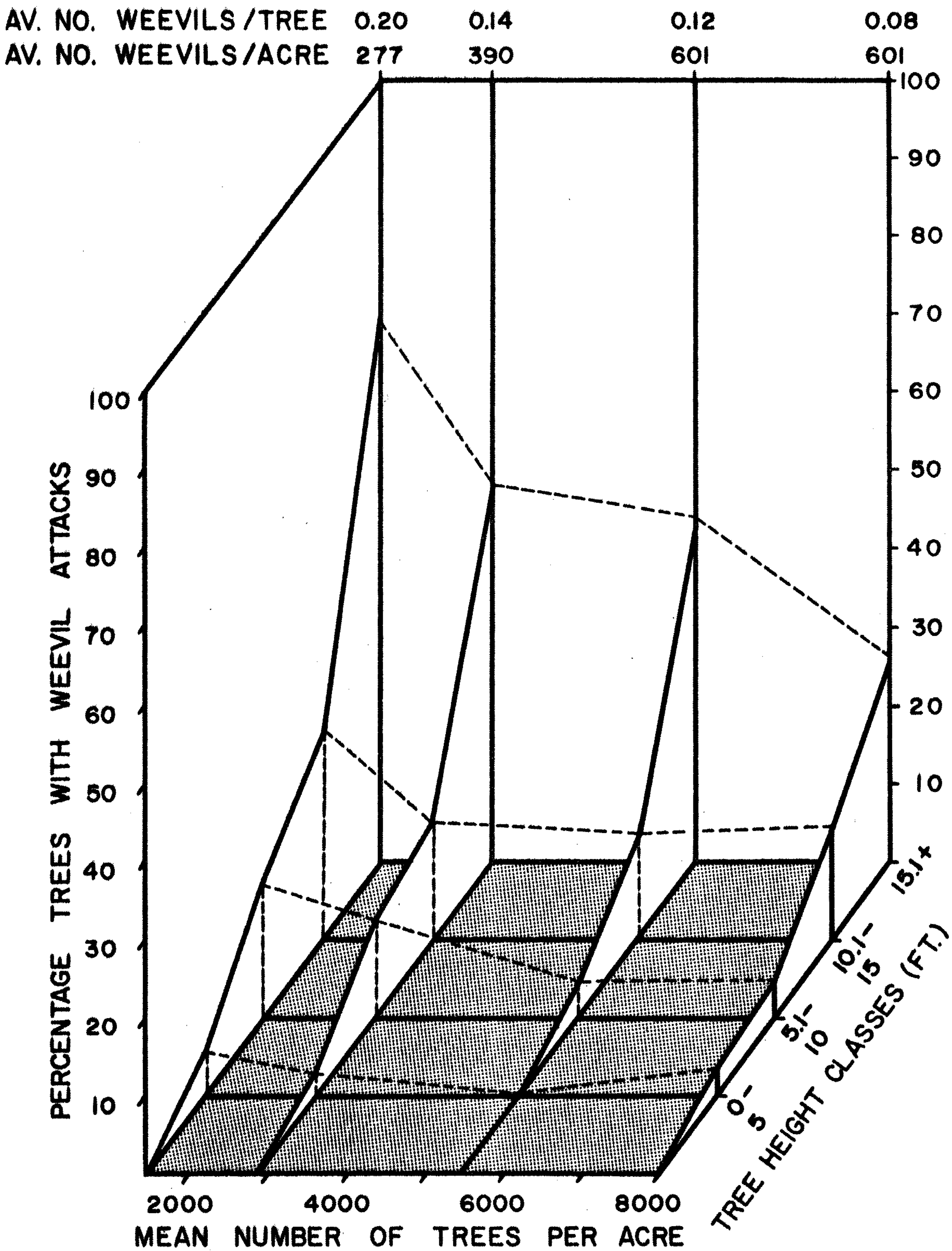

Fig. 10. Relation between stand density, tree height, and incidence of weevil attack in a 20-year-old naturally stocked lodgepole pine stand. The incidence of attack includes pooled current and old feeding wounds.

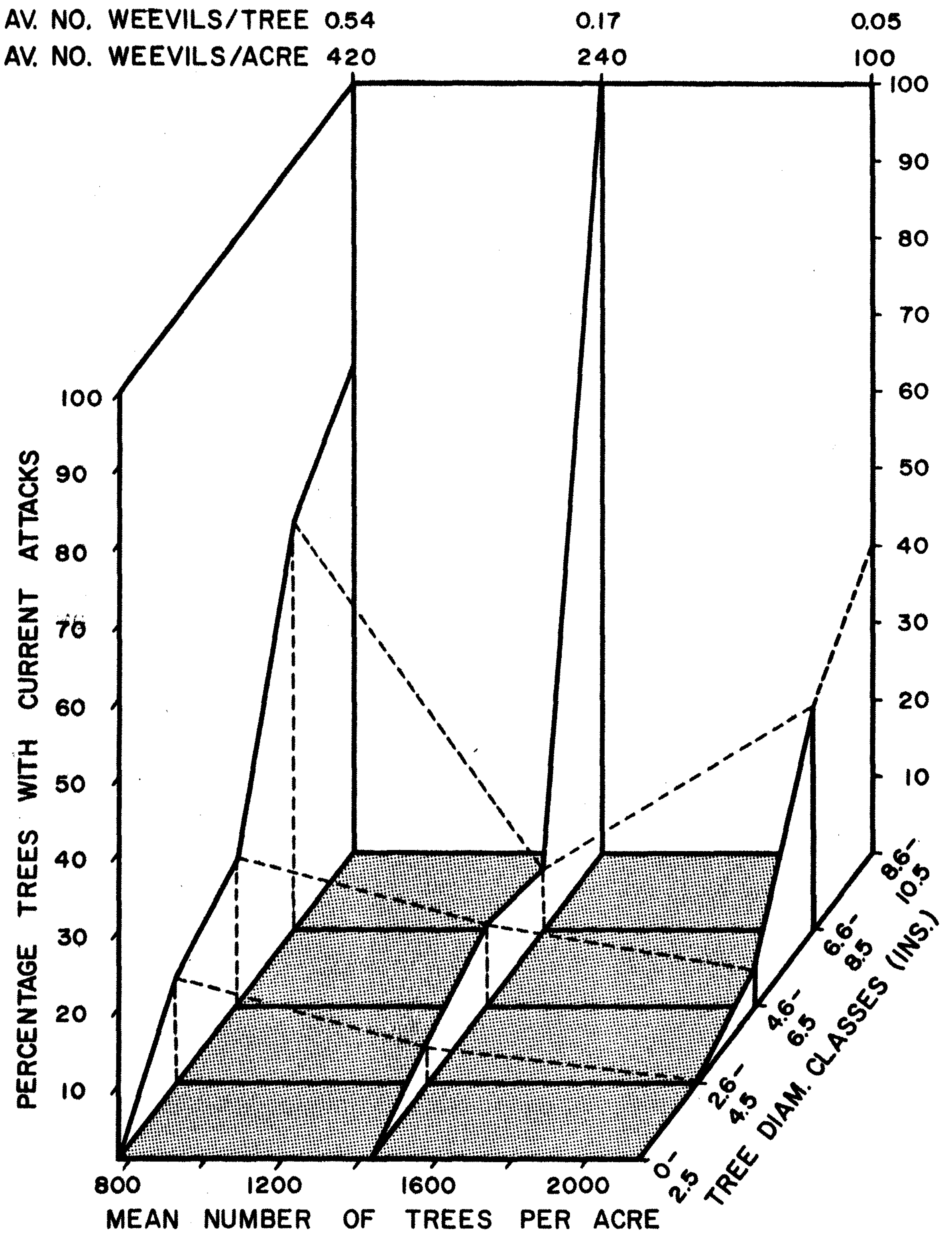

Fig. 11. Relation between stand density, tree diameter, and incidence of current weevil attacks in a 45-year-old lodgepole pine stand.

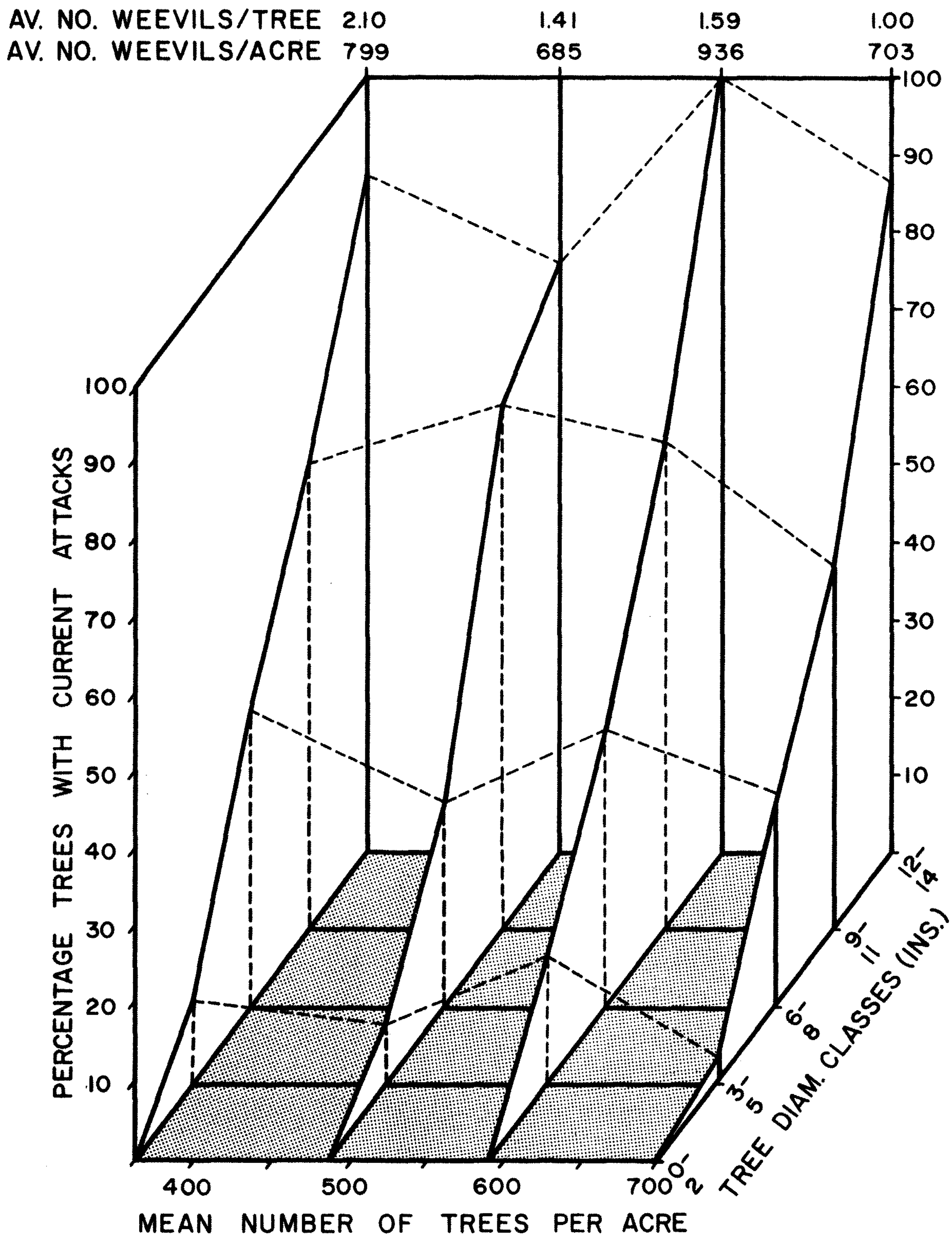

Fig. 12. Relation between stand density, tree diameter, and incidence of current weevil attacks in a 65-year-old lodgepole pine stand.

Weevil numbers per tree increased directly with tree size regardless of stand density. The general implication in the latter is that the weevil has the means of distributing its eggs within the forest in a manner that tends to maximize usage of the available larval feeding universe.

The favorability of weevil habitats varies with site. The data summarized in Figs. 13 and 14 indicate that depth of duff material (i.e., living and dead organic matter to mineral soil) at tree bases provides an index of the quality of habitat. However, the influence of duff appears to act differentially for the various tree-size components within a stand. For example, weevil numbers per tree increased more sharply on dominant trees (12-inch diam. trees) with increasing duff depth than on suppressed trees (4-inch diam. trees) (Fig. 13). Consequently, large trees displayed a greater utilization of the root-collar surface area as feeding sites with increasing duff depth than did small trees.

The depth of duff material around tree bases influences the amount of oviposition and largely determines the size of the larval universe. Since weevil numbers tend to increase directly with duff depth, high populations are most likely to occur where the duff layer at tree bases exceeds 5 in.

Damage Patterns of Larval Feeding

The larvae feed for about two years. Most girdling damage occurs during the late instars when larvae attain a length of up to 0.8 in. Total decorticated gallery lengths per larva extend 9-10 in.,

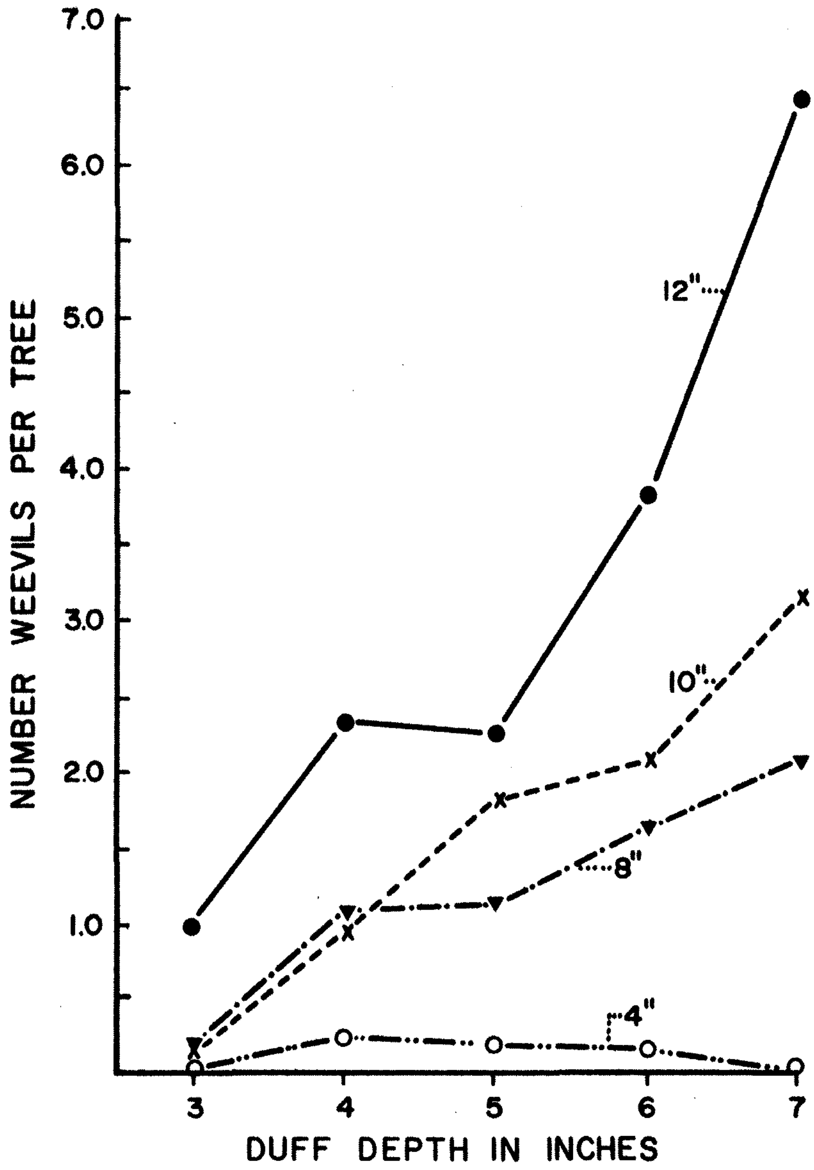

Fig. 13. Relation between mean weevil numbers per tree and duff depth at the bases of 4-, 8-, 10-, and 12-inch diameter trees sampled within a 65-year-old pine stand. Tree diameters were measured at the 10-inch stump level.

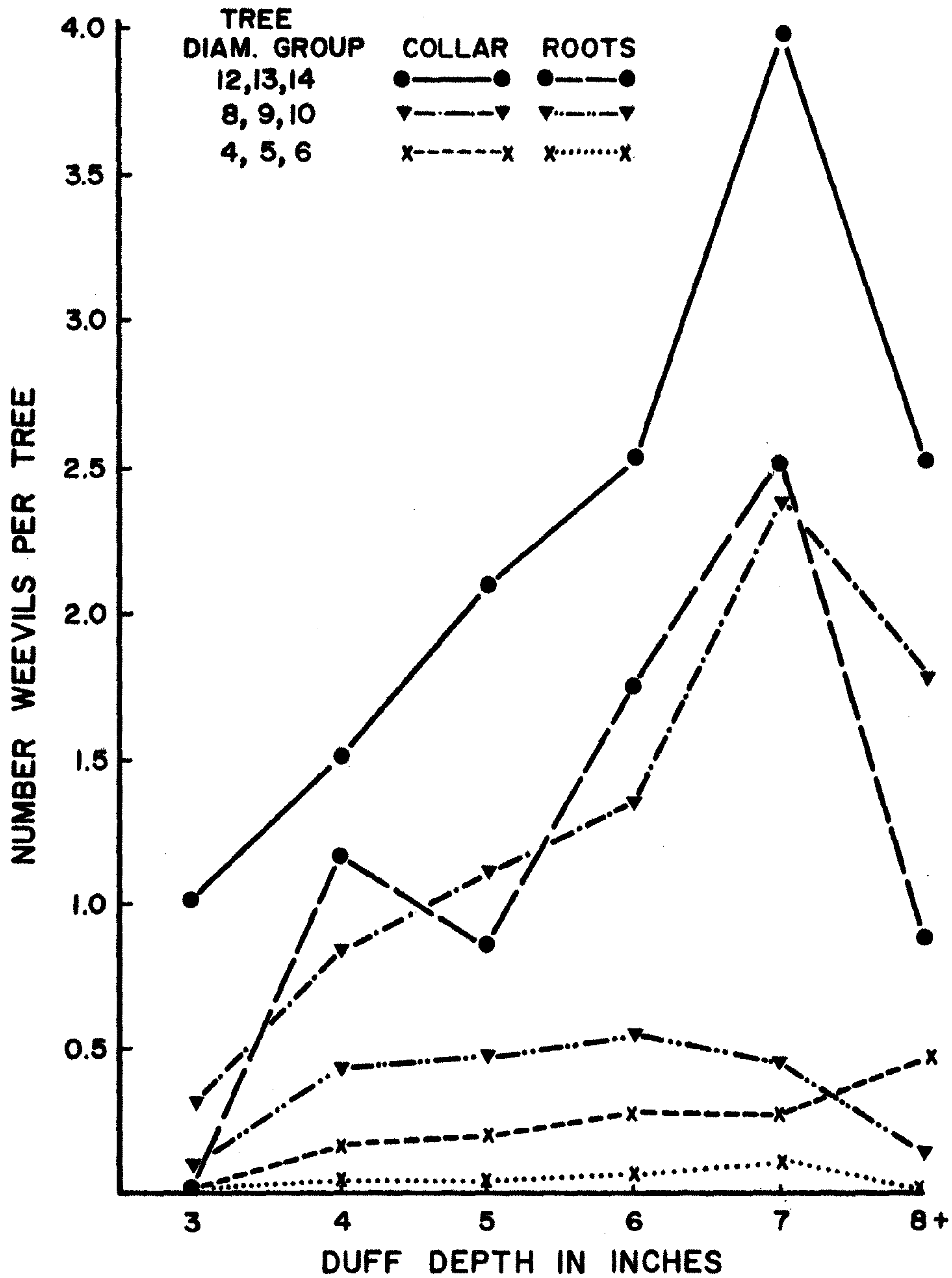

Fig. 14. Distribution pattern of weevils on its pine host, compared for three different diameter classes in a 65-year-old stand.

but the estimated average circumferential distance girdled per larva on root collars was only 2.3 in. (Cerezke, 1970). This results from the fact that galleries rarely follow a linear path. Field observations suggested that the feeding pattern differs on young trees as compared to old trees; on the former the gallery tends to be more circumferentially oriented on the root collar (Fig. 15), on the latter it tends to occur in patches (Fig. 16). In addition, larval feeding tends to become more frequent on the lateral roots with increasing tree size and is confined mostly on upper and lateral surfaces. These findings provide one explanation why most observed tree mortality has occurred in stands less than 30 years of age. On young trees, fewer larvae are required to girdle an amount equivalent to that on older trees.

Growth Loss Estimates

In stands up to about 30 years of age, tree mortality resulting from weevil feeding rarely exceeds 10%, and in most cases is less than 5%. Indirect losses include reduced radial growth and tree height, which are difficult to measure. Since dominant and co-dominant trees in stands are preferred during attack, the damage impact is mostly concentrated on potential crop trees, regardless of stand age.

Preliminary studies in 20-year-old lodgepole pine stands were undertaken to estimate radial increment and terminal shoot length losses on trees that sustained approximately 50% girdling of their root collars (Cerezke, 1970). At this attack level the data indicated that 17.2% reduction in radial increment occurred during a two-year period after attack. Similarly, 11.5% reduction occurred in the terminal shoot length during

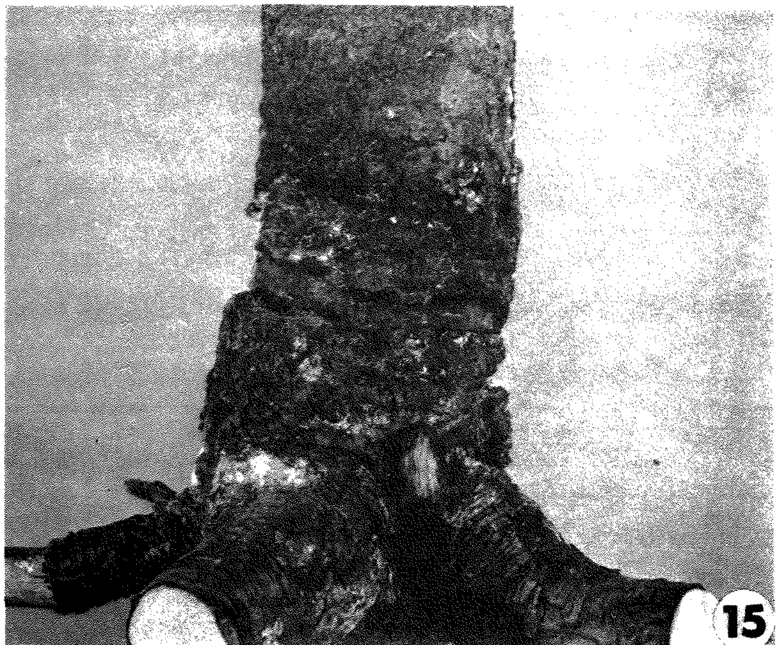

Fig. 15. Fifteen-year-old lodgepole pine showing circumferential feeding pattern on the lower main stem.

Fig. 16. Sixty-five-year-old lodgepole pine stump with bark removed to show patches of typical weevil-scarred areas.

the same two-year period. The studies did not reveal how long after attack the effects may last. Further studies are in progress to determine experimentally the critical level of partial girdling necessary to cause tree death, and to establish a relationship between degree of girdling and amount of growth loss.

Weevil Damage and Fungal Diseases

Some indirect effects of weevil damage involve the relationship between larval wounds and fungal diseases of the stem and root system. In white spruce stands in Manitoba and Saskatchewan, it was shown that *Hylobius* wounds provided an important avenue of infection for root rotting and staining fungi (Warren and Whitney, 1951; Whitney, 1952; Whitney, 1961). Whitney (1962) also showed that the wounds were a significant factor in the development of stand opening disease (caused by a combination of adverse soil conditions and *Polyporus tomentosus* Fr. root rot).

During the investigations of *H. warreni* populations in a variety of lodgepole pine stand-age classes in Alberta, little evidence was found to suggest that larval wounds contributed significantly as courts of entry for disease organisms except in one mature stand.

SILVICULTURAL CONTROL OF *H. WARRENI*

The biological information on *H. warreni* provides a basis for establishing some guidelines for its control. By present standards of management in Alberta, this insect does not pose a serious problem to lodgepole pine forests; damaging populations currently exist in only a few localized areas. An important aspect of this report is to point out which forestry practices are most conducive to enhancing weevil survival and spread, and those which are detrimental to its survival.

The decision of the forest manager to carry out control measures on the weevil involves a rational assessment of timber losses, weevil abundance, and site potential. Losses occur in the form of tree mortality and growth reduction from accumulated larval feeding. Estimates of growth reduction are difficult to obtain, but studies with that objective are in progress. However, it can be stated that losses in the radial and height dimensions of the tree will result when the degree of girdling of root collar circumferences exceed 50% (Cerezke, 1970). The proportion of trees within stands having 50% or more of girdling might be used as one criterion for establishing the severity of infestation. At the same time, weevil abundance can be estimated with the survey sampling technique developed for even-aged lodgepole pine stands (see Appendix I). An evaluation of site potential may be in terms of both weevil habitat and tree growth potential. In this respect pine stands rated in Productivity Classes I and II (Smithers, 1962) need only be considered as potential problem areas.

Within the geographical range of the weevil, stands most likely to require control occur within Productivity Classes I and II in the Lower Foothills Section of the Boreal Forest Region and at lower elevations in the Upper Foothills. Control will be most efficient during the period between crop removal and 20-30 years after establishment of the new crop. Attention should be directed toward keeping weevils out and in restricting their numerical increase and spread within newly established regeneration. In general, this degree of control can be achieved with the methods of harvesting and site preparation now in use in lodgepole pine. Highly favorable weevil sites tend to remain high over long periods (Cerezke,1970), so that an assessment of the weevil can be made in mature stands prior to cutting.

In infested mature stands, clearcutting destroys a large portion of the weevil population (estimated 67%), but larvae can still complete their development in the cut stumps one and two years after tree removal (Cerezke, 1969). Heavy scarification applied soon after cutting would likely hasten mortality of larvae and pupae in the cut stumps. Exposed soil would also be detrimental to adult survival since they are unable to withstand direct exposure to heat, and additionally require a moist habitat. Where scarification is not applied, a prescribed burn or disposal of slash may be adequately effective.

The newly developed adults from the cut stumps pose a problem to any advanced regeneration or uncut trees. Since they are long-lived, they are also of concern in the timing of initiating the new stand and in the clearcutting of residual strips or blocks. So, a complete clearcut of the infested and adjacent stands is recommended, including any advanced regeneration pine and white spruce. Pine seedlings do not appear susceptible to attack at least for the first few years. The earliest age of attacked pine recorded in clearcut areas was 6 years. In heavily infested pine stands clearcut in alternate strips or in block patterns, the residual strips and blocks should not normally be retained longer than 2-4 years.

Studies in stands 15 to 25 years old indicated that the rate of adult dispersal into these stands was at least 35 to 45 ft per year

(Cerezke, 1969). While the actual rate may vary widely in different stands, there may be some merit in enlarging the cutting area in some cases.

Immigration of weevils into young stands may be retarded initially by their high density. However, in less dense stands, an aspen intermixture or an understory of black spruce may favor a decrease in the rate of population build-up.

A preliminary study to determine the effects of pre-commercial thinning upon weevil abundance was undertaken in a 25-year-old infested pine stand. The study revealed that, after two years, there was a decline in weevil abundance, a decrease in the percentage of trees with current attacks and an increase in the percentage of trees with old attacks (Table 1). One possibility to account for the decline is that thinning resulted in an initial concentration of the weevil on the residual trees. Thus, the percentage of trees with old and current attacks in thinned plots was still considerably higher after two years than in control plots. This explanation is reasonable since the less-susceptible hosts were removed during thinning. These studies need to be continued to determine the cumulative damage and population changes over the next few years. Similar studies are also required in younger stands, particularly where regeneration originates from natural seeding and planting on clearcut sites. Presently in Alberta, there exist few areas where stands originating by artificial means are old enough to be susceptible to the weevil. Because the duff material is important to weevil survival, losses from tree mortality and growth reduction will likely be higher in artificially regenerated stands than in those originating after fire or having extensive site preparation treatment.

Table 1. Summary of a 2-year pre-commercial thinning study in 25-year-old lodgepole pines infested with H. warreni

Plot no. and year estab-lished	No. trees sampled	% trees attacked: current	old	old + current	% tree mor-tality	% trees with 50 + % girdled	Estimated weevil population: nos. per acre	tree
1 (1967)	261	18	7	25	0	-	313*	0.24*
1 (1969)	261	11	27	33	0.4	5.0	170	0.13
Control (1969)	130	9	15	19	0	3.1	140	0.11
2 (1967)	185	8	4	12	0	-	83*	0.09*
2 (1969)	184	7	15	18	0.5	1.6	75	0.08
Control (1969)	92	2	5	7	0	2.2	30	0.03

* Values estimated from technique described by Cerezke (1970).

The importance of duff material at the tree base, in providing essential habitat requirements for all stages of the weevil's life cycle, is fairly well known and Warren (1956b) has postulated that H. warreni may be controlled by removing this material from the vicinity of the root collar and major roots. Similar treatment applied in plantation pine reduced a closely related species (H. radicis) to below an economic level (Wilson, 1967).

It has been pointed out by Warren (1956b) that plantations of native pines may be more vulnerable to H. warreni than naturally grown stands. In addition, exotic pine species have occasionally suffered more severely than native species. For example, 63% mortality from H. warreni feeding was recorded in a 40-year-old Scots pine plantation in Quebec (Finnegan, 1962). In Newfoundland, tree mortality in pine plantations has reached as high as 29.2% (Warren and Parrott, 1965). For any pine plantations anticipated in Alberta, whether native or exotic species, care should be taken in the selection of weevil-free sites.

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of intersection a value is read on the decision line which gives the percentage of trees with current attacks. This value is then located on the X-axis in Fig. 18 and an estimate of weevil abundance is read on the Y-axis. Weevil abundance is expressed as average numbers per tree, and can also be expressed as numbers per acre if stand density is known.

For convenience during field surveys Fig. 17 may be used directly as a tally sheet prepared on suitable graph paper with the horizontal and vertical axes labelled as in the figure. The decision line can be determined by substituting values of p in the following equation and solving for pn and n.

$pn = 4p^2q/0.1^2$, where p varies from 0 to 1 and is that proportion of trees in a sample with current attacks.

$q = 1 - p$

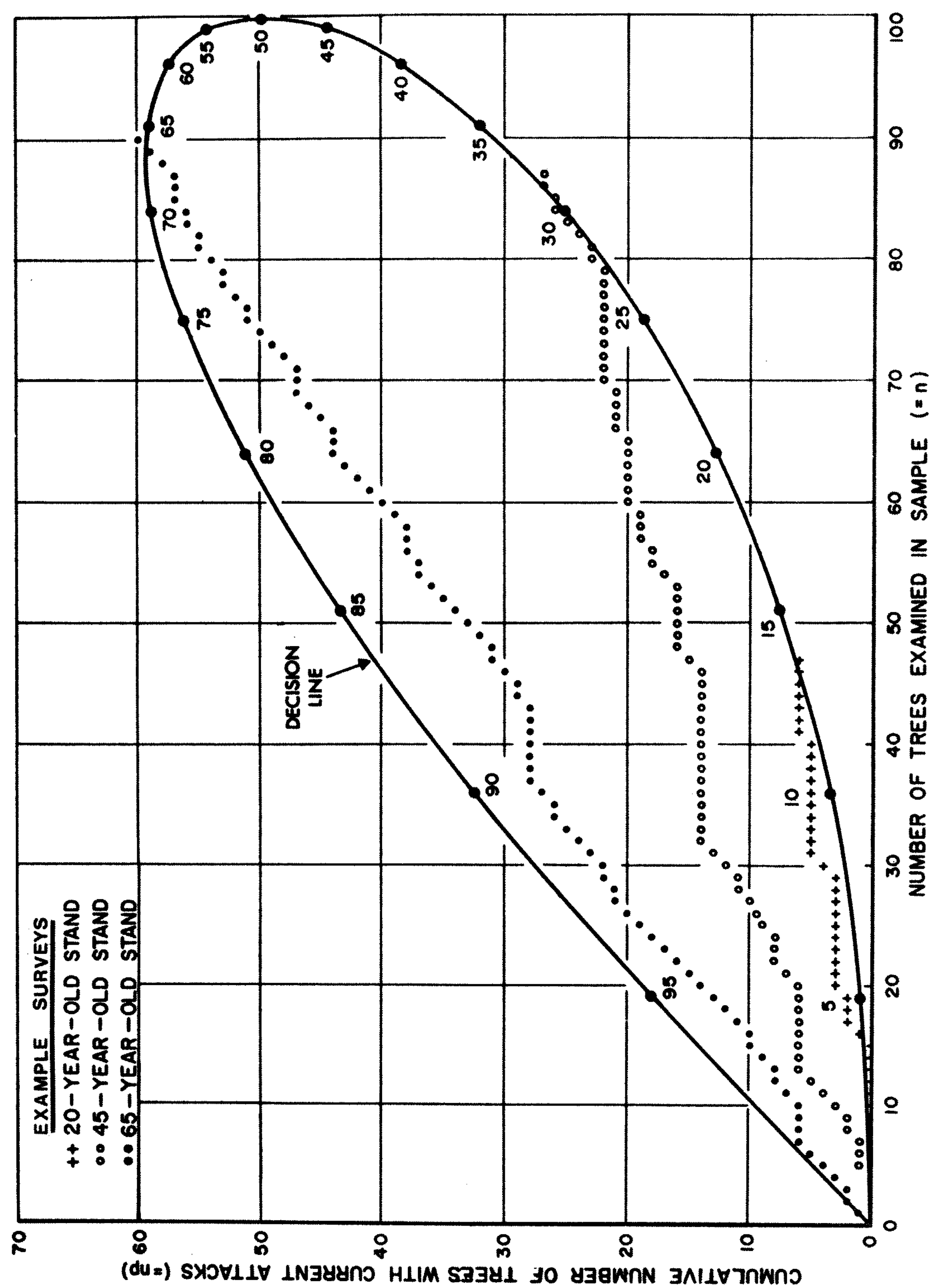

Fig. 17. Relation between cumulative number of trees with current attacks and total number of trees examined. In the three example surveys given for the 20-, 45- and 65-year-old stands, the respective sampling lines intersected the decision line at 13-14, 31, and 66% current attacks. The number of trees required to obtain an estimate of weevil abundance for the three surveyed stands was 47, 87, and 90 respectively.

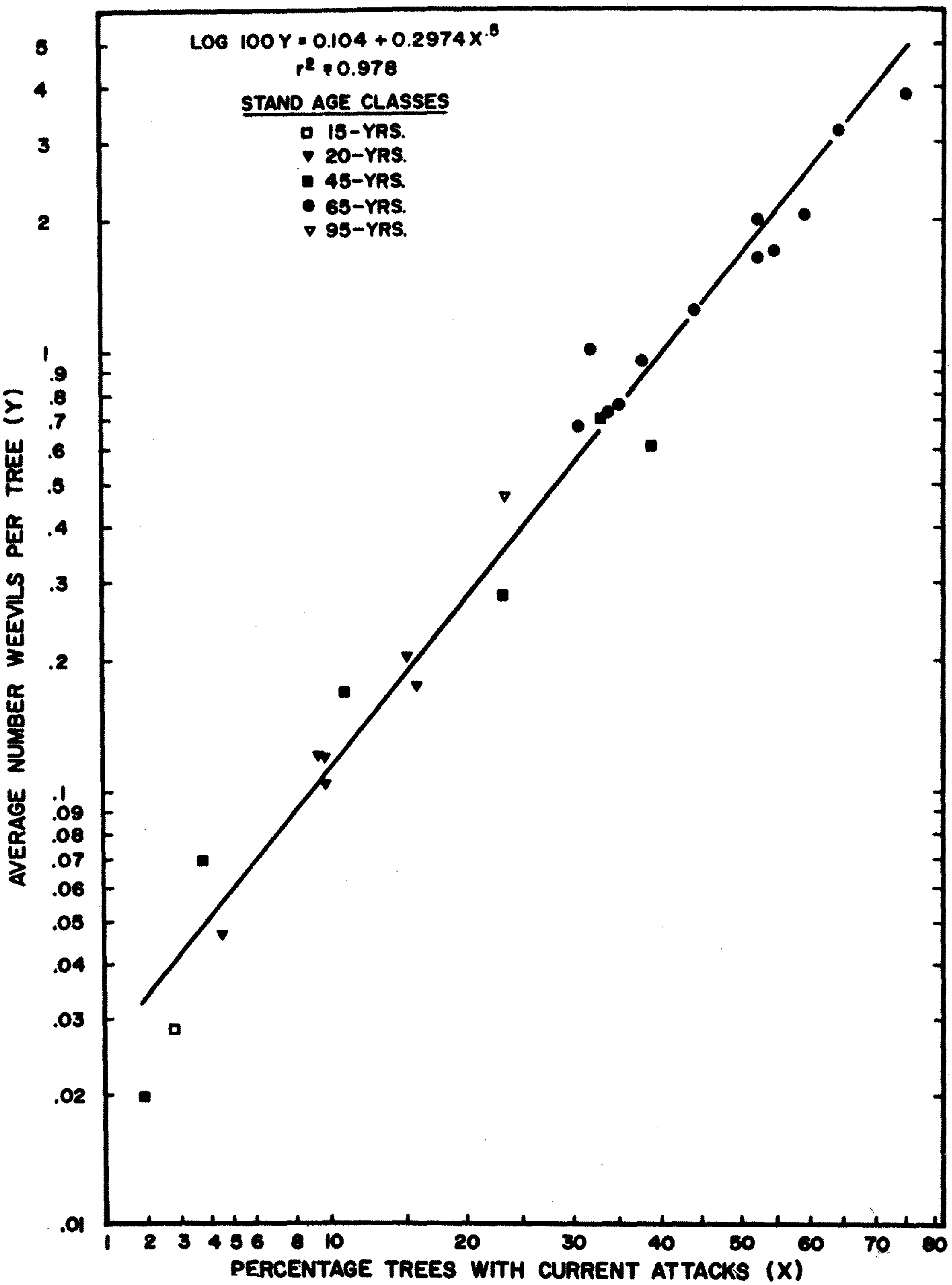

Fig. 18. Relation between mean number of weevils per tree and percentage of trees with current attacks.