THE WHITE PINE WEEVIL IN ONTARIO: RECENT AND CURRENT STUDIES RELATED TO THE IMPROVEMENT OF WHITE PINE QUALITY

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During the past 50 years the growing of white pine, *Pinus strobus* L., for timber production has met with discouragement. Because of the limitations imposed by the environment on the growth of this species and the damage caused by its natural enemies, it has been necessary to practice more intensive management, supplement natural regeneration with reforestation programs, and intensify and expand the research program to cover many aspects of white pine growth. The latter program has, of necessity, been concerned with various areas of research, including the effect of site quality on growth, the effect of environmental factors on seedling development and survival, and control of the more important natural enemies, *Cronartium ribicola* Fischer and *Pissodes strobi* Peck, Some aspects of these studies are still in progress and the following remarks will be confined to a brief review of recent and current investigations of the white pine weevil undertaken to provide information to the practicing forester engaged in the production of high quality timber.

In Ontario the insect became the subject of considerable attention from entomologists and foresters about 30 years ago. At that time there had accumulated a considerable volume of literature on its life history, habits, injury, and control, the latter including the recommendation that some system of silviculture could be profitable used to provide shade to the young pines during their most susceptible period, This general recommendation led to the initiation of discrete observational studies of weevil attack in white pine, annual records being maintained over a 12-year period of the attack in individual trees in open growing natural regeneration and white pine understories, The results showed that the individual factors, expo sure, height, leader length, leader diameter, etc., are not mutually independent and it was impossible to determine the influence of each factor, separately, on susceptibility of the tree to weevil attack, owing to the fact that the dependent variable, namely weevil attack in the individual tree, is a qualitative attribute, not a quantitative one, In general terms, however, the records of weevil attack did illustrate the dangers inherent in establishing white pine plantations on open sites, where injury is likely to be most severe in the best trees, They also illustrated the unsatisfactory results that may be obtained when white pine is intermixed with red pine, or underplanted under rapidly-growing aspen or other hardwoods; weevil attack maybe light, but survival of the white pine may be very unsatisfactory. Strip logging in 2-chain strips encouraged the growth of white pine regeneration, but exposed the young trees to increased weevil attack, On the other hand, thinning of

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crop trees in well developed second growth stands had little influence on the incidence of weevil attack in the crop trees.

These attempts to reach conclusions on the susceptibility to weevil attack, of various types of plantations and of natural regeneration under various types of overstorey, proved unsatisfactory. In the absence of critical data on weevil activity, behaviour, and abundance under different environmental conditions, it could not be determined whether the protection afforded the white pine occurred because of a direct relationship between the weevil and the physical environment, or indirectly through growth and vigour of the understorey trees. It was concluded that further progress in white pine weevil studies would depend on much more detailed knowledge of the physical and biological requirements of the weevil. This phase of investigation was initiated in 1951.

The work began with studies of weevil behaviour and development in the microenvironments of open-growing stands of white pine< Feeding, mating, oviposition and flight of individuals was correlated with microclimatic conditions in the field. Fitting 2nd-, 3rd-, and 4th-degree polynomials to the accumulated data showed that temperature, solar radiation, and atmospheric moisture influenced weevil activity and development but these variables sometimes had combined effects that had to be considered in order to predict changes in activity. Accordingly, activity isopleths were constructed to describe the probability of weevil attack in mixed (i.e., shaded) stands. Pertinent weather records were obtained in young white pine stands under different aspen-canopy densities throughout the critical season of weevil activity and the maximum level of activity was calculated from information gained in the open-growing stands.

The investigation showed that marked changes in the microclimates of shaded habitats occur as foliage of an aspen overstorey develops, because insolation is reduced in proportion to the amount of foliage growth in the canopy. Before the aspen leaves open, increasing solar elevation and radiant heating bring the temperatures of overtopped white pine leaders closer and closer to those of the fully exposed leaders of open-growing pines. When the leaves of the aspen overstorey begin to appear in early May, however, bark temperatures of the overtopped stems begin to lag behind those in the open. In June, when the overstorey canopy is fully developed, the overtopped white pine stems may be as much as 11°C below comparable stems in exposed stands. Only a low level of weevil activity can be expected in such shaded stands, and effective activity is likely to be eliminated entirely when the microenvironmental efforts combine with the effects of the growth characteristics of white pine stems on weevil behaviour. Weevils exhibit a preference for leaders of high vigour, but these rarely develop in the most shaded stands. Consequently, in many parts of a properly shaded stand, low levels of activity combined with weak responses to the type of pine stem available greatly reduce the number of eggs a female will lay. If too few eggs are deposited in a stem, there are not enough larvae to form the ring-like feeding aggregation that is so essential for the survival and development of young larvae in the resinous leader of a pine tree.

These studies have shown that weevil damage is negligible in young white pine understories if clear-day insolation is reduced 60 to 80 percent by a fully developed overstorey canopy of red oak, closely spaced aspen, or mixed hardwoods and softwoods. When the canopy consists of widely spaced aspen, insolation is reduced only 25 to 50 percent, and weevil damage may be appreciable. These results were tested by introducing weevils into some of the more extreme habitats so that we could observe behaviour and survival. Weevils liberated into heavily shaded areas left before they had done more than nominal damage. Leader vigour and microclimate varied in relation to the patchy distribution of shade, however, so that some of the more exposed pines in mixed stands provided the weevils with conditions closer to those in open-growing, fully exposed pine stands. If the weevils found such trees, they attacked. Nevertheless, the studies demonstrated that the shade factor could be used as a criterion for determining the degree of protection afforded understorey pine, even though earlier, uncritical attempts to exploit it failed. Establishing and maintaining the necessary amount of shade until the understorey pine can be released is mainly a silvicultural problem, The silviculturist can, however, approach the problem with more exact information concerning what conditions must be created and when they are required.

Two extensive silvicultural programs currently are testing these conclusions to determine what further refinements are necessary. One program is being conducted at the Petawawa Forest Experiment Station by A. B. Berry, W. M. Steill, and L. G. Brace, in which the main objectives are,(a) to modify the overstorey to allow white pine reproduction to make the best rate of growth commensurate with minimum damage by the weevil, and (b) to develop methods of determining volume and value losses associated with weevil damage as background for later assessment of the economics of weevil control measures in established stands. These studies have only recently begun with pilot studies designed as aids in establishing observational methods. The technique used by Berry and Steill includes clear cutting north-south oriented strips of prescribed width in relation to stand height to admit 25, 50, 75 or 100 percent full daily light at the centre of each strip. Height growth and crown expansion can be compensated for simply by enlarging the openings. Assessment of the results will be based on records of weevil attack and growth performance of white pine transplants, taken annually until the pines have reached a height of about 20 feet. By means of a detailed stem analysis of both weevilled and unweevilled white pine, L. G. Brace expects to develop regression equations relating a weevil-damage index to height and volume loss and lumber degrade due to rot, cross-grain, knots and reaction-wood associated with weevil crooks. Among other features, he will be able to eliminate broad generalizations about hidden weevil damage by defining different damage intensities and noting actual rates at which certain degrees of crooking are obscured by diameter growth.

The second silvicultural program is conducted by K. W. Horton and L. W. D, Boekhoven in Boulter Township, a few miles southeast of North Bay, Ontario. The work deals with treatments for reconciling release and weevil control in understorey white pine. A basic assumption is made that both growth rate and weevil damage can be controlled by canopy density manipulation, an insolation level of about 50 percent of full sunlight on clear days considered a fair compromise, The experiment is designed to test the effects of this and other light levels on a practical silvicultural scale. Secondary objectives involve testing the efficiency of insecticide spraying as an alternative weevil control measure, and a long-term study of pine tree development under various treatments. A randomized distribution of treatments will permit analysis of variance for comparing results after several years' records of growth response and weevilling incidence have been obtained.

The possibility of producing a strain of pine resistant to the white pine weevil is currently being investigated by Dr. Heimburger. At the present time he is evaluating the physical qualities of white pine leaders as they affect weevil attack and survival with special reference to heritable characteristics and host resistance. The selection and testing of five-needle piney was undertaken initially to breed strains resistant to blister rust since the screening of materials for resistance to the rust is much less time consuming than screening for resistance to weevil attack. This procedure has been adhered to for obvious reasons; materials suitable for reforestation programs should be resistant to blister rust and at least to moderately heavy weevil attack, the latter maintained by adequate silviculture to prevent the buildup of heavy weevil populations. White pine is amenable to breeding and certain species and hybrids have shown promise of resistance to the weevil, Direct selection of Pinus strobus and P. peuce for weevil resistance was made in areas of heavy weevil infestation, with emphasis on freedom from weevilling and growth rate and form. Selection of most other materials could not be made in this way since they were not growing in areas exposed to heavy weevil damage, Therefore, emphasis was placed on grafting scions on native pine in areas of high weevil damage and observations have been made to determine their growth performance and incidence of weevil damage.

The method for determining the suitability of leaders for attack was determined in earlier studies dealing with the biological interrelationships of the insect and its host. Studies showed that weevil oviposition and feeding is confined to leaders of high vigour, Selection is not related to leader length, nor to the incidence of needle clusters per unit area of the leader, Rather, in its initial attack, the insect exhibits a definite preference for leaders with upper diameters (measured one inch from the top) exceeding about five millimeters. In addition, selection appears to be influenced by bark thickness although the limits have not been well defined since a progressive increase in bark thickness is accompanied by increases in outer diameter measurements. Bark thickness is not currently taken into consideration in the field assessments, of weevil damage, but it is recognized as a factor which should receive attention in future studies of resistance in selected material, At the present time Dr. Heimburger is concerned with measuring the external physical attributes of white pine leaders and correlating these with injury in an attempt to rank their susceptibility,

Two separate experiments are in progress in Ontario to test the weevil resistant qualities of selected pine stock. In the first, 400 scions of Pinus strobus and P. peuce selected specifically for resistance or susceptibility to weevil attack were grafted on Scots pine and examined annually for five years. Preliminary analysis indicated that scions selected for susceptibility to weevil attack were, indeed, more susceptible than scions selected for resistance to attack. Greater differences in susceptibility occurred between clones of P. strobus than between clones of P, peuce and, in general, the latter species was much less susceptible to weevil attack than the former. Certain clones contained scions with leaders suitable for attack. Within the former group, the lack of weevil attack may be attributed to the physical qualities of the leaders. Within the latter group, however, failure to attack certain clones while others were heavily attacked, indicated that some factor or factors unrelated to leader vigour influences the selection,

In the second experiment, approximately 2400 scions, collected in Canada, United States, and Europe, were top-grafted to white pine in an attempt to compare growth performance and incidence of weevilling in species and hybrids hitherto growing in areas outside the range of the weevil, with material normally occurring within the range of the insect. Materials grafted included Po griffithii, P. koraiensis, P, monticola, P. peuce, P. strobus, and hybrids of P. strobus X P parviflora, P. strobus X P. peuce, and P. strobus X P. griffithii. Selection of particular scions for further study will be made on the basis of growth performance and incidence of weevilling.

It should be pointed out that these are preliminary experiments designed to permit an appraisal of weevil resistance and selection of material worthy of further consideration in the breeding program. Ultimately, the value of the weevil, resistant material must be judged under the natural conditions in which they will be grown to determine if specific traits correlated with resistance and good growth performance are heritable We can hardly expect to develop a strain completely resistant to the weevil- A more realistic approach would be to try for good growth performance and moderate weevil resistance in material suitable for reforestation programs and for adequate regeneration of white pine of satisfactory growth by proper manipulation of the environment.