RACIAL VARIATION OF THE LEADER CHARACTERISTICS OF PINUS STROBUS L. CORRELATED WITH FEEDING BY THE WHITE PINE WEEVIL[1]

Robert C. Stroh[2]

INTRODUCTION

If one or more characteristics of the leaders of eastern white pine could be established as consistently correlated with damage by the white pine weevil, Pissodes strobi Peck, tree improvement work could advance to the stage of further developing these traits via selection and breeding. The advantages of using a correlated character approach in breeding for insect resistance have been rather fully described in a paper to be presented at the World Consultation on Forest Genetics and Forest Tree Improvement by Gerhold and Stroh (1963).

Several researchers have reported the association of various characteristics of eastern white pine with damage by the white pine weevil. One of the first characters reported was leader diameter (Hoist, 1955; Kriebel, 1954; MacAloney, 1930; Plummer and Pillsbury, 1929; Prebble, 1951). The general finding was that the amount of weevil damage was less on trees of smaller leader diameter. Closely associated with diameter is bark thickness. It was observed by Kriebel (1954) and by Sullivan (1961) that less weevil damage was associated with leaders with thinner bark. Sullivan (1961) also noted evidence that there may be an upper limit of bark thickness as well as a lower limit. The density of needles per unit area of the leader was found to be not significantly correlated with weevil damage by Sullivan (1961). The work being done in California on resistance to the pine reproduction weevil, Cylindocopturus eatonii Buch., has

[1] Partial support of Northeast Regional Research Project NE 27, U. S. D. A. is acknowledged,

[2] Graduate Assistant, School of Forestry, Pennsylvania State University, University Park, Pennsylvania,

produced some interesting results concerning resin and resin ducts as a possible resistance mechanism (Miller, 1950), Apparently the only similar relationship regarding the white pine weevil was reported by Fowler (1958) in the statement that in some instances Pinus peuce Griseb demonstrated resistance to the weevil possibly due to the heavy resin flow of the species.

With the aid of the knowledge gained in previous studies and with the desirability of a correlated character in mind, an investigation was begun in 1962 to assess the relationship of twelve physical leader characteristics of eastern white pine and the number of feeding cavities made by the white pine weevil.

MEASUREMENT OF WEEVIL DAMAGE

The number of feeding cavities present on the leader was used as the measure of weevil damage since this represented the first of a sequence of events which culminates in the well known weevil injury, The number of feeding cavities may also be shown to be related to the length of larvae feeding (figure 1) and the number of eggs deposited. Sullivan (1961) has shown that the length of larval feeding is also related to the number of adults emerging to form the fall weevil population and, subsequently, the spring population, It was thus felt that characteristics correlated with the number of feeding cavities would prove the most fruitful and convenient for this study.

CORRELATED CHARACTERS

The twelve leader characteristics considered in this study included:

1. Leader diameter
2. Number of needle fascicles on upper 3" of leader
3. Number of inside cortical resin ducts
4. Number of outside cortical resin ducts
5. Bark thickness
6. Tangential diameter of inside cortical resin ducts
7. Tangential diameter of outside cortical resin ducts
8. Radial depth of inside cortical resin ducts
9. Radial depth of outside cortical resin ducts
10. Sum of inside duct diameters
11. Sum of outside duct diameters
12. Ratio of sum of all duct diameters to leader circumference.

Thirty dominant and codominant trees were sampled in late May and early June of 1962 in each of four different 12-year-old eastern white pine plantations. Two of the areas were in Huntingdon County and two were in Clearfield County in central Pennsylvania. Because of the differences which existed between the four areas in terms of slope., soil, exposure., etc., and because the leader characteristics differed significantly between locations, the correlation analyses were conducted separately for each plantation. The results of these calculations indicated that only bark thickness and the two duct depths were at all consistently correlated with the number of feeding cavities.

FIGURE 1

Relationship of Length of Larval Feeding to Number of Feeding Cavities

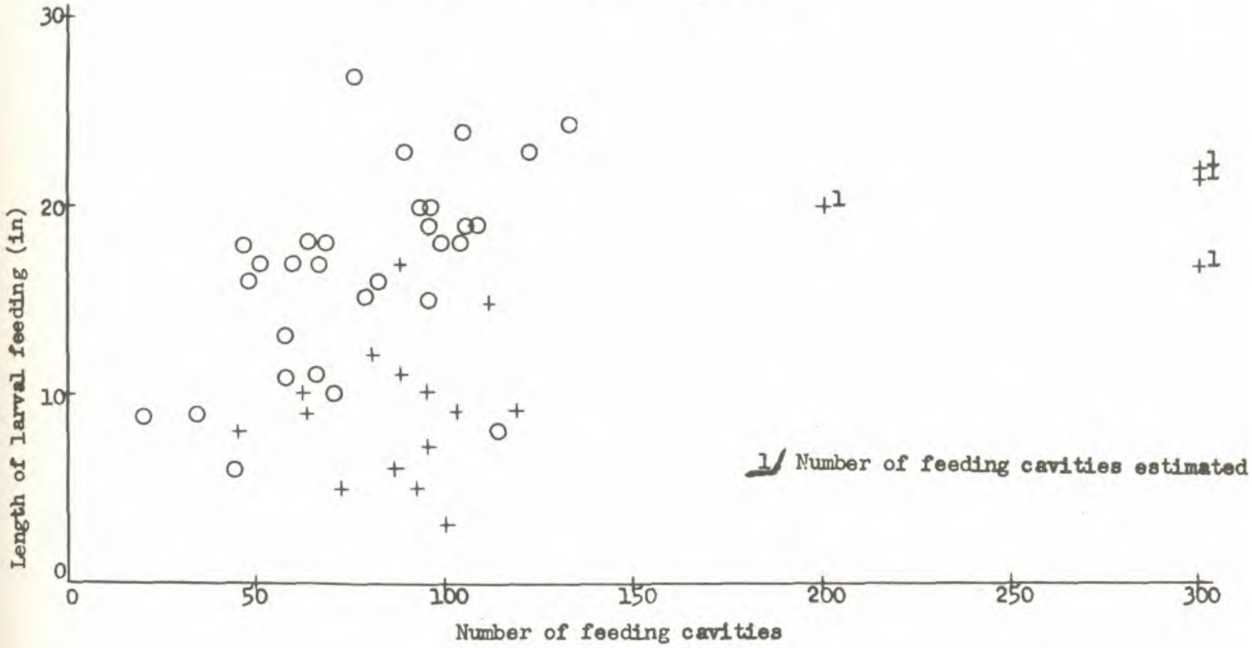


Table 1.--Means, standard deviations, and correlation coefficients for bark thickness and duct depths, 1962 and 1963.

Area	Bark thickness (cm)			Depth inside ducts (mm)			Depth outside ducts (mm)		
	$\bar{x}$	s	r	$\bar{x}$	s	r	$\bar{x}$	s	r
					1962[1]				
1	0.15	0.020	0.578**	0.52	0.15	0.425*	0.16	0.06	0.546**
2	0.16	0.027	0.444*	0.48	0.10	0.588**	0.14	0.04	0.521**
3	0.17	0.026	0.448*	0.57	0.17	0.243	0.18	0.05	0.246
4	0.18	0.032	0.361	0.54	0.12	0.389*	0.17	0.04	0.439*
					1963[2]				
2A	0.15	0.026	0.363*	0.65	0.18	0.165	0.23	0.06	0.312*
3A	0.10	0.017	0.397*	0.47	0.09	0.406**	0.16	0.04	0.448**

1/ Based on sample of 30 trees in each area
2/ Based on sample of 40 trees in each area
** Significant at 99% level of confidence
* Significant at 95% level of confidence

A similar analysis was conducted in 1963 using different portions of the two Clearfield County plantations, The number of needle fascicles was not included in the 1963 analysis since the lack of significant correlation in 1962 agreed with the findings by Sullivan (1961). The last three characteristics of the previously cited list were also deleted in 1963 since they were essentially measured by other traits being sampled. Internal characteristics were sampled by removing a small bark patch from the leaders in mid April prior to the initiation of growth. The correlation analyses produced significant correlations for leader diameter as well as bark thickness and the two duct depths in area 3A. A similar set of results was obtained for area 2A with the exception of the depth of the inside ducts which was found not significantly correlated with feeding cavities. The diameter of both inside and outside ducts was also significantly correlated with feeding in area 2A.

The lack of association of leader diameter with feeding in 1962 was rather disconcerting and is as yet not fully explained. One possible source of difficulty may have originated from the difference in time of sampling with respect to initiation of growth from 1962 to 1963. The work by Sullivan (1961) which demonstrated the association of leader diameter and weevil feeding was based on diameter measurements made prior to the growing season.

Recognizing that an unexplained source of variation is operative in the data, the means, standard deviations, and correlation coefficients for bark thickness and duct depths are presented in table 1. These three characteristics appear to represent the most promising traits thus far studied.

Data gathered to provide a biological interpretation of the statistical relationships thus far established will not be presented in this paper. It is possible, however, to suggest the response of a weevil to feeding on a white pine leader with thin bark and associated shallow cortical resin ducts. Hypothesis: If the weevil encounters an outer resin duct immediately after penetrating the periderm, it retreats and seeks a new feeding site. After a number of unsuccessful attempts at feeding due either to immediate contact of outer resin ducts or to encountering sufficient difficulty in feeding around the inside resin ducts, as is the case when the inside ducts are very shallow, or both, the weevil leaves the leader and seeks a new host tree to satisfy its instinctive efforts to feed and oviposit.

RACIAL VARIABILITY

The data for the analysis of racial variability of the leader characteristics of eastern white pine was gathered in a provenance planting established by the Northeastern Forest Experiment Station near Kennett Square, Pennsylvania. Nine provenances were sampled including:

Provenance	Latitude
Georgia	34°46'N
Maryland	39°24'N
Pennsylvania - Clearfield Co.	40°46'N
Pennsylvania - Monroe Co.	41°05'N
New York	42°00'N
Massachusetts	42°30'N
Maine	44°51'N
Quebec	46°29'N
Minnesota	47°25'N

An analysis of variance for a randomized block design was employed to detect any significant differences between provenances for the various characteristics. A significant F-ratio was calculated for the number of inside and outside resin ducts ($\alpha = 0.01$), the depth of the inside resin ducts ($\alpha = 0.05$), and diameter and length of leader ($\alpha = 0.01$). The F-ratios calculated for both bark thickness and depth of outside resin ducts were both slightly below significance at the 95% level of confidence.

Shown in figures 2, 3, and 4 are the means of the duct depths, the numbers of ducts and the bark thickness by latitude of provenance, respectively. The average bark thickness and average outside duct depths are plotted solely to indicate the variation present among the provenances with no implication of significant racial variability.

The average leader diameter and average leader length of the Kennett Square planting were compared with other plantings of the same nine provenances to determine if the growth performances were similar. Shown in figure 5 are the average leader diameters as calculated from the Kennett Square data (bottom) and from the Stone Valley data (top). The Stone Valley planting was part of the same range-wide provenance study of Pinus strobus as that at Kennett Square. Leader diameter at Kennett Square was somewhat more variable than at Stone Valley but displayed, in general, a similar trend of decreasing with increasing north latitude. The average total heights of the provenances from an independent white pine provenance study in the southern Appalachians as reported by Sluder (1963) as well as the average total heights at Stone Valley and the average leader lengths at Kennett Square are plotted in figure 6. The Stone Valley data (middle) displayed less variation than either the data from Sluder (top) or the data from Kennett Square (bottom) but all three showed the same trend of decreasing height, or leader length, with increasing north latitude.

These comparisons of the three provenance plantings indicate that the Kennett Square planting is displaying racial variation of growth characteristics similar to the other two areas. Since the resin duct depths and bark thickness are significantly correlated with leader diameter and slightly less than significantly correlated with leader length, it is likely that the internal leader characteristics of the Stone Valley planting and those described by Sluder (1963) could be shown to display racial variability similar to the Kennett Square planting.

CONCLUSIONS

The conclusions which may be drawn from the preceding analyses are:

1. Bark thickness, depth of inside cortical resin ducts, and depth of outside cortical resin ducts are the physical leader characteristics which appear most consistently correlated with extent of adult weevil feeding.

2. The inconsistencies present in the association of the physical leader characteristics with extent of weevil feeding indicate that replication by location as well as by year is of importance.

FIGURE 2

Average Duct Depth by Latitude of Provenance

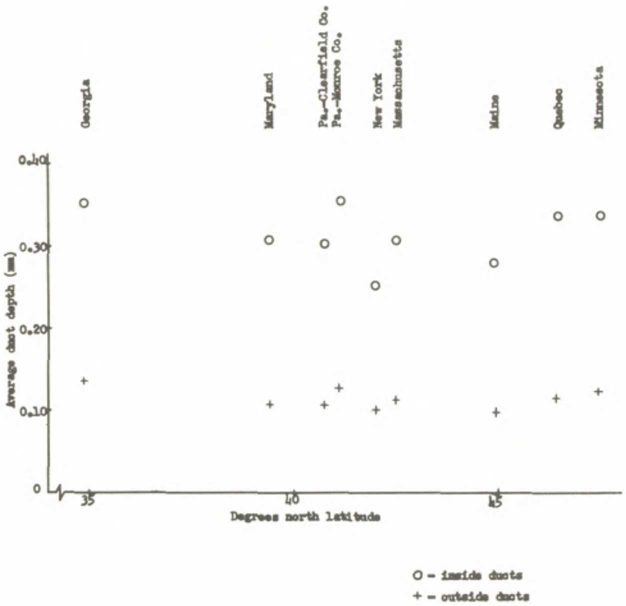


FIGURE 3

Average Number of Ducts by Latitude of Provenance

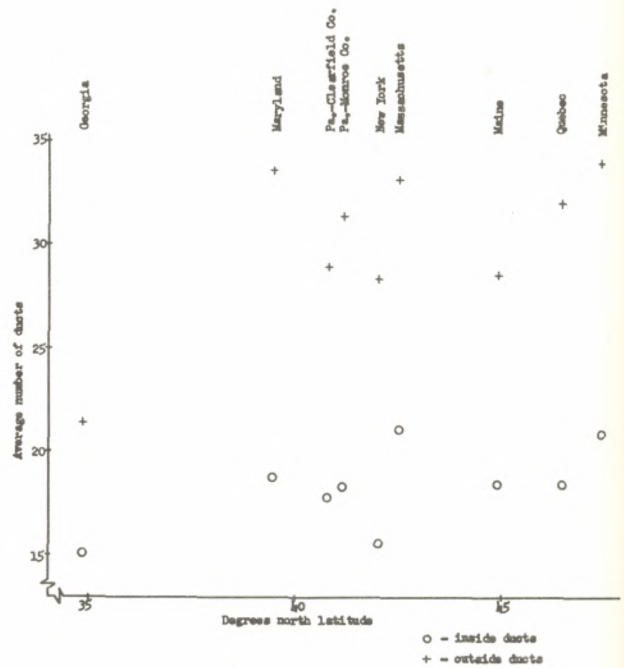


FIGURE 4

Average Bark Thickness by Latitude of Provenance

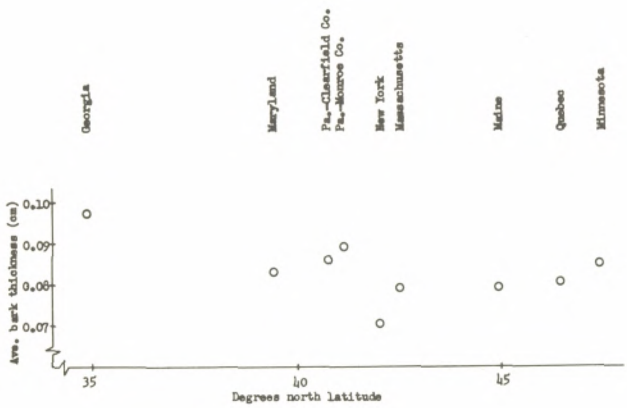


FIGURE 5

Leader Diameter Variation by Latitude of Provenance

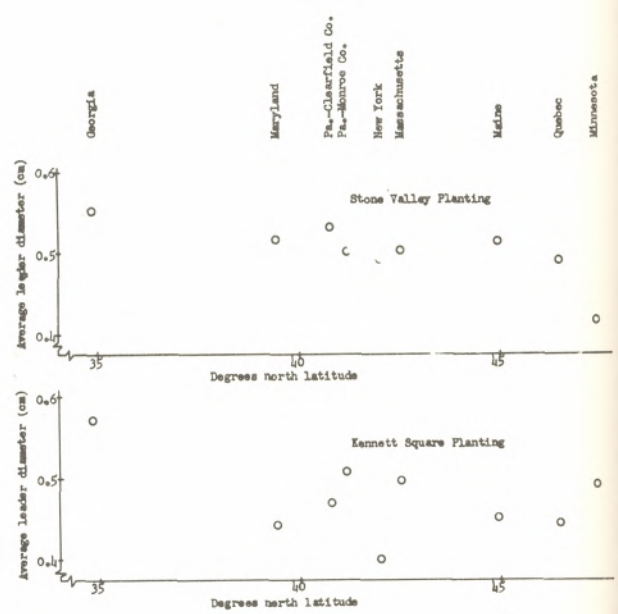
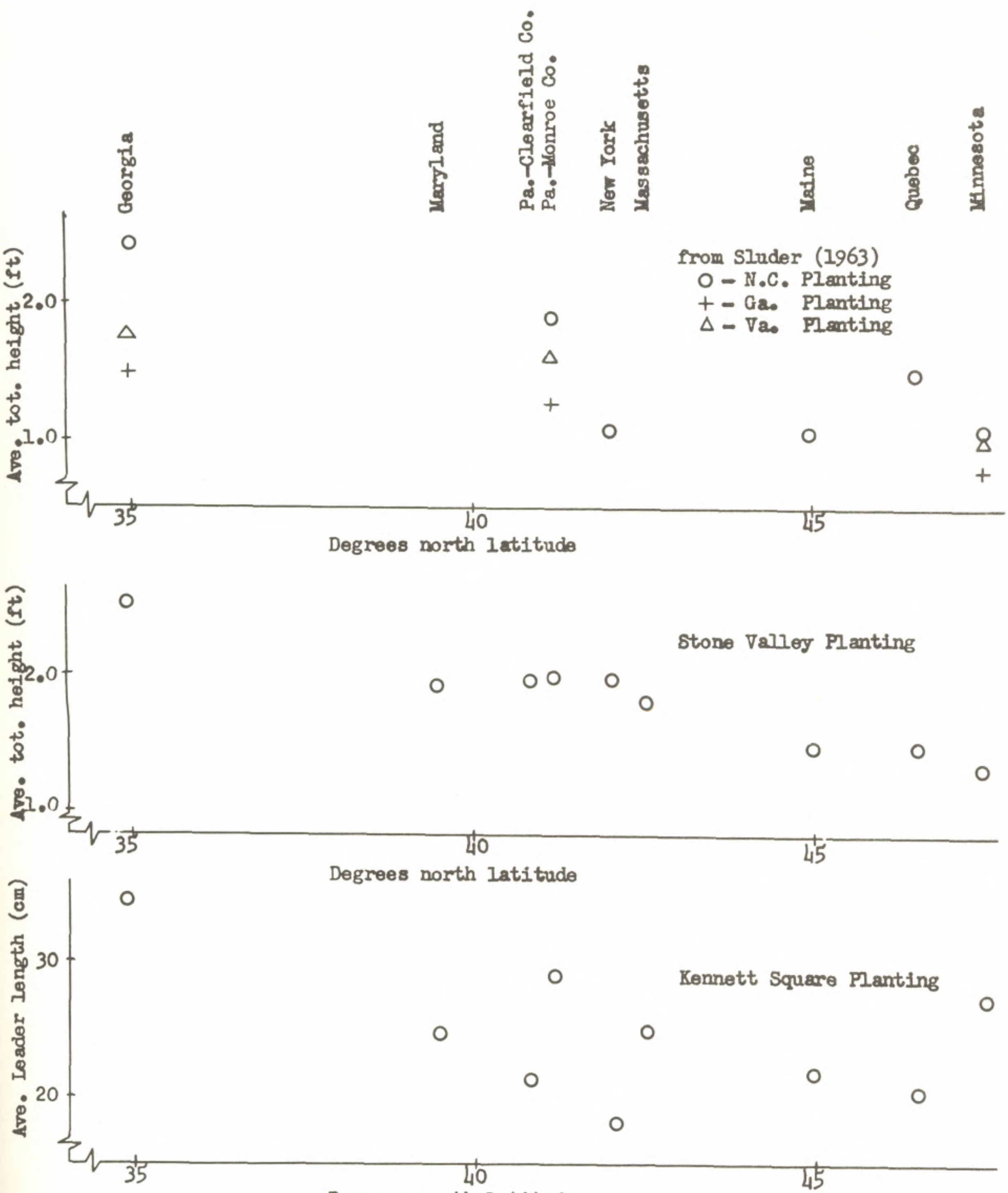


FIGURE 6

Height Variation by
Latitude of Provenance



3. The time of sampling with respect to the initiation of growth may influence the correlation of the leader characteristics with number of feeding cavities, This would result from changes in leader diameter, leader length, bark thickness, and resin duct depths as the growing season progresses.

4. A significant amount of racial variation exists in bark thickness and depth of inside cortical resin ducts although association with latitude of seed source is lacking. The number of inside and outside cortical resin ducts as well as leader diameter and length also display significant racial variability.

5. A side effect of selection of eastern white pine for weevil resistance based on the present knowledge of correlated characters might be indirect selection for slower growing trees with smaller and less vigorous leaders.

Tree improvement work directed toward weevil resistant eastern white pine is still at the stage of seeking a characteristic consistently correlated with weevil resistance. Evaluation of chemical as well as physical characteristics of eastern white pine must be considered. Inter-species hybridization, possibly with Pinus monticola Dougl., is another possibility which should not be neglected. In general, continued individual and cooperative efforts are essential to the successful accomplishment of the task.

REFERENCES CITED

1. Fowler, D. P. 1958. In discussion of Heimburger, C. 1958, Forest tree breeding work in Canada. Fifth NEFTIC Proc. 1957: 26.
2. Gerhold, H. D. and R. C. Stroh. 1963. Integrated selection for white pine weevil resistance and its components. Paper to be presented at World Consultation on Forest Genetics and Forest Tree Improvement. Stockholm, Sweden.
3. Hoist, M. J. 1955. Breeding for weevil resistance in Norway spruce. Z, f. Forstgenetic u. Forstpflanzenzuchtung. 4: 33-37.
4. Kriebel, H. B. 1954. Bark thickness as a factor in resistance to white pine weevil injury. Jour. Forestry 52: 842-845.
5. Miller, J. M. 1950. Resistance of pine hybrids to the pine reproduction weevil. Calif. For. and Range Expt. Sta. Res. Note 68: 17 pp.
6. Plummer, C. C. and A, E. Pillsbury, 1929. The white pine weevil in New Hampshire, U.N.H. Expt. Sta. Bull. No. 247: 27 pp.
7. Prebble, M. L. 1951. Summary of investigations of attack by the white pine weevil in plots at the Petawawa Forest Experiment Station 1936-1948. For. Insect Lab., Sault Ste. Marie, Ontario.
8. Sluder, E. R. 1963. A white pine provenance study in the southern Appalachians. Southeastern For. Expt. Sta. Res. Paper SE-2: 16 pp.
9. Sullivan., C. R. 1961. The effect of weather and the physical attributes of white pine leaders on the behavior and survival of the white pine weevil, Pissodes strobi Peck, in mixed stands. Canad. Ent. 93: 721-741.