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INFESTATION TRENDS OF BALSAM WOOLLY APHID IN AN *ABIES ALBA* PLANTATION IN NORTH CAROLINA

Abstract. --Infestations of the balsam woolly aphid, Adelges piceae (Ratz.), on European silver fir trees in a plantation were observed over a 7-year period. Infestations were usually light, but occasionally increased to heavy. Heavy infestations declined within 1 or 2 years without killing the trees or causing them apparent damage.

INTRODUCTION

Few reports are available to describe infestation trends of balsam woolly aphid (Adelges piceae (Ratz.); Homoptera: Phylloxeridae) on European silver fir, Abies alba (L.) Miller, outside continental Europe. The work of Varty (1956) describing infestations in A. alba plantations in Scotland and the brief mention by Mitchell (1966) of lack of damage to silver fir planted in the northwestern United States are the only references known to the authors. The objectives of this paper are to present observations of the aphid on A. alba in a plantation established in 1924 near Mt. Mitchell, North Carolina, and to demonstrate resistance to the aphid of trees outside Europe.

The balsam woolly aphid originated in Europe and was accidentally introduced into North America about 1900, probably on nursery stock (Balch 1952). It was discovered in North Carolina in 1957 (Speers 1958). The rapid mortality of Fraser fir (A. fraseri (Pursh) Poir.) from 11,000 trees in 1958 to about 1.75 million at the present time suggests the aphid had not been in the area long before its discovery.

Damage and mortality occur to North American firs through the indirect effect of a growth stimulating substance in the saliva of the aphid (Balch 1952; Balch, Clark, and Bonga 1964). The substance stimulates cells in the bark to enlarge and develop thick walls and the cambium produces an enlarged xylem ring with cells having thick, hard, brittle, reddish walls. Balch (1952) and Mitchell (1967) suggest that water stress, the consequence of reduced lumen area in the cells in aphid-affected wood, may cause death of the tree.

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Although the bark of silver fir is affected by aphid feeding, aphids die after formation of a secondary periderm and death of the outer layers of bark (Kloft 1957). Thus, the aphids are unable to insert their mouthparts into living tissue. However, Varty (1956) stated that Adelges piceae killed some Abies alba when the trees were apparently at a susceptible age of 25 to 50 years. He noted that the xylem was unaffected by aphid feeding.

METHODS

Twenty-one A. alba trees, of a total of 66, averaging 6 inches d. b. h. and 22 feet in height were tagged for study in a plantation at 5,700 feet elevation. The d. b. h. and the aphid infestation of each tree were determined during late July or early August of each year from 1960 through 1966, and the length of new twig growth was recorded from 1963 through 1966. Aphid populations were classified as light (three or fewer aphid wax masses per square inch of bark surface), medium (four wax masses per square inch to 25 percent of the bark surface covered with wax masses), and heavy (greater than 25 percent of the bark surface covered with wax masses). Average aphid infestations on the upper, middle, and lower boles were estimated visually from the ground. Examinations were made for aphid-caused redwood by cutting away small pieces of bark and observing the exposed sapwood.

During the summer of 1967, all 66 trees within the plantation were marked and examined for survival, growth form, and stem infestation by the balsam woolly aphid. At that time, the plantation was composed of trees ranging from suppressed saplings less than 1 inch d.b. h. to dominants exceeding 11 inches d. b. h. Nineteen of these trees exhibited conspicuous deformities, consisting of multiple stems usually diverging below d. b. h. Throughout the stand seven trees were dead and three were partially dead or dying. The dead trees were later felled and wooden disks were cut at 5-foot intervals along their length. The disks then were examined in the laboratory for evidence of redwood.

In conjunction with categorizing the dead or dying trees, efforts were made to determine the extent of aphid infestation on each tree to a height of 6 feet on the trunk. Estimates of density were made by counting the wax masses on two, l-inch-square areas .of bark per tree and relating these findings to the overall distribution pattern on the lower bole. Trees were then classed as having: (1) no evidence of balsam woolly aphid attack, (2) less than one wax mass per square inch anywhere on the bark surface, and (3) more than one wax mass per square inch on the bark surface.

Finally, an adjoining Fraser fir plantation established at approximately the same time as the silver fir stand was examined for surviving trees. Increment borings were taken from all living trees and investigated for redwood.

RESULTS AND DISCUSSION

A light infestation of the aphid was found on most of the 21 tagged trees each year. These infestations occasionally reached moderate-to-heavy intensity (table 1). A large increase in moderate and heavy infestations, which was believed to be the result of pruning the lower branches of trees in the stand, occurred in 1964 and 1965. Pruning increased the amount of light penetrating the stand and possibly made other factors more favorable to the aphid. Heavy infestations of the aphid lasted only 1 or 2 years and then declined to light infestations. One tree died in 1965 but is believed not to have been killed by the aphid. During the 5 years of observation, this tree grew only a total of 0.1 inch d. b. h., and shoot growth was 1 inch in 1963, 2.5 inches in 1964, and 2 inches in 1965. Therefore, tree competition probably contributed largely to its death. Surviving trees increased an average of 0.9 inch d. b. h. and shoot growth averaged 4 inches in 1963, 3.8 in 1964, 4.5 in 1965, and 4.1 inches in 1966.

Table 1. --Trends in infestation of balsam woolly aphid on 21 European silver fir trees near Mt. Mitchell, N. C.

Infestation classification	Year						
	1960	1961	1962	1963	1964	1965	1966
	Percent						
Uninfested	38	5	33	5	0	9	29
Light	62	90	62	81	24	53	57
Medium	0	5	5	14	52	24	9
Heavy	0	0	0	0	24	9	0
Dead	0	0	0	0	0	5[1]	5[1]

[1]Not killed by the aphid.

The seven dead trees discovered in the plantation in 1967 consisted of one deformed and six normal trees (table 2). The latter varied in height from 9 to 18.6 feet and from 0.9 to 6.2 inches d. b. h. It is likely that the 0.9-inch sapling was a victim of competition from surrounding taller trees, while a broken top may have contributed to death of the 6.2-inch tree. However, signs of aphid-discolored sapwood were not evident in any of the disks obtained from the seven trees. Similarly, wax masses were not found on the trunks of any of the trees prior to cutting.

In addition to the dead firs, one double-stemmed and two normal-stemmed trees were either dying or had already suffered partial mortality. In the double-stemmed, deformed tree, only one fork remained viable. Of the two normal-stemmed trees, one had a dead top and the other appeared to be gradually dying in the upper 2/3 of its crown, All three trees had stem infestations in 1967, but these consistently averaged

Table 2. --Survival of Abies alba trees and extent of balsam woolly aphid infestations in a plantation on Mt. Mitchell, N. C., 1967

Classification	Type of stem			Total
	Normal	Deformed		
		Twins	Triples	
	--Number--			
Tree category				
Healthy	39	15	2	56
Dead	6	1	0	7
Dying or partly dead	2	1	0	3
Total	47	17	2	66
Aphid infestation[1]				
None	7	1	1	9
<1/sq. in.	17	9	1	27
>1/sq. in.	17	6	0	23

[1]Dead trees had no remnants of aphid wax and are therefore excluded.

well below one wax mass per square inch anywhere on the bark surface. A consistent relationship between tree form and tree mortality was not demonstrated.

Wax masses were not found on nine of the remaining 56 living silver firs in the stand. Twenty-seven trees had maximum wax mass concentrations averaging less that 1 per square inch, whereas 23 exceeded this level (table 2). However, in only eight of these 23 trees were wax masses uniformly distributed throughout the first 6 feet of the trunk. Of the five normal trees in this group, the average d. b. h. was 8.6 inches, which compares to 6 inches average d. b. h. for all normal, healthy trees in the plantation. This might indicate that the larger trees support the largest aphid populations.

In an adjoining Fraser fir stand consisting of 70 trees, only 6 were still alive in 196'7. Increment borings all revealed evidence of redwood growth, and the virtual lack of new twig growth on four of the trees suggest that, at best, these trees are only marginal survivors.

Differences in susceptibility of A. alba and A. fraseri in adjacent stands can be considered primarily tree-related because of similarities in site, climate, and predator populations. In Europe, population fluctuations on A. alba have been attributed to the joint action of predators and the host tree (Karafiat and Franz 1956), but primarily to the tree (Pschorn-Walcher and Zwölfer 1960).

The results of this study do not eliminate the balsam woolly aphid as a factor in the observed mortality of the European silver firs planted on Mt. Mitchell, even though redwood was not detected and other causes could be more reliably implicated in specific cases. Simply stated, no evidence was uncovered that visibly links the balsam woolly aphid to the death of any of these trees. The study does, however, demonstrate the striking resistance of A. alba to prolonged aphid infestation.

Minckler (1940) indicated that the experimental plantings on Mt. Mitchell were established originally in plots of 100 trees each. He concluded that, of the 20 native and foreign conifer species tested, Fraser fir was the best for survival and growth while European silver fir was included among the species classed as failures. The subsequent effects of the balsam woolly aphid provide a vivid example of the impact a major forest pest can have on the long term success of such plantings, and how previously drawn conclusions can be invalidated.

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