THE DISTRIBUTION OF DOUGLAS-FIR FOLIAGE BY AGE[1]

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ABSTRACT

The percentage of Douglas-fir, Pseudotsuga menziesii (Mirb.) Franco, foliage by age was calculated for four trees for four consecutive years. The percentage of foliage for the five youngest years was 28, 23, 17, 13, and 10 per cent, respectively. Distribution of foliage by age was fairly uniform within individual branches. Although there was considerable variation between crown levels, trees, and years, the averages were reasonably uniform.

INTRODUCTION

The spruce budworm, *Choristoneura fumiferana (Clem.)*, infestation in the Lillooet River Valley which started in 1954, introduced several considerations which, although not strictly entomological in nature, are inseparable from insect problems. In order to estimate how much defoliation a Douglas-fir tree can tolerate before death is imminent it is necessary that defoliation estimates be made as accurately and as uniformly as possible. Uniformity is also required so that the records can be used for comparison with future and past spruce budworm outbreaks. It is also desirable to have some means of measuring tree recovery. Defoliation is now estimated as (a) per cent loss of the current year's foliage, and (b) total defoliation of the tree crown. It has been demonstrated that ocular estimates based on these criteria are acceptable for estimating per cent defoliation (Silver, 1959).

A rule of thumb used in British Columbia was based on the belief that Douglas fir normally retained its needles for five years. It was further assumed that the total amount of foliage was divided evenly between each year. Thus the current year's foliage would represent 20 per cent of the total amount of foliage, and each year before that an equal proportion. Examination of Douglas-fir foliage cast some doubts on the reliability of this assumption as twigs much older than five years bore a considerable number of needles, but it was not known what proportion of the foliage was over five years old. This study was therefore started to obtain more accurate information on the distribution of foliage by age.

Preliminary investigation was started during the winter of 1955 when two trees were analysed. Two additional trees were sampled in 1957. The difference in the percentage of foliage between the two years was great enough to warrant further work which was started in 1959. The results of the work prior to 1959 are not given in this paper, although the earlier information obtained was used to refine the sampling method.

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Methods

Four dominant or co-dominant Douglas-fir trees were selected in a stand near Becher Bay about 15 miles southwest of Victoria. The site is well drained with a southern exposure, and is featured by rock outcroppings on low sharp slopes. The stand is predominantly Douglas-fir with about 150 stems per acre. The trees are about 80 years old and 70 feet in height with an average d.b.h. of 14 inches. The average length of crown was about 30 feet. The four trees sampled were considered representative of the stand, most of which has now been logged.

The trees were sampled for four consecutive years starting in the winter of 1959. The crowns were divided into three sections of equal vertical length designated A, B, and C from top to bottom. Two branches were selected from the mid-point of each crown level each year. At first the entire branch was sampled, but the branches were divided into lateral halves. When the results were compared they agreed so closely that it was decided to sample only half-branches. Because of the variance between the two branches from the same crown level it was concluded that a better estimate of needle distribution could be obtained by sampling two half-branches from each crown level and averaging the data. In 1958 it was found that almost identical results were obtained by using every other side lateral to compute percentage of foliage by years. As the percentages, with few exceptions, varied by less than one per cent the reduced sample size was used in sampling from 1959 to 1961.

Starting at the tip of each branch each side lateral was cut into pieces according to age. The length of needle-bearing twig was then measured to the nearest 1/10 inch, and the number of twigs of the same age recorded. Needle counts were made on five side laterals of each branch. The main stem of each side lateral only was used; this was cut into pieces by age, the length measured, and the total number of needles counted.

The length of needle-bearing twigs was totalled by age for each branch. This was multiplied by the average number of needles per inch for the appropriate year. The total number of needles was used as a basis for calculating foliage complement.

Results

The percentage of Douglas-fir foliage by age for the four trees for the years 1958 to 1961 inclusive is shown in Figure 1. Although foliage up to 10 years old was present, over 90 per cent of the total foliage complement was contained in the youngest five years. The average percentage of foliage for the youngest five years was calculated at 28, 23, 17, 13, and 10 per cent, respectively. The standard deviations from the means, as shown in Figure 1, indicate considerable variation which decreases progressively with the decrease in percentages. It is of interest to note that on the trees sampled half the total foliage was carried on the current and one-year-old twigs.

The values given in Figure 1 are an average for all crown levels for all trees. Accordingly, variations between individual trees, between crown levels, and between years are not shown.

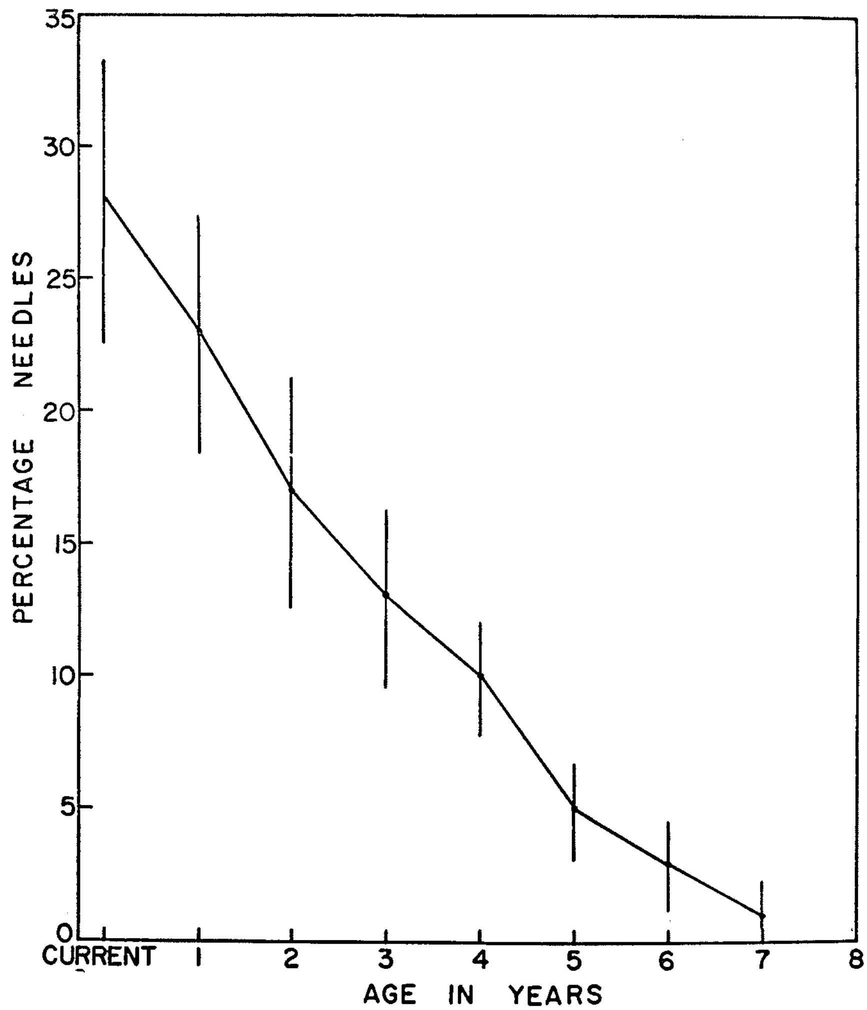

Figure 1. Percentage of Douglas-fir needles by age. Values are an average for four trees for years 1958 to 1961. Vertical bars are standard deviations.

The average and range in percentages of needles by crown levels for four trees was calculated for one year, 1960. These data for the first three years are shown below:

Age of foliage (year)	A		B		C		All crown levels
	Av.	Range	Av.	Range	Av.	Range	
1960	36	30-41	23	20-33	26	22-37	27
1959	27	19-34	22	14-31	24	14-29	23
1958	18	17-20	19	16-21	17	14-21	18

The greatest difference between crown levels was in the current year's foliage where the percentage ranged from a low of 23 to a high of 36 with an average of 27 per cent. Although the range of percentages from the average within each crown level was considerable, the average for all crown levels was similar to the overall average obtained for all trees for all years.

The proportion of new growth was greatest in the top third of the crown. About 63 per cent of the total number of needles in level A were current and one year old, with nearly all the remaining needles contained in the next three years. Thus the foliage in the upper crown levels of Douglas-fir trees is younger than the average for the entire crown. The distribution of needles in crown levels B and C was similar, and closer to the average for the entire crown.

The relative proportion of needles by crown levels was calculated for one tree for four years. The distribution of needles compared favourably with the results obtained from four trees for one year. The percentage of new foliage was always greater in the upper third of the crown; crown level B was, in the younger years, greater or the same as C. The average for the four trees was similar to the overall average shown in Figure 1, differing in all age groups by at most only one per cent.

The results of this cross analysis indicate that although there was considerable variation from the means for different trees within the same year, and between the same trees for different years, the variations were compensating and the final proportions were similar. In this particular study acceptable values for the proportionate age of needles could have been obtained by sampling one tree for four years, or by sampling four trees for one year.

One of the dangers of basing a study of this type on one year's data is the possible effect of a relationship between rainfall, principally in April, May, and June, and the proportion of current year's growth. Weather records from the official weather station at Becher Bay were compared with the percentage of current year's growth from 1958 to 1961. The differences in rainfall were not great for the months of April to June. There was also no difference in the proportion of current year's foliage for the first three years of the study; the percentage of current year's growth was greatest in 1961, the year with the least rain. There is, therefore, no indication that weather conditions had any appreciable effect on foliage production during the four years of this study. A heavy flower crop in 1959 had no apparent effect on foliage growth.

The average number of needles per inch of needle-bearing twig gives an indication of needle drop (Table 1). The data shown are for trees 1 to 4 for the 1960 season. With few exceptions there were a larger number of needles per inch in the upper crown level. There was also a tendency for the number of needles to decrease after the second year, but there were also exceptions in this respect such as Tree 3-B where the number of needles per inch remained at a higher level for six years. Needle drop, after five years, was generally heavy, and few needles were retained more than eight years.

TABLE 1

AVERAGE NUMBER OF NEEDLES PER INCH OF TWIG BY CROWN LEVEL AND AGE. FOUR TREES ANALYZED JANUARY, 1961

Tree no.	Crown level	1960	1959	1958	1957	1956	1955	1954	1953	1952	1951	1950
1	A	57	64	46	42	39	12	1	—	—	—	—
	B	55	53	62	47	37	44	16	14	6	2	—
	C	53	50	53	40	21	17	6	2	4	—	—
2	A	58	47	35	40	17	22	11	—	—	—	—
	B	33	15	23	39	18	15	10	5	—	—	—
	C	52	28	19	29	13	8	11	4	—	1	—
3	A	55	48	42	42	29	13	—	—	—	—	—
	B	40	42	45	43	45	40	21	19	9	6	—
	C	37	36	43	39	39	33	25	20	14	6	5
4	A	57	59	50	44	29	12	2	4	—	—	—
	B	60	56	54	45	38	25	12	1	—	—	—
	C	55	52	32	29	40	26	13	6	1	—	—

Early in the study the uniformity within individual branches was found to be so consistent that it was possible to reduce the sample size considerably. In the final analysis this was carried one step further by calculating the percentage of foliage by years using only the five side-laterals on which needle counts were made. This was done for a total of eight trees in different years. The differences in percentage varied by less than one per cent with but few exceptions, the greatest difference being 1.8 per cent. Therefore, a reliable estimate of the proportion of foliage by age can be obtained by sampling only five side laterals per branch. This reduces the time required to sample by more than half.

DISCUSSION

The results of this work should prove of considerable value in appraising defoliator outbreaks in Douglas-fir stands. Although there was some variation between the trees studied it is believed that the averages are representative of the proportion of foliage by relative age. As defoliation estimates are invariably based on averages of plots containing from 10 to 100 trees, there would be a strong tendency for the average to compensate for individual tree differences. In most instances it would be impossible to analyse the foliage on trees when an infestation is in progress as loss of foliage by defoliation would make it impossible to obtain needle counts. The average distribution of foliage by age as shown in Figure 1 could therefore be used as a guide.

The last five year's of foliage growth, on an average, accounts for approximately 90 per cent of the total foliage complement. Complete loss of the current year's foliage represents about 28 per cent of the total foliage, and successive years, in decreasing order about 23, 17, 13, and 10 per cent respectively. However, ocular defoliation estimates in the field are usually made to the nearest 10 per cent, or at most to the nearest five per cent. It might therefore be justifiable to round the percentages, from current to four-year-old foliage to 30, 20, 20, 15, and 10 per cent respectively.

The upper third of the crown contains a very large proportion of current year's foliage, and on some trees 65 per cent of the total foliage in this level was current and one year old growth. As spruce budworm larvae feed on new foliage first, and then move to progressively older foliage when the new is destroyed, this distribution of foliage would explain the heavy top defoliation and top kill which is characteristic of spruce budworm outbreaks in Douglas-fir stands. Crown levels B and C were both nearer to the average distribution for the tree, with the midcrown being closer than the lower third in more instances.

Because of the difference in the average number of needles per inch between trees, crown levels, and age, it would be necessary to do needle counts each time foliage was analysed to obtain accurate data.

The distribution of foliage by age could be used to good advantage as a measure of tree recovery in post-outbreak studies. This method was used in the Lillooet River Valley with satisfactory results (Silver, 1960). An acceptable estimate of tree recovery, based on foliage, may be obtained by analysing two branches from the mid-crown area of four or more trees in a specific locality.

Literature Cited

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