SOME EFFECTS OF DWARF MISTLETOE ON WESTERN HEMLOCK¹

By R. W. WELLWOOD²

Born in Victoria, B.C., 1912; 1935, B.A.Sc., U.B.C. in Forest Engineering; 1938, M.F., Duke University, Durham, N.C.; 1943, Ph.D., Duke University, Durham N.C.; Field experience with B.C. Forest Service, Victoria Lumber and Manufacturing Co. Ltd., and Lake Logging Co. Ltd.; June, 1943—July, 1946, Wood Technologist, Commonwealth Plywood Co. Ltd., Ste. Therese, P.Q.; July, 1946—to date, Dept. of Forestry, and Faculty of Forestry, U.B.C., present rank: Professor. Member of the Board of Examiners, Association of Professional Engineers of British Columbia. Vice-Chairman, Pacific Northwest Section, Forest Products Research Society.

Acknowledgement is made to the various students who assisted with laboratory work, and to the late Dr. D. C. Buckland for a critical review of the paper. Funds were provided by research grants from the University of British Columbia.

INTRODUCTION

Stands of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) are frequently plagued with dwarf mistletoe (*Arceuthobium campylopodum* forma *tsugensis* (Rosend) Gill), whose presence is observed in the form of large club-like brooms of living (or dead) branches, enlarged branch stubs, and stems malformed by cankers (See Fig. 1). References that relate to the effect of this parasite on both rate of growth and wood characteristics are infrequent in the literature. In a comprehensive article by Buckland and Marples (3), the writers consider the effect of dwarf mistletoe on mature hemlock stands and suggest suitable practices to overcome the disease in a managed forest.

On the University Research Forest at Haney, B.C., stands containing western hemlock are typical of those on many areas of the Lower Coast, where the disease is common. One particular area appeared so badly infected that it was decided to clear cut and establish a new stand. Approximately 10 acres of merchantable hemlock and balsam fir were logged during 1953. From this area sufficient material was collected for a preliminary study of the effect of the disease upon the characteristics of tree growth. A forest pathologist³ co-operated in the selection of sample trees and the description of visual characteristics.

STAND HISTORY

In 1867 a fire burned over much of the University Forest, killing most of the timber. Excepting a few veteran cedar and Douglas fir, any live individuals remaining apparently were advanced reproduction or suppressed understory trees of hemlock and balsam fir. Only in isolated places in the forest did these understory trees survive. Where hemlock and balsam fir have re-

¹ Research Paper No. 13, Faculty of Forestry, University of British Columbia. Submitted for publication November 10, 1955.

² Professor, Faculty of Forestry University of British Columbia.

³ Mr. A. C. Molnar, Forest Biology Division, Canada Science Service, assisted in selecting the trees and identifying fungi.

covered from their original suppression to become the main stand, the hemlock is almost universally infected with dwarf mistletoe. The parasite has also spread to hemlock in the 80-year-old reproduction.

MATERIAL

Ten standing trees were selected for study. (See Table 1.) Four of these showed severe attack by mistletoe, with large witches' brooms throughout the living crown. Three of these four had prominent stem swellings (often referred to as "burls") and one of them had top die-back, a characteristic of mistletoe infection (2,3). Three other trees were moderately infected, in that brooms were common in the lower crowns, but the upper crowns were full and normal; no stem swellings were present. Three trees had either no visible infection (a rarity in the area) or only a few small brooms in the lower crowns, and were classed as "lightly infected."

Diameters (breast height) ranged from 27.8 in. to 38.4 in., and ages from 146 years (stump height) to 256 years. The diameter-age relationship was weak, as would be expected for a tolerant species. In some instances the central core contained rot so that total age was interpolated. Site index was about 140 according to the western hemlock tables (1).

Trees were felled and bucked into 16-foot logs. Discs were removed at these intervals, to provide stem analysis data and material for study of the wood. Further cuts were made at specified points to determine the effects of swellings or of large witches' brooms. The discs were further reduced to wedges or segments, taken along radii, to include normal wood, and where present, wood close to an abnormality (limb having a witches' broom, or stem swelling). Smaller samples, in addition to these, also were removed from the outer two inches of sapwood.

Standard procedures were used to determine moisture content of the pieces, and specific gravity based on oven-dry weight and volume. It would have been desirable to have followed typical logs through a sawmill to determine grade and volume recoveries, but this was not feasible at the time.

EFFECT OF MISTLETOE

A. On Rate of Growth

1. Results.

Standard stem analysis procedures established rates of diameter and height growth. Volumes were computed for the time of cutting and for each decade of the past 100 years (i.e. 1953, 1943 1853). The most obvious effect of the mistletoe would be to reduce the vigor of the tree, which would show in an analysis of decadal volume growth.

Where all data within each group are pooled, the result is somewhat misleading since volume is directly correlated with diameter and since a range of diameters was included. Figure 3 shows the results obtained by grouping trees of comparable diameters. It is seen that the lightly infected trees (Fig. 3a) have the greatest decadal growth over the past 50 years, but that growth of the moderately infected trees was similar over much of the past century. The severely infected trees (Fig. 3a) were growing well until about 50 years ago, but since then their rate of growth has decreased rapidly.

Growth of tree 11 (lightly infected) is compared with that of trees 3

Fig. 3. Volume increment per decade (cubic feet) for trees of light, medium (moderate) and severe infection with hemlock mistletoe, segregated by diameter groups (a) and (b).

TABLE 1
DESCRIPTION OF BASIC DATA, HEMLOCK MISTLETOE STUDY

Infection Class	Tree No.	D.B.H. inches	Total height feet	Total Age at Stump Years	Remarks
Light	6	29.1	155	184	A few witches' brooms only, restricted to lower crown.
	7	27.8	163	230	No visible infection.
	11	34.0	171	(245)	Few dead witches' brooms in lower crown. Core of heart rot at stump; total age estimated.
Moderate	5	28.0	157	146	Witches' brooms in lower crown; upper crown uninfected.
	8	30.8	164	207	Witches' brooms numerous in lower crown; upper crown uninfected. Stem swelling at 16 ft.
	9	28.9	147	(165)	Witches' brooms numerous in lower crown; upper crown uninfected. Heart rot; total age estimated.
Severe	1	31.2	121	256	Large witches' brooms common; stem swellings present, with sporophores showing advanced decay. Top has die-back.
	2	31.8	144	216	Large witches' brooms common in lower crown; upper crown healthy.
	3	38.4	166	246	Many large witches' brooms, dead and alive. Swollen branch stubs show sporophores; severe butt and stem rot. Foliage sparse and faded, tree dying.
	4	36.7	164	(200)	Many large witches' brooms, dead and alive. Sporophores at swollen branch stubs; lower stem severely decayed.
					Total age estimated.

and 4 (severely infected) in Figure 3 (b). The effect of the mistletoe would seem apparent. Tree 11, although of lesser diameter than the others, was growing much faster. A confounding factor was that trees 3 and 4 had severe heart rot also and, in fact, for much of their length were mere shells of living sapwood over a punky core. Here, mistletoe could not be accountable for all growth retardation. Sten cankers and dead stubs of broomed branches were, however, the apparent means of entry for the pathogens, and thus were accountable for the internal condition of these trees if not for the lack of growth vigor.

Another method of comparing growth would be to express decadal volume increase as a percentage of tree volume at the start of the decade. Data were arranged in this way and plotted (Figure 4). Since a large tree is unlikely to increase its percentage volume at the same rate as a smaller tree, present diameter again is used to classify the data. The differences are apparent, with the severely infected trees showing the lowest percentage volume growth, and the other two groups being similar to one another.

2. Conclusions.

(a) Moderate infection by dwarf mistletoe, i.e. witches' brooms in the lower crown, has no serious effect on tree vigor.

(b) Severe infection, as characterized by numerous, large brooms in the crown, has a serious effect on tree vigor.

(c) Although mistletoe brooms affect tree vigor, they are not the apparent direct cause of tree death. They do reduce the tree's resistance to insect attack (2, 3) and may cause die-back of the top (2, 3). The large branch stubs resulting from the witches' brooms and stem swellings, are avenues of entry for fungi.

(d) Silvicultural measures to remove mistletoe from hemlock stands would prove difficult but would be desirable (3).

The above conclusions are based on only a few samples, from a limited area, but would seem to apply generally to this parasite and correspond with the findings of Buckland and Marples (3).

B. On Specific Gravity and Moisture Content

1. Results.

The outward characteristics of dwarf mistletoe (witches' brooms, stem swellings) indicate an inward effect on the tree. Stem analysis sections and special cuts made for observations reveal a number of interesting features.

(a) Stem Swellings.

Although stem swellings occur only in localized areas, they have a marked effect on the wood therein. This is well illustrated in Figure 2, where cuts through large swellings show the callus tissue, included bark, normal wood and a zone of decay that has entered through the branch stub.

(b) Witches' Brooms.

Physical weight of these brooms, sometimes several hundred pounds (3), must require strengthening tissue in the branches supporting them, and in the stem. The characteristic form of stem at a broomed limb is shown in Figure 5. The knot is extremely hard and dense, slowing the bucking in the woods and

Fig. 4. Percentage increment in volume per decade for trees of light, moderate and severe infection with hemlock mistletoe, segregated by diameter groups (a) and (b).

dulling the saw teeth in that operation and later in the sawmill. In addition the stem is not circular and the heart is off-centre. It will be shown that wood properties are affected.

Figure 6 shows the effect on a stem where three brooms are supported at the same level. Little lumber of worthwhile grade or value would be recovered in this part of the stem, and pulp yield would be low due to the extreme size of the knots.

(c) Specific Gravity or Wood Density.

Witches' brooms affect the physiology of the tree because of their weight and their water demands. One would expect denser or compression wood to develop on the side of the stem nearest the limbs supporting the brooms. This is shown in Table 2, where a comparison is made between the specific gravity of sections adjacent to and opposite from mistletoe infection. It is seen that in most cases the wood is denser on the side nearest the parasite. A statistical test of the difference between paired samples shows that these differences are significant and not due to chance. In Table 3 are shown the specific gravity data for each tree, based on normal wood only, at its respective height in the stem. Results for both the lightly and moderately infected trees are similar, and are pooled. These data are plotted in Figure 7 which shows the relation between specific gravity and height in the stem for whole sections and for the outer sapwood only. The lower values for the severely infected trees are apparent. They cannot be attributed only and directly to the mistletoe since these trees are severely infected with wood destroying fungi. The mistletoe, however, did provide an avenue of entry for the fungi.

(d) Moisture Content.

The demand of the mistletoe for water is shown when a comparison is made of the moisture contents of wood samples adjacent to and opposite from infected limbs. In Table 4 are shown the moisture contents for the appropriate sections. The lower moisture contents on the mistletoe sides are obvious for both the whole sections and the sapwood only. A test of the differences shows them as significant.

In Table 5 moisture contents are shown for each section, and these are plotted in their appropriate groupings in Figure 8. The difference between the major groups is obvious, but again the differences are in part related to the fungi and not alone to the mistletoe.

2. Conclusions.

(a) Moderate infection by dwarf mistletoe has no serious effect on the physiology of the tree.

(b) Severe infection has a serious effect on wood density.

In trees that are severely infected the average specific gravity of the wood is lower than in uninfected trees, suggesting lower strength properties and a lower pulp yield. In addition, trees that are severely infected have higher specific gravity on the side nearest the infection than on the opposite side. Variable density within one board is a major cause of warping in lumber.

(c) Severe infection has a marked effect on moisture content of the wood.

TABLE 2
TESTS OF SIGNIFICANCE OF DIFFERENCE BETWEEN SPECIFIC GRAVITY OF
SECTIONS OPPOSITE FROM AND ADJACENT TO LARGE WITCHES' BROOMS
OR STEM SWELLINGS IN MISTLETOE INFECTED HEMLOCK

Tree No.	Section No.	Height in tree feet	Specific Gravity ¹				Difference		
			Side Opposite		Side Adjacent		Whole Segment	Sapwood Only	
			Whole Segment	Sapwood Only	Whole Segment	Sapwood Only			
1	2	18	.46	.43	.46	—	.00	—	—
	3	21	.42	.39	.42	.39	.00	.00	—
	7	74	.44	.39	.42	.40	.02	—	.01
	8	90	.42	.41	.45	.38	.03	.03	—
2	2	21	.42	.40	.48	—	—	.06	—
	3	37	.40	.38	.41	—	—	.01	—
3	5	68	.43	.42	.44	.40	—	.01	—
	6	84	.44	.40	.46	.42	.02	.02	.02
	7	100	.42	.40	.43	.40	.01	.00	—
	9	124	.45	.40	.46	.47	.01	—	.07
4	5	72	.44	.41	.45	.44	—	.01	.03
	6	81	.43	.42	.44	.41	—	.01	—
	7	98	.41	.41	.44	.44	.03	.03	.03
8	3	26	.40	.38	.39	.43	.01	—	.05
	4	32	.38	.37	.40	.43	.02	—	.06
	7	83	.36	.36	.46	.37	.10	—	.01
	8	100	.38	.36	.43	.38	.05	—	.02
	9	116	.39	.39	.46	.44	.07	—	.05
9	3	26	.44	.45	.47	—	.03	—	—
	6	76	.43	.43	.45	.44	.02	—	.01
Average Difference			.023				.019		
Standard Error			.0064				.0071		
t value			3.60 *				2.67 *		

¹ Based on Oven Dry Weight—Oven Dry Volume.

* Significant at the 5 per cent level.

* Significant at the 1 per cent level.

TABLE 3
SPECIFIC GRAVITY OF STEM SECTIONS BY INFECTION CLASSES AT VARIOUS
HEIGHTS IN THE STEM, FOR NORMAL WOOD ONLY.

Tree No.	Specific Gravity by Height Classes (in feet)															
	Whole Segment							Sapwood Only								
—	0 — 19.9	20 — 39.9	40 — 59.9	60 — 79.9	80 — 99.9	100 — 119.9	120 — 139.9	140 — 159.9	0 — 19.9	20 — 39.9	40 — 59.9	60 — 79.9	80 — 99.9	100 — 119.9	120 — 139.9	140 — 159.9
LIGHT																
6	.45	.42	.40	.45	.41	.43 .43	.47		.46	.43	.40	.41	.42	.43 .43		
7	.54	.49	.46	.47	.46	.46 .51	.52		.52	.50	.47	.49	.46	.45 .48	.50	
11	.41	.40	.38	.39	.38 .44	.40	.42	.49	.39	.39	.40	.38	.37 .35	.37	.39	
Sum	1.40	1.31	1.24	1.31	1.69	2.23 .446	1.41 .470		1.37 .457	1.32 .440	1.27 .423	1.28 .427	1.60 .40	2.16 .432	.89 .445	
Mean	.467	.437	.413	.437	.422	.446 5	.470 3	.49 1	.33 3	.33 3	.33 3	.33 3	.44 4	.40 5	.2 2	
No. 3	3	3	3	3	4	5	3	1	3	3	3	3	4	5	2	
MEDIUM																
5	.50	.45	.47	.44	.44	.48 .47	.51		.50	.48	.49	.45	.42	.50 .46	.50	
8	.42	.40 .38	.38	.39	.36 .38	.39	.47		.41	.38 .37	.37	.36	.36 .36	.39	.42	
9	.47	.44	.43 .42	.43	.45	.51	.53		.50	.45	.45 .42	.43	.44	.48		
Sum	1.39	1.67	1.70	1.26	1.63	1.85	1.51		1.41	1.68	1.73	1.24	1.58	1.83	.92	
Mean	.463	.418	.425	.420	.408	.462	.503		.470	.420	.432	.413	.395	.458	.460	
No. 3	4	4	4	3	4	4	3	3	3	4	4	3	4	4	2	

(Table 3 continued on page 291.)

Tree No.	Whole Segment				Specific Gravity by Height Classes (in feet)											
					Sapwood Only											
LIGHT AND MEDIUM COMBINED																
Sum	2.79	2.98	2.94	2.57	3.32	4.08	2.92	2.78	3.00	3.00	2.52	3.18	3.99	1.81		
Mean	.465	.426	.420	.428	.415	.456	.487	.49	.463	.429	.429	.420	.398	.443	.452	
No.	6	7	7	6	8	9	6	1	6	7	7	6	8	9	4	
SEVERE																
1	.46	.42	.43	.44	.42			.43	.39	.41	.39	.41				
		.45							.40							
2		.42	.42	.38	.40				.40	.38	.37	.35				
		.40							.38							
3				.43	.44		.45				.42	.40		.40		
					.42							.40				
4			.43	.44	.43		.45	.44		.40	.41	.43		.48	.43	
					.41							.41				
Sum	1.69	1.28	1.699	1.699	2.52		.90		1.57	1.19	1.59	2.40		.88		
Mean	.46	.422	.427	.422	.420		.90	.44	.43	.392	.397	.398	.400	.44	.43	
No.	1	4	3	4	6		2	1	1	4	4	6	2	2	1	

TABLE 4
TESTS OF SIGNIFICANCE OF DIFFERENCE BETWEEN MOISTURE CONTENT OF
SECTIONS OPPOSITE FROM AND ADJACENT TO LARGE WITCHES' BROOMS OR
STEM SWELLINGS IN MISTLETOE INFECTED HEMLOCK

Tree No.	Section No.	Height in tree feet	Moisture Content ¹				Difference			
			Side Opposite		Side Adjacent		Whole Piece		Sapwood Piece	
			Whole	Sapwood	Whole	Sapwood	+	-	+	-
1	2	18	110		89		21			
	3	21	113		110		3			
	7	74	112	198	91	160	21		38	
2	8	90	122		122					
	2	21	84		89			5		
	3	37	88		89			1		
3	5	68	91	184	83	120	8		64	
	6	84	88	200	87	114	1		86	
	7	100	76							
4	9	124	98	160	96	132	2		28	
	5	72	78	158	62	134	16		24	
	6	81	81	159	57	112	24		47	
8	7	98	87	146	55	151	32			5
	3	26	104	192	74	102	30		90	
	4	32	114	200	83	125	31		75	
9	7	83	112	194	100	192	12		2	
	8	100	130	205	120	190	10		15	
	9	116	138	175	70	156	68		19	
	3	26	83	162	82		1			
	6	76	116	178	105	161	11		17	
Average Difference							15.0		38.5	
Standard Error							3.98		8.74	
t Value							3.77 ^a		4.40 ^a	

¹ Per cent.

^a at the 1 per cent level.

FIGURE 1. Stem, malformed by dwarf mistletoe, University Research Forest, Haney.

FIGURE 2 (a)

FIGURE 2 (b)

FIGURE 2. (a) and (b). Sections through large stem swellings of two trees, showing callus tissue, included bark and normal wood (a and b), and decayed branch stub (b).

FIGURE 5. Section through mistletoe-broomed limb, showing abnormal shape of stem.

FIGURE 6. Abnormal section due to three witches brooms at same height in the tree.

Fig. 7. Specific gravity of (a) stem sections, and (b) sapwood sections, at various heights in the stem for combined data of light and moderate infection, and severe infection, with hemlock mistletoe.

TABLE 5
MOISTURE CONTENT OF STEM SECTIONS BY INFECTION CLASSES AT VARIOUS
HEIGHTS IN THE STEM, FOR NORMAL WOOD ONLY.

Moisture Content by Height Classes (in feet)																	
		Whole Segment							Sapwood Only								
Tree	0—	20—	40—	60—	80—	100—	120—	140—	0—	20—	40—	60—	80—	100—	120—	140—	
No.	19.9	39.9	59.9	79.9	99.9	119.9	139.9	159.9	19.9	39.9	59.9	79.9	99.9	119.9	139.9	159.9	
LIGHT																	
6	94	88	94	75	109	101}	147	160	172	159	191	178	172}	162}			
						144}											
7	91	82	90	93	105	114}	121	127	133	146	143	159	168}	146}	137		
						114}											
11	99	100	100	98	106	—	—	191	177	168	179	193					
Sum	284	270	284	266	320	473	268	478	482	473	513	530	648				
Mean	95	90	95	89	107	118	134	159	161	158	171	177	162	137			
No.	3	3	3	3	3	4	2	3	3	3	3	3	4	1			
MEDIUM																	
5	90	90	88	107	115	120}	128	145	157	130	166	168	133}	157}	134		
						136}											
8	104	104}	110	96	112}	138	138	183	192}	149	190	194}	175}	205}	166		
		114}			130}				200}								
9	80	83	100}	116	126	112	118	119	162	152}	178	173	148				
		102}							184}								
Sum	274	391	400	319	483	506	246	447	711	615	534	740	613	300			
Mean	91	98	100	106	121	126	123	149	178	154	178	185	153	150			
No.	3	4	4	3	4	4	2	3	4	4	3	4	4	2			
LIGHT AND MEDIUM COMBINED																	
Sum	558	661	684	585	803	979	514	925	1193	1088	1047	1270	1261	437			
Mean	93	94	98	98	112	122	128	154	170	155	174	181	158	146			
No.	6	7	7	6	7	8	4	6	7	7	6	7	8	3			
SEVERE																	
1	110	113}	113	112	122			166	184}	181	198	182					
		106}							186}								
2		84}	78	92	121				202}	201	215	231					
		88}							208}								
3				91	88}		98				184	200}		160			
					76}							192}					
4			74	62	83}		82	86		173	158	159}		123	133		
					87}						146}						
Sum		391	265	357	577		180		780	555	755	1110		283			
Mean	110	98	88	89	96		90	86	166	185	189	185		142	133		
No.	1	4	3	4	6		2	1	1	4	3	4	6	2	1

Fig. 8. Moisture content of (a) stem sections, and (b) sapwood sections, at various heights in the stem for combined data of light and moderate infection, and severe infection, with hemlock mistletoe.

The reduction in moisture content along with specific gravity would cause such logs to float better, but has no other practical significance.

(d) A definite but unmeasured reduction would occur in lumber yield and value as a result of:

- (i) swellings which produce abnormal tissue;
- (ii) large and extremely hard knots from limbs that support or have supported witches' brooms. Such knots will remain intergrown for a much longer period than normal knots;
- (iii) decay, which enters the tree at cankerous zones.

(e) Results merely indicate trends or conditions. A much larger sample would be required to establish definite relationships.

REFERENCES

1. BARNES, G. H. 1949. Site classification of even-aged stands of western hemlock. Research Note No. 50, Pacific Northwest Forest and Range Experiment Station.
2. BOYCE, J. S. 1948. Forest pathology. Ed. 2; p. 550. McGraw-Hill Book Company, Inc. New York.
3. BUCKLAND, D. C. and E. G. MARPLES. 1952. Management of western hemlock infested with dwarf mistletoe. Brit. Col. Lumberman 36 (5): 50, 51, 136, 138, 140. May.