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MOISTURE CONTENT AND INFLAMMABILITY IN SPRUCE, FIR, AND SCOTS PINE CHRISTMAS TREES

by
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by
C. E. Van Wagner[1]

INTRODUCTION

A dry Christmas tree is recognized as a fire hazard by all fire protection authorities. No statistics of fires starting in Christmas trees are available for Canada as a whole, but some individual provinces keep records. In Ontario, for instance, 35 such fires in which five lives were lost occurred during the 1960 Christmas season. New Brunswick reports 20 Christmas tree fires resulting in seven deaths during the past five years. Nova Scotia and Manitoba, however, report very few fires and no fatalities. Electrical defects in decorative tree-lighting systems are mentioned as the most frequent cause of ignition, and there is general agreement that a tree becomes more inflammable as it dries. Many fire authorities warn annually against keeping the Christmas tree indoors too long.

There are practical ways of reducing the Christmas tree fire hazard. According to the U.S. Forest Products Laboratory (Anon. 1947), freshly cut spruce and balsam fir cannot be set on fire while standing in water. Leatherman (1938, 1939) has described a method of fire-proofing by allowing the tree to absorb through its butt a solution containing ammonium sulfate or calcium chloride. Sprayed-on fire retardant coatings based on water glass or borax have also been suggested (Anon. 1947).

There seemed to be, however, no clear statements of how long after installation a tree becomes inflammable or whether the hazard varies with species. This experiment was therefore undertaken to discover: 1) how quickly conifers dry when brought indoors, 2) whether species differ in inflammability, 3) the effect of moisture content on inflammability, and 4) the degree of protection afforded by immersing the butt in water.

MATERIALS AND METHODS

Three conifers were tested: Scots pine (*Pinus sylvestris* L.). balsam fir (*Abies balsamea* (L.) Mill), and white spruce (*Picea glauca* (Moench) Voss). The fir and spruce were obtained from open areas on the Petawawa Forest Experiment Station at Chalk River, Ontario, and the Scots pine from a local plantation[2]. All trees were chosen to secure reasonable uniformity within each species as to size, shape, and density of foliage (Figure 1). The average foliage density was maintained as high as possible. Only balsam fir and white spruce with considerable internodal branching were suitably dense. The Scots pine, having no internodal branches, filled in their internodes with densely-foliated upturned twigs, leaving a foliage-free hollow inside.

Table 1 lists dimensions and characteristics of the test trees. Crown volume was calculated by assuming the trees to be simple cones of known height and

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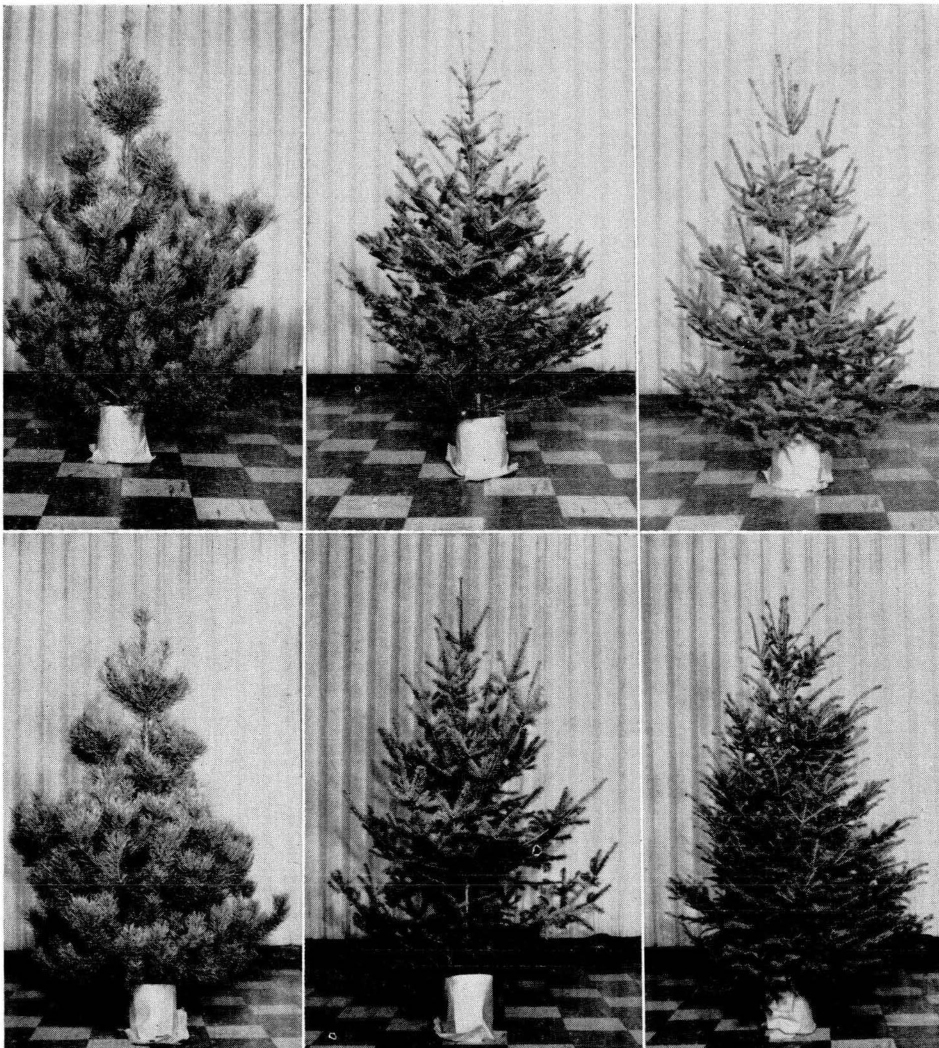
[2] Thanks are due the Ontario Department of Lands and Forests (Pembroke District) and the Kiwanis Club of Pembroke for help in securing the Scots pine test trees.



Scots pine Balsam fir White spruce

Figure 1. Typical test trees.

radius. The foliage was completely stripped from four chosen average trees (one pine, two fir, one spruce) and weighed. The weights of foliage permit a rough comparison between species of crown density.

TABLE 1. TEST TREE CHARACTERISTICS
(means and coefficients of variation)

Characteristic	Scots pine (10 trees)	Balsam fir (10 trees)	White spruce (8 trees)
Height (tip to bottom whorl) (ft.)	4.9± 6%	5.1±10%	5.4± 7%
Maximum crown diameter (ft.)	3.5± 3%	3.2± 3%	3.4± 8%
Butt diameter (ins.)	2.0± 5%	1.5± 9%	1.6± 16%
Annual whorls	4.2±15%	6.5±21%	6.6±17%
Years' needles present	2 to 3	4 to 6	4 to 6
Crown volume[1] (cu. ft.)	15.7	13.7	17.3
Crown density[2] (lbs. foliage per cu. ft.)	0.171	0.093	0.100

[1] Calculated from average dimensions.
[2] Determined for four chosen average trees: 1 pine, 2 fir, 1 spruce.

Half the trees were cut in mid-November and stored 6½ weeks under unheated shelter; the other half were cut two days before the indoor test period was started. All trees were then installed upright in the same room for 21 days during January—one half of each group with the butts in water, the other half dry. A fresh butt surface was sawn on the stored trees. The trees were supported in one-gallon containers partly filled with clean crushed stone (Figure 1), and were installed in a large hall adjacent to a kitchen; cooking thus noticeably affected humidity as it might in a normal household.

The experiment was performed in duplicate, no further replication being possible because of space limitations. In addition, two Scots pine and two balsam fir were set up with butts immersed in a 15 per cent calcium chloride solution. In all, 28 trees were tested in five treatments as listed below:

1. Stored—dry butt (two of each species)
2. Stored—wet butt " "
3. Fresh—dry butt " "
4. Fresh—wet butt " "
5. Fresh—Ca Cl_2 (two pine and two fir)

Water in the wet butt tree containers was replenished daily; the calcium-chloride treated trees received nothing further after the original dose of solution. Continuous records of temperature and relative humidity were kept with hygrothermographs during both the storage period and the indoor test.

A summary of these records is as follows:

	Temperature, F°		Relative Humidity, per cent	
	Average	Range	Average	Average daily range
Unheated storage	25	−2 to 48	71	63 to 79
Indoor test	73	68 to 78	17	9 to 32

Every two or three days, two 1-gram samples of foliage were removed from each tree and oven-dried to obtain moisture content. All moisture contents referred to are of the foliage only, and are expressed as a percentage of oven-dry weight. No moisture content gradients were detected within the trees, neither up and down the stem nor from the stem outwards.

As soon as twigs cut from an individual tree showed signs of sustaining combustion, the tree was tested for inflammability under a laboratory hood (Figure 2) with common 2-inch wooden matches as the ignition agent. In each test up to eight matches, held in a long-handled clamp, were successively applied to different points in the lower half of the crown. The duration of the flame and the proportion of crown volume destroyed were recorded after each successful ignition. The test was repeated every second day on each tree until enough of its crown had been lost to interfere with further testing. In all, 38 sets of these tests were carried out, 15 on pine, 14 on fir, and 9 on spruce. A Bunsen flame was applied to a number of trees that failed to ignite from matches.

Figure 2. Laboratory flame hood with partly consumed 5-foot balsam fir.

During the inflammability testing, matches were applied only at points where ignition of the foliage was most likely. Each test result, therefore, indicates whether a tree could be set alight by matches and, if so, the extent of the damage.

RESULTS

Moisture Content

Table 2 summarizes the data on moisture content. The fresh foliage of the three species showed no obvious moisture changes from early November to early January. The mean moisture contents of about 15 trees of each species sampled at different times during this period were therefore compared directly. The difference between Scots pine and balsam fir (or white spruce) is highly significant; no true difference can be demonstrated between fir and spruce.

TABLE 2. MOISTURE CONTENTS OF FOLIAGE
(per cent)[1]

	Scots pine	Balsam fir	White spruce
Freshly-cut trees in winter	128[2]	114	111
After unheated storage for 6½ weeks	106	101	82[2]
Upper limit for match ignition	65	50	—[3]
Average daily moisture loss in range from 100 to 20 per cent	5.4	6.4	7.2
Average moisture level maintained by wet-butt trees during indoor test period	136.	126.	112.[2]

[1] All values are based on dry weight.
[2] Significantly different from other two species at 5% level or better.
[3] Value for spruce highly variable owing to needle drop.

The remaining data in Table 2 are based on four trees of each species and therefore some of the differences shown cannot be verified statistically. White spruce did, however, differ significantly from the other two species in the two respects noted in Table 2.

The daily rate of moisture loss of the dry-butt trees in the range between 100 and 20 per cent moisture content was nearly constant throughout the indoor test, and averaged 6.3 per cent per day for all 12 dry-butt trees. The differences in this property shown in Table 2 are not significant; most of the apparent variation was caused by two trees, one fast-drying spruce and one slow-drying pine.

Moisture loss during the 6½-week unheated storage period was equal to about four days of indoor drying; moreover, both stored and fresh dry-butt trees dried at about the same rate after being set up indoors. This allowed pooling of the data for stored and fresh trees for the drying curves in Figure 3.

The four calcium-chloride treated trees absorbed moisture for several days until the initial supply of solution was exhausted. The two treated balsam firs then dried at an average daily rate of 3.8 per cent, about half the rate of untreated dry fir. The average drying rate of the two Scots pine, however, was 6.2 per cent per day, approximately the same as that by untreated dry trees. The presence of calcium chloride in these trees was demonstrated by qualitative chemical tests on both treated and untreated foliage.

The moisture contents of all wet-butt trees remained above 100 per cent throughout the 3-week indoor test period (*see* Figure 4). Each tree in this group attained a maximum moisture content higher than its initial value. The stored trees in particular gained moisture rapidly at first, their average rise in moisture content during the first two days being 20.3 per cent.

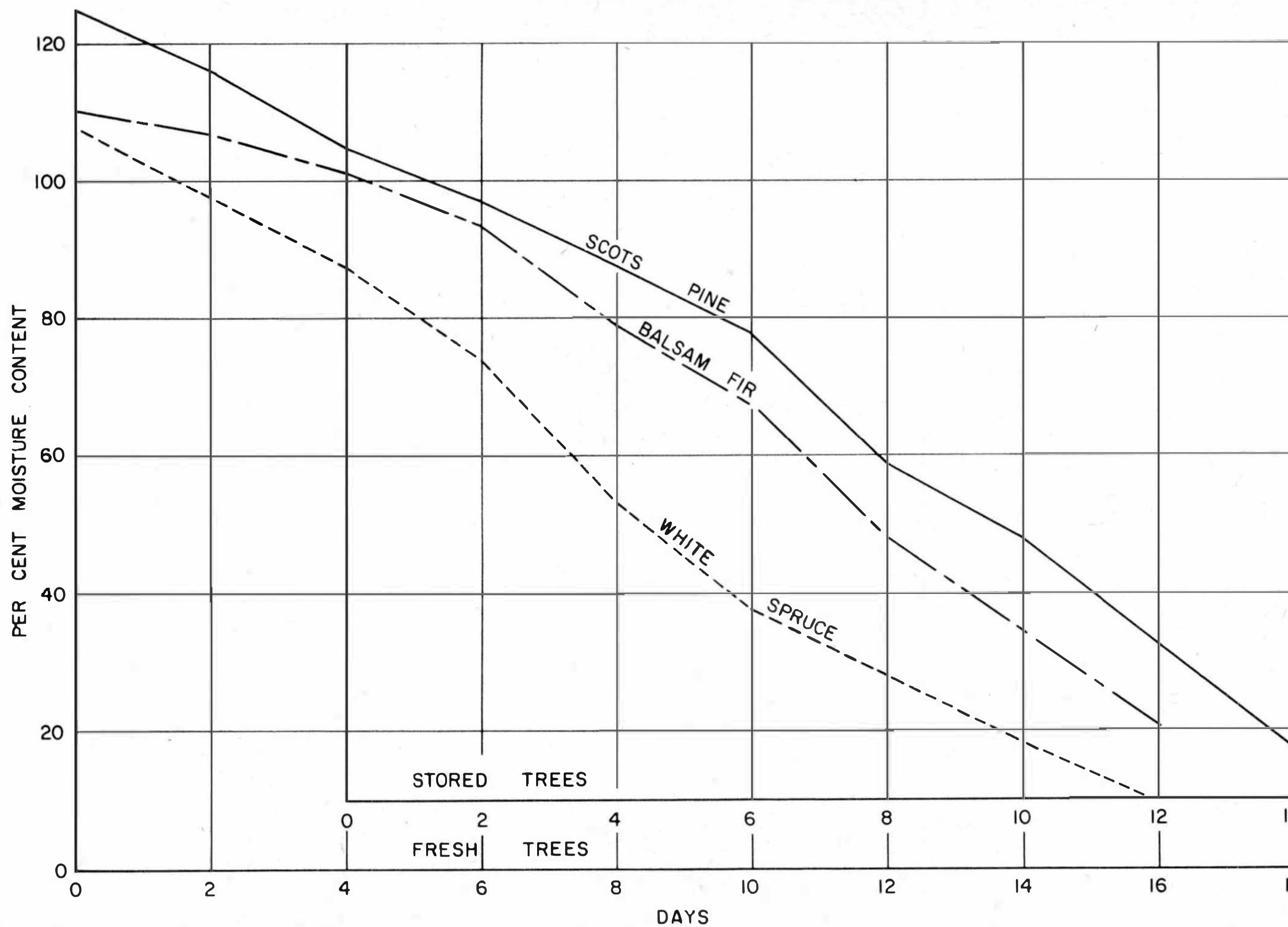


Figure 3. Indoor drying rates of dry-butt trees (stored and fresh combined).

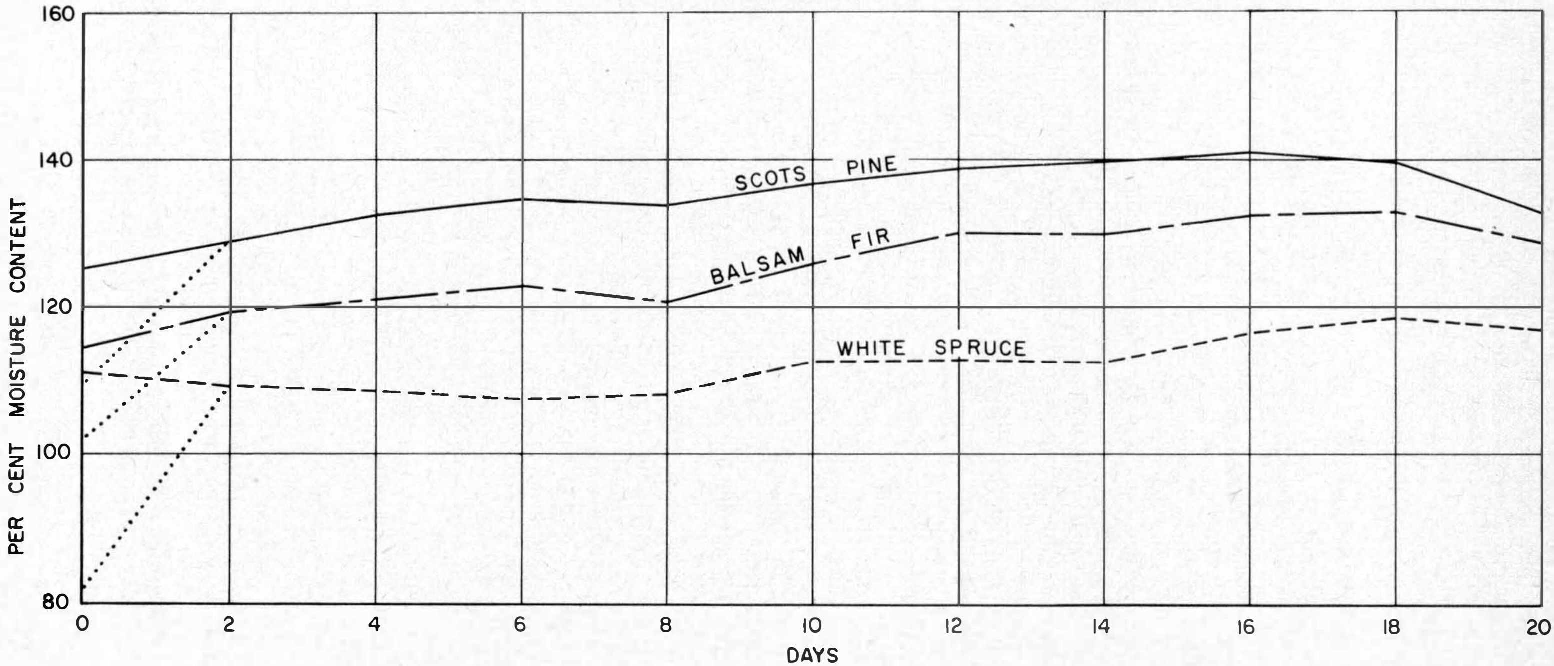


Figure 4. Moisture contents of wet-butt trees (stored and fresh trees combined after second day).

During the last few days of the test a few twigs on some of the stored wet-butt trees died and dried out; otherwise all trees set in water retained their fresh greenness and shed no foliage. The dry-butt spruce dropped needles prolifically below about 60 per cent moisture content, but Scots pine and balsam fir held theirs well even at 10 per cent. The calcium chloride treatment caused a distinct brown discolouration, more pronounced in balsam fir than in Scots pine.

The daily water requirements of several wet-butt trees were recorded, as well as normal evaporation from blank containers. The daily additions were approximately constant throughout the test—about 280 millilitres per day for balsam fir and white spruce, and 540 for Scots pine[1]. Direct evaporation from the containers accounted for about 50 millilitres per day.

Inflammability

Two expressions of inflammability were chosen: the proportion of crown volume consumed per ignition, and the weight of foliage consumed per ignition. The first represents the simple visual result; the second allows for the effect of crown density on the amount of heat produced.

Some measure of the rate of heat production would also have been helpful in comparing inflammability. The duration of each flame was recorded, but the uncertain end-points and great variation in intensity during each test rendered useless any expression involving time. The impression received was that consideration of rates would not have altered the picture presented below.

Scots pine became inflammable at about 65 per cent moisture and balsam fir at about 50 per cent (*see* Figure 5). Each species, however, reached its critical dryness after the same time indoors (7 to 14 days for fresh trees) owing to the higher initial moisture content of Scots pine. White spruce shed foliage so readily below about 60 per cent moisture content, especially when disturbed, that the crowns became too sparse to support combustion except when very dry. Inflammability data for this species are therefore sketchy and the curve for spruce in Figure 5 is included for rough comparison only.

At moisture contents of less than 20 per cent all species were highly inflammable. The balsam fir in particular quickly became wholly enveloped in flame. Flame in the Scots pine died out after consuming a V-shaped swatch, showing less tendency to spread downwards or to the side. When enough foliage remained, white spruce behaved somewhat like balsam fir.

The curves for weight of foliage consumed (Figure 6) were constructed by merely applying crown density factors to the curves of crown volume consumed (weight loss after each ignition was not recorded). Nevertheless they illustrate the effect of the greater density of Scots pine on the total heat produced per ignition, which was indeed noticeable during the tests. No curve is presented for white spruce.

At a given moisture content, the presence of calcium chloride did not affect inflammability. The results of tests on the calcium chloride treated trees were therefore included with the others.

The wet-butt trees, which remained at over 100 per cent moisture content throughout the indoor test period, could not be ignited with matches. An 8-inch Bunsen flame was applied for 10 seconds to a number of them; combustion ceased immediately after removal of the burner. Flame persisted for a few seconds after this severe treatment in some trees at moisture contents between 60 and 100 per cent.

During the burning tests flame typically flashed through the foliage leaving the twigs intact. Only on the driest balsam firs was some wood consumed.

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[2] 568 millilitres equal 1 Imperial pint.

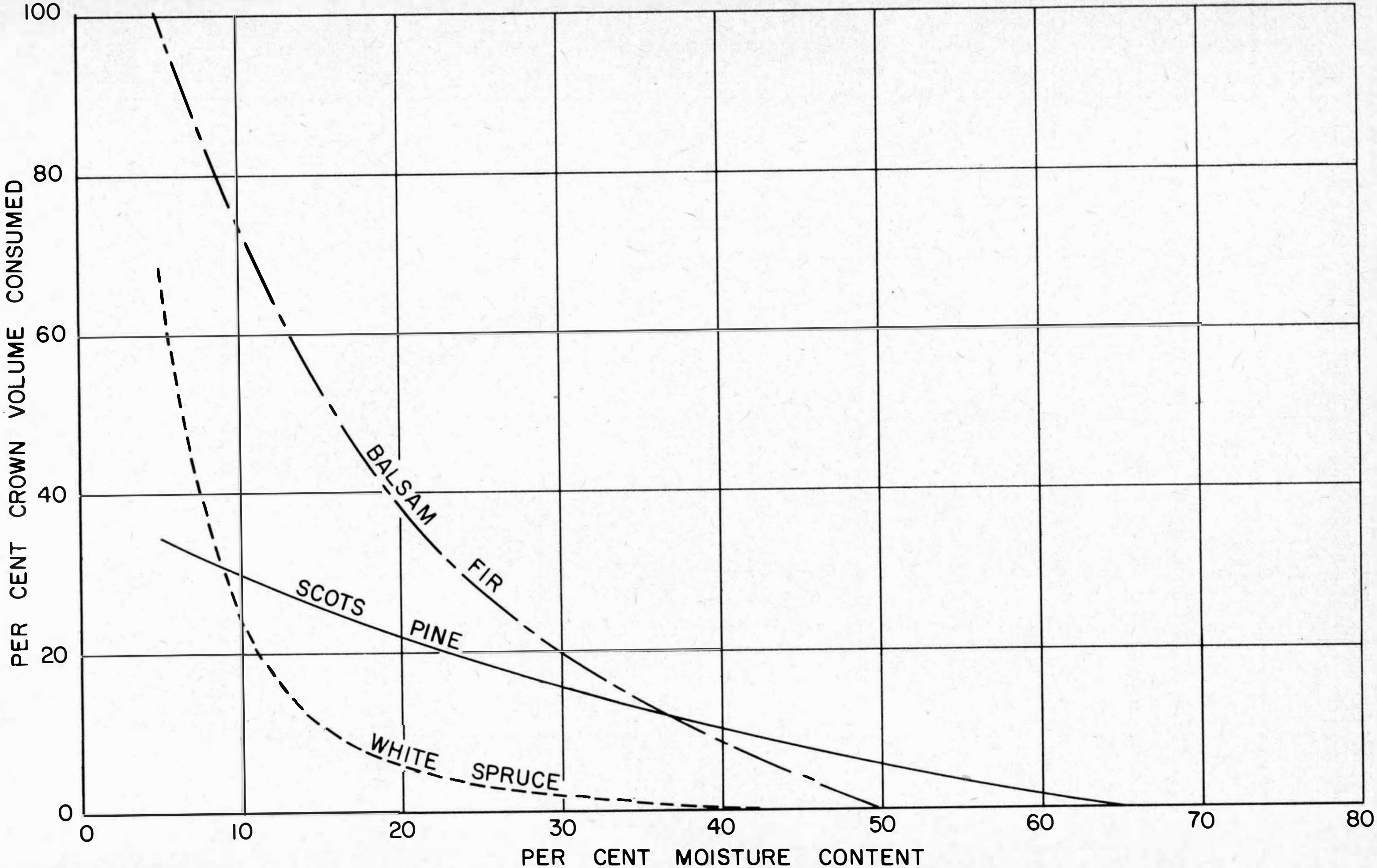

Figure 5. Effect of moisture content on crown volume consumed.

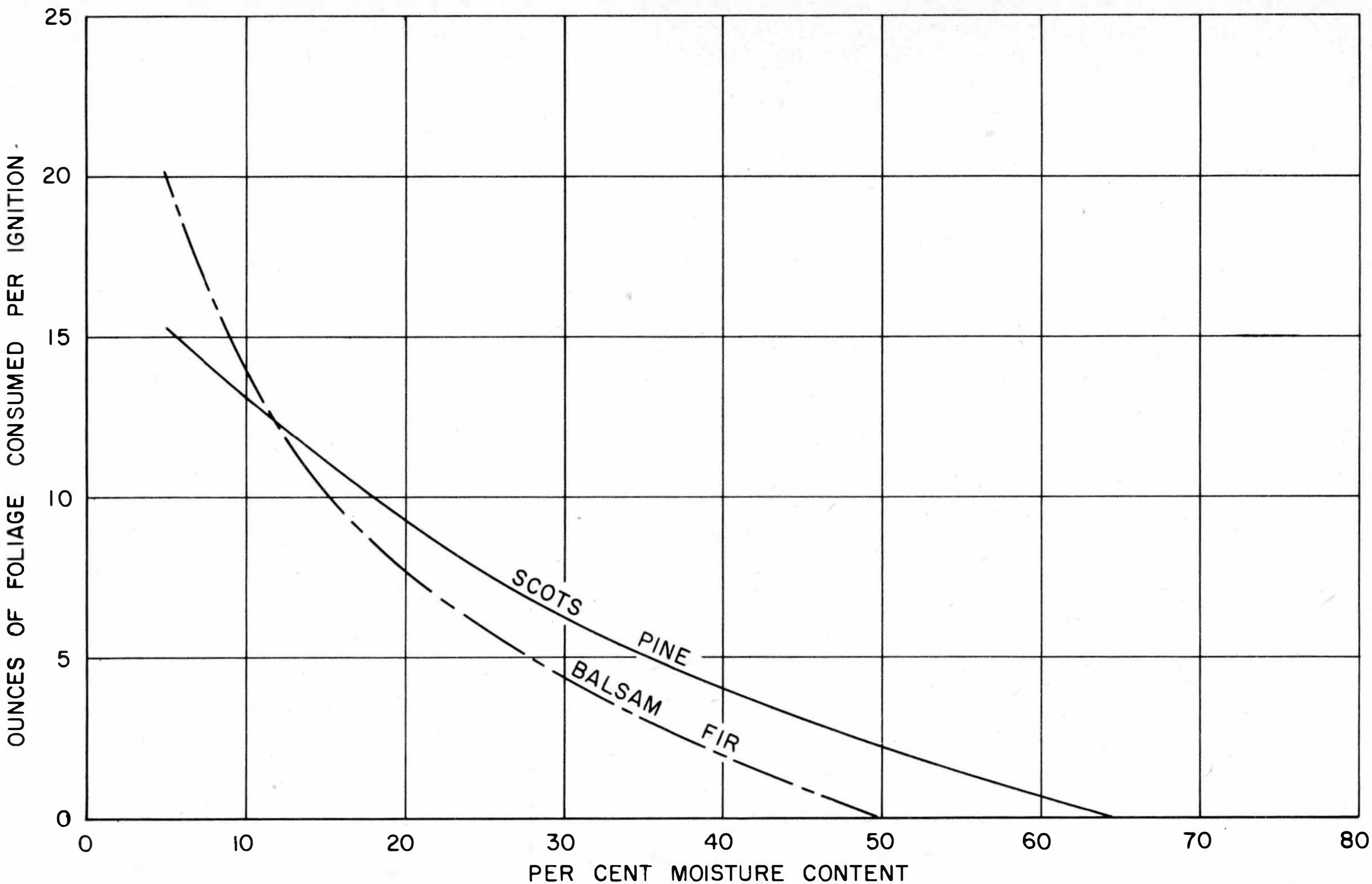

Figure 6. Foliage weight consumed in relation to moisture content.

DISCUSSION

Trees of all species were in good condition after 6½ weeks of unheated storage under shelter, which corresponds to cutting on November 6 and installing indoors on December 21. There is little doubt that the Scots pine and balsam fir could have been stored longer without excessive loss of moisture. Hawboldt (1953) recommended cutting balsam fir in Nova Scotia after November 1, and Stiell (1957) mentioned cutting Scots pine and balsam fir as early as October without undue drying. The storage period in this experiment was equivalent to about four days indoors, i.e., 12 days storage equalled one day indoors.

The stored white spruce performed well when the butts were immersed, but even freshly-cut spruce shed foliage within a week indoors when left dry. The allowable storage time for spruce thus depends on its subsequent indoor treatment. Stiell (1957) suggested cutting spruce no earlier than December 1.

The most important result of the experiment was the complete resistance to ignition of all wet-butt trees. These trees were not strictly fire-proof; their foliage did burn when a match or Bunsen flame was applied. Such combustion, however, added nothing to the applied flame, and ceased immediately the flame was removed. The three species were equal in this respect; differences in moisture content above 100 per cent are apparently unimportant so far as combustion in individual trees is concerned.

Comparisons of fire hazard between dry trees of the different species are complicated by the differences in the behaviour of fire in each. At extreme dryness balsam fir is the most dangerous because flame spread most quickly through the entire crown. At intermediate levels of dryness, however, the Scots pine gave off the most heat per ignition. Well-foliated white spruce behaved like balsam fir, but the species was normally the least inflammable because of needle-drop.

The calcium chloride treatment reduced the drying rate of the balsam fir, thus conferring some degree of protection. The lack of effect on the Scots pine is probably owing to its greater weight, both in wood and foliage. According to Leatherman (1939), a tree requires for adequate protection a weight of salt equal to 25 per cent of its own weight; somewhat less was used here. However, even if the treatment offered complete protection from fire, the foliage discolouration would be unacceptable to most people.

CONCLUSIONS

Christmas tree fires can be practically eliminated by keeping the tree butt in water. Whether cut fresh or stored unheated for a reasonable period, trees of the species tested will then remain non-inflammable for at least three weeks.

When the tree is brought indoors a fresh butt surface should be sawn and the tree set in water immediately. A diagonal cut rather than a square one, should be made to expose a greater surface. The container should hold several days water supply and be replenished regularly. The daily water requirements for trees 5 feet tall are about 1 pint for Scots pine, and ½ pint for balsam fir and white spruce.

Butt immersion also preserved the fresh greenness of the foliage. White spruce in particular must be set in water to prevent needle-drop, unless it is cut fresh and used for less than a week. Scots pine and balsam fir retained their needles at all moisture content levels observed.

Treatment of the trees with a hygroscopic salt such as calcium chloride or a fire retardant salt such as ammonium sulphate offers no advantage over simple immersion of the butt in water. A side-effect is unattractive discolouration of the foliage.

Freshly cut trees of the three species become inflammable within 7 to 14 days indoors if allowed to dry naturally; trees with prior outdoor storage will burn after only 3 to 10 days indoors. In another 4 to 6 days, moisture content drops below 20 per cent, and the trees become very dangerous.

When dry, white spruce is usually less hazardous than Scots pine or balsam fir simply because it sheds its foliage; an undisturbed spruce may nevertheless be highly inflammable.

When very dry, balsam fir is more dangerous than Scots pine because it burns more violently, but the ranking of the two species is not clear-cut. The difference in any case does not seem great enough to warrant primary consideration when choosing a tree.

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