Forest Research Branch

FLAMMABILITY OF CHRISTMAS TREES

by

C. E. VAN WAGNER

Sommaire en français

Department of Forestry Publication No 1034
Ottawa 1963

72349-4—1

NOTE

This publication is a revision and extension of Technical Note No. 109, "Moisture Content and Inflammability in Spruce, Fir, and Scots Pine Christmas Trees", 1961, the original publication on this subject published by the Department of Forestry. Supplementary experiments have strengthened some of the findings, have defined better the limitations of butt immersion as a safety precaution, and have led to conclusions not previously reported.

Technical Note No. 109 is now out of stock and will not be reprinted.

Published under the authority of
THE HONOURABLE JOHN R. NICHOLSON, P.C., O.B.E., M.P.
Minister of Forestry
Ottawa 1963

TABLE OF CONTENTS

72349-4—2

ABSTRACT

The flammability of conifers used as Christmas trees depends mainly on the foliar moisture content and also on the crown density. Trees allowed to dry can be ignited with matches when the moisture content falls to about 50 per cent, and will burn with great violence when moisture content falls below 20 per cent. Trees standing in water remain at over 100 per cent moisture content and cannot be ignited with a point source of flame; they will, however, ignite when flame is applied in a ring around the base. Butt immersion was equally effective in reducing hazard for all three species tested: Scots pine, balsam fir, and white spruce. But if the moisture content of the foliage has already dropped below 75 to 85 per cent, the tree will continue to dry even though set in water.

72349-4—2½

FLAMMABILITY OF CHRISTMAS TREES[1]

by

C. E. Van Wagner[2]

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 period 1956-1960. 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 flammable 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. Both the Office of the Dominion Fire Commissioner (Anon. 1957) and the U.S. Forest Products Laboratory (Anon. 1947) recommend standing the tree 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). Tryon (1962) recommends standing the tree in water, and discusses the effect of decorations on the fire hazard.

There seemed to be, however, no clear statements of how long after installation a tree becomes flammable 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 flammability, (3) the effect of moisture content on flammability, and (4) the degree of protection afforded by immersing the butt in water.

MATERIALS AND METHODS

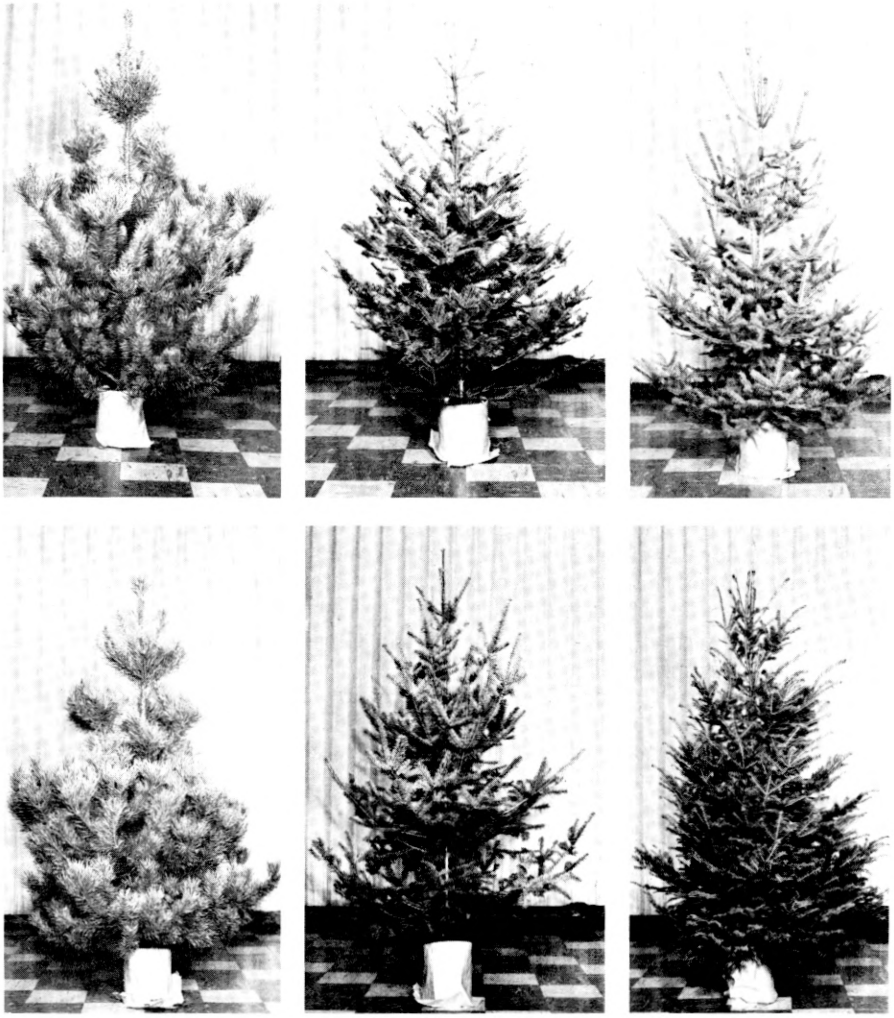
Three conifers were tested: Scots pine (*Pinus sylvestris* L.), balsam fir (*Abies balsamea* (L.) Mill), and white spruce (*Picea glauca* (Moench) Voss). The fir and spruce were obtained from open areas on the Petawawa Forest Experiment Station at Chalk River, Ontario, and the Scots pine from a local plantation.[3] 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.

---

[1] Department of Forestry, Canada, Forest Research Branch Contribution No. 551.

[2] Research Officer, Forest Research Branch, Petawawa Forest Experiment Station, Chalk River, Ont.

[3] 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.

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 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 of crown density between species.

Half the trees were cut in mid-November and stored $6\frac{1}{2}$ 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.

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* (cu. ft.)	15.7	13.7	17.3
Crown density** (lbs. foliage per cu. ft.)	0.171	0.093	0.100

* Calculated from average dimensions.

** Determined for four chosen average trees: 1 pine, 2 fir, 1 spruce.

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 hygro-thermographs during both the storage period and the indoor test.

A summary of these records is as follows:

Location	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 with the trees, either up and down the stem or from the stem outwards.

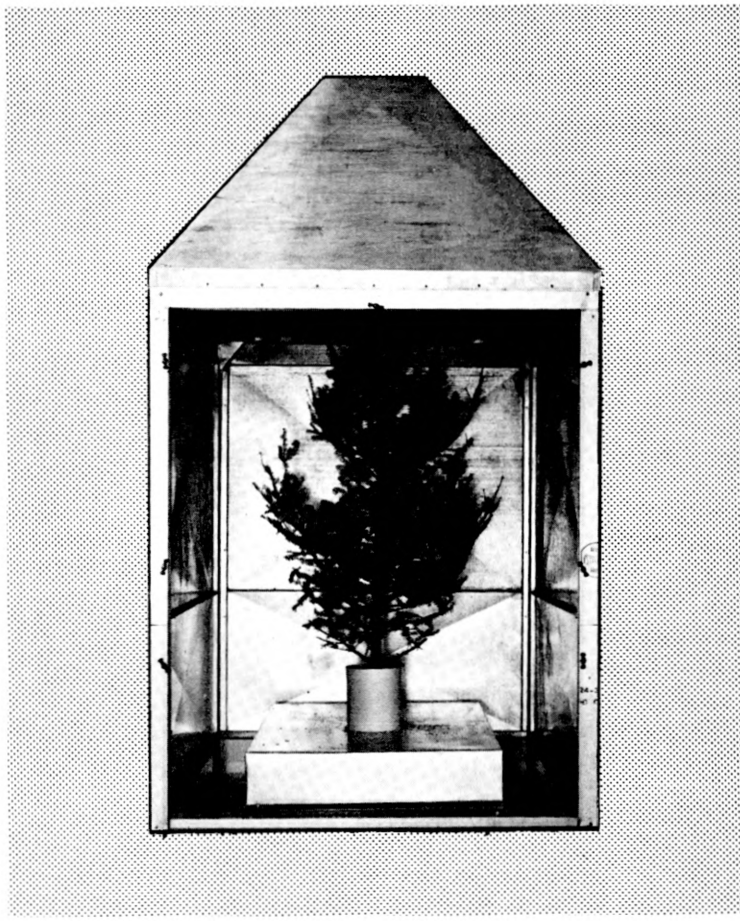


Figure 2. Laboratory flame hood with partly consumed 5-foot balsam fir.

As soon as twigs cut from an individual tree showed signs of sustaining combustion, the tree was tested for flammability 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.

During the flammability 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.

During the two years following the experiment just described, two additional smaller studies were carried out to determine more precisely the limitations of butt immersion as a safety precaution.

The first of these was a more severe flammability test, applied to two spruce, two balsam fir and two Scots pine, all freshly-cut and similar to those described previously. Ten single sheets of newspaper (about $\frac{1}{4}$ pound) were balled and crushed, arranged in a circle 18 inches in diameter around the tree base, and ignited at four points simultaneously. The pattern of crown consumption was observed.

The second additional study was designed to provide more data on indoor drying rates, and to discover the effect of butt immersion on trees of various degrees of dryness. About a dozen trees of each of the three species were cut in November and placed indoors to dry. One after another, at intervals over a 16-day period, they were set in water. Foliage samples for moisture content determination were removed at the time of cutting, at the time of butt immersion, and after one week in water.

One balsam fir was set in water and decorated with two strings of parallel-type indoor Christmas tree lights. After three weeks, matches were applied to the foliage around the light bulbs, and the results observed.

RESULTS

Moisture Content and Drying Rates

The fresh foliage of the three species showed no important moisture changes from early November to early January. The means of the moisture contents of about 25 trees of each species sampled throughout this period were therefore compared directly. These and the other moisture content data described below appear in Table 2.

TABLE 2. FOLIAR MOISTURE CONTENTS AND DRYING RATES UNDER VARIOUS CONDITIONS

—	Basis, No. of trees per species	Moisture content per cent		
		Scots Pine	Balsam fir	White spruce
Freshly-cut trees in late autumn	25	128*	117	114
After unheated storage for 6-1/2 weeks	4	106	101	92
Wet-butt trees after full recovery	9	138*	125*	114*
Lower limit for recovery in water	—	85	75	75
Upper limit for match ignition	—	65	50	50**
Average daily loss indoors when left dry	14	4.1*	6.4	6.2

* Significantly different from other two species at probability level 0.5 or better.

** Indefinite because of needle-drop.

The moisture contents of all wet-butt trees remained above 100 per cent throughout the 3-week indoor test period. All trees in this group except some spruces attained maximum foliar moisture contents higher than their initial values. The stored trees in particular gained water rapidly at first, rising an average of 20.3 per cent in moisture content during the first two days of butt immersion. When fully recovered, there was no apparent difference between stored and fresh trees. The averages in Table 2 include trees from both experiments.

In the original experiment the day-to-day rates of moisture loss for the individual dry-butt trees indoors were nearly constant in the range between 100 and 20 per cent moisture content. After the additional experiments, all drying rate data were pooled, on the assumption that the day-to-day losses in the second set of trees were also equal. A statistically significant difference not found in the original set of only 12 dry-butt trees now showed up: Scots pine dried more slowly than the fir or spruce, whose drying rates were almost identical (see Figure 3).

The unheated storage period of 6½ weeks was equivalent to about 4 or 5 days of indoor drying. Both stored and fresh dry-butt trees dried at the same rate after being set up indoors.

From the later study, it is evident that a critical moisture content exists below which the foliage of the test species will continue to dry when the tree is set in water, but above which the moisture content will increase. In Figure 4 the results are plotted as moisture content after one week of butt immersion over moisture content at time of immersion. Points above the diagonal lines represent trees whose moisture content increased and *vice versa*. The critical moisture contents seem to be about 75 per cent for balsam fir and white spruce and 85 per cent for Scots pine, although some overlap exists in each graph.

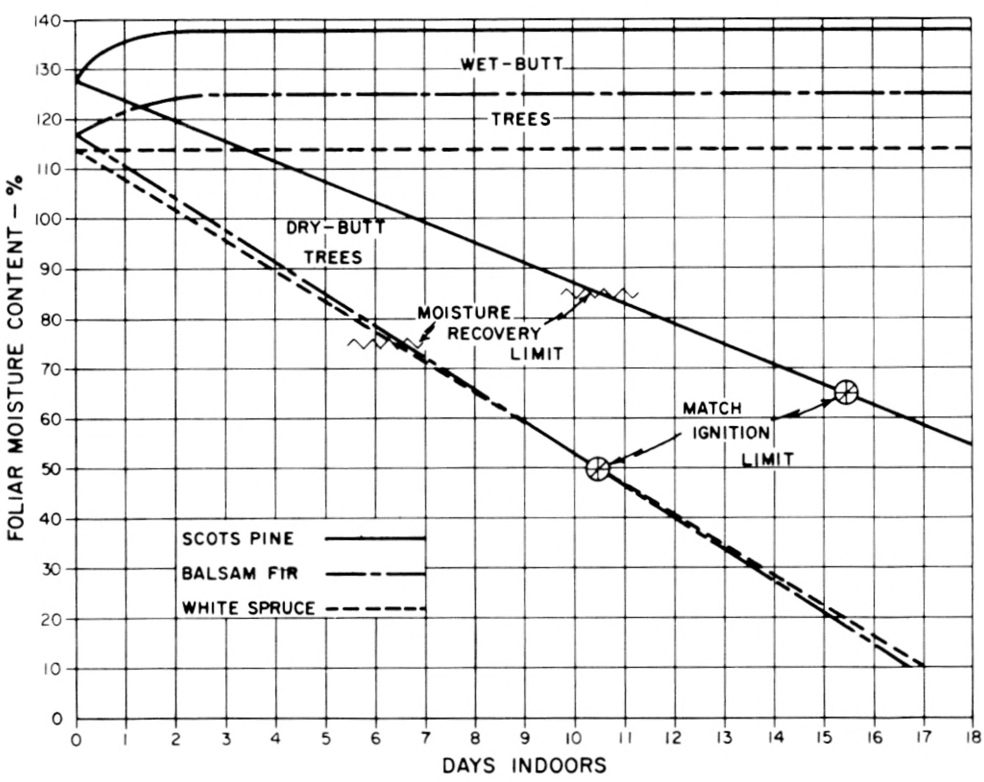


Figure 3. Moisture content of fresh wet-butt trees and fresh dry-butt trees of average drying rate.

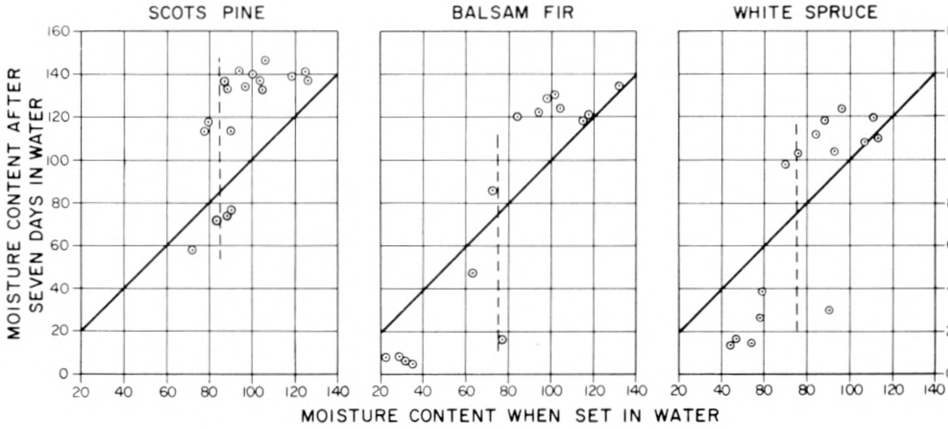


Figure 4. The critical limits for moisture recovery when set in water.

The four calcium-chloride-treated trees absorbed moisture for several days until the initial supply of solution was exhausted. The two treated firs then dried at about half the rate of untreated firs, and the treated pines at about the same rate as untreated pines. The presence of calcium chloride in these trees was demonstrated by comparative chemical tests on treated and untreated foliage. A distinct brown discoloration was evident in the treated trees.

During the last few days of the indoor test a few twigs on some of the stored wet-butt trees died and dried out; otherwise all retained their fresh greenness and shed no foliage while set in water. 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 daily water requirements of a number of 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. Direct evaporation from the containers accounted for about 50 millilitres per day. (One Imperial pint equals 568 millilitres.)

Flammability

Two expressions of flammability 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 flammability. 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 flammable by match ignition at about 65 per cent moisture content and balsam fir at about 50 per cent (see Figure 5). 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. Flammability data for this species are therefore sketchy and the curve for spruce in Figure 5 is included for rough comparison only.

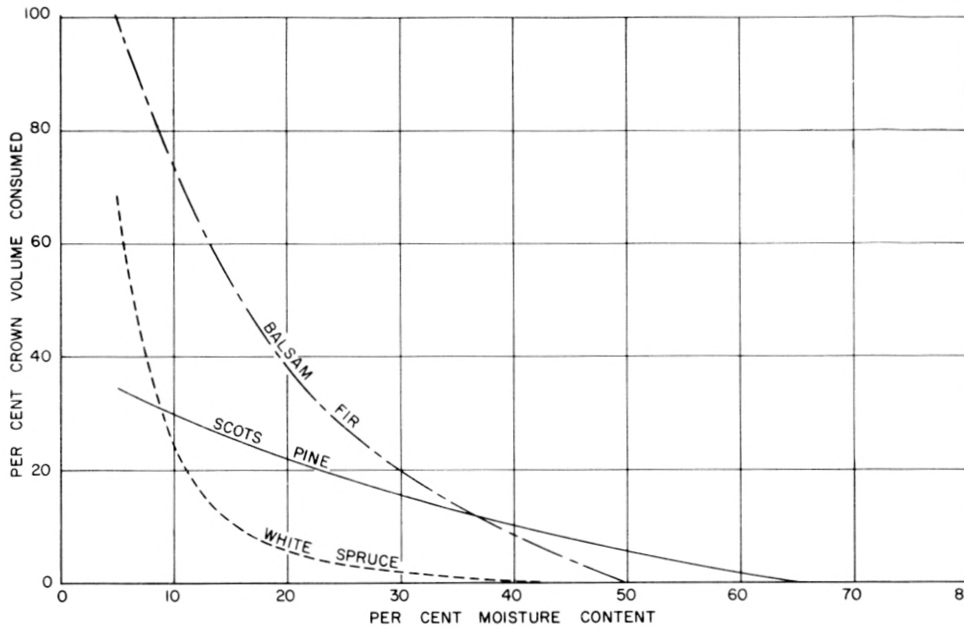


Figure 5. Effects of moisture content on crown volume consumed during match ignition test.

At moisture contents of less than 20 per cent all species were highly flammable. The balsam fir in particular quickly became wholly enveloped in flame. Flame in the Scots pine died out after consuming a V-shaped swathe, 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 flammability. 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 test period, could not be ignited with matches. When the 8-inch Bunsen flame was applied, some foliage burned, but combustion ceased immediately upon removal of the burner. Flame persisted for a few seconds after this treatment in some of the dry-butt trees at moisture contents between 60 and 100 per cent.

The trees subjected to the crushed newspaper flammability test ranged in moisture content from 80 to 150 per cent. Each was mostly or completely consumed, although the flames spread more slowly at higher moisture contents.

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

Around the light bulbs on the decorated wet-butt balsam fir, tiny pockets of dry, dead needles developed where the bulb was in actual contact with the foliage. These pockets of dead foliage flared up when touched with a match, but the flame never advanced into the rest of the crown.

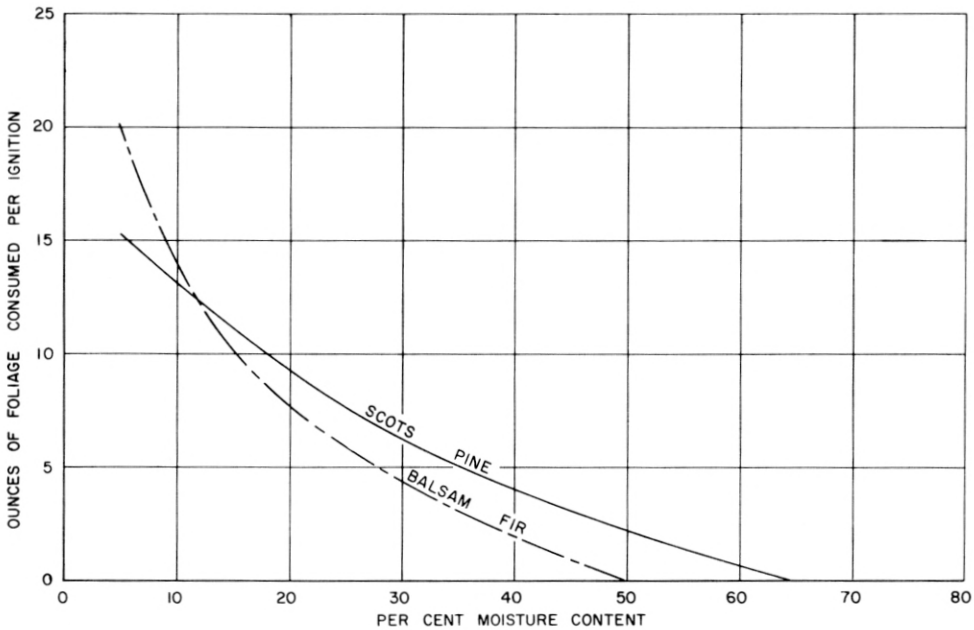


Figure 6. Foliage weight consumed in relation to moisture content during match ignition tests.

DISCUSSION

Trees of all three species were in good condition after 6½ weeks of unheated storage under shelter, which corresponds, for example, 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. Stored white spruce performed well when the butts were immersed, but freshly-cut spruce, when left dry, shed foliage within a week indoors. Stiell (1957) suggested cutting spruce no earlier than December 1. The results of this storage test may not, of course, apply where the storage conditions are greatly different from those used in this experiment. Each mode of storage probably requires a specific test.

The most important result of the experiment was the demonstration that the wet-butt trees of all three species could not be ignited with a point source of heat, even an 8-inch Bunsen flame. The foliage did burn when a match or Bunsen flame was applied, but such combustion ceased immediately when the flame was removed. The more severe test with crushed newspaper, however, showed that the wet-butt trees were not fire-proof, and would not withstand application of heat over a large area of the crown surface. (Crowning forest fires, of course, bear witness to this limitation.) Even when afire, however, the wet-butt trees could be considered less dangerous than dry trees, since flame spread more slowly at higher moisture contents.

Comparisons of fire hazard between dry trees of the different species are complicated by the differences in the type of fire behaviour in each. At extreme dryness, flame spread most quickly in balsam fir. Nevertheless, Scots pine, owing to its greater crown density, produced nearly as much heat per ignition as balsam fir at extreme dryness, and more at intermediate moisture contents. Well-foliated white spruce behaved like balsam fir, but the species was generally the least flammable because of needle-drop.

Dry-butt trees of Scots pine became flammable to match ignition at higher moisture content than fir or spruce, but their higher initial moisture content and slower drying rate kept them safe several days longer. The times required for freshly-cut trees of average initial moisture content and drying rate to reach the match ignition limit indoors were 10 days for balsam fir and white spruce, and 15 days for Scots pine. The fastest-drying third of the trees, however, became flammable in 3 days less. The outdoor storage further cut the required indoor period by 4 or 5 days. Thus some fir or spruce could be ignited with matches after only 3 days of indoor drying, and some pine after 7 days (see Table 3).

TABLE 3. TIME INDOORS FOR TREES LEFT DRY TO REACH MATCH IGNITION LIMIT

Species	Days to reach match ignition limit			
	Average tree		Fastest drying third of trees	
	Fresh	Stored	Fresh	Stored
Scots pine	15	10	12	7
Balsam fir	10	6	7	3
White spruce	10	6	7	3

The critical moisture contents below which the trees would not recover when set in water were fairly well demonstrated, but there is unfortunately no easy way to estimate moisture content. The average purchaser would be unable to tell how many days his tree would remain fairly safe indoors if left dry. By the time needles and twigs become brittle, it is too late for recovery in water.

The calcium chloride treatment reduced the drying rate of balsam fir, thus conferring some degree of protection. The lack of effect on Scots pine was possibly due to its greater weight of 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. Certain salts (e.g. ammonium sulphate) act as fire retardants; others (e.g. calcium chloride) exert a hygroscopic effect which slows drying. The U.S. Forest Products Laboratory (Anon. 1947) concluded that no salt treatment was superior to continuous butt immersion .in plain water. The resultant foliage discoloration would in any case be unacceptable to most people.

CONCLUSIONS AND RECOMMENDATIONS

Since the three eastern species tested in these experiments behaved in a basically similar manner, there is little doubt that the general conclusions and recommendations listed below apply to conifers used as Christmas trees elsewhere in Canada as well.

Christmas trees with their butts immersed in water will remain safe from ignition by a point source of heat for at least three weeks if installed reasonably fresh. On the other hand, 5-foot trees with prior outdoor storage may become flammable to matches within 3 to 8 days indoors if left dry.

Butt immersion also preserves 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 retain their needles well even when dry.

The butt immersion treatment has two limitations which should be stressed along with its effectiveness and simplicity. First, if flame is applied simultaneously all around the base, the tree will burn even at its maximum foliar moisture content. **Second, a tree that has dried below the moisture recovery limit will continue to dry even though standing in water.**

Treatment of the tree with a fire retardant or hygroscopic salt offers no advantage over simply standing the tree in water and is less convenient. A side-effect is unattractive discoloration of the foliage.

When left dry, Scots pine has some advantage over balsam fir and white spruce because it takes several days longer to reach the same degree of flammability. Otherwise the ranking of the three species for fire hazard is not clear-cut. Moreover, if the tree is stood in water, concern about its hazard rating as a dry tree is avoided.

The sensible approach to Christmas tree installation, then, is as follows: Store the tree outdoors in the shade until ready for use. When it is brought indoors, immediately make a diagonal cut removing at least one or two inches of the butt and stand the tree in water. The water must be replenished regularly, sometimes more than a pint a day. If the tree is reasonably fresh to start with, needles and twigs will remain alive and flexible for at least three weeks. If, in addition, the lighting system is in proper order and the base of the tree kept free of combustibles, then the chances of a Christmas tree fire are infinitesimal.

SUMMARY

A series of experiments was performed with 5-foot Scots pine, balsam fir and white spruce to determine both their flammability as Christmas trees and the degree of protection afforded by standing the tree in water. The general conclusion was that flammability depends mainly on the moisture content of the foliage and to a lesser extent on the crown density. Some specific conclusions are:

1. Below about 50 per cent foliar moisture content, Christmas trees ignite readily from matches, and at less than 20 per cent they burn with great violence.

2. Trees standing in water maintain moisture contents over 100 per cent, and cannot be ignited with matches or Bunsen gas flame (i.e., a point source of heat).

3. No matter how high the foliar moisture content, however, flames in a ring at the base of the tree (e.g., from Christmas parcel wrappings) do ignite the crown, although combustion is slower at high moisture content.

4. Trees stored for reasonable periods recover and maintain high foliar moisture contents when set in water; if however, moisture content is allowed to fall below 75-85 per cent, they continue to dry out even if the butt is then immersed in water.

5. If left to dry, Scots pine has some advantage over balsam fir or white spruce in its slower drying rate; a pine with a history of prior storage may nevertheless reach the match ignition limit within several days indoors.

The recommendation to stand the Christmas tree in water, made by all fire authorities, is thus soundly based.

SOMMAIRE

Une série d'expériences effectuées à l'aide de pins sylvestres, de sapins baumiers et d'épinettes blanches de 5 pieds de hauteur ont permis de déterminer leur inflammabilité lorsqu'ils servent d'arbres de Noël, et aussi le degré de sécurité qu'offre l'immersion de leur pied dans l'eau. On est arrivé à la conclusion générale que l'inflammabilité dépend principalement de la teneur en humidité du feuillage, et, à un degré moindre, de la densité du houppier. Voici les principales conclusions auxquelles on est arrivé:

1. Lorsque la teneur en humidité du feuillage est au-dessous de 50 pour cent, on peut facilement y mettre le feu au moyen d'allumettes, et à moins de 20 pour cent, il brûle avec rage.

2. Les arbres dont le pied est immergé dans l'eau, conservent leur teneur en humidité à 100 pour cent et ne prennent pas feu au contact de la flamme d'une allumette ou de celle d'un brûleur de Bunsen (source initiale de chaleur).

3. Si élevée que puisse être la teneur en humidité du feuillage, un cercle de flamme sous le houppier de l'arbre, par exemple le papier d'emballage de cadeaux de Noël en flammes, met le houppier en feu; toutefois, l'allure de combustion est plus lente lorsque la teneur en humidité est élevée.

4. Les arbres entreposés pendant une période raisonnablement brève peuvent encore absorber de l'eau et la teneur en humidité de leur feuillage reste élevée; néanmoins, si la teneur en humidité des arbres s'abaisse à moins de 75 ou 85 pour cent, ils continuent à se dessécher, même si leur pied est immergé dans l'eau.

5. Même desséché, le pin sylvestre offre certains avantages que n'offrent ni le sapin baumier ni l'épinette blanche, parce qu'il se dessèche plus lentement; le pin qui a été entreposé, peut néanmoins être mis en feu à l'aide d'une allumette, quelques jours après son installation à l'intérieur le pied à sec.

La recommandation, faite par tous les services d'incendie, de placer le pied de l'arbre de Noël dans l'eau est donc profondément judicieuse.

REFERENCES

ANON. 1947. Treating spruce and balsam fir Christmas trees to reduce fire hazard. U.S. For. Serv., For. Prod. Lab., Tech. Note 250.

——— 1957. Christmas fire safety. Canada Dept. of Public Works, Office of the Dominion Fire Commissioner, Tech. Information Bull. No. 4.

HAWBOLDT, L. S. 1953. Christmas trees are a crop. N.S. Dept. of Lands and Forests, Bull. No. 11.

LEATHERMAN, M. 1938. Lessening the Christmas tree fire hazard. U.S.D.A. Bureau of Chemistry and Soils, Naval Stores Div.

——— 1939. Fireproofing Christmas trees. U.S.D.A. Leaflet No. 193.

STIELL, W. M. 1957. Christmas tree growing in Canada. Canada Dept. of N.A. and N.R., For. Br., Misc. Pub. No. 7.

TRYON, G. H. 1962. Christmas trees and decorations. National Fire Protection Association Quarterly. October, 1962.