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**OCCURRENCE AND EFFECTS OF SUMMER FROST
IN A CONIFER PLANTATION**

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Occurrence and Effects of Summer Frost in a Conifer Plantation

by

René Pomerleau¹ and R. G. Ray²

Introduction

During the month of September, 1946, a large number of red pine trees (*Pinus resinosa* Ait.) in the extensive plantation of the Valcartier Forest Experiment Station were reported dead or in various stages of deterioration. In view of the importance of the damage, it was agreed that an investigation should be made of this problem.

Ever since white pine (*Pinus strobus* L.) has lost favour for reforestation in pure stands in Eastern Canada, because of its susceptibility to blister rust (*Cronartium ribicola* Fisher) and weevil (*Pisodes strobi* Peck) depredation, red pine has become the more popular of the two species. Except for occasional infestations by the red-headed pine sawfly (*Neodiprion lecontei* Fitch) and the European pine shoot moth (*Rhyacionia buoliana* Schiff.), this species has no very common insect enemy. Among parasitic plants only minor attacks by a needle rust (*Coleosporium solidaginis* (Schw.) Thüm.), a few fungi causing needle cast (*Hypoderma desmazierii* Duby, and *Lophodermium pinastri* (Schröd.) Chev.), and a weak parasite (*Pullularia pullulans* (de Bary) Berkshaw) were reported on red pine in Eastern Canada. Therefore, any pathological conditions which may occur on this species deserve close attention.

Extent of Damage

Located at the Valcartier Forest Experiment Station, 20 miles northwest of Quebec City, the plantation was set out between 1933 and 1936 on abandoned farm land. Some 750,000 trees were planted during these years and a few thousand more up to the year 1940, making a total of 762,000 trees on an area of 493 acres. Of this number, 302,000 were white pine, 290,000 red pine, 5,000 Scots pine, 1,000 lodgepole pine, 161,000 white, red, black, and Norway spruce, and 3,000 hardwood trees.

In 1945, after four years without observation, a remarkable change was noticed in the plantation. In some places, all the red pine were dead and in others they were more or less decimated. This high mortality rate is corroborated by examinations of sample plots in 1935, 1939, 1946, and 1954-55 as summarized in Table I. While an average of 28 per cent of the red pine planted on 28 plots were dead in 1939, the average mortality was 93 per cent in 1946 and 95 per cent in 1955. In individual plots the mortality varied between 50 and 100 per cent in 1946 and in 1955.

In white pine plots the mortality was considerably less, as shown in Table II. The average killing in all plots was 40 per cent in 1946 and 50 per cent in 1955; in individual plots it varied from 12 to 56 per cent in 1946 and 34 to 77 per cent in 1955.

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TABLE I.—SURVEY OF MORTALITY IN RED PINE

Year Planted	No. of Plots	Number of Trees Planted	Average Mortality (per cent)			
			1935	1939	1946	1954 and 1955
1934.....	6	6,602	13	24	89	91
1934.....	21	2,436	12	28	91	98
1936.....	1	490	—	33	96	98
Total.....	28	9,528	Average 12	28	93	95

From the above data, it can be deduced that up to the year 1946, more than 200,000 red pine died in a plantation of 290,000 trees. Although the loss in white pine was much lower than in red pine, part of the mortality at least could be attributed to the same factor which caused the extensive dying in the latter species. These records (Tables I and II) indicate also that most of the damage occurred between 1940 and 1946.

TABLE II.—SURVEY OF MORTALITY IN WHITE PINE

Year Planted	No. of Plots	Number of Trees Planted	Average Mortality (per cent)			
			1935	1939	1946	1954 and 1955
1933.....	3	3,855	30	34	50	71
1933.....	4	452	19	26	38	55
1934.....	5	6,115	8	12	38	63
1935.....	4	2,492	—	17	30	47
1935.....	6	677	—	—	33	55
Total.....	22	15,074	Average 19	22	40	50

Symptoms

When trees in this plantation were examined in 1946 and 1947, typical examples of all phases of the injury were easily seen. This was no longer possible a few years later, when the trees were either dead or the branches were defoliated. The most obvious change on injured red pine was the reddish-brown colour of the needles and, often, of the entire shoot. A year or two following their death, the needles turned greyish and finally hung on the shoot before falling off. In the year following the death of the foliage, shiny black fungous fruit-bodies burst through the epidermis.

In the present case, the distribution of the dead needles seemed most significant. Usually, when examined not later than a year or two following the damage, all the needles of the last shoots of a branch are seen to be discoloured and dead, while those on the previous year's growth and even two years back are still living. When all the needles of terminal shoots of a branch are killed these shoots die back to the previous season's growth, and a year or two later the entire branch dies.

Another interesting observation upon the disease is the clear-cut line of demarcation of the injury on the needles of a shoot. In numerous cases, needles on the lower side of a horizontal shoot were found dead whereas those on the upper side were normal. Sometimes only a portion of the length of the needles on the lower side bore trace of the injury while the rest of the shoot was still healthy. On most trees examined in 1946 and 1947 the killed shoots appeared to have attained their full length for the season.

Certainly the most peculiar feature about this damage was the regularity of the killing of terminal shoots of the lower branches. All the lower branches up to three, four, or five feet on living red pine bore dead terminal shoots and later were completely defoliated (Figure 1). Symptoms never appeared on isolated branches only. The demarcation between the living foliage and dead branches of all trees in the group forms a straight horizontal line (Figure 2). Among the trees with dead lower branches, many of the smaller trees had been killed. Sometimes, only small clusters of living branches with green needles were found. In a few areas, especially in ground depressions, all the red pine trees were dead (Figure 3).



Figure 1.—Red pine in the Valcartier plantation showing only small clusters of living branches after summer freezing.



Figure 2.—Straight horizontal line formed by the killing of lower branches in the red pine plantation on the plain at Valcartier.



Figure 3.—General view of a ground depression in the Valcartier plantation showing complete killing of red pine.

Cause of the Injury

All possible agents which may have induced such injury were carefully examined in 1946 and after. The responsibility for the damage could not be attributed to an insect or a disease-causing organism, in spite of close observations. Moreover, it cannot be explained how a fungus, an insect, or any other pathogen could have attacked all the needles of branches up to a height of 3 to 5 feet above the ground and left the rest unscathed.

Accidental factors, such as ground fire and shelling in this artillery testing area, were also eliminated as the cause of the injury after close examination of the ground and vegetation. Edaphic factors, such as high soil temperature, drought, and soil mineral deficiencies could, however, have brought about a somewhat similar disorder. The ground moisture is likely to be rather low during hot dry weather and the coarse sandy soil of the plain is definitely poor. But even if these conditions may reduce the growth and cause the death of some seedlings, none of these factors can entirely explain the extensive dying which occurred in the plantation. The strongest argument against edaphic factors is that when tree tops above a certain level remain green, they survive and most of them grow well thereafter. Also, neither mineral deficiencies nor drought can account for the new shoots dying only on the lower branches of such a large number of trees. Therefore, elimination of all these factors leaves only one field to the explored, namely the climatic factors.

The symptoms, as described above, particularly the dying of the new shoots and needles up to a consistent level, suggested the effects of frost. In fact, the regularity of the killing of branches on the lower part of red pine up to 3 or 4 feet from the ground (Figure 2) was a good indication of the effect of frost on the tender current needles and shoots. This was corroborated by differences in the rate of mortality depending upon the ground topography. Further, the damage did not occur every year. Such microclimatic behaviour was important enough to justify a study of its effects.

Susceptibility to Frost of Some Tree Species

Tree species are known to vary in hardiness, and their order of susceptibility to frost has been noted (3). Differences in resistance to cold were sometimes detected within provenances or races of the same species (1). But apparently very little is known about the sensitivity of different tree species to summer frost. The damage therefore provided an opportunity to list some species according to their susceptibility during the growing period. Besides red pine and white pine, which form the greatest part of the plantation, Scots pine, lodgepole pine, Norway spruce, white spruce, black spruce, and red spruce were planted, and natural reproduction of balsam fir, black spruce, white spruce, grey birch, white birch, aspen, elm, and maple also occurs in the plantation.

Red pine is no doubt the most vulnerable species. Symptoms to that effect were most obvious in 1946 and the following year. This species also suffered much greater loss than any other; in fact, on the plains none of the red pine escaped frost injury, at least on the lower branches.

White pine appears to be less susceptible to summer frost, although similar effects were noticed on the lowest branches in some areas. However, under more severe conditions in depressions, many white pine trees were also killed. A large number of white pine died from other causes, mainly blister rust.

Scots pine appears to be resistant, at least in the area where it was planted. This species, listed as frost-resistant in Europe (2, 3), has shown here only slight damage on lower branches up to about one foot above ground-level. Since no Scots pine were planted in depressions, it was impossible to know how it would have behaved under such conditions.

The few Norway spruce planted have not done well. A number of trees were dead or stunted and bushy in form. Frost injury was noted on new growth of trees still alive in 1946 and 1947. This peculiar conical and compact form in conifers is often the result of repeated "unseasonable frosts" (6).

Natural growth of balsam fir, white spruce, red spruce, and black spruce also showed signs of frost injury. In small depressions, those trees that succeeded in growing beyond a certain level were usually stripped of foliage at their base, or at least the length of branches was restricted. Birch and aspen which grow naturally on the plain did not show such obvious signs of frost injury, but very few were growing under the worst conditions in depressions. It should be added that the action of repeated frost is visible on the ground vegetation such as spirea, goldenrod, and moss, particularly in small depressions.

Microclimatic Data

The phenomenon known as the "frost pocket" has been noticed and studied in both Europe and North America (4, 8). It is described as an area where a layer of cold air resulting from intense radiation or temperature inversion accumulates near the surface of the ground during clear summer nights. However, the cooling of the ground surface and the adjacent layer of air by outward radiation is modified by air turbulence, drainage, humidity, type of vegetation, and topography. On the other hand, Geiger (4) states that local damaging frost is intensified by the following conditions: clear sky, dry air, absence of wind, poor heat conductivity of the earth, strong evaporation, local advection of cold air, and lack of natural protection. At the Valcartier Station, a wide sandy plain bordered by hills provides the ideal physiographic conditions for summer frosts.

To demonstrate this fact, minimum thermometers were placed at four points or stations and at various levels above ground without shelter. These instruments were installed during the spring of 1947 and replaced at the same points in 1948 and 1949. Readings were taken every two or three days; and at headquarters, some two miles away, data were recorded daily from thermometers in a shelter. Records of summer minimum temperatures are available for 1947, 1948, and 1949.

From the selected data presented in Table III, for days when the temperature was below 32°F. at any one of the stations, there is ample evidence of frequent frost in this area during the summer. For instance, when the minimum temperature is well above 32°F. in June and July at headquarters, it may drop to as low as 20°F. at the one-foot level above ground in one depression, and at the same time be at 21°F. at one foot above ground on the plains (June 23, 1948). Other examples of temperature behaviour (July 8, 1948; July 6, 1949; July 11, 1949) taken from these records all show similar differences from station to station. The existence of a typical frost area is therefore sufficiently well established.

There can be little doubt that summer freezing is the cause of extensive injury in red pine and other tree species in this plantation. The conditions under which the damage occurred are further discussed.

As mentioned before, the plain of Valcartier, bordered by hills and largely devoid of forest cover, offers ideal conditions for this microclimatic phenomenon. During clear and still summer nights the cold air flowing down the surrounding slopes and accumulating in the plain from which it cannot easily escape forms into a lake over the ground, except where broken up by forest cover. The temperature drops still lower and the layer of cold air is thicker in the occasional ground depressions or troughs which also exist. Evidence of this stratification appears in the temperature records and in the almost straight line formed by

the junction of the dead and living foliage. For the same reason, small trees with little or no foliage above the cold layer were killed, whereas fast-growing ones with longer crowns survived.

TABLE III.—MINIMUM TEMPERATURES IN FOUR STATIONS FOR NIGHTS WHEN FROST WAS RECORDED

Date	Station 1*	Station 2	Station 3			Station 4					
	1	2 3	4	5	6	7	8	9	10	11	12
1947											
June 13.....	33	29 30	24	26	28						
July 4.....	42	33 34	30	30	34						
August 29.....	43	30 30	26	26	30						
September 3.....	49	25 29	24	26	28	24	27	25	27	22	22
1948											
June 16.....	32	28 33	25	26	29	25	25	21	24	18	20
June 18.....	31	27 33	25	25	28	31	31	28	32	25	27
June 21.....	40	28 35	23	23	27	28	28	25	27	20	22
June 23.....	37	32 41	25	25	29	27	27	25	27	21	23
July 4.....	49	33 29	30	30	34	34	34	30	33	28	30
July 8.....	38	32 39	28	28	32	30	31	29	31	27	29
July 10.....	45	36 45	34	34	38	37	38	35	37	27	34
September 1.....	39	33 31	29	29	33	31	30	27	31	26	27
1949											
June 24.....	41	36 27	28	28	32	32	33	30	32	27	29
July 6.....	40	21 34	30	32	34	29	30	27	29	22	25
July 8.....	43	22 36	28	28	32	32	32	30	33	26	31
July 11.....	44	34 37	32	34	32	31	32	29	31	27	29
July 22.....	47	34 38	34	34	37	33	35	34	35	29	31
August 17.....	42	28 29	30	30	31	30	31	28	30	27	32
August 19.....	45	30 34	30	32	34	35	42	32	35	28	32
August 24.....	41	— 28	30	30	31	25	27	23	25	19	21
August 27.....	44	— 28	24	24	25	25	27	25	27	22	24
September 9.....	32	— 19	24	24	26	26	27	23	25	19	21

- Station 1—Weather station at headquarters.
“ 2—Along a slope near headquarters: (2) foot of hill; (3) top of hill
“ 3—In the plantation: (4) 1 foot above ground; (5) 3 feet; (6) 6 feet.
“ 4—In ground depression: (7) top of slope, 1 foot; (8) 3 feet; (9) middle of hill, 1 foot; (10) 3 feet; (11) foot of hill, 1 foot; (12) 3 feet.

* Readings were taken every 2 or 3 days in stations 2, 3 and 4, and daily at headquarters; therefore a reading in station 1 is that of the minimum of the 2 or 3 previous days.

Another important aspect is the frequency of killing frosts and their intensity in this area. It would appear that such conditions occur only occasionally. Otherwise the young trees would have been killed soon after planting. This was not the case since most trees, even in ground depressions, have grown for some years before they were killed; and on the flat a good number of them were not injured at the base until about ten years after planting.

In order to cause severe damage to trees, the low temperatures must occur during the period between the bud opening and the hardening of shoots and needles. At Valcartier it was noted that red pine buds opened about June 15 in 1947 and by July 21 the new shoots had grown about 2 inches in length. By July 24 the new shoots had not yet reached their final growth but on August 5, the growth of the needles was almost complete. Therefore, late frost occurring before June would not likely cause injury. This would mean that only when a layer of cold air is formed in late June or in July, or possibly in early August, is important damage to young trees to be expected.

Although temperatures below 28°F. were recorded during July at one station or another each year from 1947 to 1949, it is not certain that they occurred every year during the critical period. Many reasons may be given to explain this irregularity. Aside from the many conditions which must all coincide to produce the accumulation of the cold layer of air, the vegetation itself may influence this process, as noted by many authors (4, 7, 6). Potzger (7) stated that the very presence of plants means modification of the purely climatic conditions. Geiger (4) reports: "F. Innerebner has shown that a cold air lake can form even on a slightly inclined plateau, especially at those places where the air is hindered in its flow by apparently insignificant obstacles". In other words, a certain early stage in growth of planted trees and natural vegetation could even increase the danger of frost by preventing air movement. On the other hand, as the forest increases in density and height and forms a canopy, the cooling due to night radiation is lessened and therefore the danger from frost is much reduced.

It has been demonstrated that in meadows with grass, temperature falls lower than on bare soil (4). Plants have a braking effect on the movement of air and "will create a deep layer of cold air able to cause frost injury", according to Day and Peace (3).

It seems therefore quite probable that the sparse natural tree growth, low ground vegetation, and the small planted trees at Valcartier helped to stabilize the air on the plain and favoured, at least for the first 15 years, the formation of a lake of cold air. However, even when the vegetation had reached the stage of development most likely to encourage summer freezing, this occurred only when the general atmospheric conditions were propitious. Like damaging late and early frosts, summerfreezing does not necessarily occur every year.

Effects of Frost on Red Pine

Through the clinical diagnosis of the injury and the study of the temperature records, it has been well established that the Valcartier plain is a typical frost area. However, since interest in the case was greater than merely finding the cause of the extensive damage, the opportunity was taken to study the effect of such conditions on the trees. For this purpose seven sample plots were established in representative areas on the plains. On each of these plots, about 100 red pines were tagged and tallied in 1946 and re-examined in each of the three consecutive years.

This study, summarized in Table IV, indicates that out of 573 living trees tagged in 1946, 121 died in the course of the three subsequent years. In 1947, 197

TABLE IV.—EFFECTS OF SUMMER FROSTS ON RED PINE AT THE VALCARTIER PLANTATION

(573 trees in 6 sample plots)

Years of observation	Average height (feet)	Average length of leader (inches)	Number of dead trees	Number of poor-growing trees
1946.....	7.10	12.9	0	59
1947.....	7.43	8.2	65	197
1948.....	7.79	6.9	93	196
1949.....	8.09	9.3	121	149

trees were badly affected, but 48 of them have subsequently recovered. Reduction in vigour is shown by the average length of the leader and the number of poor trees. From 1946 to 1948, a general decrease in growth of leaders occurred in all plots. In 1949, however, recovery took place in every plot.

To complete the information about the killing effect of summer frost upon parts of the foliage of red pine, the internode length of a number of trees was measured on three sample plots. The average growth in length for each year in the observed trees is given in Table V. For the first group of 24 trees the internode length, after a gradual increase up to 1940, quite suddenly decreased until 1945. Approximately the same tendency can be found in the second sample plot. However, in sample plot No. 3, located on a different site, the decline began only after 1945.

Such data indicate, for most of the survivors, that, due to the loss of their lower branches, the growth of the leader has declined after the occurrence of summer frosts and it has regained vigour with the gradual building up of new foliage above the cold air. The examination of a large number of trees has already shown that the growth of 1945 was severely injured and that the growth of 1943 also suffered. Data from two sample plots indicate also that during the summers of 1940 and 1941 the same conditions had prevailed and initiated this decline.

TABLE V.—MEAN ANNUAL GROWTH IN INTERNODE LENGTH IN INCHES

Year	Sample plot No. 1 (24 trees)	Sample plot No. 2 (22 trees)	Sample plot No. 3 (40 trees)
1934.....	5.	3.2 ± 1.2*	
1935.....	3.7 ± 1.2*	3.4 ± 0.79	
1936.....	4.3 ± 1.1	6.6 ± 1.4	2.7
1937.....	7.5 ± 1.5	9.6 ± 1.4	4.8 ± .64*
1938.....	9.4 ± 1.1	11.3 ± 2.8	6.4 ± .95
1939.....	8.8 ± 1.2	9.9 ± 1.3	7.3 ± .70
1940.....	10.5 ± 1.9	10.8 ± 1.3	8.6 ± .79
1941.....	10.5 ± 2.3	9.9 ± 1.5	8.7 ± 1.3
1942.....	9.08 ± 1.3	7.3 ± 1.3	8.8 ± 1.1
1943.....	8.3 ± 1.5	5.6 ± 1.3	10.8 ± 1.3
1944.....	4.9 ± 1.2	4.09 ± 1.4	9.8 ± 1.3
1945.....	4.7 ± 1.4	7.8 ± 2.1	11.1 ± 1.3
1946.....	6.7 ± 1.9	9.04 ± 2.3	10.7 ± 1.6
1947.....	6.6 ± 1.7	9.8 ± 1.9	8.05 ± 1.8
1948.....	5.9 ± 1.3	7.9 ± 1.6	6.9 ± 2.9
1949.....	8.7 ± 1.6	10.7 ± 2.3	8.7 ± 1.6

* Standard Error $\times t \cdot 01$

The behaviour of affected trees indicates clearly that a sudden killing of the foliage causes a reduction in the growth of the tree. When a tree is small and completely covered by the cold layer of air in summer, all the needles and shoots of the current season are killed and usually the tree dies after a year or two when the older foliage ceases to be active. On the other hand, taller trees escape death because a larger part of their foliage is above the cold layer. If too large a proportion of the foliage is injured, the vitality may be reduced to a point where recovery is impossible.

Action of Cold in Ground Depressions

One of the best indications of the existence of summer frost in the Valcartier area was the heavy killing which occurred in ground depressions or pockets (Figure 3). This fact was particularly evident in two areas of the

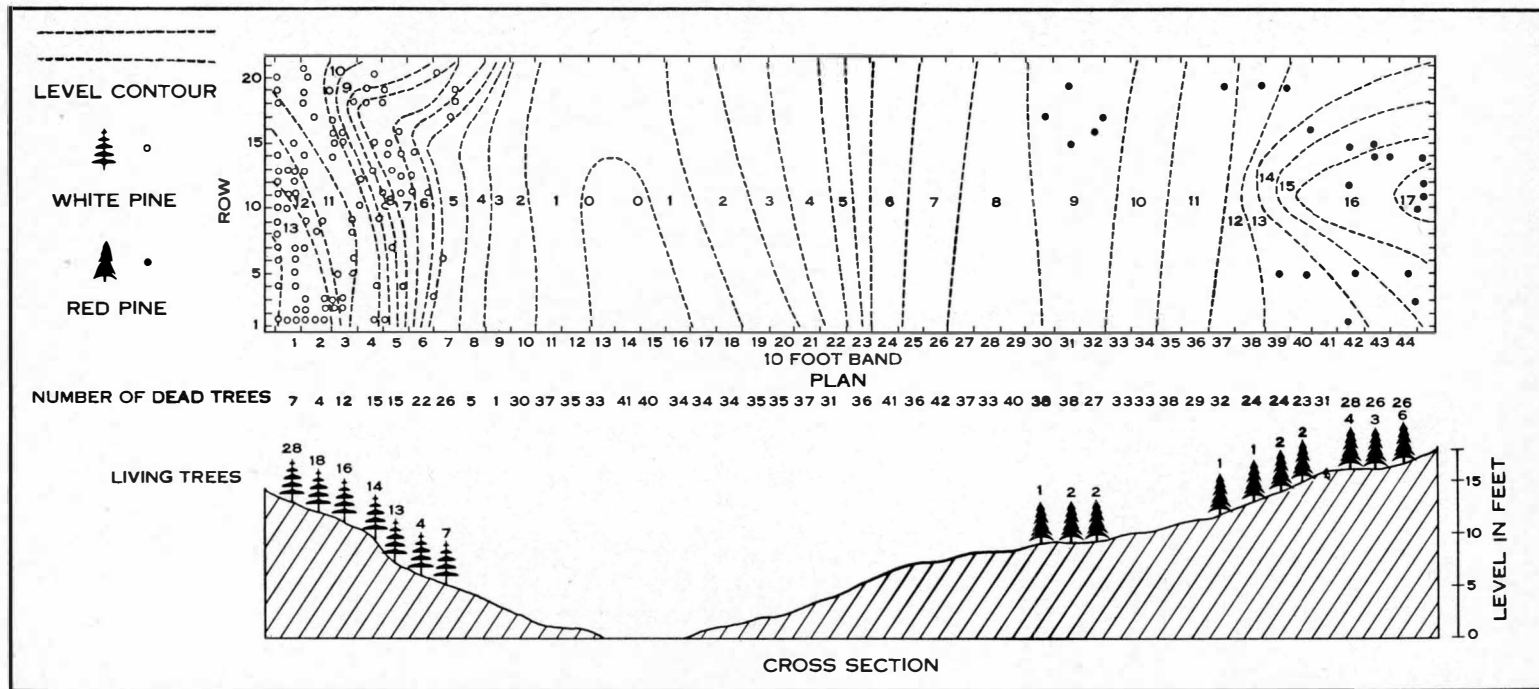


Figure 4.—Contour plan and topographical cut of a ground depression in the Valcartier plantation, showing the location and number of living white pine and red pine remaining after summer freezing.

plantation where troughs cut across the plain. During the autumn of 1947 a sample plot was laid out in each of these localities comprising 20 rows of planted trees and divided into strips 10 feet wide across the rows. Ground level contours were surveyed and plotted for both areas. The numbers of living white and red pine trees in these plots are shown in Figures 4 and 5 in relation to the elevation above the lowest point in each area.

In the first plot, 440 feet long, the difference in level was as much as 17 feet. White pine planted on one side appeared to be fairly resistant to cold, although the number of killed trees increased on the lower levels. All of the red pines planted in the bottom of the depression up to the 9-foot level were dead at the time of the survey. Above this elevation, on the other side of the depression, an increasing number of trees have survived. Judging from the length and number of internodes and dead trees in this low point, frost damage occurred there before it occurred on the plots above. In the second plot, while pines on the bottom were also largely eliminated by frost, the number of survivors at the lower levels was far less than at the higher levels on each side of the depression.

Action of Frost on Red Pine Planted in 1947

By the time frost injury was first noticed at Valcartier, most of the damage had been done. In order to demonstrate experimentally the effect of this peculiar climatic condition on trees of different provenance, a number of red pine were again planted at different localities on the station in the spring of 1947.

The trees, supplied by the Berthierville Provincial Tree Nursery, and grown from seed collected in Quebec and New York State, were about one foot high and six years old, and they were in excellent condition when planted. Results are recorded in Table VI.

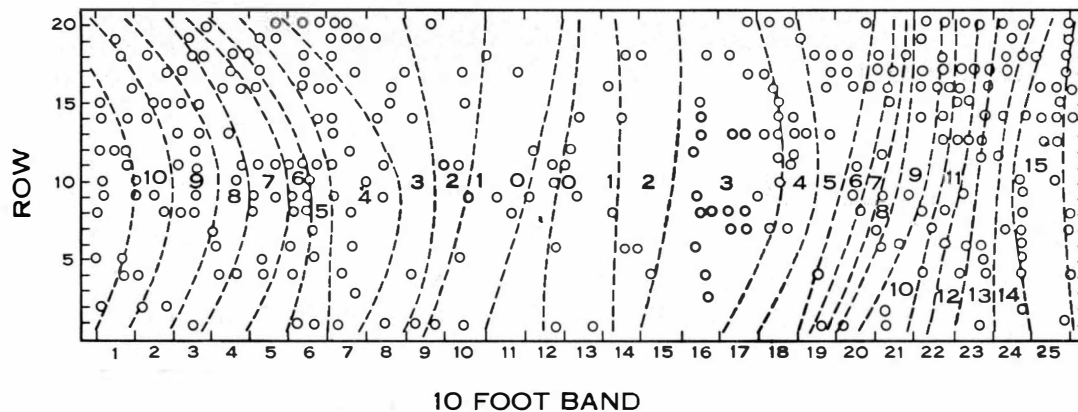
TABLE VI.—NUMBER OF RED PINES PLANTED IN 1947 AND FROST-KILLED IN THE FOLLOWING YEARS

Location	No. of trees planted	Number of dead trees in			
		1947	1948	1949	1950
Steep slope.....	141	4	14	26	26
Hardwood forest.....	25	1	1	1	1
Flat area.....	27	0	27	27	27
Flat area.....	28	1	27	28	28
Depression.....	112	4	25	73	112
Total.....	333	10	94	155	194

On the steep slope near headquarters many of these trees died from frost, mostly at the base of the hill, and a few others succumbed from other causes. Twenty-five trees planted on a low flat under a moderate birch cover escaped summer frosts. In the open flat area and in the depression all these recently planted trees were killed during the three years following. When referring to Table II showing temperature data during these years, it is not surprising to see that small trees could not survive long when immersed occasionally during the growing period in the cold air of this frost pocket.

LEVEL
CONTOUR

WHITE PINE



NUMBER OF
DEAD TREES

6 2 7 11 12 11 12 27 28 30 26 23 31 33 28 24 28 21 23 9 14 14 11 15 15

LIVING TREES

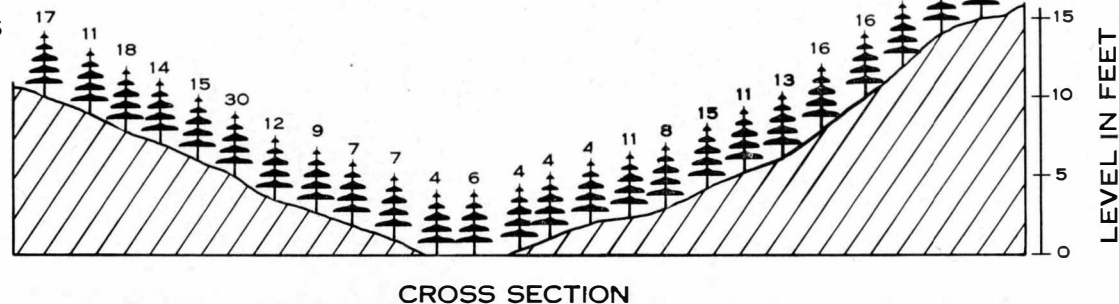


Figure 5.—Contour plan and topographical cut of a ground depression in the Valcartier plantation showing the location and number of living white pine remaining after summer freezing.

Summary and Conclusions

The injury reported at Valcartier on red pine and a few other species is typical, and it leads to various interpretations regarding its origin. Therefore, it was most important to evaluate all surrounding influences, as well as micro-organisms and insects, before assuming that one factor was responsible. It was particularly important to determine the true cause of this extensive damage in the red pine plantation since this tree species is presently popular for reforestation on sandy soil. If a parasite or an insect was capable of inflicting such an injury in so short a period, the whole program of red pine reforestation in Eastern Canada would be jeopardized. Outside of the intrinsic interest, it was desirable to clarify this problem for the sake of the future of this species as a tree for plantations. The example of destruction of white pine plantations by blister rust is still present in the memory of those who, some years ago, placed so much confidence in that valuable tree.

By clinical diagnosis, based on the symptoms and the physiography of the ground, and by microclimatological study, the primary cause of the extensive killing of red pine and, to a lesser extent, of white pine, was attributed to summer frosts. Such a condition occurs occasionally in this area during summer months when the current needles and shoots are still tender. During clear nights a layer of cold air a few feet thick spreads over flat areas and accumulates in small depressions of the plains. When this occurs in July and August the effects are disastrous.

After trees have been planted in a frost pocket, it is too late to apply control measures and it is out of the question to avoid the effects of night radiation by smoke over so large an area, as is often done in fruit orchards. Before planting with susceptible conifers some information on the prevailing microclimate should first be obtained, in order to avoid extensive losses such as those reported here.

It has been suggested also that forest cover minimizes the effects of soil heat radiation. Therefore, the correction of this peculiar condition may gradually take place as a result of natural reforestation and the planting of trees of fast-growing species. This forest cover will serve more and more effectively as a screen to reduce the cooling from night radiation and to prevent damaging frost.

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