LOW TEMPERATURE AS IT AFFECTS THE SELECTION OF WOODY ORNAMENTALS IN BRITISH COLUMBIA

by

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ABSTRACT

LOW TEMPERATURE AS IT AFFECTS THE SELECTION OF WOODY ORNAMENTALS IN BRITISH COLUMBIA: by Hubert L. J. Rhodes

Low winter temperature was taken as the most important factor influencing the selection of ornamental trees and shrubs for different areas of British Columbia. The locality around a meteorological station was made the unit of investigation, with the meteorological station as a reference point. Average extreme lowest temperature of the year for each British Columbia meteorological station was calculated from figures compiled for the ten year period 1940-49.

Certain methods were used to interpret low temperature information in an original way: the use of the winter rather than the calendar year as the unit in considering low temperature, the application of statistical analysis to express variation in low temperature between winters, and the conversion of statistical estimates to temperatures corresponding to a convenient probability ratio easily understood by practical workers. Average extreme lowest temperature of the winter based on the ten-winter period from 1940-41 to 1949-50, standard deviation, and the ninety percent point were calculated for selected B. C. meteorological stations.

ABSTRACT - Cont.

The ninety percent point is that temperature above which the extreme lowest temperature of a station will fall in approximately nine out of ten winters, and below which the extreme lowest temperature will fall in approximately one out of ten winters, according to mathematical expectancy based on statistical analysis of temperatures observed over a period of winters. This concept combines the information to be obtained from the average extreme lowest temperature and the standard deviation. The ninety percent point is found by subtracting the standard deviation multiplied by 1.3 from the average extreme lowest temperature of the winter.

A survey was conducted to obtain an estimate of the injury to ornamental trees and shrubs in British Columbia following two severe winters. The information was used to test the usefulness of low temperature data as a guide in selecting woody ornamentals for hardiness in a locality, and to get accurate low temperature limits in the Pacific coastal region for a number of ornamental species. Low temperature information was found useful within limitations as an indication of the amount of winter injury to woody ornamentals to be expected in a locality of British Columbia after a severe winter.

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LOW TEMPERATURE AS IT AFFECTS THE SELECTION OF WOODY ORNAMENTALS IN BRITISH COLUMBIA

INTRODUCTION

One of the important steps in the development of horticulture in any region is the obtaining of information on suitable ornamental plants for different parts of the country. The accumulation of such information is usually the result of considerable experience involving a large amount of trial and error with a range of plant materials.

In the older parts of the world the behaviour of ornamental plants and their suitability for different areas is well known. As little known or newly discovered plants are introduced to gardens their suitability for particular districts is determined with the help of information about plants which have been long in cultivation in these districts. Great Britain is an example of a country which has a well developed horticulture in connection with its long period of civilization. Detailed information on suitable ornamentals is generally available for all the different localities from the southwestern coast to the northern islands.

In the settlement of the new world immigrants customarily brought with them the plants with which they had been familiar in their old surroundings. They soon found which of these would survive in the new land where they happened to settle. People have tended to rely on those introduced trees and shrubs which have proved successful, rather than explore the possibilities of native species or other plants which they had not known in their old surroundings. Nurseries have made a practice of growing only the plants for which there is considerable demand. Consequently there has been a conservative trend in the planting of ornamentals.

There are usually a few species of good ornamental plants which are particularly well suited to the climate of an area. These species may be overlooked unless a well organized scheme of trials is conducted. Before our surroundings can be satisfactorily landscaped, a thorough knowledge of the best existing plant materials must be attained.

In British Columbia there is a definite need for better organized and more readily available information as to which plants may be grown in different localities. Even in the well settled districts around Vancouver there are few gardens where possibilities in plant materials are exploited. Most gardeners have to make a choice of plants without any real knowledge of the wide array of good ornamentals which might be used. Some plants which are particularly adapted to local conditions are not readily available at the local nurseries, and consequently they are not widely grown. Others which are available have been avoided because they have been thought to be not hardy enough. Many of these plants could be grown successfully if given a suitable location and adequate care.

Better practical horticulture in British Columbia must depend primarily on the application of the best scientific methods of obtaining information that are at our disposal. In this investigation every attempt has been made to use the tools of sciences related to horticulture in attacking a horticultural problem. Climatological methods, especially the statistical analysis of temperature data, have been found most useful.

Of the numerous factors which determine the suitability of ornamental trees and shrubs for particular localities, low winter temperature is undoubtedly very important. This is especially true if, as in this investigation, the area under study is characterized by marked climatic diversity. In British Columbia there is a wide range in the severity of winter temperature in different localities. Around Victoria on the southern tip of Vancouver Island the winters are generally mild enough to permit the outdoor culture of nearly any woody plant from the temperate zones of the world. At Prince George, toward the other extreme, only a few notably cold resistant trees and shrubs will survive.

The purpose of this investigation is to provide a foundation for a sound appraisal of localities of British Columbia as to suitability for the growth of different species of ornamental trees and shrubs. Although the problem has a number of important aspects, investigation is confined here to the study of low winter temperature as it affects the selection of woody ornamentals.

REVIEW OF LITERATURE

One would expect that an appreciable amount of investigation on trees and shrubs suitable for British Columbia would be under way, considering the youth of the province as a settled area. Unfortunately there has been little detailed work for specific purposes.

The Dominion Experimental Farms Service have taken the lead in trying out ornamental plants for different climatic regions in Canada. Their work has been quite valuable for Canada as a whole, especially the cold regions which occupy the majority of the country. Such work applies to the cold interior of British Columbia, but not to the warm coastal region of the province, where the population is concentrated. Some detailed local work has been done at branch farms and stations, but little of this is published. From Ottawa have come bulletins on hedges (Macoun, 1931), trees (Oliver, 1945), shrubs and climbers (Oliver, 1944), and perennials (Preston, 1946). Oliver's bulletins give tables showing hardiness of the trees and shrubs which have been tried at different branch farms and stations.

In the Horticultural Branch of the Provincial Department of Agriculture the major attention has been directed toward fruit crops rather than ornamentals. Interest in the suitability of ornamentals has been confined chiefly to answering queries from the public. District

Horticulturists undoubtedly have accumulated some good information relating to individual districts. This information would be more useful if it were compiled and published for the use of people who are not familiar with the province.

There has been some attempt at The University of British Columbia to recommend plants suitable for the province. The list of ornamental trees and shrubs compiled by F. E. Buck (1946) has been useful, but it makes no distinction between different areas of the province. Brink and Farstad (1949) in an approach to the problem of recommending suitable crop plants, have summarized the physiography of the agricultural areas of British Columbia, and Brink (1950) has organized some climatological information for the use of agricultural investigators in the first of a series of four publications. Muirhead (unpub.) has done some original work in his investigation of suitable street trees for Vancouver. There is promise of an increased interest in local problems of this nature.

In the American States south of British Columbia the exploration of local possibilities has progressed more rapidly. Grant and Grant (1943) have given a good summary of the newer ideas in a book on trees and shrubs for the Pacific Northwest. Snyder's (no date) list of shrubs for Washington is applicable to parts of B.C., but it does not give any details of climatic suitability. Graham and

McMinn (1941) have considered shrubs and vines for the Pacific coast. McMinn and Maino (1935) include ornamentals in their account of trees of the Pacific coast.

Numerous articles in semi-popular gardening magazines contain valuable but scattered fragments of information on the culture of trees and shrubs in the Pacific Northwest. Grant (1944), for example, has written on rhododendron culture in the area.

The study of climate in relation to the growth of plants has attracted wide attention in the last twenty-five years, owing to the stimulus of the new science of plant ecology. The first comprehensive quantitative classification of climate by Thornthwaite (1931) is well known. The application of Thornthwaite's system to a particular problem such as the selection of trees and shrubs should be preceded by careful consideration of the factors involved. Any one factor such as temperature is dealt with very generally in such a complex classification; one temperature category includes almost all the British Columbia stations. Since differences in winter temperature are very important in the selection of trees and shrubs, Thornthwaite's classification has a limited use in this kind of work. A new classification by Thornthwaite (1948) has appeared, and this has been applied to a classification of the climates of Canada by Sanderson (1948).

Another development in the science of climatology is the statistical approach. Although statistical methods have not been used as extensively as they might in climatological work, there has been an increased attempt to apply such methods to climatic studies in the last decade, particularly for military purposes. An authoritative text covering fundamentals and recent applications of statistical climatology by Conrad (1944) has stimulated a wider use of these methods, especially in relation to agriculture. Foster (1948) has demonstrated the possibilities of the statistical approach in his book on hydrology.

Brink (1950) emphasizes the value of a thorough appraisal of the climate of British Columbia for improving the efficiency of agricultural production. Quoting Landsberg (1946) he shows that climate is in essence an inexhaustible natural resource which, since it is fairly constant over a period of years, can be treated as a calculable risk.

Writings with specific reference to the B. C. climate have been rather numerous. Connor dealt with temperature and precipitation in an early publication (1915), and more recently (1949) has discussed the frost-free period. A summary of the B. C. Climate by Denison (1925) is found in the Monthly Weather Review. Koeppe (1931) included some detailed remarks about the climates of districts of British Columbia in his book on the Canadian climate. The work of Brink (1950) is mentioned above.

Characteristics of mountain climates of Western North America have been discussed by F. S. Baker (1944). The behaviour of temperature in mountains has been treated fully by Peattie (1936).

The history of the development of methods of classifying plants according to climatic requirements and of classifying climates according to their suitability to plants is a long one dating into antiquity and associated with the origin and development of botanical gardens. Yet only during the twentieth century have attempts been made to put these climatic studies on a quantitative basis.

The development of a plant growth region map by F. L. Mulford of the United States Department of Agriculture was an early attempt to classify the United States for plants. Originally intended as a basis for recommending roses and street trees, Mulford's system was modified and refined with the aid of many specialists in the U.S.D.A. The original thirteen regions were increased to thirty-two (Mulford, 1926). Van Dersal (1938) gives a detailed account of Mulford's system, with characterizations of the different regions under (a) climate according to Thornthwaite's Classification, (b) length of growing season; and (c) average annual snow cover. These descriptions reveal the complexity of Mulford's system and the difficulties that would be involved in applying this system to British Columbia. The climates of the regions occupying mountainous areas are very diverse, sometimes defying description. Mulford's system undoubtedly has practical value for areas of regular climate, but it is too complex to be useful in distinguishing growth regions in British Columbia. Van Dersal (1938, 1942) has applied Mulford's growth regions to his work with American woody plants, listing the regions for which each plant is recommended.

Another quantitative approach to the classification of plants for climate was the development of a system of winter hardiness zones for cultivated trees and shrubs by Alfred Rehder of the Arnold Arboretum. Information about the hardiness of different species had been steadily accumulating as a result of the introduction and testing of plants from the East through the botanical gardens of Europe and America. Rehder (1927) made this information available in his manual on cultivated trees and shrubs. He divided North America into eight climatic zones based on the "lowest mean temperature of the coldest month". The numeral for the corresponding zone (I-VIII) was given with the description of each species in the manual. A plant of Zone III would be hardy in Zones III to VIII, but not in Zones I to II. In the second edition of his manual (1940) Rehder explained the basis of his classification somewhat differently. The number of zones was reduced to seven, and these zones were based on the "annual minimum temperature". The average annual minimum temperature listed for the different zones is as follows:

Zone I:	exceeding		-50°F
II:	-50°	to	-35°
III:	-35°	to	-20°
IV:	-20°	to	-10°
V:	-10°	to	-5°
VI:	-5°	to	+5°
VII:	+5°	to	+10°

A map showing the approximate location of these zones in North America is included with the manual. This map is adapted from a map of average annual minimum temperature in the <u>Atlas of American Agriculture</u> (O. E. Baker, 1936). The usefulness of Rehder's map for determining the zone of a place is limited by the small scale and the lack of detail in outlining the zones. It is clear from Rehder's explanation of his system that he believes many other factors besides winter temperature have an important bearing on the hardiness of plants.

The general recognition of Rehder's taxonomic work on cultivated trees and shrubs has been accompanied by a wide acceptance of his winter hardiness zones as a basis for classifying woody plants according to climate. Wyman (1938) referred to Rehder's winter hardiness zones as standard for the United States. He assigned somewhat modified ratings based on Rehder's system to each species in his list of hedge plants. Grant and Grant (1943) have extended his zones from seven to ten to include the mild coastal areas of the Pacific Northwest, and they assigned hardiness ratings to each species in their list of plants for this area. The quantitative basis for the extended zones is not given in their explanation of their modification.

Writings describing investigations of the nature of winter injury and the factors influencing winter hardiness have been very extensive (Imperial Bureau of Plant Breeding and Genetics, 1939; Levitt, 1941). Some discussions of the problem of winter hardiness in relation to ornamental plants are those of Bowers (1947), Crane (1947), Skinner (1944), and Teuscher (1941).

The assessment of winter injury to ornamental plants after particularly extreme winters has been given some attention in recent years by the Royal Horticultural Society. Reports were published after the winters of 1939-40 (R.H.S., 1941), 1940-41 (Balfour, 1941), and 1946-47 (Harrow, 1948; R.H.S., 1948). The Frost Damage Survey conducted after the 1946-47 winter was used as a guide for the survey conducted in connection with this investigation.

ANALYSIS OF THE SUBJECT

Development of the Method

The interacting factors which determine the relation of a plant to its environment are known to be extremely complex. Even the study of climatic effects involves many factors, none of which acts by itself. Nevertheless, these different factors must be separated for purposes of investigation. A general approach to a complicated problem is unlikely to bring about material progress in any field of science. A specific approach allows the selection of the most vital factor for investigation, and consequently leads to a thorough knowledge of one important phase of the problem.

The environmental factors influencing the growth of cultivated plants may be grouped under two main headings: edaphic factors and climatic factors. While soils can be modified greatly when plants are grown under close cultivation, the climatic factors are much more difficult to control.

The groups of climatic factors affecting cultivated plants include moisture, light, temperature, and the movement of air. Moisture in the soil is relatively easy to regulate, especially when it is naturally in short supply during the growing season. Atmospheric humidity usually is not important if the amount of soil moisture is properly adjusted. The effects of wind can be reduced by sheltering arrangements, although adequate shelter often involves the growing of wind resistant plants where they will protect the more susceptible ones. Light can be increased only with some difficulty, but it is easily reduced by shading measures. Temperature is difficult to modify unless plants are grown in some type of structure.

Light is not usually a limiting factor in the growth of ornamental woody plants, except in special circumstances. Temperature remains the most critical and the least easily modified environmental factor affecting the growth of woody ornamentals.

Within the temperate zones differences in winter temperature between areas have a great influence on the kinds of woody plants which can be grown successfully. Although the extent of winter injury is often determined by many complex factors, extremely cold temperatures in severe winters are primarily responsible for the serious economic losses which limit the number of species of ornamental woody plants it is practical to grow in a specified locality.

A climatic study of an area such as British Columbia where the topography is extremely varied and irregular involves certain problems which do not assume importance in a study of a more gradually changing and fairly uniform area like the continental plains. Meteorological stations are not representative of areas between them when they are separated by extensive ranges of mountains. For this reason, broad zones in respect to a meteorological element such as temperature are difficult to determine in mountain regions. However, since the meteorological stations usually are located at lower elevations in the general vicinity of agricultural lands and urban settlements, they may be quite valuable in the climatic assessment of limited areas around them. Brink (1950) discusses the literature dealing with mountain climates and the caution which is necessary in using data relating to mountainous areas.

In view of the problems discussed above, the following approach was adopted in this investigation:

Low winter temperature was taken as the most important factor influencing the selection of ornamental trees and shrubs for a locality, and a recognized expression of this climatic element was determined for most meteorological stations of the province.

The locality surrounding one or more meteorological stations was taken as the unit for investigation, and the meteorological station was used as a reference point. Little attempt was made to indicate relationships broader than between different localities.

Certain methods were used to interpret the information on low winter temperatures in an original way. These methods are the use of the winter rather than the calendar year as the unit in considering low temperature, the application of statistical analysis to express the amount of variation in low temperature from one winter to another, and the conversion of statistical estimates from mathematical values to convenient probability ratios easily understood by practical workers without scientific training.

A survey was conducted to obtain an estimate of the injury to ornamental trees and shrubs following two severe winters. The information obtained was used to test the usefulness of low temperature data as a guide in selecting woody ornamentals for hardiness in a locality, and to get accurate low temperature limits in the Pacific coastal region for a number of ornamental species.

Extreme Lowest Temperature

Extreme lowest temperature of the year

The lowest recorded temperature during a calendar year at a particular meteorological station is called the annual minimum temperature by Baker (1936). Rehder (1940), using Baker's map of average annual minimum temperature of the United States as a basis for his winter hardiness zone map, follows the nomenclature used by

Baker. "Average annual minimum temperature" corresponds to what is called "annual averages of extreme lowest temperature" by the Canadian Meteorological Service (1946). For the sake of clarity the expression "extreme lowest temperature of the year" is used here instead of the expression "annual minimum temperature".

Rehder's well-known winter hardiness zones were to be determined for British Columbia localities, and if it should prove feasible, a map showing the distribution of these zones was to be constructed. Excepting some long-term averages for the more important stations, the basic data, averages of extreme lowest temperature of the year, was not available. To get averages for all stations it was necessary to search through meteorological publications for extreme lowest temperatures for a ten-year period (1940-1949), and to average these readings. Information for the year 1940 was extracted from daily minimum temperatures in the _Monthly Record of Meteorological Observations_ (1940); for the years 1941-1948 from monthly minimum temperatures in the _Climate of British Columbia_ (1941-1948); and for 1949 from monthly minimum temperatures in the _Monthly Weather Map_ of the Dominion Meteorological Service (1949). The information collected and the averages calculated from these figures have been compiled into a table, which is on file at the Department of Horticulture, The University of British Columbia. Figures for the lowest temperatures recorded during the record cold spell of January, 1950, have been included with the table for purposes of comparison.

Average readings for the different stations, with the number of years for which figures were available during the period, are given in Table 1. These averages are also shown on a map of British Columbia included with the Appendix. Figures for those stations for which information was not available for ten consecutive years are circled on the map, since averages for shorter periods would not be reliable in making comparisons between averages of neighbouring stations. Averages covering short periods were included with the tables in order to give a rough estimate for stations from which no information could otherwise be included. Long-term averages for some stations were found in the Canadian Meteorological Service <u>Summary</u> (1946), are given in Table 1 as figures in brackets after the name of the station. The long-term averages are generally somewhat lower than the averages for the ten-year period 1940-1949.

A definite pattern is evident in the extreme lowest temperature of lowland stations in the coastal region. Stations close to the open Pacific on Vancouver Island and the Queen Charlottes have the highest averages, over 20°F. On eastern Vancouver Island averages range from over 20° in the south around Victoria to less than 15° in the middle part

TABLE 1

Ten Year Averages of Extreme Lowest Temperatures of the Year at British Columbia Meteorological Stations for the Period 1940-1949. Long Term Averages are given in brackets after names of Stations for which they are available. (Degrees Fahrenheit).

STATION	YRS.	AV.	STATION	YRS.	AV.
Abbotsford	10	11	Clayoquot (21)	9	25
Agassiz	10	14	Comox (A)	5	13
Alberni (Beaver Creek)	10	11	Coquitlam Lake	10	14
Alberni, Port	10	13	Cowichan Bay	10	19
Alliford Bay	4	20	Cowichan Lake	8	16
Armstrong	10	-14	Cranberry Lake	10	-35
Ashcroft	3	-18	Cranbrook (A) (-28)	10	-23
Atlin (-38)	6	-34	Crescent Valley	10	-8
Baldonnel	10	-39	Creston	10	-5
Barkerville (-26)	9	-28	Cultus Lake	4	12
Bella Coola (1)	10	1	Cumberland	9	11
Big Creek	9	-30	Departure Bay	10	21
Blue River	3	-31	Dome Creek	10	-30
Bralorne	10	-13	Dominion Observatory	10	21
Britannia Beach	10	18	Duncan	10	10
Bull Harbour	10	22	Estevan Point	10	23
Cape St. James	3	20	Fauquier	10	-2
Carmi	0	-13	Fernie	10	-21
Chinook Cove	7	-16	Finlay Forks	3	-54
Chute Lake	4	-23	Fort St. James	10	-32

TABLE I - Cont.

STATION	Yrs.	Av.	STATION	Yrs.	Av.
Ft. St. John (A) (-38)	9	-42	McCulloch	10	-23
Ganges	8	19	Masset (14)	10	15
Gerrard	9	-7	Merritt	10	-13
Glacier (-19)	10	-16	Mill Bay (Nass R.)	9	4
Golden	10	-27	Mission Creek	6	-14
Grand Forks (-17)	10	-14	Mission Flats	8	-6
Greenwood	10	-16	Nanaimo	10	16
Haney	4	14	Nelson (-4)	10	3
Hedley	10	-6	Newgate	8	-23
Hedley (N.P.M.)	10	-17	New Hazelton (-29)	10	-24
Hope (Little Mt.)	9	7	New Westminster	10	14
Hope (A)	10	11	Ocean Falls	10	15
Invermere	7	-25	Okanagan Centre	10	3
James Island	10	22	Oliver	10	-3
Jordan River	5	21	Osprey Lake	10	-22
Kamloops (-13)	10	-8	Pachena Point	9	22
Kaslo	10	0	Patricia Bay	7	17
Kelowna	10	-1	Pemberton Meadows	10	-8
Keremeos	10	-2	Penticton (-2)	10	-3
Kimberley	5	-21	Port Hardy (A)	5	19
Kleena Kleene	7	-34	Powell River	10	23
Langara	7	20	Premier	9	-2
Lytton	10	-2	Princeton (A)(-26)	10	-17
McBride	8	-27	Prince George (-40)	5	-25

TABLE I - Cont.

STATION	Yrs.	Av.	STATION	Yrs.	Av.
Prince George (A)	7	-36	Tappen	8	-4
Prince Rupert (-11)	10	13	Tatlayoko Lake	10	-19
Quatsino	10	20	Telkwa	10	-20
Quesnel	10	-22	Terrace	10	-2
Revelstoke (-14)	10	-11	Ucluelet	3	20
Rock Creek	8	-13	Ucluelet (A)	4	22
Rossland	9	-2	Vananda	10	18
Salmon Arm	10	-5	Vancouver (13)	5	16
Shawnigan Lake	10	14	Vancouver (A)	10	14
Sidney	10	21	Vavenby (-30)	10	-20
Sinclair Pass	9	-19	Vernon	10	-4
Smithers	10	-24	Vernon(Cold-stream)	9	-6
Smithers (A)	6	-25	Victoria (20)	10	23
Sooke	8	19	Warfield (Trail)	10	2
South Slocan	9	-6	Westwold	9	-18
Stave Falls	9	14	White Rock	10	15
Steveston	3	9	Williams Lake	7	-18
Stewart (-6)	10	-5	Wistaria	10	-24
Summerland	10	2			

at Comox. There is a gradual decrease on the Lower Mainland from over 15° near the Gulf of Georgia to less than 10° at Hope.

In the interior of British Columbia the irregular mountainous topography causes abrupt differences in averages of different stations. Near the Okanagan, Arrow, and Kootenay Lakes at low altitudes, however, the averages are all near 0°. In central British Columbia the atations represented have averages below -25°F.

A map showing the approximate location of low temperature zones in the settled part of the coastal region was drawn up. The areas represented in the four zones are roughly those areas in which arable land is found according to Brink and Farstad (1949). The average extreme lowest temperature of the year for the meteorological stations within these areas was used as the chief basis for the zones. Each zone includes stations with averages within a 5° range; for example, 5° to 10°. This map (Figure 4) follows the account of the winter injury survey.

The soundness of using a ten year period to get a representative average of a climatic element such as temperature is not now disputed. The ten year period is widely used in climatological work, since a longer period usually involves an appreciable amount of climatic change.

<u>Extreme lowest temperature of the winter</u>

For practical purposes the extreme lowest temperature taken for each calendar year provides a satisfactory basis for the calculation of averages. However, this basis would not be satisfactory for a study of variation in low temperature between different winters. The reason for the error is that the calendar year splits the winter into two halves, so that any winter may be represented twice or not at all in the data. Since a measure of the actual variation from winter to winter was required in order to get a statistical estimate of extreme lowest temperatures for important stations in British Columbia (see below), data which would represent each winter as a unit had to be obtained.

Figures for extreme lowest temperature of the winter at selected B. C. Meteorological stations for the ten-winter-period from 1940-41 to 1949-50 were compiled. Sources of information were the same as for figures based on the calendar year. Averages were calculated for those stations from which information was available for the ten winters. A table giving this compiled information is found in Appendix 1. Incomplete series of figures are included with the table.

Since the record low temperatures of the cold spell of January, 1950, are included in the figures based on the winter, but not in those based on the year, the averages from the former figures are slightly lower than those from the latter figures.

Analysis of extreme lowest temperature variations

The actual variations in extreme lowest temperature from winter to winter can be represented by means of simple bar graphs, examples of which are seen in Figure 1. The average for ten winters is used as the base, and the deviation of the minimum temperatures from this mean is shown by a darkened column above or below the line of the mean, the length of the column depending on the size of the deviation. Since the mean is shown in relation to the temperature scale, comparison of the graphs for different stations reveals differences in the average as well as in the amount of variation. Although such graphs convey a clear picture of the actual variation, they are of little use in making quantitative predictions. The only quantitative generalization to be made is the greatest spread of the deviations. The spread at Vancouver during the period was 21°; at Summerland it was 32°; at Quesnel 44°. Differences in the amount of variation are indicated by this information, but a satisfactory method of approximating these differences is necessary.

Statistical analysis provides the method which is required. A calculation of the standard deviation, though expressing no actual differences, constitutes a reliable statistical measure of the amount of variation. The probable size of future deviations can be readily predicted from the standard deviation by the use of mathematical tables.

Standard deviation from the average extreme lowest temperature of the winter was calculated for

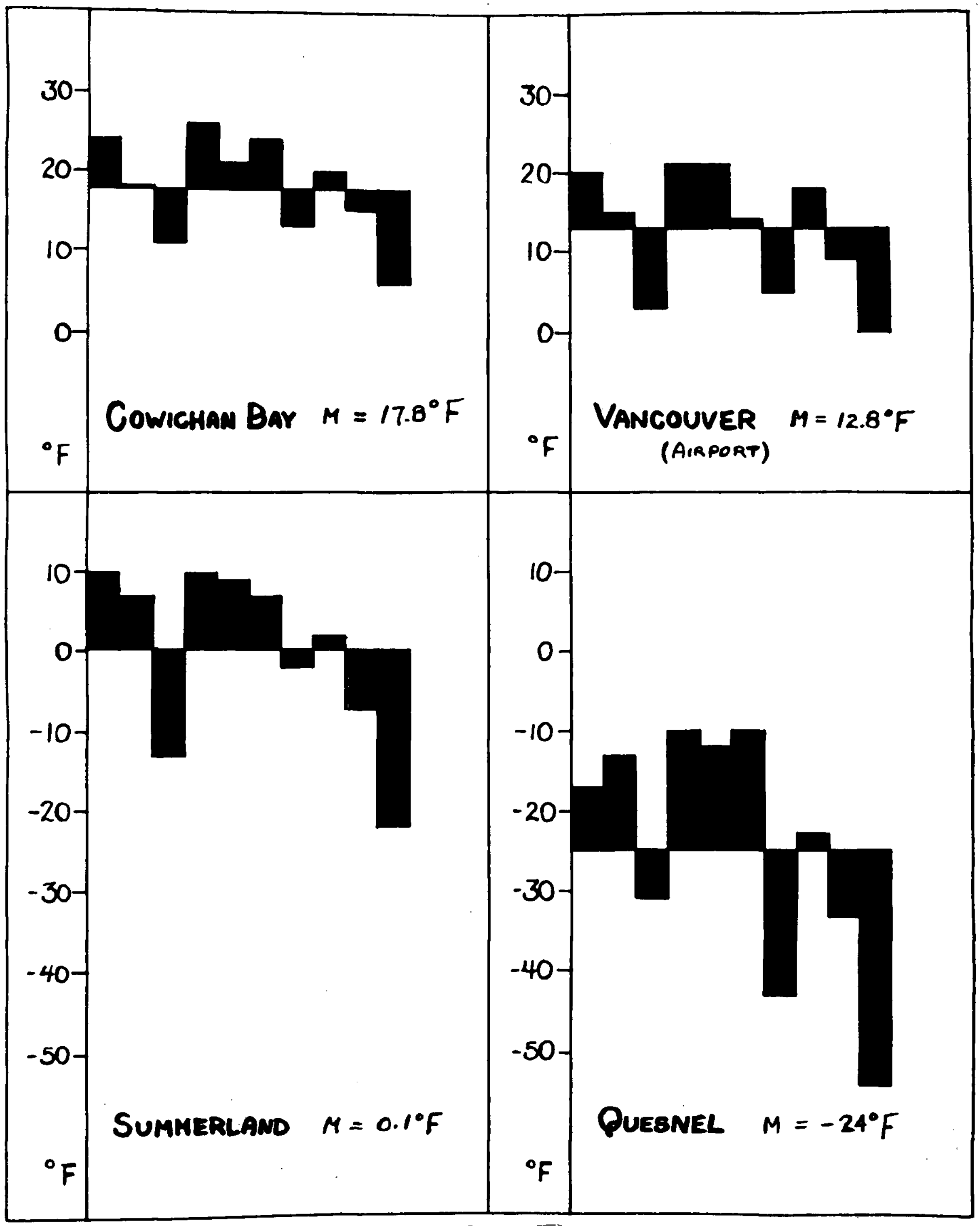

Figure 1. Variation in extreme lowest temperature of the winter during the ten winter period from 1940-41 to 1949-50 at four British Columbia meteorological stations.

(to follow page 24)

selected B. C. meteorological stations from which figures were available for the ten winters. Machine calculations were made with the use of the following formula:

$$\text{Standard deviation} = \sqrt{\frac{S\ S}{n - 1}}$$

$$S\ S = x^2 - \frac{(\Sigma x)^2}{n}$$

where S S = the sum of the squares

Σ = the sum of

x = any variate

and n = the total number of variates.

e.g. Abbotsford.

$$S\ S = x^2 - \frac{(\Sigma x)^2}{n}$$

$$= 95^2 - \frac{9025}{10} = 680.5$$

$$\text{St. dev.} = \sqrt{\frac{680.5}{9}} = \sqrt{75.6} = 8.7$$

The mean and standard deviation of each station is given in Table II. The standard deviation for coastal stations was found to be appreciably smaller than that of interior stations which are not affected by the moderating influence of bodies of water. It is evident that areas where the winters are more severe generally have a greater amount of variation in the extreme lowest temperature of the winter than areas where the winters are more mild. The gradual increase in the standard deviation as the average extreme lowest temperature decreases is shown in Figure 2, which illustrates graphically the mean and standard deviation for ten selected B. C. stations.

On theoretical grounds a calculation of the standard deviation is considered reliable if based on a random sample of sufficient numbers from a population or group which is normally distributed. The ten winter series here taken at random, though small in numbers, is similar to the ten year periods from which statistic estimates of various elements are made in climatology (Conrad, 1948). There is, however, some evidence that the distribution of extreme lowest temperatures is not completely normal. In regions with a climate similar to that of Western Europe there is some skewing to the left, caused by occasional extremely cold periods which are the result of a particular combination of weather conditions. These conditions are arctic air penetrations associated with clear skies and an effective snow cover. Clear skies and a snow cover intensify the cold periods initiated by arctic air penetrations, causing phenomenally low temperatures well out of the normal range to occur. These conditions prevailed at Vancouver during the cold spell in January, 1950.

Despite the fact that the distribution of extreme lowest temperatures over a period of winters is not quite

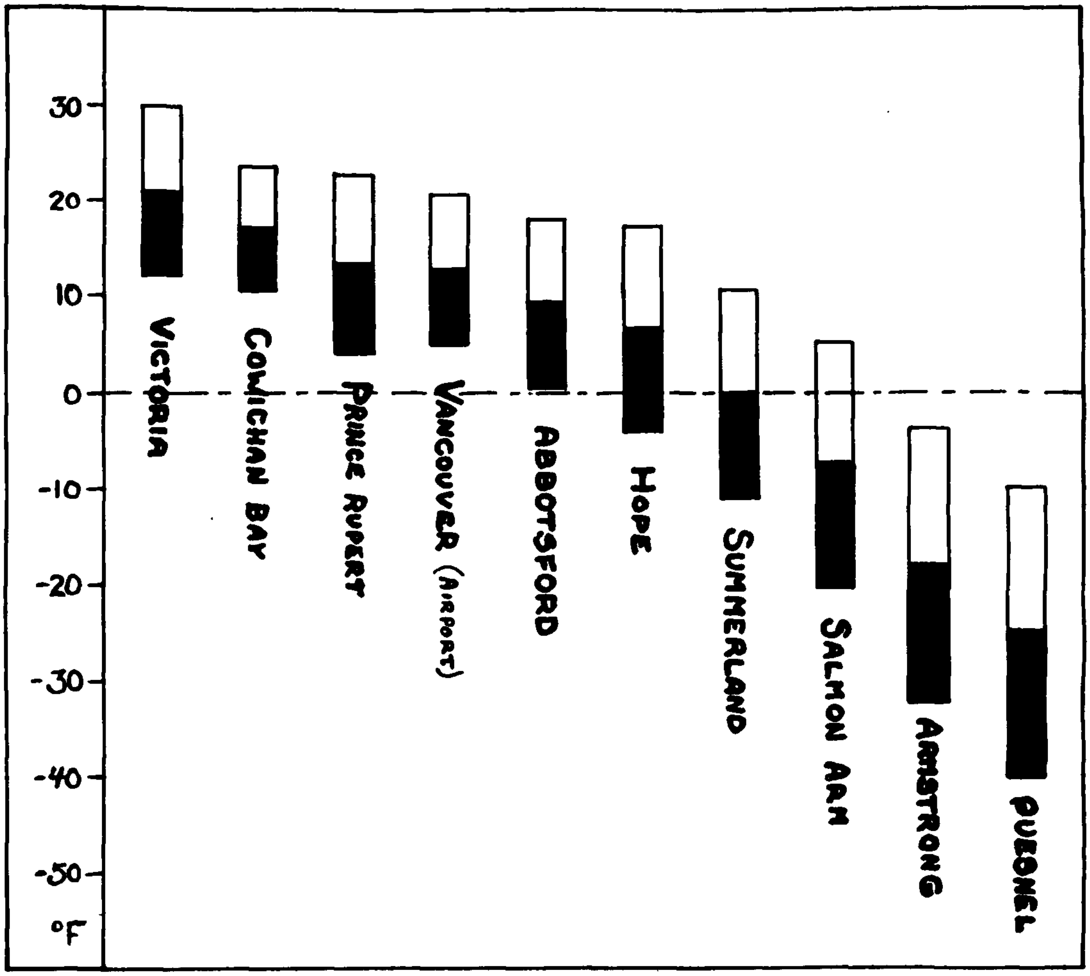

Figure 2. Statistical expression of extreme lowest temperature of the winter at ten British Columbia meteorological stations. The bar represents two standard deviations, one above, and one below the mean.

(to follow page 26)

normal, calculations relating to the central parts of the curve are expected to be reliable enough for practical purposes.

<u>The ninety percent point</u>

Application of statistical methods in analysis of temperature data permits an approximation of the relation of the mean (or average) to the range of deviations on which it is based. The standard deviation of the extreme lowest temperature of the winter is a reliable index of the amount of variation from the mean to be expected. Consequently, if the mean and standard deviation are known, the probability of any particular low temperature occurring at a station can be found by using statistical tables.

However, this technical approach would confuse the nurseryman or practical gardener who is not familiar with statistical concepts. In addition, there is a disadvantage in finding the probability of a given temperature rather than selecting a probability and calculating the temperature corresponding to it; if a selected probability is employed, comparable temperature information can be calculated for all the stations being studied. A probability which is convenient for studying the problem of selecting woody ornamentals would be the one chosen. A simple method of expressing the statistical information as a probability appropriate for the application was desired.

For these reasons a concept known as the <u>ninety</u>

percent point was formulated. The ninety percent point is that temperature above which the extreme lowest temperature will fall in approximately nine out of ten winters, and below which the extreme lowest temperature will fall in approximately one out of ten winters, according to mathematical expectancy based on statistical analysis of temperatures observed over a period of winters.

A one to nine ratio was chosen because satisfactory survival in nine out of ten winters is a reasonable level of success for woody ornamental plants. Many of the most beautiful shrubs are on the borderline of hardiness for most British Columbia localities; an enthusiastic gardener would be satisfied with a one to nine risk in any particular winter. Species which are not injured at the ninety percent point for a locality are expected to remain unharmed in nine out of ten winters when planted with due regard for horticultural requirements. When fully hardy trees or shrubs are desired, species with low temperature limits well above the ninety percent point should be selected.

The ninety percent point is offered as a practical and convenient method of providing a reliable expression of the low temperatures to be expected at a particular place. Whenever the approximate low temperature limit of a plant species is known, a knowledge of the ninety percent point of the locality will be useful in estimating the

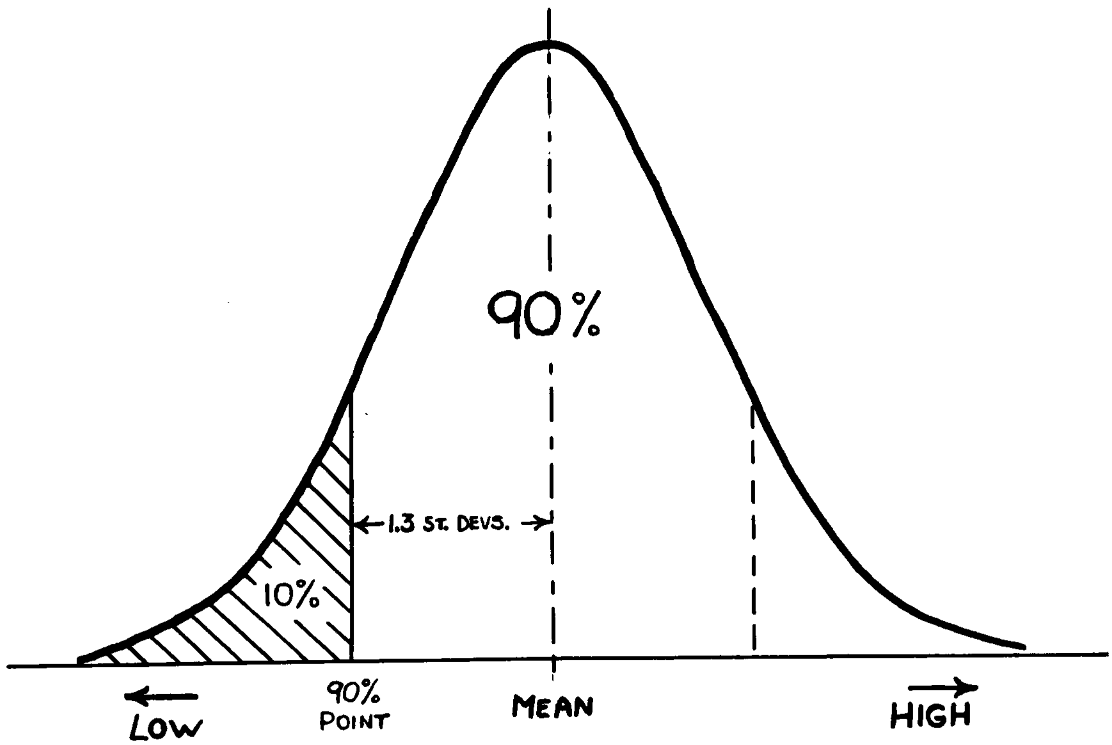

Figure 3. Normal frequency distribution curve showing approximate proportions divided by the ninety percent point.

(to follow page 28)

risk involved in growing the plant.

A method of converting information in terms of standard deviation to information in terms of the ninety percent point was developed. The ninety percent point is found by subtracting the standard deviation multiplied by 1.3 from the average extreme lowest temperature of the winter. The factor 1.3 is based on a calculation of the deviation which divides a series so that greater deviations will represent twenty percent of the total number of observations (i.e. ten percent in each of the tails). According to a table given by Simpson and Roe (1939), a deviation of approximately 1.3 times the standard deviation divides a normally distributed series in the above proportion. Part of this table is given below in rearranged form:

Areas of the normal curve

% area outside	% area inside	deviation / st. dev.
23	17	1.10
19	81	1.30

For practical purposes the factor 1.3 is sufficiently accurate to correspond to the value where twenty percent of the area if outside the limits. The division of the normal curve at the ninety percent point is shown by a diagram in Figure 3.

The following example indicates how the ninety percent point is calculated:

Abbotsford, B. C. Mean $= 9.5^{o}F.$

St. dev. $= 8.7$

$$90\% \text{ point} = \text{Mean} - (1.3 \times \text{St. dev.})$$
$$= 9.5^{o} - (1.3 \times 8.7)$$
$$= 9.5 - 11.3$$
$$= -0.8^{o}\ F.$$

The ninety percent point for extreme lowest temperature of the winter was calculated for selected B. C. meteorological stations. The mean, standard deviation, and ninety percent point for each station is found in Table II.

TABLE II. Analysis of Low Temperature Data. Average extreme lowest temperature of the winter for the ten-winter period from 1940-41 to 1949-50, standard deviation, and ninety percent point for selected B. C. Meteorological Stations.

Station	Mean	St. Dev.	90% Point
Abbotsford	9.5	8.7	-1.8
Agassiz	13.2	10.5	-0.4
Alberni (Beaver Creek)	8.0	10.4	-5.5
Alberni, Port	10.5	8.3	-0.3
Armstrong	-17.9	14.2	-36.4
Bella Coola	0.3	10.4	-10.5
Coquitlam Lake	12.4	10.0	-0.6
Cowichan Bay	17.8	6.3	9.6
Cranbrook (A)	-24.0	14.9	-43.4

TABLE II - Cont.

Station	Mean	St. Dev.	90% Point
Creston	-6.2	9.0	-17.8
Duncan	10.2	7.5	+ 0.4
Fernie	-22.2	10.2	-35.5
Golden	-28.3	10.5	-42.0
Grand Forks	-16.0	10.0	-29.0
Hope	6.8	10.7	- 7.1
James Island	21.1	8.0	+10.7
Kamloops	-11.0	14.2	-29.5
Kelowna	- 1.6	12.8	-18.2
Lytton	- 4.3	10.3	-17.7
McBride	-25.4	12.6	-41.8
Masset	14.9	7.9	+ 4.6
Merritt	-17.7	14.6	-36.7
Nanaimo	14.8	6.7	6.1
New Westminster	12.0	8.1	1.5
Ocean Falls	16.3	9.7	3.7
Okanagan Centre	+ 0.5	12.1	-15.2
Oliver	- 5.0	11.8	-20.3
Penticton	0.4	9.3	-11.7
Princeton (A)	-19.3	11.7	-34.5
Prince Rupert	13.4	9.8	+ 0.7
Quesnel	-24.8	15.1	-44.4

TABLE II - Cont.

Station	Mean	St. Dev.	90% Point
Revelstoke	-11.8	10.3	-25.2
Salmon Arm	- 7.6	12.9	-24.4
Sidney	20.0	7.2	10.6
Summerland	0.1	11.0	-14.2
Terrace	-3.9	10.4	-17.4
Vancouver (A)	12.8	7.9	+ 2.5
Vernon	-6.7	12.5	-23.0
Victoria	21.2	8.8	9.8
White Rock	13.9	7.8	3.5

The Winter Injury Survey

Purpose of the survey

Low temperature in severe winters had been selected as the chief factor limiting the number of species of ornamental woody plants which may be grown in a locality, and the degree of low temperature in different localities had been ascertained by certain methods. In order to test the value of this climatic data as a guide in the selection of plants for different localities, information on injury to ornamentals following severe winters was needed. This information could also be used to get accurate low temperature limits in the Pacific coastal region for a number of important species of ornamental trees and shrubs.

The last two winters were well suited to a survey of Winter injury. The Winter of 1948-49 was the coldest in six years in most parts of the Province, and the Winter of 1949-50 was the coldest on record in Western Canada. Consequently, there was a good opportunity to check the hardiness of those trees and shrubs which were expected to be badly injured or killed in severe winters, as well as those which are only slightly tender in some areas.

<u>Description of methods</u>

The formal winter injury survey was preceded by preliminary letters to District Horticulturists and the principal nurseries of the province. Replies to these letters indicated sufficient interest in the subject of winter injury to ornamental plants to justify compiling a form which would facilitate replies and the subsequent analysis of information received.

A list of one hundred and four species was compiled by choosing from Rehder's Manual (1940) the more common species of ornamental trees and shrubs likely to be injured during severe winters in the settled areas of British Columbia. Almost all of these species are in Zone V, VI or VII according to Rehder's winter hardiness classification. The zone number, scientific name and common name were given in the list. Columns were provided for information on the number of years planted, damage after the winter of 1948-49 and after the winter of 1949-50, and other remarks. The system of symbols used by the Royal Horticultural Society (1948) was used to indicate the amount of injury. A form letter explaining the reason for the survey was enclosed with each list sent out. A list of the species included on the survey is found in Appendix II.

Survey forms were sent to sixty-five addresses in British Columbia, including the Dominion Experimental Farms and Stations, the District Horticulturists, and most of the nurseries. In order to cover settled localities which were not represented by the above addresses, a number of forms were sent to florists, growers, and amateur gardeners; or if no information as to a suitable recipient was available, the form was addressed to the local post-master.

The information received in reply was transferred to a master form. The master form listed the localities in geographical order and the species in the order they appear on the list. This method of compiling the data allowed comparisons of the behaviour of any species in different localities to be made at a glance.

Results

Twenty-five winter injury survey forms were returned with the requested information filled in. A few forms were returned with no information. The response varied chiefly according to the part of the province from which the reply came. Replies from the interior districts were less complete than those from coastal districts, since the majority of the species on the list are not usually grown in the interior. The thoroughness of the reply also depended on how close to the subject of study the interests and training of the recipient were. Keen amateurs gave the most adequate information on less common ornamentals. Experimental Farms were able to give accurate planting dates of mature specimens. Nurserymen provided information on comparative damage to a number of species grown under similar conditions in the same location. Details of injury after the winter of 1948-49 were included in some of the replies.

A comprehensive report on the information accumulated by means of the winter injury survey is beyond the scope of this investigation. The findings of the survey are expected to be valuable for future reference, since the information constitutes the beginning of a permanent record of the behaviour of ornamental species in severe winters in British Columbia. The letters of reply, returned survey forms, and the master form have been filed at the Department of Horticulture, The University of British Columbia. Examples of the reports which were used as the basis of the conclusions are presented below.

The extent of injury to woody ornamental plants in different localities of British Columbia after the winter of 1949-50 was related more or less closely to the lowest temperatures recorded during the winter at the nearest meteorological stations. Injury to some species corresponded closely with the low temperatures to which the plants had been subjected. Injury to other species did not appear to be correlated with low temperature except over a wide range.

For example, Cedrus atlantica was reported uninjured at Sidney (8°F.), slightly injured at New Westminster (-1°), and killed at Nelson (-16°); Wistaria sinensis was reported uninjured at Hope (-11°), slightly injured at Keremeos (-23°) and badly injured at Vernon (-31°). On the other hand, Cryptomeria japonica was reported uninjured at Port Alberni (-7°), slightly injured at Victoria (6°), and slightly to badly injured at Vancouver (0°); Mahonia aquifolium was reported slightly injured at Victoria (6°), uninjured at Hope (-11°), and slightly injured at Keremeos (-23°). The above temperatures are the lowest recorded during the winter of 1949-50.

The amount of injury to low-growing shrubs depended on the depth of snow around the plants during the cold weather. At Vancouver the leaves of Cotoneaster microphylla were burned where they were exposed, but completely untouched where the snow covered them. Most injury to broad-leaved evergreens was directly related to the amount of exposure to the bright sun during the cold weather. At the coast, Prunus Laurocerasus, Prunus lusitanica, Camellia japonica and many other species often showed severe scorching on the sunny side of the plant, but no damage on the shaded parts. Injury to conifers, on the other hand, was widely distributed over the plant, or concentrated on the side exposed to wind. Injury related to exposure to wind was evident in large specimens of Cryptomeria japonica and Sequoiadendron giganteum at Vancouver.

Conclusions

The general extent of injury in certain localities was greater than the extreme lowest temperature of the winter, compared with that of other localities, would indicate. Victoria with 6° F., Vancouver with 0°, and Port Alberni with -7° all received approximately the same amount of damage. Along the east coast of Vancouver Island, although temperatures lower than at Victoria were recorded, little general injury was noticeable. Modifying factors such as exposure to wind, amount of sunshine during the cold weather, and depth of the snow cover are judged responsible. In the interior of British Columbia somewhat lower temperatures than those at the coast were required in producing similar injury for the same species.

An approximate estimate of the low temperature limits was made for fifty-six species of ornamental trees and shrubs in the Pacific coastal area. Even though numerous discrepancies are evident in the information provided by this survey, a general conclusion as to the approximate temperature at which a plant is reasonably safe from damage can be made. This was done by comparing reports of injury to each species with the lowest temperatures recorded at the corresponding stations. The low temperature limits determined are given with the list of species in Appendix II.

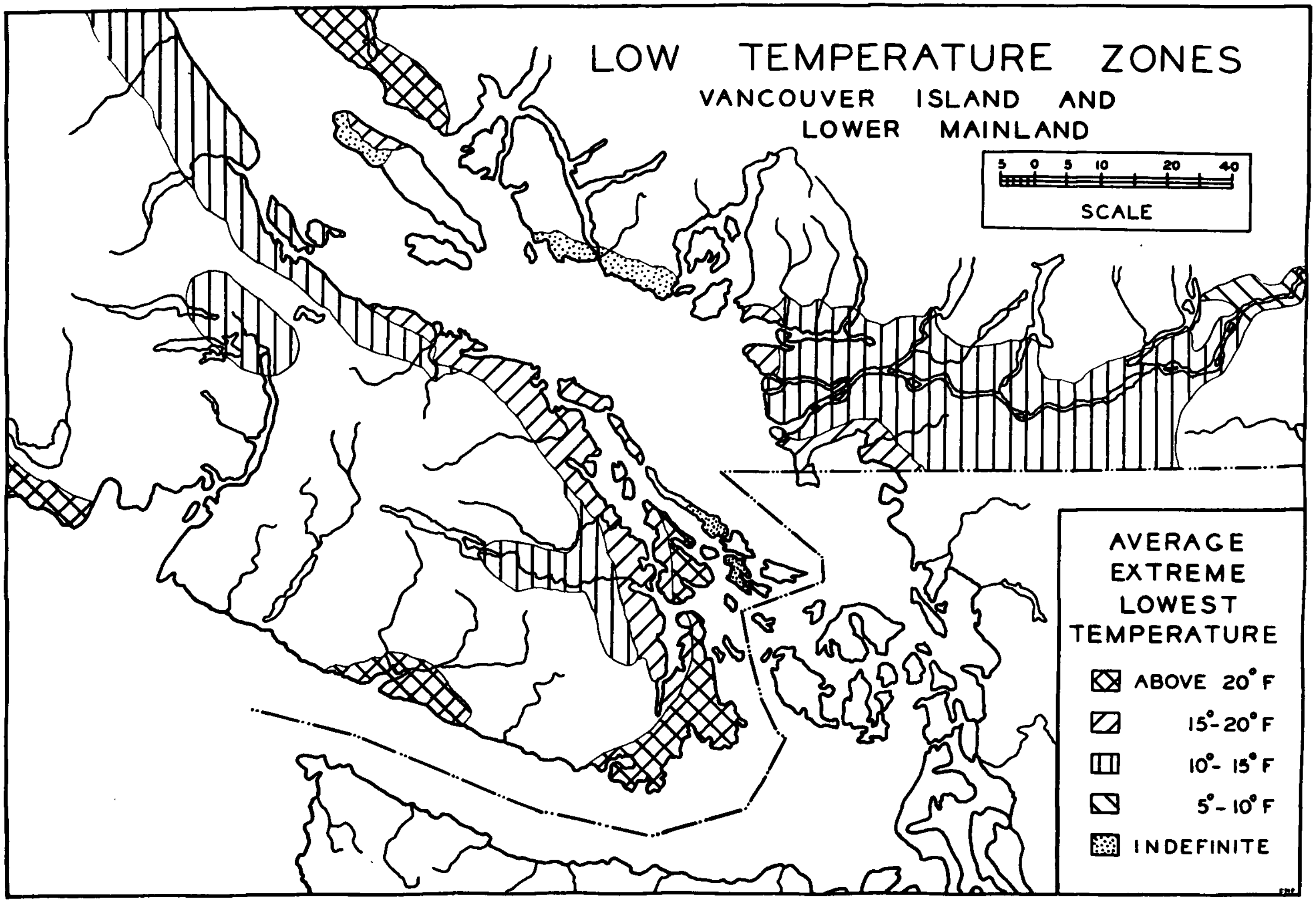

Figure 4. Approximate low temperature zones in the settled coastal region, based on average extreme lowest temperature (ten-year period 1940-49); areas zoned are arable lands as defined by Brink and Farstad.

DISCUSSION

Discussions of the different methods which were employed have been given with the explanations of the methods. For this section there remains a general discussion of conclusions.

Certain modifications should be made in Rehder's system of winter hardiness zones when this system is applied in British Columbia. According to the figures calculated here, averages of extreme lowest temperature of the year for stations in the coastal area of B. C. (see Figure 4) are above the range given for Zone VII by Rehder. Yet information from the winter injury survey and general observations indicate that most species listed as Zone VI or VII by Rehder are not fully hardy in this area. One way of overcoming the difficulty would be to alter the scale used by Rehder; localities with extreme lowest temperature averages above 20°F. would be included in Zone VII and those with averages between 10° and 20° in Zone VI. Another method would be to use the ninety percent point of a station, instead of averages, to correspond with averages given in the scale used by Rehder.

In addition to modifications in the scale for the zones, however, modifications are necessary in many of the hardiness zone ratings assigned to species by Rehder. The necessary modifications could be made by checking the zones assigned by Rehder with the information on low temperature limits of species in the Pacific coastal region, as given in Appendix II.

Low temperature zones in British Columbia and low temperature limits for species in this area are not stated here in terms of Rehder's zones because this information is considered more valuable if expressed in terms of temperature. Caution was found necessary since Rehder's system did not fit into the pattern in British Columbia. If temperature information for B. C. were stated in the symbols of Rehder's system, the accuracy of some of the information would be lost, owing to the imperfections of that system when applied to B. C.

The utility of the ninety percent point concept depends on how important a factor low temperature is as a cause of winter injury, on how representative the low temperature information is for a locality, and on how precisely low temperature limits of plant species can be determined. The results of the winter injury survey indicate that low temperature may be modified by a number of other factors in its effects on plants. Nevertheless, for most woody ornamental plant species, the amount of damage following a severe winter corresponds approximately to the low temperatures which have been endured.

The low temperature limits determined are stated within five degrees for most species. Plants will not always survive temperatures at or above the low temperature limits, unless they are grown with due regard for horticultural requirements. They may survive lower temperatures if they are given special protection, or if other factors modifying temperature are in favour of their survival. Thus, the low temperature limits must be considered approximate, and the method used to determine them a rough one.

The statistical methods used in the analysis of temperature data, on the other hand, are relatively exact. The temperature data on which the statistical analysis is based, however, is taken to represent a rather extensive area (the locality around a meteorological station). Although there may be many slight differences within a locality, these differences can be accounted for by an experienced person who is familiar with the local topography. Minor corrections in the ninety percent point to account for these differences could be made by adding or subtracting five to ten degrees, according to the amount of the difference expected.

Consequently, the main limitation in the practical application of the ninety percent point in selecting woody ornamentals is the difficulty in getting precise low temperature limits for the plant species concerned. The ninety percent point would be difficult to use with species which have ill-defined low temperature limits. It must be admitted that many ornamental species do not have as well-defined limits as had been expected. Nevertheless, within its limitations the ninety percent point concept provides a reliable method of estimating the chances of survival in a particular place for most of our important ornamental trees and shrubs.

Other applications of the ninety percent point are suggested by a glance at fields of study related to this investigation. The idea behind the ninety percent point is to express the mean and standard deviation of a series in terms of the deviation which corresponds to a selected probability. This idea should be applicable to any study of low temperature, and possible to other series of a similar nature.

Within horticulture, commercial fruit growing involves many factors similar to those studied here in relation to the selection of woody ornamentals. The low temperature limits of woody fruit plants are well known. If the risks involved in growing a certain type of tree fruit in a given location were calculated, the investment of large sums of money in new plantings could be made with a fuller knowledge of the chances involved. The risk in regard to low winter temperature, an important factor in orchard culture, could be estimated by comparing the low temperature corresponding to a selected probability for this location with the low temperature limit of the plant to be grown.

SUMMARY

To meet the need for reliable information on the suitability of settled areas of British Columbia for different species of ornamental trees and shrubs, a study of low winter temperature as it affects the selection of woody ornamentals for localities of the province was made.

Average extreme lowest temperature of the year for each B. C. Meteorological station was calculated from figures compiled for the ten-year period 1940-49. Average figures were arranged on a map of British Columbia for geographical comparison. A map showing approximate low temperature zones for settled parts of the coastal region was constructed.

Average extreme lowest temperature of the winter for each of selected meteorological stations was calculated from figures compiled for the ten-winter period from 1940-41 to 1949-50. The amount of variation in extreme lowest temperature from winter to winter was approximated statistically by calculating the standard deviation for each station. As expected, the coastal stations were found to have a generally lower standard deviation than interior stations.

A new concept called the <u>ninety percent point</u> was employed to provide a statistical expression of low

temperature in simple terms. The ninety percent point is that temperature above which the extreme lowest temperature of a station will fall in approximately nine out of ten winters, and below which the extreme lowest temperature will fall in approximately one out of ten winters, according to mathematical expectancy based on statistical analysis of temperatures observed over a period of winters. This concept combines the information to be obtained from the average extreme lowest temperature and the standard deviation. The ninety percent point is found by subtracting the standard deviation multiplied by 1.3 from the average extreme lowest temperature of the winter for the station.

A survey was conducted to obtain an estimate of the injury to ornamental trees and shrubs in British Columbia following two severe winters. The information was used to test the usefulness of low temperature data as a guide in selecting woody ornamentals for hardiness in a locality, and to get accurate low temperature limits in the Pacific coastal region for a number of ornamental species.

Low temperature information was found useful within limitations as an indication of the amount of winter injury to woody ornamentals to be expected in a locality in British Columbia. Many species react to given temperatures in a predictable way under most conditions. Some species behave as though factors other than low temperature are mainly responsible for the extent of injury.

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APPENDIX

APPENDIX I. Extreme Lowest Temperature of the Winter at Selected B. C. Meteorological Stations for the Ten-Winter Period from 1940-41 to 1949-50. Averages are given for stations from which information was available for all ten winters. (Degrees Fahrenheit).

Station	1940 -41	41-42	42-43	43-44	44-45	45-46	46-47	47-48	48-49	49-50	Average
Abbotsford (A)	21	15	-1	22	11	9	7	8	9	-6	+9.5
Agassiz	22	18	-4	25	20	19	3	19	12	-2	13.2
Alberni (Beaver Ck)	19	9	-3	17	8	17	5	16	6	-14	+8.0
Alberni, Port	20	12	9	17	13	20	2	12	7	-7	10.5
Armstrong	-8	-5	-39	-12	-5	-6	-16	-17	-27	-44	-17.9
Ashcroft	-23						-26	-15	-22	-35	
Barkerville	-23	-23	-45	-17	-22	-20	-52	-26			
Bella Coola	5	7	-5	15	9	4	-10	4	-12	-20	+0.3
Comox						19	9	13	1	-6	
Coquitlam Lake	22	14	5	24	20	19	4	18	4	-6	12.4
Cowichan Bay	24	18	11	26	21	24	13	20	15	6	17.8
Cranbrook (A)	-12	-22	-41	-12	-19	-16	-22	-20	-35	-41	-24.0
Creston	7	0	-18	4	-4	-5	-10	-3	-13	-20	- 6.2
Cultus Lake							8	15	11	-5	
Cumberland	17	13	-3	22	16	15	3	15			
Dominion Observatory	25	24	7	28	26	23	14	21			
Duncan	15	9	9	19	13	19	7	14	2	-5	10.2
Fernie	-18	-17	-30	-9	-18	-12	-20	-21	-38	-39	-22.2
Golden	-15	-31	-40	-18	-26	-17	-30	-23	-36	-47	-28.3
Grand Forks	-6	-7	-30	-12	-10	-8	-18	-11	-25	-33	-16.0
Haney							9	18	9	-5	
Hope	17	13	-8	20	12	12	-3	12	4	-11	+6.8
James Island	26	25	7	29	27	27	17	25	20	8	21.1
Jordan River						26	17	20	19	4	
Kamloops	2	0	-27	2	2	-2	-20	-10	-20	-37	-11.0
Kelowna	9	4	-15	9	10	10	-9	2	-12	-24	-1.6
Keremeos	7	0	-17	6	2	7	-5	1	-10	-22	-3.1
Kimberley						-8	-18	-18	-32	-40	
Lytton	0	1	-15	6	4	6	-11	0	-9	-25	-4.3
McBride	-20	-19	-43	-8	-20	-12	-35	-28	-23	-46	-25.4
Masset	20	21	5	26	22	19	4	12	14	6	14.9
Merritt	-2	-8	-33	-8	-2	-11	-21	-16	-30	-46	-17.7
Nanaimo	24	13	6	22	19	20	13	15	13	3	14.8
Nelson	10	1	-13	12	5	10	0	6	2	-16	+1.7
New Westminster	20	16	-1	21	17	18	7	11	12	-1	12.0
Ocean Falls	18	23	-1	25	27	22	3	22	17	5	16.3
Okanagan Centre	9	6	-16	15	11	9	-5	2	-4	-22	+0.5
Oliver	11	3	-21	3	3	0	-10	1	-17	-23	-5.0
Penticton	10	9	-10	7	11	0	-4	4	-7	-16	+0.4
Port Hardy (A)						23	14	22	17	6	
Powell River	27	25	11	30	28	28	13	26			

APPENDIX I-Cont.

Station	1940 -41	41- 42	42- 43	43- 44	44- 45	45- 46	46- 47	47- 48	48- 49	49- 50	Average
Princeton (A)	-9	-16	-37	-11	-11	-9	-22	-14	-22	-42	-19.3
Prince George (A)					-28	-25	-52	-39	-46	-58	
Prince Rupert	15	22	1	26	24	21	-3	10	12	3	13.4
Quesnel	-17	-13	-35	-10	-12	-10	-43	-23	-33	-52	-24.8
Revelstoke	-3	-12	-30	0	-6	-1	-14	-10	-15	-27	-11.8
Salmon Arm	6	-1	-26	5	0	3	-15	-5	-13	-30	-7.6
Sidney	26	22	10	28	24	26	13	24	19	8	20.0
Smithers	-20	-21	-32	-11	-17						
Stave Falls	17	10	-3	20	18	19	12	14			
Steveston		11	2	21		13	-2	16			
Summerland	10	7	-13	10	9	7	-2	2	-7	-22	+0.1
Terrace	3	-3	-10	14	6	-3	-17	-6	-2	-21	-3.9
Vancouver (A)	20	15	3	21	21	16	5	18	9	0	12.8
Vernon	1	2	-25	4	4	2	-7	-4	-13	-31	-6.7
Victoria	28	25	7	31	28	25	17	26	19	6	21.2
Warfield (Trail)	11	3	-16	13	5	5	-2	4	-5		
White Rock	21	17	2	22	19	18	8	19	12	1	13.9
Williams Lake	-15	-13	-42	-12	-10	-24					

APPENDIX II

Species of Trees and Shrubs Included in the Winter Injury Survey, 1950. Approximate low temperature limits in the Pacific coastal region, as determined from information obtained by means of the survey, are given for certain species. (Degrees Fahrenheit).

Botanical Name	Low Temp. Limit
Taxus baccata	-5 to +5
T. cuspidata	-10 to +5
Cephalotaxus drupacea var. fastigiata	
Araucaria araucana	0 to +5
Abies pinsapo	
A. concolor	
Cedrus atlantica	-5 to +5
C. deodara	+5 to +10
Pinus radiata	
Sequoia sempervirens	+5 to +10
Sequoiadendron giganteum	+5 to +10
Cryptomeria japonica	-5 to +10
Cunninghamia lanceolata	
Thujopsis dolobrata	
Cupressus arizonica	
C. macrocarpa	+10 to +15
Chamaecyparis lawsoniana	0 to +10
Juniperus spp.	
Salix bablonica	
Garrya elliptica	
Juglans regia	-5 to +5
Carya Pecan	
Quercus virginiana	
Peonia suffruticosa	
X Clematis jackmani	
Mahonia aquifolium	
Berberis buxifolia	
X B. stenophylla	-5 to +5
B. darwini	+5 to +10
B. Thunbergi	
X Magnolia Soulangeana	
M. grandiflora	+5 to +10
M. stellata	
Carpenteria californica	
Umbellularia californica	
Hydrangea macrophylla var. Hortensis	0 to +10
Escallonia rubra	+10 to +15
X langleyensis	+15 to +20

Botanical Name	Low Temp. Limit
Cotoneaster Francheti	+10 to+15
C. microphylla	+5 to +15
Pyracantha coccinea	
P. crenato-serrata	
Photinia serrulata	+15 to +20
Stranvaesia Davidiana	+5 to +10
Rosa vars.	
Prunus triloba	
Prunus lusitanica	+10 to +15
Prunus Laurocerasus	+15 to +20
Cercis Siliquastrum	+10 to +15
Spartium junceum	+10 to +15
Laburnum anagroides	
Indigofera spp.	
Wistaria sinensis	+5 to +10
Choisya ternata	+15 to +20
Skimmia japonica	+5 to +10
Sarcococca spp.	+5 to +10
Pachysandra terminalis	
Buxus sempervirens	+5 to +10
B. microphylla	
Ilex aquifolium	+5 to +10
I. opaca	
Euonymus Fortunei var. radicans	0 to +10
E. japonica	+5 to +10
Pachystima myrsinites	
Acer palmatum	
X Ceanothus Delilianus	+15 to+20
C. velutinus	+5 to+10
Vitis vinifera	-5 to +5
Hibiscus syriacus	+5 to +10
Camellia japonica	+15 to +20
Camellia Sasanqua	
Hypericum calycinum	+5 to +10
Tamarix anglica	0 to +5
Cistus ladaniferus	+5 to +10
Opuntia spp.	
Daphne laureola	+5 to +10
Eucalyptus Gunnii	+10 to +15
Fuchsia magellanica var. Richartonii	+10 to +15

APPENDIX II - Cont.

Botanical Name	Low Temp. Limit	Botanical Name	Low Temp. Limit
Hedera helix	+5 to +10	Buddleia Davidi	+10 to +15
Fatsia japonica	+10 to +15	Rosemarinus officinalis	
Aralia chinensis		Salvia officinalis	
Aucuba japonica	+10 to +15	Lithospermum diffusum	+10 to +15
Cornus Nuttallii		Paulownia tomentosa	
Rhododendron spp. (half hardy spp.)		Hebe spp.	+10 to +20
Arbutus Menziesii	+5 to +10	Viburnum Davidi	+10 to +15
Arctostaphylos tomentosa		Viburnum tinus	+15 to +20
Vaccinium ovatum		X Abelia grandiflora	+15 to +20
Forsythia spp.		Olearia Haastii	+10 to +15
Ligustrum lucidum		Ruscus aculeatus	
Osmanthus ilicifolius			
Jasminum nudiflorum	+5 to +10		


AVERAGE
EXTREME LOWEST
TEMPERATURE
for the
TEN-YEAR PERIOD
1940-49
(based on the calendar year)
○ around figure indicates average was calculated from an incomplete series.
BRITISH COLUMBIA
DEPARTMENT OF LANDS AND FORESTS
Honourable E. T. Kenney, Minister
Scale
MILES
PACIFIC OCEAN
DIXON ENTRANCE
HECATE STRAIT
QUEEN CHARLOTTE SOUND
YUKON
ALBERTA
U. S. A.
MAP No. 1CX