The Resin Canals of Pinus Contorta Loudon *

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Summary.

THE purpose of the investigation was to attempt to (1) clarify the position regarding the number of resin canals found in the leaves of *P. contorta* Loudon and var. *latifolia* Engelm., and (2) find some feature of the resin canals which may be used to distinguish different provenances of the species. Examination of the needles of nine provenances growing at Millbuie Forest, Easter Ross, Scotland, revealed the existence of primary and secondary resin canals which have not been previously observed in the species. These two main types may be further subdivided according to the length and position of the resin canals in the needles. The occurrence of some of the different types of resin canals in the provenances indicates that there are large areas within the natural distribution of *P. contorta* Loudon in which many resin canal characteristics are uniform. It also appears to be the case that it is possible to distinguish individual provenances within these areas by the occurrence of other resin canal characteristics, although further work is required before a satisfactory key can be devised.

Introduction.

In recent years it has become apparent that *Pinus contorta* Loudon has an important part to play in afforestation. Considerable attention has been paid to the question of selecting suitable provenances, and to the more striking differences between these provenances. Vigour, form, needle colour, and other characteristics have been studied fairly intensively with a view to (a) assessing the probable value of provenances for planting, and (b) distinguishing coastal and inland forms of the species, as well as different provenances. Little detailed anatomical work, however, has been performed.

The principal objective of the present study is to investigate one aspect, resin canals, of the anatomy of the species and determine its usefulness in distinguishing different provenances. An examination of the literature indicates that it may be possible to distingush the coastal form of the species, *P. contorta* Loudon, from the inland one, var. *latifolia* Engelm., by the number of resin canals. Most of the recorded details of the resin canal number are, however, rather contradictory and it is intended that the present investigation will clarify this situation, at least, to some extent.

The specimens examined in the course of the investigation were obtained from trees growing in a provenance trial at Millbuie Forest, Easter Ross. In all, ten needles from each of two-hundred-and-fifty

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trees, belonging to nine different provenances, were sectioned and examined. Four of the provenances were of coastal origin, and the remainder originated from inland areas in the natural distribution of the species.

Literature.

One feature of the literature dealing with the species is the lack of agreement on the number of resin canals occurring in the needles. Britton and Shafer (2) state that *P. contorta* Loudon has two median resin canals, and Martinez (9) reports the same number for var. *latifolia* Engelm., the inland form. Harlow (6) records that the former usually has two resin ducts, occasionally one or three, and that they are rarely absent. However, other authorities, while agreeing that one or two resin canals may be present, state that they may be frequently absent (3, 5). Beissner (1), in fact, uses this feature as one point to distinguish *P. contorta* Loudon and var. *latifolia* Engelm. According to him resin ducts are often absent in the former, and normally present in the latter. It has been noticed, however, that resin canals are often absent from var. *latifolia* Engelm. (7) and, indeed, Sutherland (11) could not find any at all. From the foregoing it is apparent that a considerable amount of confusion exists as regards the number of resin canals.

One article dealing with samples taken from many points in the species natural range, has clarified the position to some extent. Critchfield (4) found that the great majority of needles have 0, 1, or 2 resin canals but the number may range from 0 to 7. He also found that the mean number of resin canals per needle in individual trees ranged from 0 to 3.9, and that the sample mean for groups of trees varied from 0 to 2.1 resin canals per needle. However, he summarised his results in the statement that:

". . . . . the frequency of resin canals shows much greater differences within geographic provinces than between them".

The only exception to this was in the Mendocino white plains area where resin canals were found to be totally absent. He also studied some specimens from plantations grown at Placerville in California, New Zealand, and Yorkshire, and concluded that:

". . . . . geographic variation in resin canal number is principally controlled by genetic differences between local populations".

Resin canal types.

In studying the resin canals, sections were usually cut at (1) the base, (2) the mid-point, and (3) the middle of the top third of the needle's length. Sections were frequently cut at other points but the three enumerated above were those adhered to in most of the work. The basal section was cut at the point where the two needles of a single fascicle separate and was, therefore, situated just above the apex of the dwarf shoot from which the needles arise.

The resin canals can be divided into two distinct types :—

Primary : resin canals which arise at the extreme base of the needle, and thus can be seen in sections cut at this point.

Secondary : those which arise at a point situated above the base of the needle and thus cannot be seen in the basal section, although sections cut elsewhere in the needle may have resin canals present.

The primary resin canals can, on the basis of length, be sub-divided as follows :—

(a) the primary resin canal runs, more or less, the entire length of the needle.

(b) the resin canal is shorter, and is evident for about half the length of the needle. It is present at the mid-point but absent from the section cut at the middle of the top third of the needle's length.

(c) the resin canal is very short and is confined to the region just above the base of the needle.

Type (c) is generally up to 1 cm. long and, as in (a) and (b), a central cavity is normally present. Sometimes it is represented only by a small bundle of sclerosed cells, usually less than five in number. In this case it is the continuation of a resin canal which has, below the apex of the dwarf shoot, a central cavity. On the other hand, primary resin canals of types (a), (b), and the normal variety of (c) may, or may not, have a central cavity present below the apex of the dwarf shoot.

Secondary resin canals begin, and like primary resin canals, end, as a small bundle of sclerosed cells. The central cavity disappears first, then the secreting epithelium, and finally the sclerosed cells. This type, like the primary resin canals, can be sub-divided on the basis of length and position in the needle :—

(a) starts below the mid-point of the needle and finishes near its tip.

(b) found only in the middle third of the needle's length, being absent from the section cut at the mid-point of the top third of the needle.

(c) situated in the top third of the needle's length, and absent at the needle's mid-point.

A minor variant of type (c) is where the resin canal is found only at the extreme tip of the needle. In this event the resin canal begins above the point situated one sixth of the needle's length below the tip, and thus is generally found in the top 5-7 mm. of the needle. Its occurrence is rare.

The occurrence of resin canals within individual needles.

Generally, the needles have 0, 1, or 2 resin canals present. In the case of needles having 2 resin canals, both are usually of the same type i.e. either primary or secondary. However, some needles have 1 primary and 1 secondary resin canal.

The resin canals are normally median in position and are situated at the corners of the needles. If the needle has 3 resin canals, as is occasionally the case, the third resin canal is usually situated in a median position in the middle of the abaxial side of the needle. In this case the third resin canal is often secondary and the two normal resin canals primary, but all three canals may be primary. Needles having 4 resin canals have been found, in which event three of them are usually primary and one secondary. The primary ducts are situated at the corners and in the middle of the abaxial side, the secondary resin canal being situated between one of the corner resin canals and the one on the abaxial side.

Material and method.

Nine provenances growing in an experiment at Millbuie Forest on the Black Isle, Easter Ross, were selected for examination. (Table I). Thirty trees were chosen at random from each provenance, with the exception of Shuswap Lake from which only ten were taken. Shuswap Lake and Salmon Arm are practically similar as regards position, the main difference being in altitude (Table I), and it was considered that ten trees would be sufficient to indicate any possible difference between them.

Needles were collected from vigorous vegetative shoots of the current year situated in the top third of the crowns of the trees, the leaders being excluded. The shoots were from all aspects. Only needles from the upper exposed side of the shoot, about its middle point, were collected. Fifty needles from each tree were measured, one needle being taken from each of fifty fascicles. The average needle length per tree was then calculated. The ten needles nearest the average, and situated on either side of it, were chosen for further examination. These needles were sectioned as described in that part dealing with resin canal types.

Results.

The results are summarised in Tables I-V. The figures for Shuswap Lake have been multiplied by 3, whenever necessary, to make them directly comparable with those given for the other provenances.

(a) The total number of resin canals present at three levels in the needles of the provenances. (Table II).

Six of the provenances examined show a decrease from base to top in the total number of resin canals counted at each of the three levels investigated. This feature is most marked in the two southern coastal provenances, Olympic Peninsula and Grays Harbour, in which the total number of resin canals present in the sections cut at the middle of the top third of the needles' length is only about half the number present in the sections cut at the base of the needles. Three provenances exhibit a totally different trend in which the total number of resin canals increases from the base to the top of the needles. The prominence of secondary resin canals in these provenances is, of course, the reason for this trend.

It may be stated that Table II indicates that there are three distinct trends exhibited by the provenances examined :—

(1) Queen Charlotte Islands, and Sonora Island–New Westminster. These two northern coastal provenances have a high number of resin canals and the bulk of them run the entire length of the needle.

(2) Shuswap Lake, Salmon Arm and Priest River Valley.
These three inland provenances show a marked departure from the normal in that the total number of resin canals increases from the base to the tip of the needles. This feature is very marked in the Priest River valley provenance which is the most southern of the three. In this case, however, the maximum is reached, not at the top of the needles, but in the middle. It is also more outstanding in the Salmon Arm provenance than in one from Shuswap Lake, and in this connection it is an interesting point that the Salmon Arm provenance comes from a lower altitude than the Shuswap Lake provenance.

(3) Olympic Peninsula, Grays Harbour, Prince George, Williamson River.
The remainder of the provenances are characterised by a distinctly lower number of resin canals than are present in the two northern coastal provenances, and by the same decrease in number from base to top. As has already been stated this decrease is most marked in the two southern coastal provenances, Olympic Peninsula and Grays Harbour.

(b) The distribution of needles having no resin canals, or resin canals of different types, in the provenances examined (Table III).

An examination of the number of needles having no resin canals indicates that the provenances may be grouped as follows :

(1) Queen Charlotte Islands and Sonora Island–New Westminster. These two northern coastal provenances are characterised by the low number of needles having no resin canals.

(2) Grays Harbour, Shuswap Lake and Williamson River.
In these three provenances approximately one-third of the needles examined had no resin canals.

(3) Olympic Peninsula, Prince George, Salmon Arm and Priest River valley.
The other provenances are distinguished by the fact that about half of the examined needles exhibited no resin canals.

However, although these groups are distinct it should not be construed that statistically significant differences are absent within each group. For example, the first group obviously has far fewer needles with no resin canals than the provenance with the next lowest number, Williamson River, but the difference between Queen Charlotte Islands

and Sonora Island—New Westminster is still of such an order as to be statistically significant at the 1% level. Similarly, in the second group mentioned in the preceding section, there are significant differences at the 1% level in the proportions of resin canals at the base, middle, and top of the needles.

Critchfield (4) in his study of the species found that:

". . . . . a needle is more likely to have either two or no resin canals than to have only one".

Table III indicates that this is true of most of the provenances. If primary resin canals only are considered then the exceptions are Salmon Arm and Priest River valley: if secondary resin canals are considered the exceptions also include Shuswap Lake. Addition of the number of needles having both types of resin canals shows that all three provenances have more needles with one resin canal than with two, the feature being most marked in Salmon Arm.

	Needles having:—		
	No resin canals	1 resin canal	2 resin canals
Shuswap Lake	105	99	93 (96)
Salmon Arm	154	88	49 (58)
Priest River valley	164	65	51 (71)

If the number of needles having one primary and one secondary resin canal are added the values given for the number of needles having two resin canals are altered to those given in brackets. In this light it appears that the only exceptions to Critchfield's statement are Shuswap Lake and Salmon Arm, and the difference in the number of needles having either one or two resin canals is small in the case of Shuswap Lake.

One of the most outstanding features of Table III is the large proportion of needles having secondary resin canals in three of the inland provenances. It is evident that this is a character peculiar to Shuswap Lake, Salmon Arm, and Priest River.

Table IV gives some indication of the distribution of these needles in relation to the trees sampled in each provenance. It should be emphasised that the classification employed is arbitrary. For example, in a particular tree only one of the ten needles examined may exhibit resin canals, if these resin canals are primary the tree is classified as having only primary resin canals. Similarly, if only one secondary resin canal was found in the ten needles examined the tree would be classified as exhibiting only secondary resin canals.

(c) The variation in the number of primary and secondary resin canals of different types in the provenances examined. (Table V).

An examination of the distribution of primary resin canals by type in the coastal provenances shows that there are two distinct groups. The two southern coastal provenances exhibit a smaller number of type

(a) and a larger number of type (c) when compared with the two northern ones. Statistically significant differences in the distribution of primary resin canals by type are absent within each of the two groups. This is also true of a group of the inland provenances consisting of Shuswap Lake, Salmon Arm, and Priest River valley. Comparison of the two remaining provenances, Prince George and Williamson River, revealed the existence of a significant difference at the 1% level as regards the distribution of primary resin canals by type.

The three types of secondary resin canals are common in only three inland provenances, Shuswap Lake, Salmon Arm, and Priest River valley. It is obvious from Table V that there are large differences in the distribution by type between the three provenances. This is in complete contrast with the position as regards the distribution of primary resin canals by type within the same three provenances.

Discussion.

It is evident from the details given in the previous sections that the provenances examined may be divided into groups, and that the composition of the groups will vary with the feature under consideration. However, it would also seem to be the case that some divisions of the provenances cover several features and, thus, appear to be more natural, or generally applicable. In the coastal provenances the most suitable grouping appears to be (1) Queen Charlotte Islands and Sonora Island —New Westminster, and (2) Olympic Peninsula and Grays Harbour. Within each of these groups statistically significant differences are absent in respect of many features e.g. the proportions of resin canals at the base, middle, and top of the needles; the average number of resin canals per needle; and in the distribution of primary resin canals by type. Similarly, the inland provenances may be divided into two groups: (1) Prince George and Williamson River, and (2) Shuswap Lake, Salmon Arm, and Priest River. Again, statistically significant differences are absent in respect of numerous features e.g. the average number of secondary resin canals per needle and the division of needles with resin canals between those having primary or secondary resin canals.

Some features obviously follow the pattern described above and, yet, may exhibit significant differences within the groups. The proportions of needles with no resin canals in the coastal provenances indicate that Queen Charlotte Islands should be grouped with Sonora Island—New Westminster, and Olympic Peninsula with Grays Harbour. Significant differences at the 1% level are present within both groups, but the difference between the groups is much greater than that within the groups. In the inland provenances the distribution of primary resin canals by type also indicates that the division of provenances given previously is satisfactory. There are no significant differences within the second inland group, but a significant difference at the 1% level between Prince George and Williamson River. Table V, however,

shows that Prince George and Williamson River are the only inland provenances to exhibit primary resin canal types (b) and (c) in any quantity. The proportions of resin canals at the base, middle, and top of the needles in the inland provenances also confirm the given grouping. In this case there is no significant difference between Prince George and Williamson River, and the significant difference at the 1% level within the second group is due to the Priest River provenance. Inspection of Table II shows that Priest River has a greater affinity with Shuswap Lake and Salmon Arm than with any other provenance, or group of provenances. Secondary resin canals occur in quantity only in the second group of inland provenances and, hence, though there are significant differences between the provenances they are not of the same magnitude as the difference between the group as a whole and the rest of the provenances. In summary, it can be stated that although significant differences may be present within the described groups the differences between the groups are generally of a larger order.

It may be contended that the first inland and second coastal groups of provenances appear to have much in common and, thus, these two groups should be amalgamated. However, the differences in the distribution of primary resin canals by type, and the effect of this on the numbers of resin canals found at the three investigated levels in the needles, would appear to be sufficiently large to warrant the two groups being kept separate.

Critchfield (4) found that resin canal frequency showed much greater differences within geographic provinces than between them. This would appear to be contrary to the present results. However, he was concerned only with the number of resin canals per needle as counted in sections cut at the middle of the needles. It is clear from the data given that this method will give, in many cases, an underestimate of the number of resin canals per needle. For example, Grays Harbour exhibits an average of 0.73 resin canals per needle when only those situated in the middle of the needle are considered (Table II). In fact the average number of resin canals per needle for this provenance is 1.107 (Table V). Another point which is of much greater importance is that his geographic provinces were extremely large e.g. one covered the Rocky Mountains, another the Sierra-Cascade mountain chain. Hence, it is clear that although Critchfield is correct in his findings there are still large areas within the geographic provinces, as defined by him, which exhibit a high degree of uniformity in respect of, at least, some of the features examined.

Four subspecies of *Pinus contorta* Douglas ex Loudon were distinguished by Critchfield (4). They were :—

Subspecies		Geographic province or group
contorta	...	Coastal.
bolanderi	...	Mendocino white plains.
murrayana	...	Sierra Nevada, Oregon Cascades.
latifolia	...	Rocky Mountains.

The four coastal provenances examined, naturally, can be classified as ssp. *contorta.* All the inland provenances investigated, with the exception of Williamson River, belong to ssp. *latifolia.* The Williamson River provenance originates from the natural range of ssp. *murrayana.* On this basis Williamson River might be expected to exhibit some features, concerning the resin canals, which would enable it to be easily separated from the other inland provenances. It may be distinguished from the three eastern inland provenances e.g. by the small number of secondary resin canals, but, it has already been shown that Williamson River is very similar to Prince George. Williamson River has fewer needles and trees with no resin canals than Prince George. These are outstanding distinctions between them, but it should be noted that Williamson River and Shuswap Lake have comparable numbers of needles with no resin canals, and Salmon Arm and Williamson River have similar numbers of trees with no resin canals. The distribution of the primary resin canals by type (Table V), however, reveals a significant difference at the 1% level between Williamson River and Prince George. It is interesting to note that this feature does not show the presence of significant differences within the other groups i.e. the two northern and the two southern coastal provenances, and the three eastern inland provenances.

Examination of characters, other than the resin canals, indicates that Williamson River is distinct from the other provenances. Table I shows that it has the shortest needles of the inland provenances. It also has, by far, the broadest needles of all the provenances examined. The mean values for the coastal provenances range from 1.43 to 1.50 mm., the mean of the other inland provenances vary from 1.51 to 1.61 mm. and that for Williamson River is 1.85 mm. In this connection it is interesting to note that Critchfield (4) describes ssp. *contorta* and ssp. *latifolia* as having leaves of medium width, while ssp. *murrayana* has wide leaves.

Critchfield (4) found that both leaf width and resin canal number increased regularly with increasing altitude. The main difference between the origins of Shuswap Lake and Salmon Arm is probably in altitude and Shuswap Lake has wider needles, 1.59 mm. as opposed to 1.51 mm., and a higher average number of resin canals per needle. In view of Critchfield's results this is not surprising. The total numbers of primary and secondary resin canals evidently increase with altitude, the former exhibiting a much larger increase than the latter. This is only to be expected in view of the fact that no evidence was found of the existence of a correlation between the presence of secondary or primary resin canals. Table V shows the distribution of secondary resin canals by type is also liable to be changed. Secondary resin canal type (c) increases with altitude, but type (a) decreases with altitude. Table III indicates that an increase in the altitude of the origin of the provenance results in an increase in the number of needles having one secondary resin canal, while the number of needles having one primary

resin canal drops. The table also shows that there is a sharp rise in the needles with two primary resin canals.

Although the position is undoubtedly complicated there is some evidence of the existence of latitudinal, altitudinal, and longitudinal clines. Critchfield's (4) results suggested a latitudinal cline in resin canal number in his coastal samples, but he concluded that the existence of a general association between latitude and resin canal number within the species was doubtful. In this case it would appear more reasonable to look for existing clines within divisions of the species rather than within the species as a whole. Primary resin canal type (c) becomes more frequent in the southern coastal provenances, and secondary resin canal type (a) evidently becomes increasingly frequent to the east in the inland provenances. As regards altitude, Salmon Arm and Shuswap Lake give some indication of the relationship between this factor and the behaviour of the resin canals. Finally, it should be pointed out that it may be too much to expect a clear cut relationship between the resin canals and the origins of the provenances as expressed in terms of latitude, longitude, and altitude. The climate at the origin of a provenance is not solely determined by its absolute position as given by these three factors, and climate may be connected with the resin canal characteristics of a population. It is known, for example, that the resin content of *Euphorbia biglandulosa* is increased by growing it under conditions of lower average and absolute minimum temperatures (10).

It was emphasised by Critchfield (4) that there was no over-all coincidence in the variation patterns of any two characters within the species. Critchfield found that although leaf width was more or less constant in all coastal samples, the average number of resin canals per needle increased from about 0.2 in the south to over 2 in the north. Similarly, if the relationship between leaf width and resin canal number had been absolute, Williamson River would have exhibited the highest number of resin canals in the present study. The present study, however, showed that there was a negative correlation significant at the 5% level between the average number of resin canals per needle and the needle length.

It is clear from the data given in the tables that it is possible to distinguish groups, and individual provenances within these groups. This being the case it is possible to devise a botanical key to assist the tracking down of the provenances studied; such a key could, for example, be based on the distribution of primary resin canals by type. This would enable a provenance to be placed within its correct group, and then named. A slightly different type of key is given in Appendix I. The usefulness of a key of this type is indicated by evidence given in literature which states that frequently there is no record of the origin of well formed stands (8). There are numerous difficulties connected with the formulation and use of a key of this type but the example

given is, at least, a step in the right direction. Some of the difficulties are summarised as follows:—

(1) The key is based on the characteristics exhibited by a population, and to attempt to find the origin of a plantation random samples have to be taken from the whole plantation. It is impossible to tell the origin of a single tree by its resin canal characteristics alone, although it is possible to do this in some cases if other features of the tree are considered. In some cases, however, it may be comparatively easy to place an individual tree within a group of provenances. For example, if a tree has numerous secondary resin canals and no primary resin canals then it may be placed within the group comprised of the three eastern inland provenances.

(2) The samples examined in the present study were taken from unthinned plantations and it may be assumed that they are representative of the natural populations at the origins of the provenances. If a plantation has been heavily thinned the samples taken may not be wholly representative of the natural population. One comparatively minor point is that the present samples are taken from populations which probably differ considerably in size.

(3) Only a small number of provenances were studied and this may well lead to difficulty in placing provenances which have not been examined. More information is also required concerning any possible effects of different site conditions. However, it would appear to be the case that there is, at least, a reasonable chance of placing a provenance in its correct group.

Critchfield (4) examined material from plantations grown at Placerville and in Yorkshire and found that the variation pattern of resin canal frequency, of the seed sources represented in these plantations was almost identical to that of the natural populations. Hence, it may be concluded from the present results that within the natural distribution of *Pinus contorta* Loudon there are large areas in which many resin canal characteristics are uniform. Within the coastal provenances examined there are two distinct groups, one being situated to the north of the other. In the inland provenances there are again two groups, but in this case one is situated to the east of the other. The results also show that it is possible to distinguish individual provenances within these groups by the examination of other resin canal characteristics.

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TABLE I.

Details of the provenances.

Origin	Latitude (north)	Longitude (west)	Altitude (ft.)	Year of seed collection	Mean needle length (cms.)
Queen Charlotte Islands, B.C.	52°–54°	131°–133°	0–150	1935	4.95
Sonora Island	50° 25′	125° 25′	0	1933	4.90
and New Westminster, B.C.	49° 12′	122° 56′	0		
Olympic Peninsula, Washington	47°–48°	123°–125°	300–400	1933	5.10
Grays Harbour, Washington	47° 5′	124° 0′	?	1936	5.29
Prince George, B.C.	53° 56′	122° 43′	1,867	1933	7.15
Shuswap Lake, B.C.	51° 0′	119° 0′	2,100–2,700	1933	6.76
Shuswap, Salmon Arm, B.C.	50° 42′	119° 18′	1,200	1934	6.32
Priest River valley, Idaho	48° 20′	116° 15′	2,380	1933	6.31
Williamson River, Klamath, Oregon	42° 30′	122° 0′	3,400–5,000	1934	5.69

The first four provenances are from coastal regions; the others are from inland areas and, hence, are examples of var. *latifolia* Engelm.

TABLE II.

Variation in the number of resin canals as counted from sections cut at the base, middle and top of the needles.

Origin	Total number of resin canals at:— Base	Middle	Top
Queen Charlotte Islands	592	584	551
Sonora Island and New Westminster ...	543	529	493
Olympic Peninsula	225	182	123
Grays Harbour	332	219	149
Prince George	242	221	179
Shuswap Lake	132	192	285
Shuswap, Salmon Arm	77	150	196
Priest River valley	58	189	179
Williamson River, Klamath	329	272	214

TABLE IV.

The number of trees in each provenance having primary, secondary, or no resin canals.

	Primary resin canals only	Primary and Secondary resin canals	Secondary resin canals only	No. resin canals
Queen Charlotte Islands ...	27	3		
Sonora Island and New Westminster ...	28	2		
Olympic Peninsula	21	3	1	5
Grays Harbour	29			1
Prince George	17	3	1	9
Shuswap Lake	3	9	15	3
Shuswap, Salmon Arm ...	2	11	10	7
Priest River valley		14	10	6
Williamson River, Klamath	24	3	2	1

TABLE III.

The distribution of needles having no resin canals, or resin canals of different types.

Origin	Needles having no resin canals	Needles having resin canals which are :— Primary: Number of resin canals 1	Primary: Number of resin canals 2	Primary: Total number of needles	Secondary: Number of resin canals 1	Secondary: Number of resin canals 2	Secondary: Total number of needles	Number of needles having 1 primary resin canal and 1 secondary resin canal
Queen Charlotte Islands	0	6	291	297	0	0	0	2
Sonora Island and New Westminster	24	11	257	268	0	0	0	0
Olympic Peninsula	140	57	99	156	4	0	4	0
Grays Harbour	101	67	132	199	0	0	0	0
Prince George	158	33	104	137	4	0	4	1
Shuswap Lake	105	9	60	69	90	33	123	3
Shuswap, Salmon Arm	154	28	20	48	60	29	89	9
Priest River valley	164	16	11	27	49	40	89	20
Williamson River, Klamath	90	59	134	193	8	7	15	2

The number of needles examined in each provenance, with the exception of Shuswap Lake, was 300. However, the numbers shown for the two northern coastal provenances do not add up to 300. This is due to the presence of one and six needles, each having 2 primary resin canals and 1 secondary resin canal, in the Queen Charlotte Islands and Sonora Island—New Westminster provenances respectively. One needle having 3 primary resin canals and another having 3 primary and 1 secondary resin canal were also found in the Sonora Island—New Westminster provenance.

TABLE V.

Variation in the number of primary and secondary resin canals of different types in the provenances examined.

	Primary resin canals Types			Secondary resin canals Types			Total number of primary resin canals	Total number of secondary resin canals	Total number of resin canals
	a	b	c	a	b	c			
Queen Charlotte Islands	549	33	10	1	1	1	592	3	595
Sonora Island and New Westminster	491	31	21	2	5	0	543	7	550
Olympic Peninsula	121	57	77	2	2	0	255	4	259
Grays Harbour	149	70	113	0	0	0	332	0	332
Prince George	174	46	22	1	0	4	242	5	247
Shuswap Lake	126	6	0	60	0	99	132	159	291
Shuswap, Salmon Arm	72	3	2	71	4	53	77	128	205
Priest River valley	51	7	0	110	21	18	58	149	207
Williamson River, Klamath	191	69	69	11	1	12	329	24	353

APPENDIX I.

1. Total number of resin canals greater at base than top of needles 2
   Total number of resin canals less at base than top of needles: secondary resin canals common 6

2. Few needles with no resin canals: bulk of needles (i.e. about 85%) have 2 resin canals which run entire length of needle. Queen Charlotte Islands and Sonora Island—New Westminster. Fairly high number of needles (i.e. above 30%) with no resin canals 3

3. Approximately $\frac{1}{3}$ of needles with no resin canals 4
   Approximately $\frac{1}{2}$ of needles with no resin canals 5

4. Proportion of total resin canal number at base to resin canal number at top of needles more than $\frac{2}{1}$: primary resin canal type (c) more common than type (b) ..... Grays Harbour. Proportion of total resin canal number at base to resin canal number at top of needles about $\frac{1.5}{1}$: primary resin canal type (c) as common as type (b) ..... Williamson River.

5. Primary resin canal type (c) half as common as type (b) ..... Prince George. Primary resin canal type (c) more common than type (b) ..... Olympic Peninsula.

6. Needles having 1 primary resin canal 1/6th as frequent as those having 2 primary resin canals ..... Shuswap Lake. Number of needles having 1 primary resin canal greater than number having 2 primary resin canals 7

7. Needles having 2 secondary resin canals only half as common as those having 1 secondary resin canal: secondary resin canal type (c) more than ten times as frequent as secondary resin canal type (b) ..... Salmon Arm. Number of needles having 2 secondary resin canals nearly as large as number having 1 secondary resin canal: secondary resin canal type (c) nearly as common as secondary resin canal type (b) ..... Priest River Valley.