GEOGRAPHIC VARIATION IN SEED WEIGHT, SOME CONE SCALE MEASUREMENTS AND SEED GERMINATION OF DOUGLAS-FIR *PSEUDOTSUGA MENZIESII* (MIRB.) FRANCO

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ABSTRACT

The principal objectives of the study were to investigate geographic variation of, and relationship between, 1000-seed weight and cone-scale morphology and variation of germination percent of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) from within its natural range in Northwest America. One hundred twenty four seed sources representing eight climatic regions from British Columbia to California (lat. 38°50' to 53°37', long. 117°00' to 127°27') were collected in 1966 and 1968 by the International Union of Forestry Research Organizations, Section 22.

From the seed samples, filled seed (which constituted 1000-seed weight) were selected using soft X-ray fluoroscopy. Five cone-scale measurements were taken; cone-scale width, bract width, cone-scale length, 1st prong length and 2nd prong length. The position of the bract in relation to the scale was rated.

For germination testing, 56 filled seeds were selected to represent each of 12 trees in each of 114 provenances. The total of 76,608 seeds from 1,368 individual trees were sown untreated in two replications on ten relatively uniform nursery beds during May, 1969.

Seed weights varied greatly. One thousand-seed weight increased clinally from low to high elevation and from north to south. Latitude appeared to affect seed weights more than elevation.

Cone-scale characteristics differed significantly from tree to tree, provenance to provenance, as well as sub-region to sub-

region. Cone-scale widths and lengths were only significantly different between regions. These characteristics again showed a clinal variation which increased from low to high elevations and from north to south in some regions, and revealed that latitude affected cone-scale morphology more than elevation.

Thousand-seed weights were generally positively correlated with cone-scale size.

Germination percent was significantly affected by latitude around 36 days after sowing, but this effect disappeared by 50 days. Elevation and longitude appeared not to affect germination percent during the observed period (0 - 92 days after sowing).

The results of this study illustrate the importance of geographic origin as a source of phenotypic variability in Douglas-fir.

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TABLE CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Douglas-fir, Pseudotsuga menziesii (Mirb.) Franco, not only is a widely-distributed but also an economically important forest tree species in western North America. The natural range of Douglas-fir extends more than 2,000 miles from northern central British Columbia into Mexico and almost 1,000 miles from Pacific Ocean to the eastern slopes of Rocky Mountains. The species grows under more diverse climatic conditions than any other important North American commercial tree species. However, although geographic races exist over this large area, many of them are unsuitable for commercial use (Allen, 1961).

The phenotypic variability within the species through its geographic range has been investigated by many workers and a large portion of this variability was attributed to the local environment (Irgens-Moller, 1958 and 1962; Bramhall, 1966). It is still possible to study the variability wherever the species grows, and there are advantages in doing so in natural forests. Cones as the generative organ of gymnosperms are least affected by external conditions and have characters which will permit the recognition of lower taxonomic units within species. Cone and seed characteristics are less influenced by environment and most revealing in variation studies (Sziklai, 1964). Although variation in cone morphology and seed weight as well as the relationships between these characteristics in conifers have been studied by a number of investigators (Squillace, 1957; Simak, 1960 and 1967; Sweet, 1965 and Sziklai, 1969), these studies did not show how cone-scale morphology influenced seed weight in Douglas-fir.

The primary aims of this study are divided into four parts; Part A - to investigate the geographic variation of 1000-seed weight; Part B - cone-scale morphology (cone-scale width, cone-scale length, bract width, 1st prong length, 2nd prong length and rating of bract); Part C - relationships between these characteristics for a wide range of Douglas-fir provenances; and Part D - to determine the range in seed germination percent and the geographic factors influencing germination in Douglas-fir.

Because of the fewer number of samples from Regions 4, 6 and 8 (4, 2 and 1 provenance respectively), these regions were not included in subsequent regression analyses.

The germination in a relatively uniform nursery environment was investigated. In particular, the relationships between seed germination percentage and latitude, longitude, and elevation of the seed source were studied.

LITERATURE REVIEW

A. Variation

Variation within Douglas-fir was noted by Larsen in 1937 as follows:

> "One has to travel very widely throughout the natural range of Douglas-fir in order to get an impression of differences in geographical type, but standing on one place one can, without moving a foot, see many individuals differing widely in their structure... It does not matter if one chooses in California a site in the Coast Range or in the Sierra Nevada, passes through Oregon and Washington, or in British Columbia selects a place on Vancouver Island or in the Rocky Mountains; everywhere one is bound to be impressed by the great individual variation of this tree-species."

Stebbins (1957) stated as follows:

> "One advantage is that it makes possible the analysis of the individual characters of these combinations and is the first step toward the causal analysis of these differences in terms of selection or any other factors. It also focuses attention on the continuous variation in quantitative characteristics which is present in many wide-ranging species and is of great importance in their adaptation to the environment..."

Sziklai (1967) emphasized the importance of variation in the following way:

> "The variation pattern from tree to tree and from stand to stand, as well as the population composition throughout the range of the species, should be known before any intensive forestry work can be planned on a logical basis."

B. Variation in cone and seed characteristics

Willis and Hoffmann (1915) observed that in Douglas-fir the size of cone was directly dependent upon the vigor of the cone-bearing shoot.

Perry and Coover (1933) reported that seeds from the upper crowns of shortleaf pine (Pinus echinata Mill.) and pitch pine (Pinus rigida Mill.) were more viable than those from middle and lower crowns. They also found that larger cones generally yield larger seeds in pitch pine, but that many small and medium-size cones contained more and better seeds than the larger cones in shortleaf pine. They noted that pitch pine cones varied in size from tree to tree with little variation within trees and found no association between cone size and vertical position of the cone in the tree.

Wright (1945) found that the fresh weight of Eastern white pine (Pinus strobus L.) seed increased significantly from small to large cones and from the apex to the base of the cone.

Simak and Gustafsson (1954) noted that in Scots pine (Pinus silvestris L.), cone size and cone weight did not only influence seed production and average seed weight but also embryo development and, through this, the subsequent germination capacity. Seed weight per cone increased with rising cone weight and decreasing seed number in the mother trees but these correlations could not be established in the grafts. In morphological respects there are distinct differences between seed obtained from natural trees and from grafted individuals.

Simak (1960) reported on cone samples that were collected from two trees of Scots pine close to each other in a stand at Bogesund, Sweden, in different years - 1952/53, 1953/54, 1954/55 and 1955/56. Through his investigation, it was found that number of seeds per cone, and average size of seed increased with increasing cone weight. The frequency of empty seeds decreased when weight increased. He concluded that the relationships of these properties appeared to be determined by the genotype of the tree and that they were strongly modified by the yearly climatic variation.

Allen (1961) found that variation within a Douglas-fir cone was random and of about the same order as the variation among the cones of the same parent. The genetic implications were evident in the case of the single cone, the single tree and the variation among trees, and these were attributed to environment, both in the cone and the tree as well as for a local population of trees.

Peace (1948) studied the northern part of the Douglas-fir range and noted the large variation in cone characteristics within the species. He found the range in cone length was from 3.4 to 8.4 centimeters. Cones from the coast tended to occupy the upper end of the range. The reflexed bract characteristics were observed on the coast while, although the reverse situation had in the past been considered to prevail, cones "without reflexed bracts" were found in the Rocky Mountain area.

Willett (1963) measured the Douglas-fir cone length and width from 22 coast and 8 interior provenances from Nimpkish Lake (Vancouver Island) to Kananaskis (Alberta) on 348 trees. The average cone length for provenances was 6.0 cm with a range from 5.1 to 7.7 cm and cone width average 2.1 with a minimum of 1.8 cm and a maximum of 2.4 cm for the different provenances.

Longitude, latitude of the collection area, the height, diameter at breast height, crown width and age of the tree explained only 9.3 per cent for cone length and 13.2 per cent from cone width of the variation. This suggests that other environmental and probably genetical variables are also important.

Tusko (1963) investigated Douglas-fir cone samples from 43 provenances across British Columbia from east to west and found the average cone length to be 5.4 cm ranging from 3.2 to 9.3 cm. The average cone width was 2.1 cm with a range between 1.6 and 2.7 cm. A certain overlap was observed in these characteristics so far as coast and interior origins were concerned but generally the coast provenances were larger.

Robinson (1963) investigated the variation in size of seed of Douglas-fir based on 348 trees from 30 different provenances and found significant differences in both the length and width of seed and wing, among the different provenances. He also mentioned that only 21.6 percent of the variation in seed weight can be explained by the age of mother tree, latitude and length of seed.

Sziklai (1967) investigated Douglas-fir cone length, length of seed, width of seed, length of wing and width of wing from 91 provenances (latitude range from 53°37' to 44°24'; longitude range from 121°27' to 177°00'). The average cone length of climatic sub-region was a range from 49.60 to 66.88 mm. The cone length for the "coastal" regions appeared to be longer (62.64 mm) than for "interior" regions (55.43 mm). The length of seed was 6.69 mm for "coastal" and 6.49 mm for "interior";

the width of seed 3.91 and 3.80 mm; the length of wing 9.15 and 7.98 mm; the width of wing 5.86 and 6.22 mm. He pointed out that a clearly-expressed clinal variation was observed in cone and seed length with an increasing trend from north to south. The other characteristics investigated such as length of wing and seed did not show a similar clinal variation pattern.

Roche (1966) studied geographic variation of cone morphology which he found to be strongly clinal in white spruce (Picea glauca (Moench) Voss) and Engelmann spruce (Picea engelmannii Parry). The populations were continuous in their distribution from Montane to Sub-alpine forest regions. Hybrid populations between both these species exist and have been recognized and delimited on the basis of cone scale morphology.

Van Deusen and Beagle (1970) reported that ponderosa pine (Pinus ponderosa Laws.) cone samples collected during 1967 and 1968 from 75 individual trees in the Bear Lodge Mountain of Wyoming, were quite uniform in length, averaging 2.6 inches over the area. Number of seeds per pound averaged 12.673 but ranged from 8,247 to 22,997 for individual trees. Number of seeds per cone was positively related to cone length. There was an average of 415 green cones per bushel.

Sweet (1965) in New Zealand examined 30 Douglas-fir provenances from the west side of the Cascades and Nevada. Samples were collected from latitudes ranging from 38°10'N to 48°15'N in 1956. Another two were collected from plantations in New Zealand in 1955 and 1956. He found highly significant differences between seed weight and: (1) altitude, (2) length of frost-free growing season and (3) mean temperature of coldest month of seed sources. He noted the correlation between seed weight and altitude of seed source was considerably higher than between seed weight and features representive of temperature regime at seed source. Provenances from higher altitudes had heavier seeds than those from lower altitudes.

Allen (1960 and 1961) had developed a method for distinguishing between coast and interior origins of Douglas-fir based on seed morphology.

C. Variation in seed germination characteristics

The germination of seed is influenced by many complex factors. Factors relating to provenance, including photoperiodic requirements and flowering habits, the nature of pollination and fertilization, the size, weight and longevity of the seed, the degree of maturity, the characteristics of dormancy, the position of the seeds in the cone and the position of the cone on the trees, and the characteristics to secondary dormancy under unfavourable external conditions are inherent in the seed itself (Baldwin, 1942).

Mirov (1936) pointed out that the germination test was used to determine the variability of seed, to estimate the amount of seed to be used in the field, or to determine the requirements for optimum germination under various environments.

The time of cones harvesting, and the techniques of seed extraction and storage affect germination. Rohmeder (1942) found that the germination capacity of fully matured <u>Ulmus</u>

montana (With.) seed was highest at the time of harvest and gradually decreased thereafter. Seed which was not fully matured was characterized by a germination capacity high at first, low during one or several months of after-ripening, and at its highest shortly after this was completed. He also mentioned that prematurely harvested seed stored better than fully matured seed and it was recommended that Ulmus montana (With.) seed should be harvested late in the season, preferably by collection from the ground. Sowing in forest or nursery should take place as soon as possible after seed harvest.

Hebb (1954) reported that the most effective way to open pond pine (Pinus serotina Michx.) cones was to dip the cones in boiling water for a moment. He found: (1) full seed from quick-scalded cones germinated 96.9 percent, the highest germination of any cone treatment; (2) seed from baked cones 94.4 percent, and (3) seed from air-dried cones opened with a knife 92.7 percent.

Allen (1957) also found that seed in green uncured Douglas-fir cones showed very heavy losses when subjected to 104°F, whereas seed in pre-cured similar cones showed no ill effect at a 122°F kiln temperature. He also stated that Douglas-fir can be safely dried at a kiln temperature of up to 122°F, but about 20 percent or more loss in Douglas-fir seed viability when the kiln temperature was raised to 140°F. The seed damaged by dewinging or having a dull, dusty-looking seed coat produced seedlings of low vigour apparently susceptible destructive contamination.

Tool et al, (1956) indicated that the great variability of temperature requirements between and within species depended on age, storage conditions and other factors.

Stone (1957) reported that sugar pine (Pinus lambertiana Douglas) seeds stored at 77°F and 0°F, in desiccators after seeds were dried at room temperature to an average moisture content of 10 percent. After two-year storage at the University of California Agriculture Experiment Station, seeds were given a germination test in Petri dishes filled with vermiculite, and it was found that the dry storage at 0°F was more effective in maintaining the seeds "fresh" condition than storage at 36°F or 77°F.

Mirov (1946) reported that germination of seed from 21 species of pine kept at California Forest and Range Experiment Station in airtight 5-gallon tin cans at 40°F for periods ranging from 5 to 15 years, showed that seed of some pines will keep for a long time without losing their viability.

With regard to the effect of seed size on germination, Wright (1945) reported that medium-size seeds showed higher germination percentage than either the large or small seeds of eastern white pine in both stratified or unstratified.

Baldwin (1942) reviewed the work of some investigators and found that the size and weight of seed had a definite effect on germination because the largest and heaviest seeds were the best, had the more food reserves, germinated more promptly, and produced the most vigorous seedlings. On the contrary, Iljin (1952) reported on tests of Scots pine in a Liebenberg germinator but failed to establish a relationship between seed weight and germination capacity and energy.

Toumey and Korstian (1948) stated that when the size of seed was not dependent upon the range of geographic distribution but rather upon local conditions, larger seed possesses a greater germinating power and produces more vigorous seedlings.

Seed germination is not only effected by seed size, but also by cone size. Kocharj (1950) divided Scots pine cones into three size groups: (1) >4.5 cm long x >1.5 cm diameter; (2) 3-4.5 x 1.5-2.5 cm; and (3) < 3 x < 1.5 cm. The laboratory germination test made on 100 seeds of each group showed that group 2 had the highest germination capacity and energy. Group 1 showed practically the same germination capacity but a considerably lower energy of germination and group 3 was very much inferior.

Stratification can also have a marked effect on germination. Allen (1958) reported that although many interior lots of Douglas-fir seed germinated rapidly without pre-treatment or special conditions, most coastal lots were sluggish unless pre-treated or subjected to special conditions during incubation. Coastal seed sown late in the spring in the nursery or field may not germinated untill the following year unless previously stratified. In general, coastal, seed appeared to be more "dormant" when untreated but was affected by seed parent and site, nutrition provided by the parent, cone and seed maturity, cone storage conditions, processing, and seed storage.

MATERIALS AND METHODS

A. Thousand-Seed Weight

A total Of 124 provenances (Table 1 and 2, Figure 1) were used in this study, of which 91 provenances collected from British Columbia, Washington and Oregon in 1966, while the collection was made for the remaining 33 provenances from Oregon and California in 1968. The expeditions were organized by International Union of Forestry Research Organization, Section 22. Come samples were collected from the south aspect of the middle part of the crown of the tree; ten to twenty dominant trees 160 to 320 feet apart in each stand were sampled (Barner, 1966 and Lines, 1967). Twenty cones were shipped to the Faculty of Forestry, University of British Columbia after collection each year.

Extraction, dewinging and cleaning were made carefully by hand at room temperature, then the seeds were stored in a cold storage room (0^o-2^o).

After seed extraction, filled seeds were separated from the empty ones using X-ray fluoroscopy. The following classes were used (Sziklai, 1964):

Endosperm:

1. Seed completely empty of endosperm.
2. Shrunken endosperm in horizontal and vertical position; length less than 1/3 of the total seed length; rounded in shape, or occupying the middle part of the seed cavity.
3. Insect larva inside.

4. Endosperm fills out most of the seed cavity. A narrow but conspicuous empty space exists between the endosperm and the seed coat.

5. Endosperm fully occupies the seed cavity.

Embryo:

1. Embryo absent.

2. Part of embryo is visible, the total length of visible part is less than 50% of the length of the seed.

3. Same as 2, but the visible part is between 50% and 75%.

4. Same as 2, but visible part is more than 75%.

The selected seeds had a well-developed endosperm and embryo that fills 75-100% of the embryo cavity.

From each tree 500 filled seeds, or as close to that number as possible, were weighed and the findings used to calculate the 1000-seed weight and the average weight of seed of a particular provenance.

The filled seed of all the samples were uniformly separated into envelopes, all of which were placed in a desiccator for 48 hours before weighing. All seeds were weighed with an analytical balance reading to 10^{-4} grams.

B. Cone-Scale Morphology

From the same provenances used in Part A, two cones were randomly selected from each tree and six scales with bracts were taken from the middle of each cone after seed extraction. These six scales were mounted, three on the abaxial and three on the adaxial side on sheets of paper (Figure 2). On the average, 15 trees from each provenance were represented by 90 cone-scales.

Five measurements were made (Figure 3/a) on each scale, width of scale (W_1), width of bract (W_2), length of scale (L_1), length of 1st prong (L_2), length of 2nd prong (L_3) and position of the bract (R) in relation to the scale was rated (Figure 3/b). All of these five measurements were measured to the nearest 0.1 millimeter using the Swedish Tree Ring measuring equipment.

The cone-scale width was measured at the widest part of the scale while the width of bract was measured at the base of the prongs.

If the two side prongs were not the same length, then the 1st prong length was measured from the base of the deeper indentation and the 2nd prong length was measured from the base of the same identation.

C. Relationship Between Thousand-Seed Weight and Cone-Scale Characteristics

Data from Parts A and B were used to investigate these relationships.

D. Seed Germination Test

Out of 124 provenances collected 114 were used in this experiment (Table 1). Fifty-six filled seeds were selected to represent two replications (28 seeds per replication) of each tree in a provenance. A total of 1,368 individual trees were represented and 76,608 seeds were sown.

Seeds were sown without presoaking or stratification in the University of British Columbia Southern Campus Forest Research Nursery between May 3-9, 1969.

Ten nursery beds were established during the spring of 1969 with three nursery beds in a row. The 30-cm nursery beds were filled with California mix (C) (Baker, 1957) to a depth of 25 cm. Seeds were sown 0.6 cm deep and covered with fine sand with 2.5 cm x 10 cm spacing.

An irrigation system was also provided.

Germination counts were made at 36, 50, 72 and 92 days after sowing.

The data were stratified according to seed collection zone maps given by Haddock and Sziklai (1966) for Canada, by Western Forest Tree Seed Council (1966) for Washington and Oregon, and by Buck et al. (1970) for California. Each climatic region was divided into several sub-regions according to geographic factors and soil and climatic conditions (Figure 1).

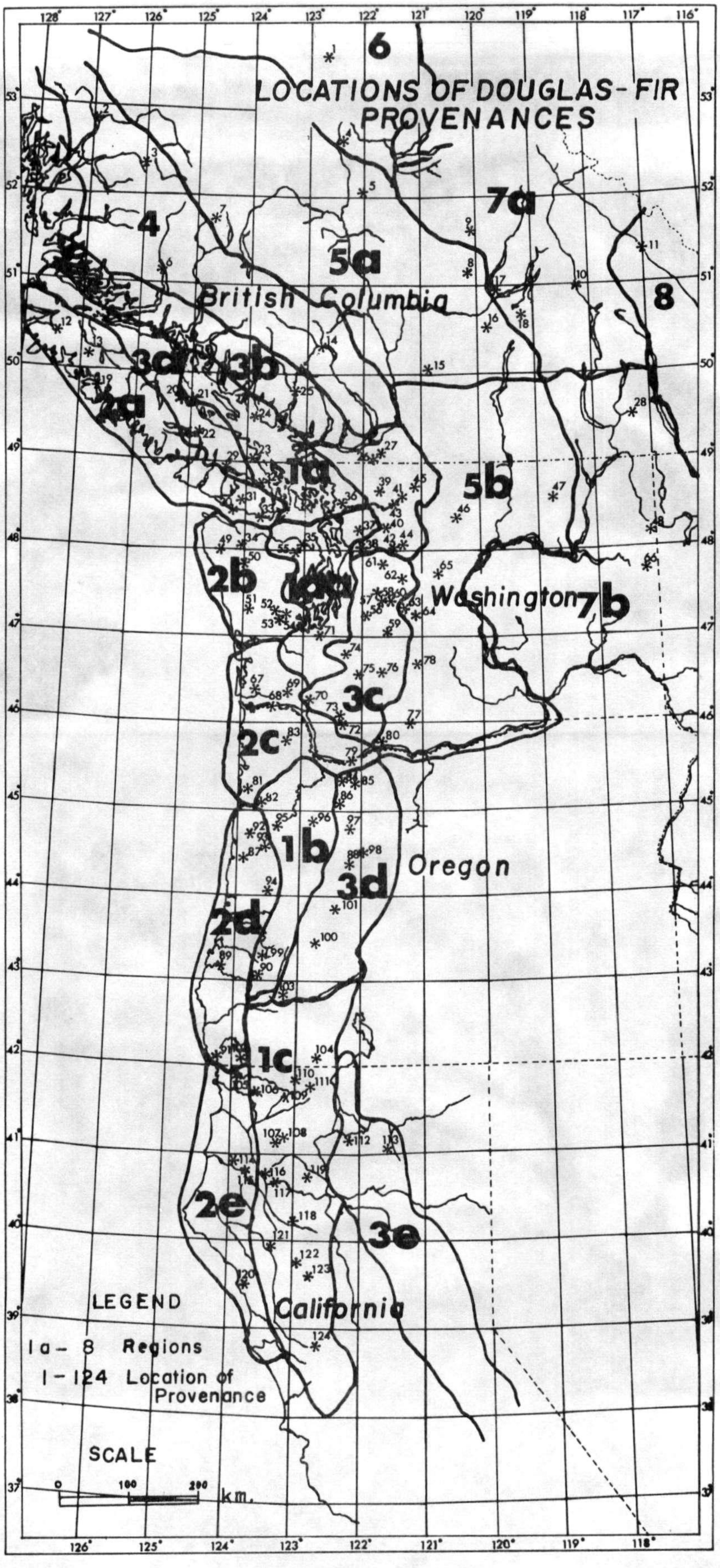

Figure 1. Geographic distribution of seed sources in the Pacific Coast of North America Douglas-fir provenance study.

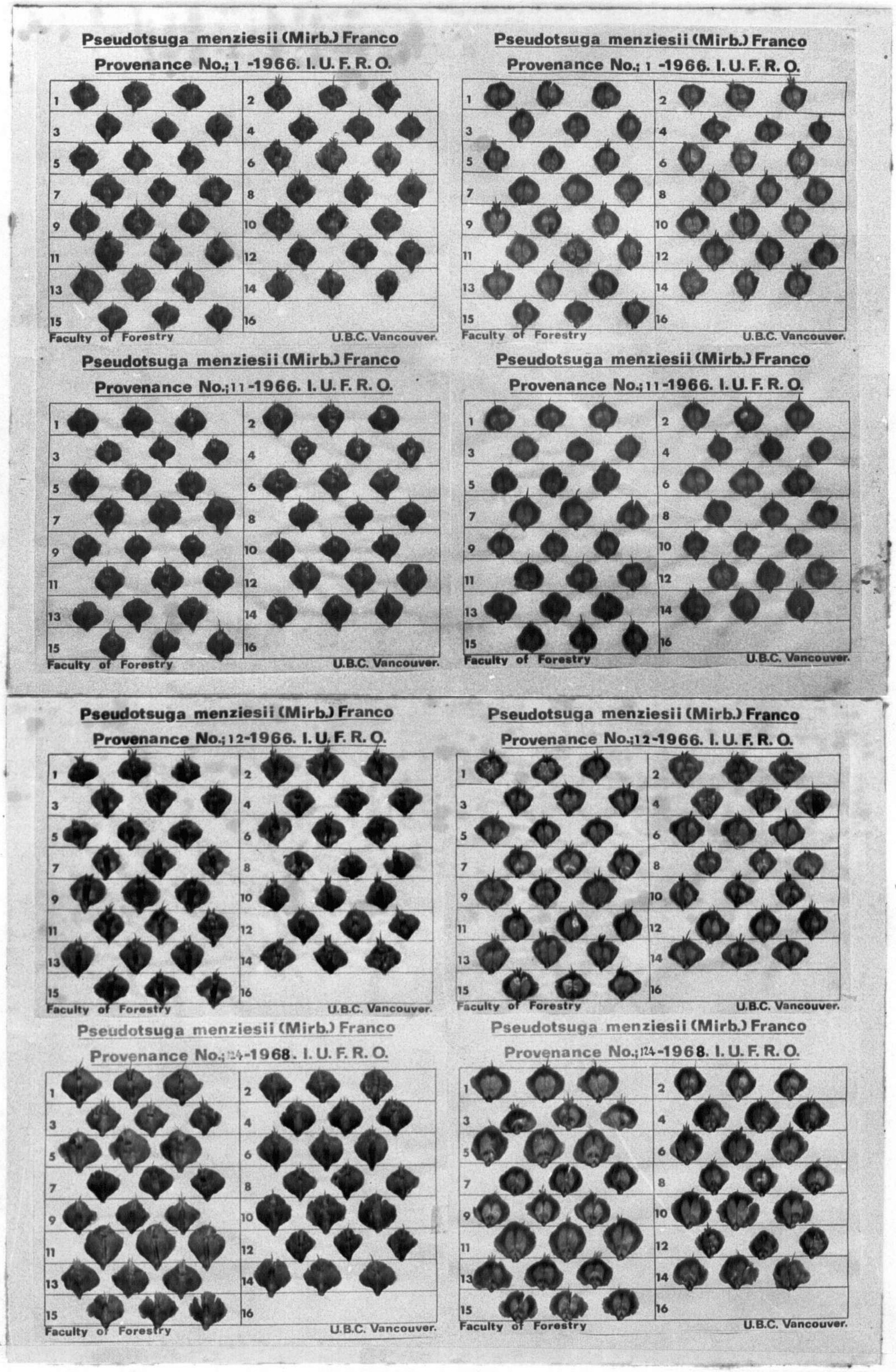

Figure 2. View of abaxial and adaxial surface of cone-scales from Prov. No. 1,11,12 and 124.

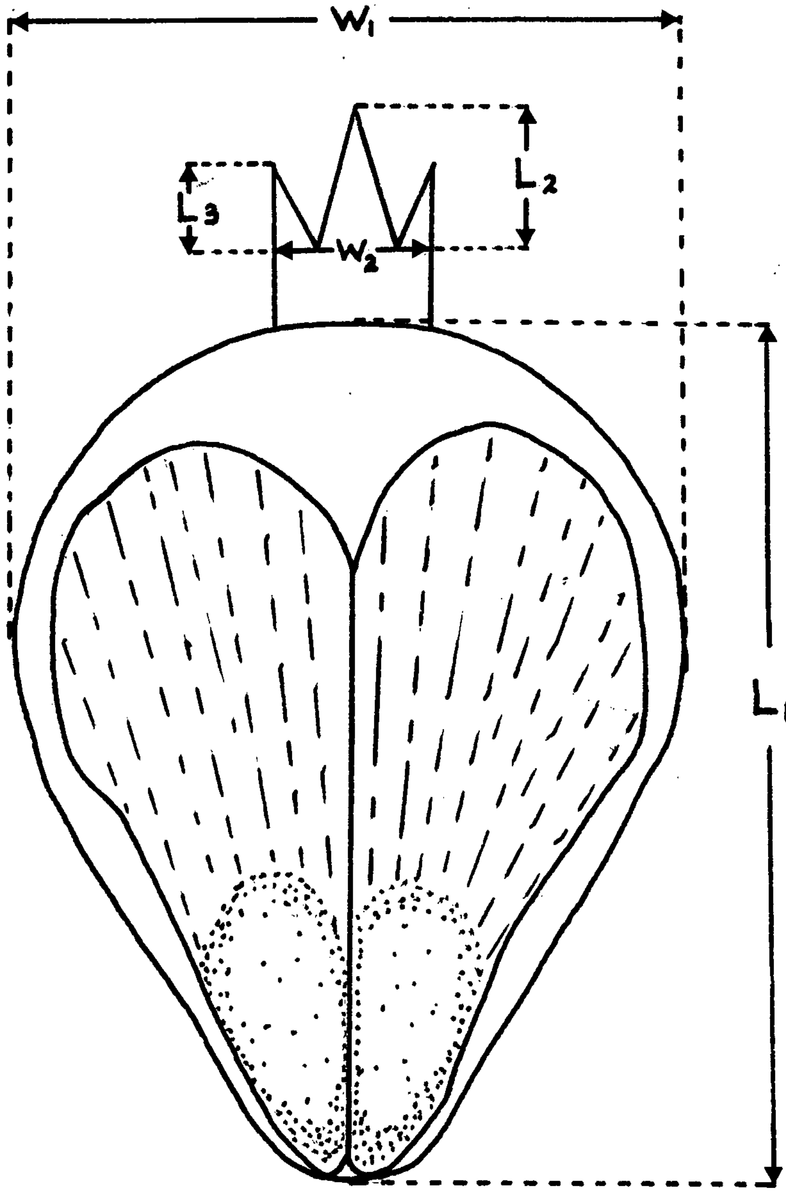

Figure 3/a · Diagrammatic represention of Douglas-fir cone-scale and bract showing five basic measurements·

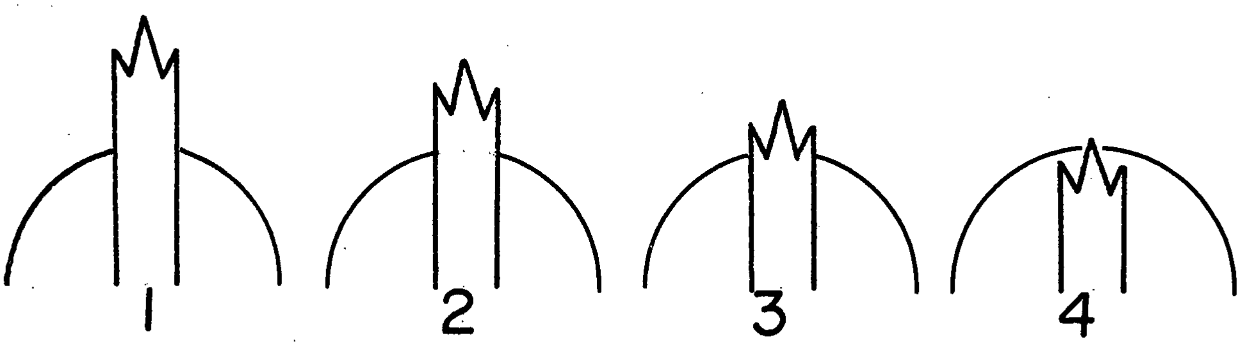

Figure 3/b · Position of the bract in relation to the scale ·

Table 1. Location of 124 Douglas-fir provenances (No. 1 to 91 were collected in 1966, No. 92 to 124 were collected in 1968).

British Columbia

Provenance No.		Average elevation feet	Latitude ° '	Longitude ° '	No. of trees
1.	Stoner	1900	53 37	122 40	15
2.	Dean	20	52 48	126 57	14
3.	Stuie*	750	52 22	126 00	6
4.	Alexandria	2100	52 41	126 26	16
5.	Williams Lake	2000	52 06	122 00	16
6.	Klinaklini*	10	51 07	125 36	10
7.	Tatla	2900	51 44	124 44	16
8.	Barriere	1400	51 12	120 09	15
9.	Clearwater	1500	51 39	120 00	16
10.	Revelstoke	2000	51 00	118 12	15
11.	Golden	2700	51 23	117 00	15
12.	Jeune Landing	550	50 27	127 27	15
13.	Nimpkish	300	50 19	126 53	13
14.	Owl Creek	700	50 20	122 43	15
15.	Merritt	2700	50 04	120 51	16
16.	Chase	1650	50 33	119 47	16
17.	Monte Creek	2100	50 37	119 54	15
18.	Salmon Arm	1550	50 44	119 13	16
19.	Tahsis Inlet*	50	49 47	126 38	11
20.	Forbidden Plateau	2000	49 40	125 09	15
21.	Courtenay	220	49 41	125 03	15
22.	Alberni	450	49 19	124 51	15
23.	Cassidy	650	49 03	123 57	13
24.	Sechelt	600	49 31	123 53	15
25.	Squamish	50	49 47	123 09	15
26.	Chilliwack Low	550	49 04	121 48	15
27.	Chilliwack High	3000	49 06	121 42	13
28.	Nelson	2700	49 03	117 16	14
29.	Caycuse	700	48 55	124 26	16
30.	Jordan River*	800	48 28	124 14	13
31.	San Juan River	700	48 35	124 05	15
32.	Duncan	200	48 45	123 45	14
33.	Sook	150	48 20	123 44	15

Washington

34.	Lake Crescent	1000	48 04	124 00	14
35.	Sequim Bay	200	48 02	124 00	14
36.	Sedro Woolley	200	48 32	122 19	16

Table 1. (Continued)

Provenance No.		Average elevation feet	Latitude ° '	Longitude ° '	No. of trees
37.	Arlington	300	48 13	122 04	15
38.	Granite Falls	300	48 05	122 02	16
39.	Concrete	1550	48 39	121 43	16
40.	Darrington	500	48 16	121 38	15
41.	Bacon Point	1650	48 36	121 23	15
42.	Perry Creek	2000	48 03	121 28	16
43.	Marblemount	400	48 35	121 24	15
44.	Sloan Creek	2150	48 05	121 18	16
45.	Diablo Dam	1450	48 43	121 07	15
46.	Twisp	2600	48 23	120 24	15
47.	Republic	2400	48 36	118 44	15
48.	Newport	2400	48 12	117 03	16
49.	Forks	300	47 59	124 24	14
50.	Hoh River	800	47 48	123 58	14
51.	Humptulips	450	47 19	123 54	14
52.	Matlock	1650	47 18	123 26	14
53.	Matlock	400	47 15	123 25	14
54.	Shelton	300	47 15	123 12	16
55.	Gard Station	1500	48 00	123 05	15
56.	Enumclaw	800	47 16	121 56	15
57.	North Bend	500	47 28	121 45	16
58.	Chest Morse Lake	2000	47 22	121 40	16
59.	Parkway	2400	47 02	121 34	15
60.	Denny Creek	1800	47 24	121 32	14
61.	Gold Bar	400	47 51	121 39	15
62.	Skykomish	1000	47 42	121 20	15
63.	Keechelus Lake	2600	47 23	121 22	15
64.	Cle Elum	2100	47 13	121 07	15
65.	Chiwachum	1800	47 41	120 44	16
66.	Spokane	2000	47 47	117 12	15
67.	Naselle	150	46 22	123 44	15
68.	Skamokawa	700	46 21	123 30	16
69.	Cathlamet	650	46 18	123 16	15
70.	Castle Rock	500	46 19	122 52	14
71.	Yelm	200	47 01	122 44	15
72.	Yale	400	46 00	122 22	15
73.	Cougar	1650	46 05	122 18	15
74.	Alder Lake	1400	46 48	122 17	16
75.	Randle	1100	46 33	122 03	16
76.	Packwood	2150	46 34	121 40	14
77.	Glenwood	1600	46 00	121 00	16
78.	Rimrock	2500	46 40	121 02	15
79.	Prindle	1500	45 37	122 08	15
80.	Willard	1650	45 48	121 41	15
Oregon					
81.	Hebo	500	45 13	123 51	15

Table 1. (Continued)

Provenance No.		Average elevation feet	Latitude ° '	Longitude ° '	No. of trees
82.	Grand Rond	600	45 06	123 36	16
83.	Vernonia	700	45 46	123 13	15
84.	Sandy	900	45 23	122 18	15
85.	Cherryville	2200	45 19	122 08	15
86.	Pine Grove	2400	45 06	121 23	15
87.	Waldport	200	44 24	123 52	15
88.	Upper Soda	3250	44 23	122 12	15
89.	Coquille	200	43 12	124 10	14
90.	Olalla*	1100	43 05	123 34	8
91.	Brookings	1000	42 07	124 12	16
92.	Burnt Woods	1100	44 36	123 42	16
93.	Mary's Park	3250	44 30	123 34	15
94.	Eugene	700	44 01	123 23	15
95.	Corvallis	250	44 42	123 13	16
96.	Mill City	550	44 48	122 24	15
97.	Detroit	1600	44 44	122 10	16
98.	Marion Forkes*	3500	44 30	122 00	6
99.	Roseburg	900	43 19	123 30	16
100.	Steamboat	5250	43 22	122 31	14
101.	Oakridge	2900	43 54	122 22	16
102.	Cave Junction	1400	42 11	123 40	16
103.	Wolf Creek	1400	42 41	123 23	15
104.	Ashland	4900	42 05	122 39	15
California					
105.	Gasquet	400	41 51	123 59	15
106.	Happy Camp	4100	41 39	123 31	16
107.	Sawyers	4750	41 16	123 09	15
108.	Sawyers Bar	3800	41 17	123 08	16
109.	Scott Bar	3300	41 44	123 06	16
110.	Seiad Valley*	2600	41 48	123 00	12
111.	Hawkinsville*	3500	41 47	122 40	15
112.	Dunsmuir	3300	41 12	122 18	13
113.	Burney	3350	41 05	121 39	14
114.	Arcata	1600	40 55	123 50	16
115.	Arcata	2900	40 54	123 46	16
116.	Big Bar	3250	40 43	123 18	15
117.	Big Bar	4300	40 47	123 12	15
118.	Wildwood	3900	40 23	123 00	16
119.	Weaversville	3750	40 54	122 44	16
120.	Fort Bragg*	200	39 30	123 43	5
121.	Covelo	3000	39 55	123 18	16
122.	Covelo	5100	39 48	122 56	15
123.	Alder Springs*	4500	39 39	122 45	15
124.	Lower Lake*	3100	38 50	122 42	15

* provenance not included in the germination tests.

Table 2. Number of provenances and trees sampled in 1966 and 1968.

Province or State	Year of collection				Total	
	1966		1968			
	Number of					
	Prove-nances	Trees	Prove-nances	Trees	Prove-nances	Trees
British Columbia	33	474	--	--	33	474
Washington	47	710	--	--	47	710
Oregon	11	151	13	191	24	342
California	--	--	20	292	20	292
Total	91	1,335	33	483	124	1,818

RESULTS AND DISCUSSION

Thousand-Seed Weight

The mean values of 1000-seed weight of the 124 provenances collected for the present study ranged from 6.9 to 18.0 grams (Table 3); these values differ from those of both Ching and Bever (1960) and Sweet (1964). From a total of 1,818 individual trees represented in this study, the 1000-seed weight from all over these trees ranged from 5.3 to 24.8 grams (Table 3), and this range covers the findings of Ching and Bever (1960) and Sweet (1964). The differences were possibly due to the fewer number of sample trees in the latter studies when compared to an average of 15 trees representing each seed source in this study. Another possible factor influencing the seed weight is the different year of sample collection. While Ching and Bever (1960) and Sweet (1964) collected in 1954 and 1956 and in 1955 and 1956 respectively. The seed samples in this study were collected during 1966 and 1968.

Regression analyses were carried out between 1000-seed weight and latitude and elevation of seed source (Part A), between cone-scale characteristics and latitude and elevation of seed source (Part B) and between 1000-seed weight and cone-scale characteristics (Part C) all based firstly on sub-regions. No significant relationships could be established, except some in sub-regions 1c, 3b, and 3c, so the regression analyses were then based on region rather than sub-region.

Significant seed-weight variances among different geographical localities, trees and stands have been reported by several authors (Squillace, 1965; Sweet, 1964; Anderson, 1965 and Simak, 1967). The data (Tables 3 and 4) showed that 1000-seed weight varied greatly among provenances, sub-regions and regions. These results were supported by Simak (1967) who studied seed weight of European larch (Larix decidua (Mill.)) from different provenances. He found significant differences in seed weight among different regions.

There are several external factors which may modify the 1000-seed weight for a tree. Perry and Coover (1933) reported that larger cones generally yield larger seeds in pitch pine. Simak (1954) also reported that cone size and cone weight were the factors influencing the average seed weight in Scots pine. He mentioned that seed weights per cone increased with increasing cone weight and decreasing seed number in the mother tree.

Other external factors, such as the position of a tree in a stand, the position of the seed in a cone, climate and edaphic factors, the age of the tree and the number of cones produced by a tree can also influence the seed weight.

However, Sweet (1964) did not recommend seed weight as a useful measure for indicating provenance differences owing to the extent to which it may be affected by degree of cleaning, year of collection and age of parent tree. All the seed samples in this study were cleaned carefully by hand. Dewinging was carried out in such a way that nothing except that portion of the wing directly attached to the seed remained with it, and so the data of seed weight in this study appears more reliable. Simak (1967) pointed out that as thousand-seed weight values of European larch seed from different geographical regions were constant and specific they could be used as a criterion for the identification of the origin of larch. However, the thousand-seed weight variation among the regions had a clinal character, which made it difficult or impossible to determine the origin of provenance material lying on the boundary of two neighbouring regions.

Figures 4, 5 and 6 show that 1000-seed weight was strongly correlated with elevation in Regions 1, 2 and 3. In other words, provenances from higher elevations developed heavier seed than those from lower elevations. While the results substantiate the findings of Sweet's (1964) work on Douglas-fir and of Simak's (1967) on European larch, they are contrary to the statements of Mirov el at. (1952) on ponderosa pine.

No relationships were observed between 1000-seed weight and elevations of seed source in interior Regions 5 and 7 (Table 5), perhaps because elevations of the provenances collected from these two areas ranged only from 1,400 to 2,900 feet, and 1,500 to 2,700 feet respectively, or because of the difference between coast and interior.

Correlations between 1000-seed weight and latitude of seed source in coastal Regions 1, 2 and 3 (1% level), and in interior Regions 5 and 7 (5% level) were negative (Figures 7 to 11). The coefficient of determination R^2 of these relationships (Table 5) was considerably higher than that for the 1000-seed weight versus elevation of seed source in both coastal and interior regions. Latitude was clearly more important than elevation in affecting seed weight, and the results indicate that seed weight was subject to clinal variation, and increased from north to south.

The 124 provenances were then divided into five different 500-feet elevation classes from sea level to 2,500-feet. Because there were only 30 provenances between 2,500 to 5,500 feet of elevation, these were combined into a simple sixth group to make their contribution more even from north to south.

Correlation analysis was carried out between 1000-seed weight and latitude for each group. Figures 12a to 12f (Table 6) indicate significant negative relationships between 1000-seed weight and latitude for each group. Seed weight appears to increase from north to south even within a certain range of elevation confirming previous findings that latitude was more important than elevation as a factor affecting seed weight. This agrees with clinal trends in seed and cone length of Douglas-fir which increased from north to south (Sziklai, 1969), and the nuclear volume and DNA content of Douglas-fir (El-Lakany and Sziklai, 1971).

The relationship between 1000-seed weight and elevation·

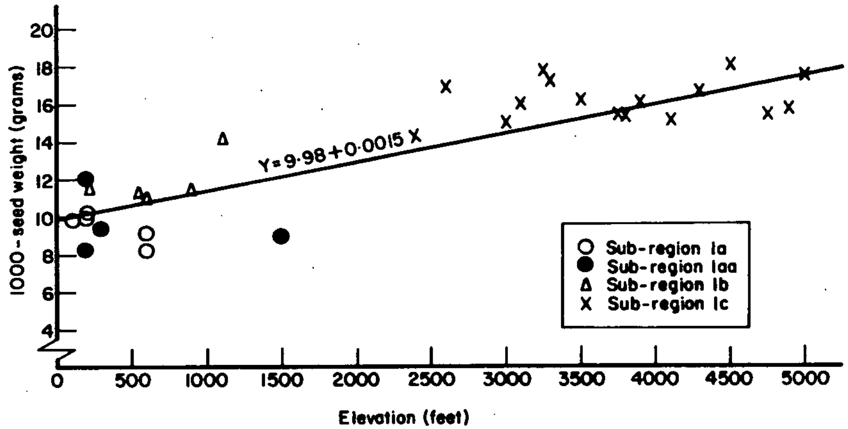

Figure 4· in region I·

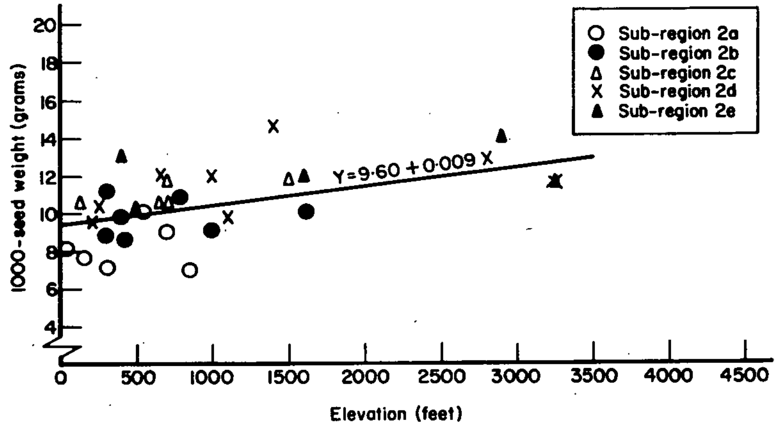

Figure 5· in region 2·

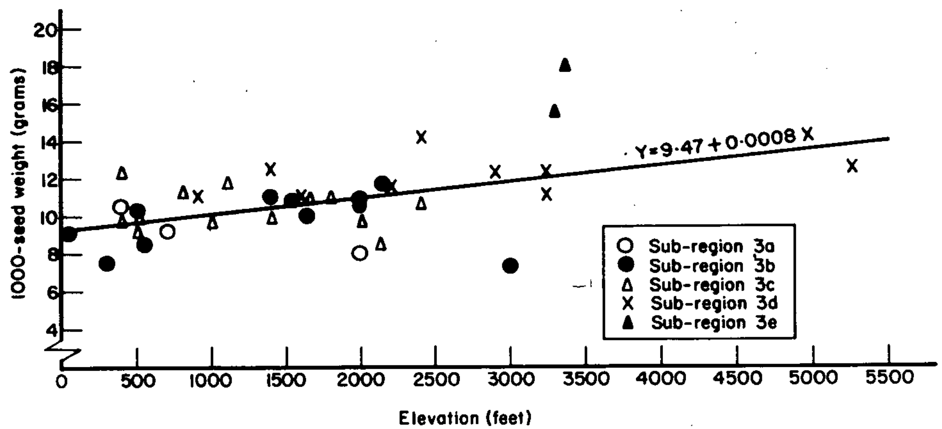

Figure 6· in region 3·

The relationship between 1000-seed weight and latitude·

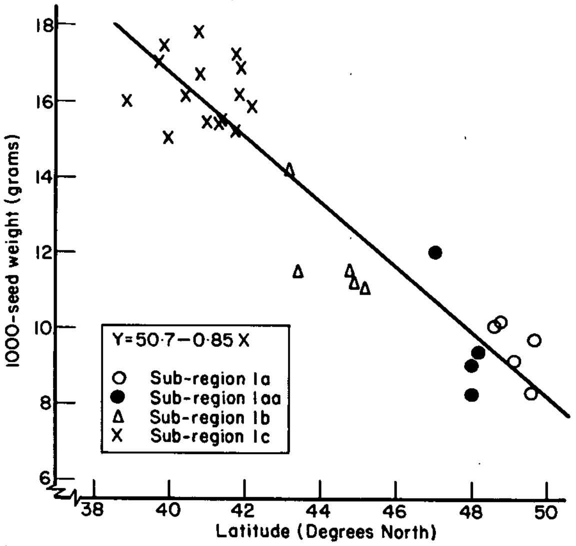

Figure 7· in region 1·

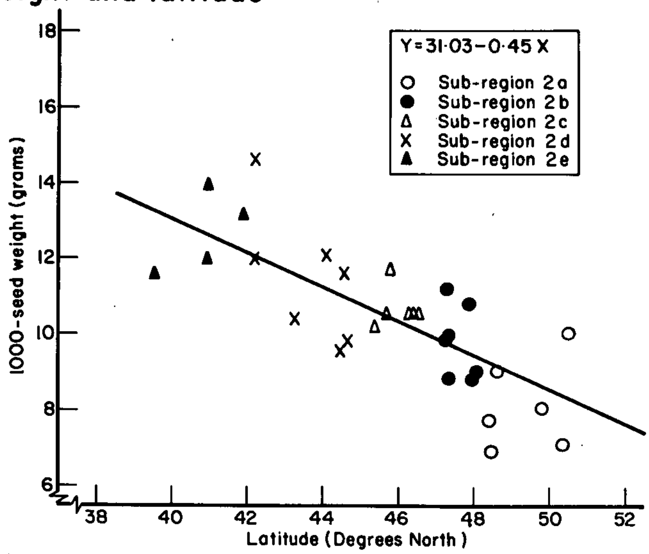

Figure 8· in region 2·

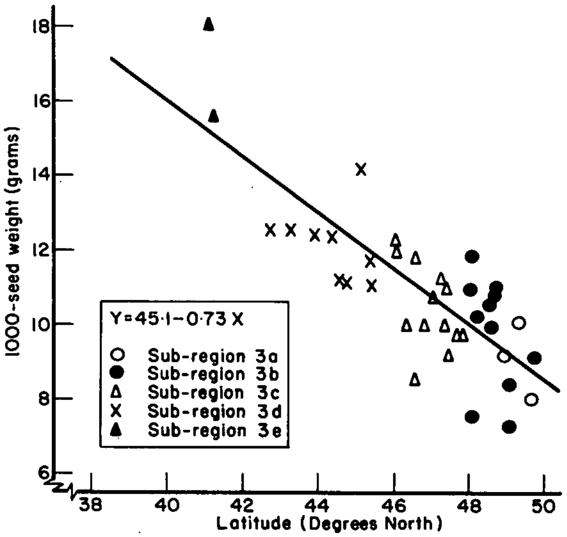

Figure 9· in region 3·

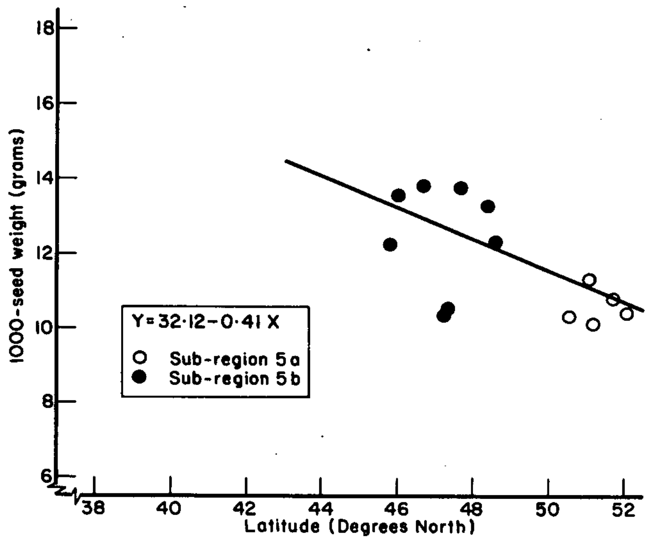

Figure 10· in region 5·

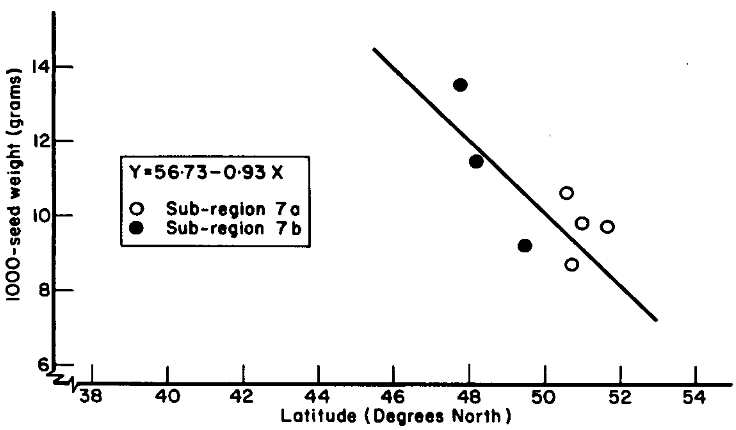

Figure 11· in region 7·

Figure 12a–12f. The relationship between 1000-seed weight and elevation from south to north for each 500 feet of elevation from sea level to 2,500 feet, and from 2,501 to 5,500 feet.

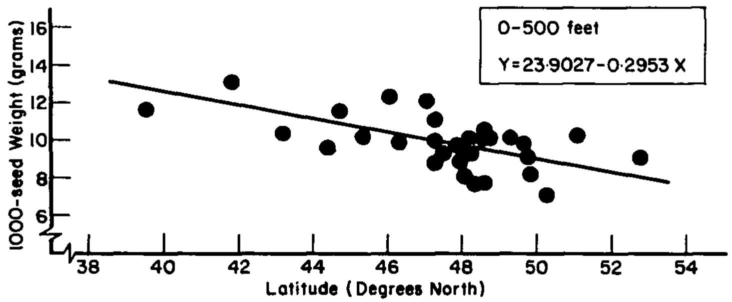

Figure 12a. from sea level to 500 feet.

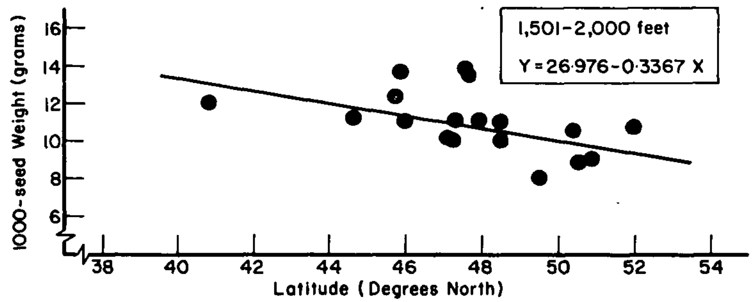

Figure 12d. from 1,501 to 2,000 feet.

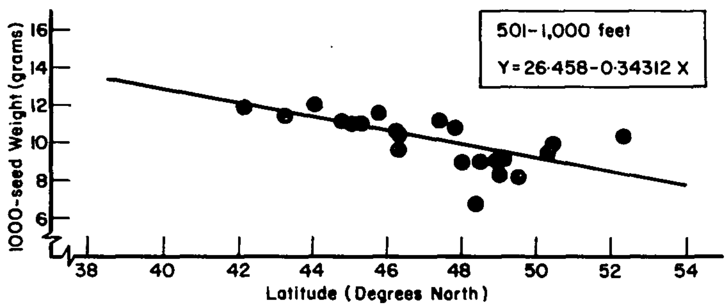

Figure 12 b. from 501 to 1,000 feet.

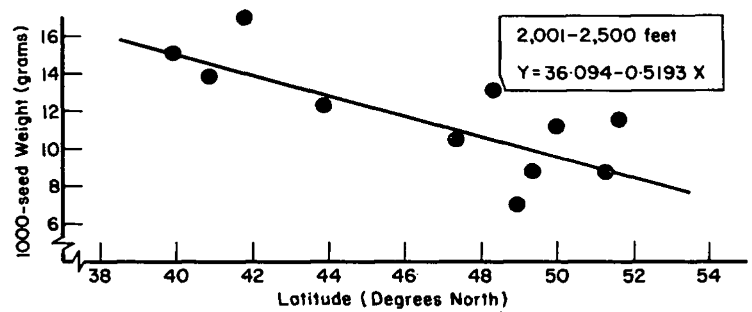

Figure 12e. from 2,001 to 2,500 feet.

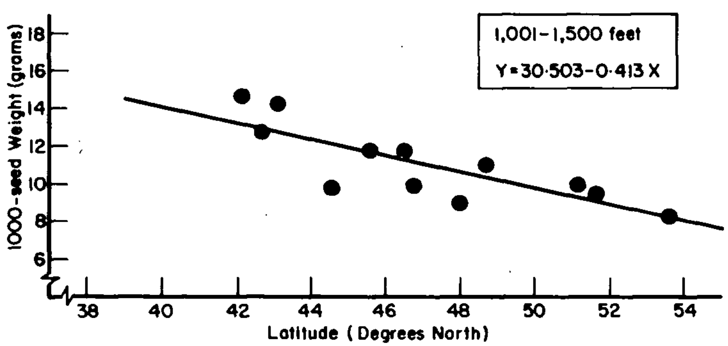

Figure 12 c. from 1,001 to 1,500 feet.

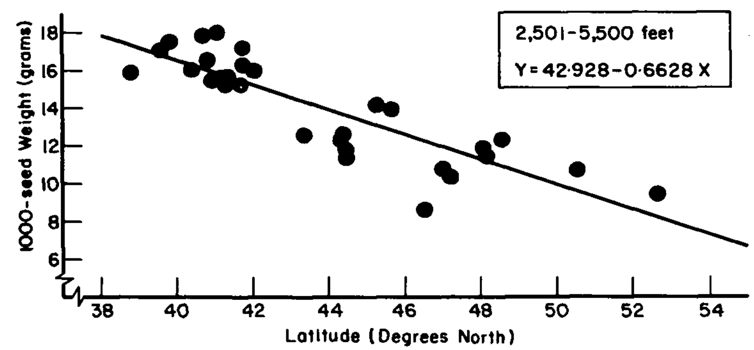

Figure 12f. from 2,501 to 5,500 feet.

Table 3. Maximum, minimum and mean values of 1000-seed weight for each provenance in grams.

Provenance No.	Maximum	Minimum	Mean
1	10.4157	7.3442	8.6076
2	11.6410	6.5926	9.1026
3	13.1456	7.8697	10.3307
4	12.5810	7.1285	9.3839
5	12.9982	7.3761	10.4723
6	12.4570	8.7799	10.3733
7	13.4160	8.7580	10.7942
8	14.0160	7.7428	10.1530
9	13.1684	7.4110	9.6942
10	10.4410	6.7078	8.8204
11	10.3789	7.4270	9.0777
12	12.5692	8.7835	10.0874
13	8.6244	5.7190	7.1422
14	11.7630	6.7380	9.7725
15	14.4784	8.3531	11.3622
16	12.7020	7.4768	10.3224
17	15.2941	8.5368	10.6012
18	11.0748	6.3776	8.7206
19	9.7637	5.4673	8.1081
20	10.0879	5.9247	8.0032
21	11.1611	8.9212	9.8105
22	11.2878	8.9323	10.1293
23	13.8250	7.1690	9.1725
24	9.9979	6.4736	8.3230
25	11.4429	7.5006	9.0917
26	10.9955	6.4779	8.4357
27	9.5923	5.8902	7.3223
28	12.1609	6.9940	9.2489
29	12.3010	8.1506	10.1977
30	8.1280	5.6000	6.9189
31	11.0671	6.4799	9.0643
32	13.3383	7.4621	10.2133
33	9.7581	5.2818	7.7601
34	11.7197	7.2520	9.0075
35	11.0112	6.7916	8.3056
36	12.1210	7.8681	10.0224
37	11.7188	6.7659	9.4333
38	11.4486	6.1281	7.5752
39	13.2034	8.8963	10.8358
40	12.3391	7.8600	10.2248
41	12.5974	6.7740	9.9574
42	13.4100	8.4724	10.9612
43	13.8350	8.4024	10.5608
44	14.5243	8.2532	11.8493
45	14.1661	9.1316	11.0600
46	18.6756	10.6655	13.2947
47	17.2660	8.1290	12.3406
48	13.4961	8.8019	11.4489

Table 3. (Continued)

Provenance No.	Maximum	Minimum	Mean
49	11.5065	6.9489	8.8598
50	14.6888	8.2028	10.8120
51	10.0324	7.2561	8.8665
52	13.3207	8.0791	10.0426
53	13.2467	6.3729	9.9037
54	13.6776	8.7912	11.2815
55	11.5000	6.8756	9.0224
56	14.5576	8.0860	11.2797
57	13.7705	5.6535	9.1742
58	13.1992	6.8344	9.9714
59	12.9394	8.9466	10.7419
60	12.4396	9.2474	10.9442
61	11.4245	6.8340	9.6996
62	13.4964	7.9117	10.7041
63	12.2926	7.7674	10.5624
64	13.7598	8.4684	10.3615
65	18.4404	8.4940	13.7989
66	16.6393	10.6508	13.5056
67	13.4847	7.8562	10.5983
68	12.2843	8.3971	10.5509
69	13.1826	9.3753	10.5858
70	11.6980	8.5478	9.9515
71	13.9639	9.8874	12.0033
72	14.3908	10.4883	12.2660
73	13.7189	9.0957	10.9332
74	12.1506	8.3853	9.9349
75	14.9367	9.0173	11.7957
76	10.1613	6.5407	8.4889
77	15.6414	10.4312	13.5443
78	16.4904	12.0572	13.7810
79	13.8138	9.2682	11.7812
80	15.9030	8.2644	12.2576
81	12.8976	8.2129	10.8803
82	13.5474	8.3798	11.0515
83	14.2596	8.4120	11.7173
84	15.3184	6.9978	11.1045
85	14.0440	9.4015	11.7882
86	17.4502	9.2063	14.2043
87	13.6275	7.0437	9.5850
88	15.3074	9.7304	12.3854
89	13.2626	8.0658	10.4077
90	17.3469	12.0451	14.2130
91	16.0316	7.6047	12.0091
92	12.5676	8.1660	9.8074
93	15.4916	8.5444	11.6376
94	14.9245	9.2127	12.1002
95	14.1150	9.1581	11.5786
96	14.2228	8.2909	11.2457
97	13.3039	8.1863	11.1186
98	12.2684	10.3650	11.1930
99	13.8706	7.8593	11.4927

Table 3. (Continued)

Provenance No.	Maximum	Minimum	Mean
100	15.6991	9.0286	12.5702
101	18.8851	9.4846	12.4379
102	18.1974	11.6566	14.6608
103	14.3925	10.3434	12.5340
104	19.4334	13.8145	15.8762
105	15.1628	10.2818	13.1355
106	18.7659	11.9469	15.2213
107	20.3956	11.9888	15.4023
108	18.3912	11.7760	15.4171
109	22.4733	12.8328	17.2340
110	20.5615	14.8266	16.9969
111	22.2198	12.8112	16.1968
112	20.6708	10.9028	15.1707
113	20.8763	15.7712	18.0451
114	14.7973	9.7002	11.9590
115	18.7719	11.0146	13.9353
116	20.9691	15.0369	17.8080
117	20.0613	13.2789	16.7025
118	21.0619	13.0980	16.1422
119	19.5550	11.5797	15.4638
120	12.5857	10.8928	11.6085
121	18.8295	11.8890	15.0325
122	22.7006	12.1657	17.4883
123	20.0666	14.0297	17.1401
124	24.7686	11.9000	16.0461

Table 4. Average values and standard deviations of 1000-seed weight by climatic regions in grams.

Region	Total No.of Prov.	1000-seed weight	
		$\bar{X}$	±SD
1a	5	9.5149	1.5403
1aa	4	9.6752	1.8886
1b	5	11.6758	1.8765
1c	15	16.1499	2.3421
2a	6	8.2456	1.5382
2b	7	9.8539	1.7017
2c	6	10.9166	1.4496
2d	7	10.9298	1.9904
2e	4	12.8700	1.9803
3a	3	9.4598	1.4708
3b	11	9.8484	1.9645
3c	13	10.3819	1.7187
3d	9	12.2069	1.9473
3e	2	16.8537	2.4813
4	4	9.7720	1.4528
5a	5	10.4696	1.6847
5b	8	12.5120	2.2363
6	2	9.0082	1.2938
7a	4	9.3664	1.6537
7b	3	11.4500	2.2864

Table 5. Relationship between 1000-seed weight and location of seed source.

Character	Elevation		Latitude		No. of Prov.
	R^2	r	R^2	r	
Region 1 1000-seed weight	0.78	0.88**	0.87	0.93**	29
Region 2 1000-seed weight	0.19	0.44*	0.59	0.77**	30
Region 3 1000-seed weight	0.23	0.48**	0.64	0.80**	38
Region 5 1000-seed weight	0.01	0.06NS	0.40	0.63*	13
Region 7 1000-seed weight	0.03	0.17NS	0.63	0.79*	7

R^2 and r values in the above Table represent the relationships between 1000-seed weight and elevation (Figs. 4-6), between 1000-seed weight and latitude (Figs. 7-11). Only the significant relationships were graphed.

NS = not significant.
* = significant at 5% level.
** = significant at 1% level.

Table 6. Relationship between 1000-seed weight and latitude within varying ranges of elevation.

Character	Latitude		No.of Prov.
	R^2	r	
1000-seed weight elevation range 1-500 ft.	0.33	-0.57**	31
1000-seed weight elevation range 501-1000 ft.	0.43	-0.64**	22
1000-seed weight elevation range 1001-1500 ft.	0.50	-0.71*	12
1000-seed weight elevation range 1501-2000 ft.	0.33	-0.58**	18
1000-seed weight elevation range 2001-2500 ft.	0.62	-0.78**	11
1000-seed weight elevation range 2501-5500 ft.	0.74	-0.86**	30

R^2 and r values in the above Table represent the relationship between 1000-seed weight and latitude from figures 12a to 12f.

* = significant at 5% level.
** = significant at 1% level.

Cone-Scale Morphology

The average width of cone-scales (W_1) for all 124 provenance was 22.81 mm with a range (Table 7) from 19.57 (Prov. No. 8, Barriere, B.C.) to 26.17 mm (Prov. No. 117, Big Bar, California). The average value of cone-scale width of different climatic sub-regions was with a range (Table 8) from 20.1 (Region 6 - no sub-region) to 24.9 mm (sub-region 3e).

Analysis of variance (Table 9/b) from the data of cone-scale width shows significant differences among trees within provenance. among provenances within sub-regions, among sub-regions within regions and among regions.

The width of cone-scale was correlated with elevation in Region 1 (Figure 13) (1% level) and Region 3 (Figure 14) (5% level). This indicates that provenances from higher elevation in Regions 1 and 3 had wider cone-scales. No relationship could be established between width of cone-scale and elevations in Regions 2, 5 and 7 (Table 9/a).

Width of bract (W_2) tended to be correlated with elevation and was found to be significant only in Region 7 (Figure 15, and Table 10/a).

The average length of cone-scale from 124 provenances combined was 18.69 mm with a range (Table 7) from 15.82 (Prov. No. 17, Monte Creek, B.C.) to 22.05 mm (Prov. N_o.123, Covelo, California). The average length of cone-scale of different climatic sub-region (Table 8) from 16.4 (sub-region 7a) to 21.0 mm (sub-region 3e)

The length of cone-scales were strongly correlated (1%

level) with elevation in Region 1 (Figure 16) while Figure 17 indicates a significant correlation (5% level) with the elevation in Region 3.

Neither width nor length of cone-scale were correlated with elevation in coast Region 2 and interior Regions 5 and 7 (Tables 9/a and 11/a). In other words these characteristics appeared to be independent and not influenced by elevation in these regions.

The average length of 1st prong (L_2) for all 124 provenance was 8.13 mm with a range from 5.85 (Prov. No.40, Darrington, Washington) to 10.75 mm (Prov. No.103, Wolf Creek, Oregon). Analysis of variance (Table 12/b) from the data shows that 1st prong lengths are significantly different among trees within provenances, among provenances within sub-regions and among sub-regions within regions, but not among regions. From regression analysis carried out between 1st prong length and elevation, a significant relationship (5% level) (Figure 18) was found in Region 1 only.

In addition a regression analysis was carried out between 2nd prong length (L_3) and elevation. The length of 2nd prong is significantly correlated (5% level) with elevation in Regions 1 and 7 (Figures 19 to 20 respectively). The overall average of 2nd prong length from combined provenances was 3.70 mm with a range 2.46 (Prov. No.8, Barriere, B.C.) to 4.48 mm (Prov. No. 109, Scott Bar, California). Analysis of variance of 2nd prong length (Table 13/b) shows significant difference among trees within provenances, among provenances within sub-regions and among sub-regions within regions.

Analyses of variance for the above-mentioned cone-scale characteristics showed clearly the great intraspecific variation of Douglas-fir within its natural range in Northwest America. Larsen (1937) pointed out that great individual variation of Douglas-fir exists even from the same geographical area. Haddock (1962) stated "Considerable variation in cone and leaf morphology, color of foliage, etc. has been noted throughout the range of the species." Sziklai (1967) mentioned "The variation itself is a product of differences among individuals which are the effect of environmental modifications, genetic recombinations and mutation."

Figures 23 and 25 show a highly significant linear relationship between cone-scale width and latitude in Regions 1 and 5, and a curvelinear relationship (Figure 24) in Region 3. Width of cone-scale increased significantly from north to south, and length of cone-scale (Figures 26 to 28) were also related to latitude in Regions 1 and 3 (1% level), and in Region 5 (5% level). These results tend to show that in Regions 1, 3 and 5 both width and length of cone-scale increased from north to south.

The relationship between cone-scale size and cone size was studied by Sziklai (1964) and Squillace (1957). Sziklai (1964) found that wider cones had longer cone scales in Douglas-fir. Squillace (1957) reported that average scale size was strongly related to cone length, longer cones usually having larger scale (mm^2) in western white pine (<u>Pinus monticola</u> Dougl). He did not give further details on whether cone length was directly related to cone-scale length or cone-scale width. Squillace also showed that the average width of cone-scale had a positive correlation with average length of cone-scale in western white pine.

The finding in the present study indicated that width and length of cone-scale show a clinal variation from north to south in Regions 1, 3 and 5. This agrees with the regional clinal variation pattern found by Sziklai (1969) in Douglas-fir cone and seed lengths, which also increased from north to south.

The width and length of cone-scale were not affected by elevation and latitude, however, in Regions 2 and 7, unlike Regions 1, 3 and 5 (Tables 9/a and 11/a). This may possibly be due to Region 2 being on the Pacific Coast (Figure 1) and having high moisture and relative humidity conditions; alternatively cone-scale size in Region 2 could possibly be under strong genetic control. The lack of any relationships in Region 7 might be because of the smaller number of samples (7 provenances) collected in this area.

Figures 30 to 32 show that the lengths of 1st prong have a highly significant negative curvelinear relationship with latitude in Regions 2 and 3, and highly significant negative linear relationship in Region 5. Figure 29 shows that the 1st prong length increased from sub-region 1a to 1b and then decreased to sub-region 1c. A similar trend was found for the relationship between 2nd prong length and latitude in Region 1 (5% level) (Figure 33) and in Regions 2, 3 and 5 (1% level) (Figures 34 to 36). A cone-scale with a longer 1st prong probably also has a longer 2nd prong, generally with a regional clinal variation, both prongs increasing from north to south.

Tables 9/a, 10/a, 11/a, 12/a and 13/a clearly show that elevation had a weaker effect on cone-scale characteristics than latitude. That latitude affected the cone-scale size was clearly shown in the present study and this is supported by Tusko (1963) who described a strong correlation between the width of the cones and certain environmental factors, and by Sziklai (1964) who demonstrated that the width of Douglas-fir cones appeared to be more plastic or genetically "loosely" controlled than the length of cone. Width and length of cone-scale, and length of 1st and 2nd prongs increased from north to south much more noticeably than their increase from low to high elevation.

The cone-scale measurements for the "coastal" regions appeared to be greater than for "interior" regions (Table 15). These findings agree with those by Peace (1948), by Tusko (1963) and by Sziklai (1969).

The average rating of bract (Table 15) was 2.19 for "coastal" and 2.25 for "interior" regions, indicating that "coastal" regions have longer bracts than "interior" ones.

The rating of bract had a curvilinear relationship with latitude and a positive linear relationship with elevation in Regions 1 and 3 (Figures 21, 22, 37 and 38, Table 14/a). This indicates that the relative length of the bract increased from low to high elevation and from north to south latitudes. Elevation appeared to have more influence than latitude.

Analysis of variance (Table 14/b) indicates highly significant differences among trees within provenances, among provenances within sub-regions and among sub-regions within regions. No significant differences were found among regions.

The relationship between the width of cone-scale and elevation·

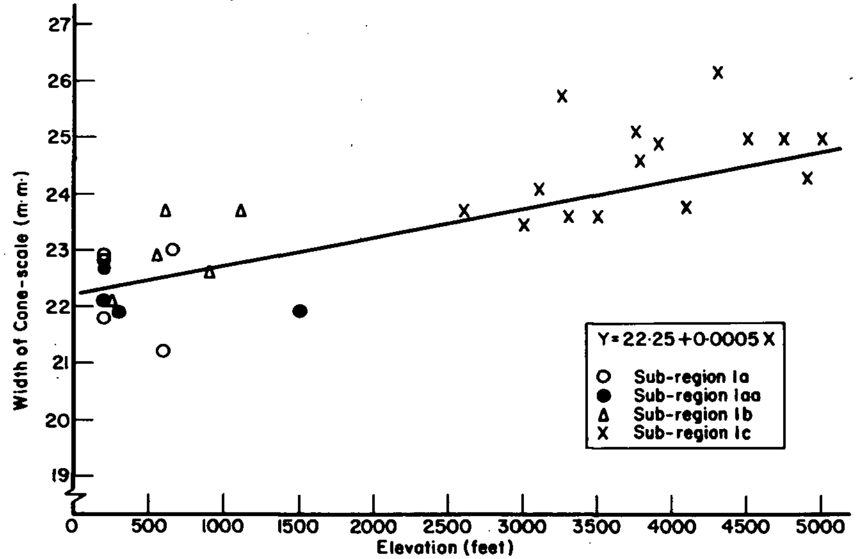

Figure 13· in region 1·

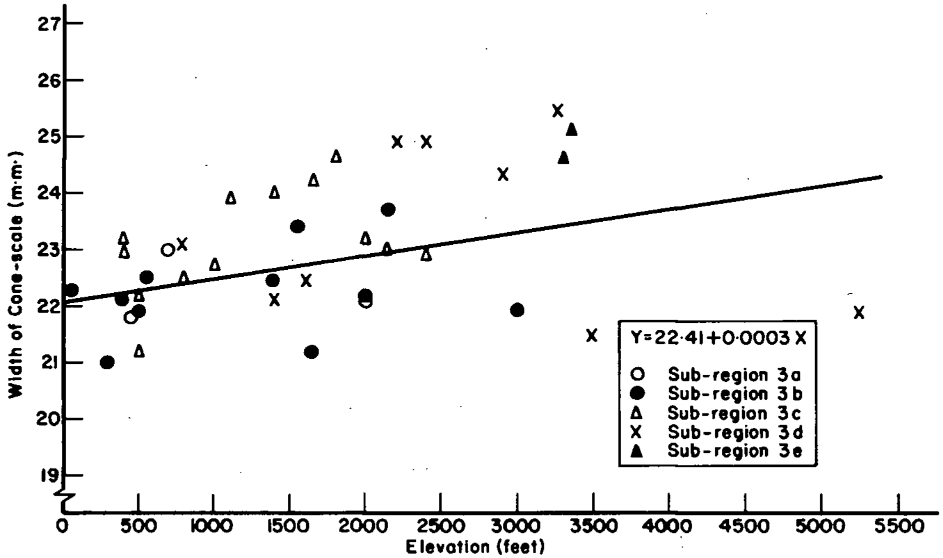

Figure 14· in region 3·

The relationship between the width of bract and elevation·

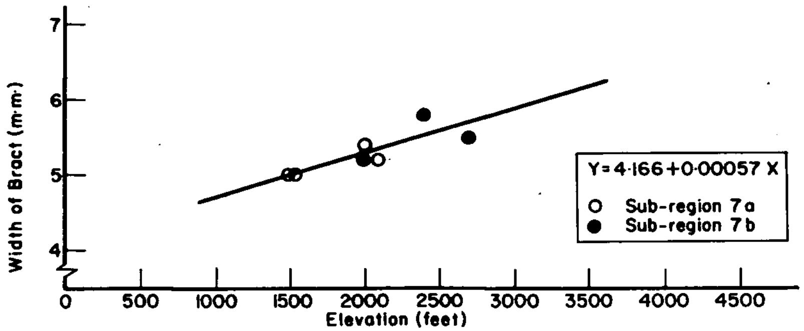

Figure 15· in region 7·

The relationship between the length of cone-scale and elevation·

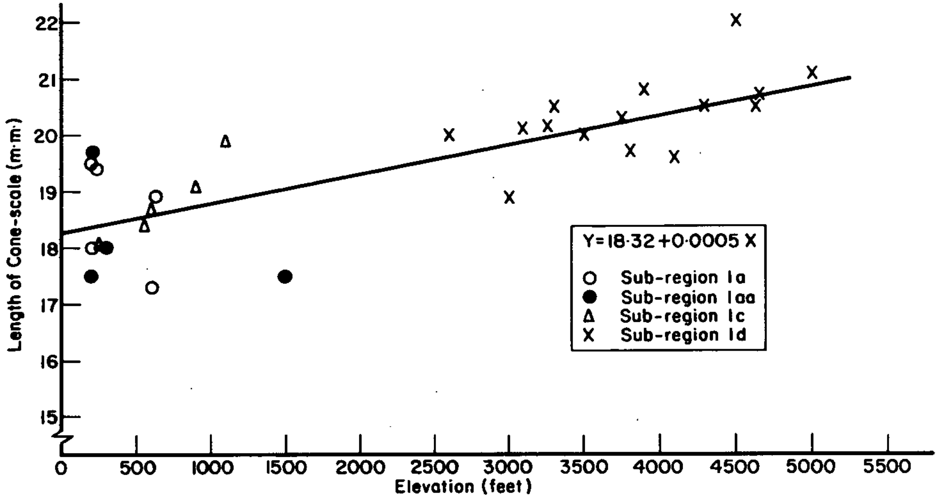

Figure 16· in region 1·

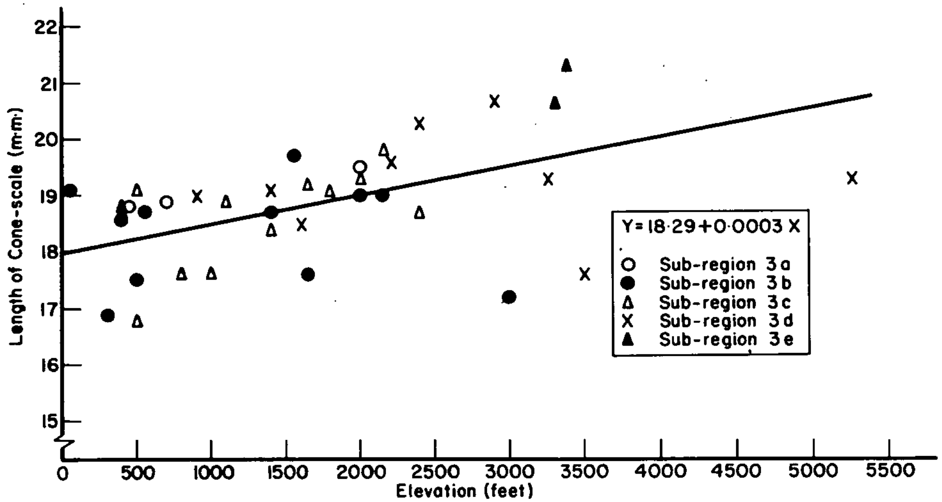

Figure 17· in region 3·

The relationship between the length of 1st prong and elevation·

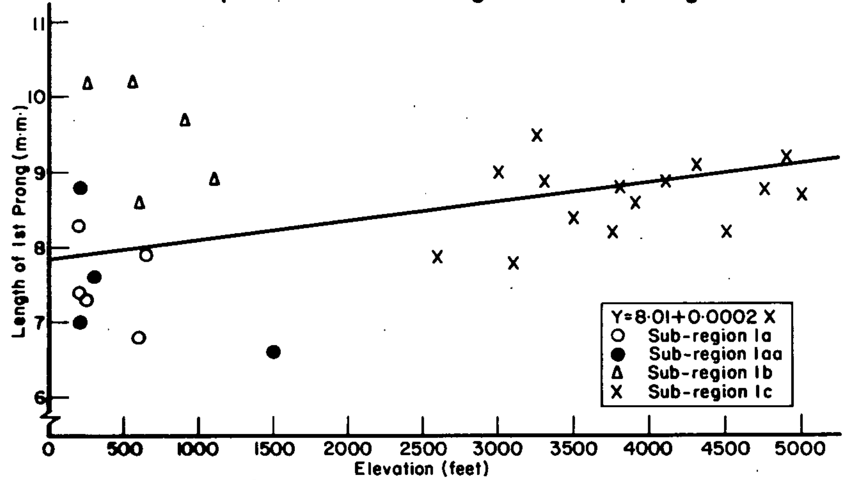

Figure 18· in region I·

The relationship between the length of 2nd prong and elevation·

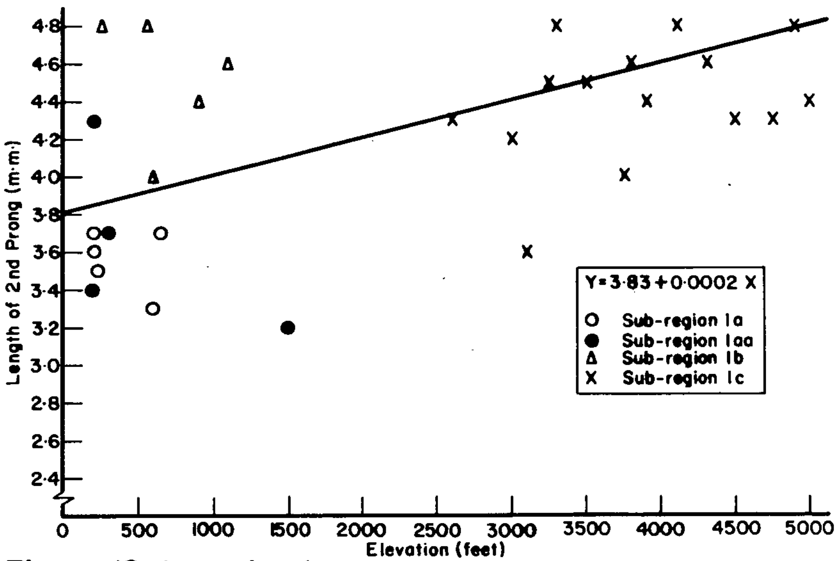

Figure 19· in region I·

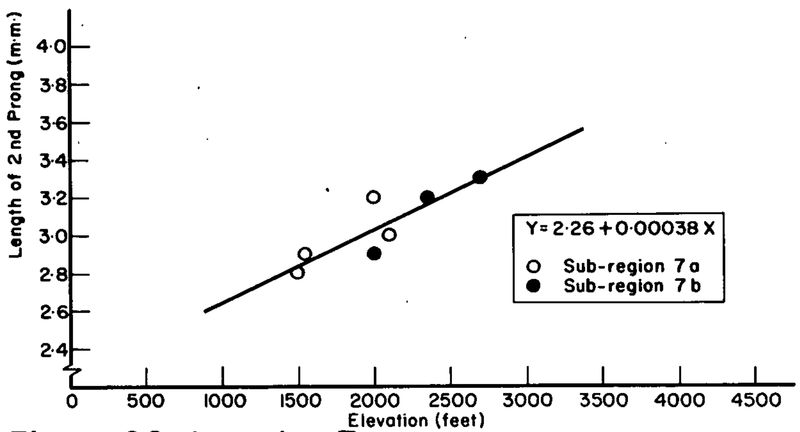

Figure 20· in region 7·

The relationship between the rating of bract and elevation·

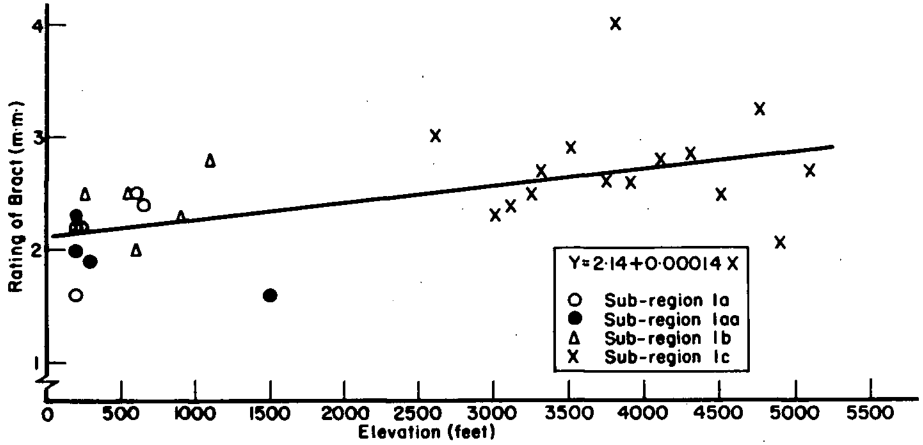

Figure 21· in region I·

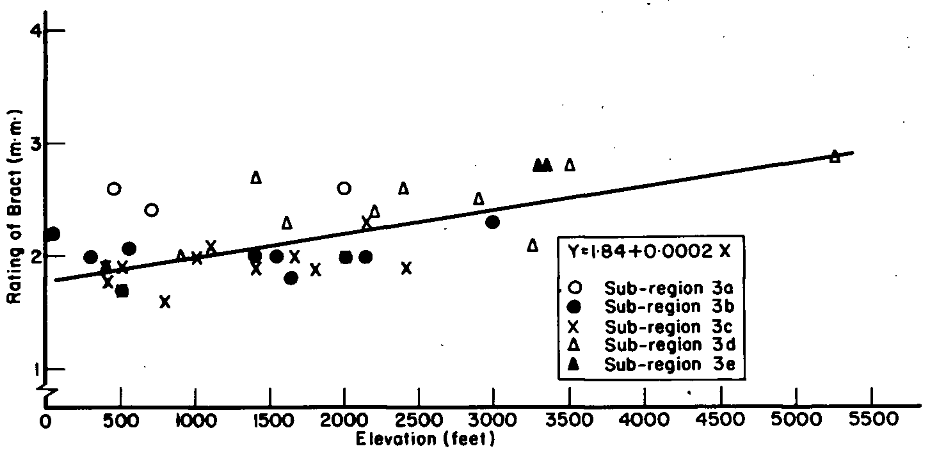

Figure 22· in region 3·

The relationship between the width of cone-scale and latitude·

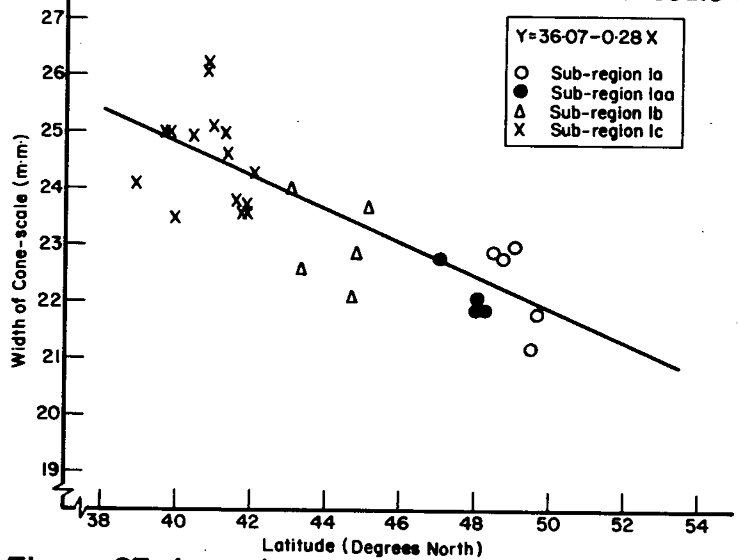

Figure 23· in region I·

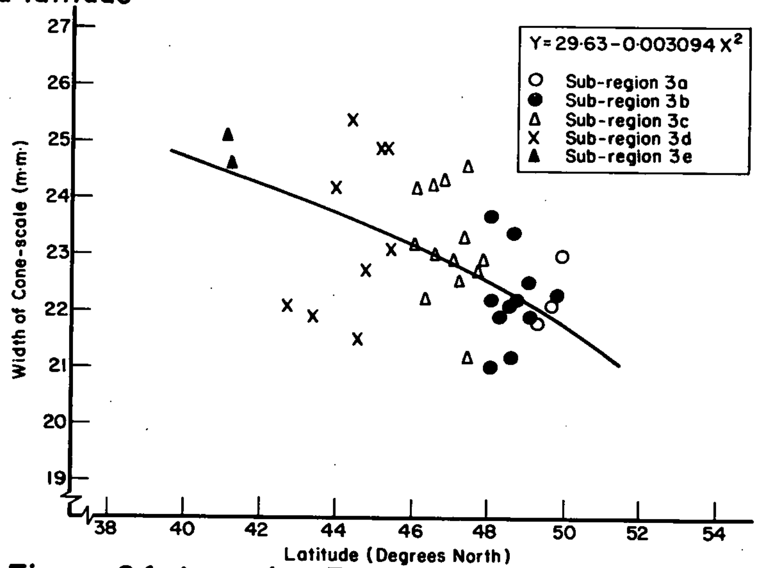

Figure 24· in region 3·

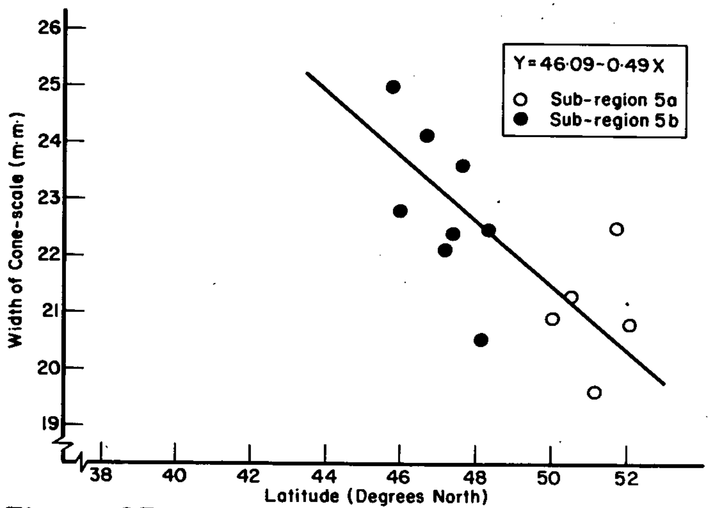

Figure 25· in region 5·

The relationship between the length of cone-scale and latitude·

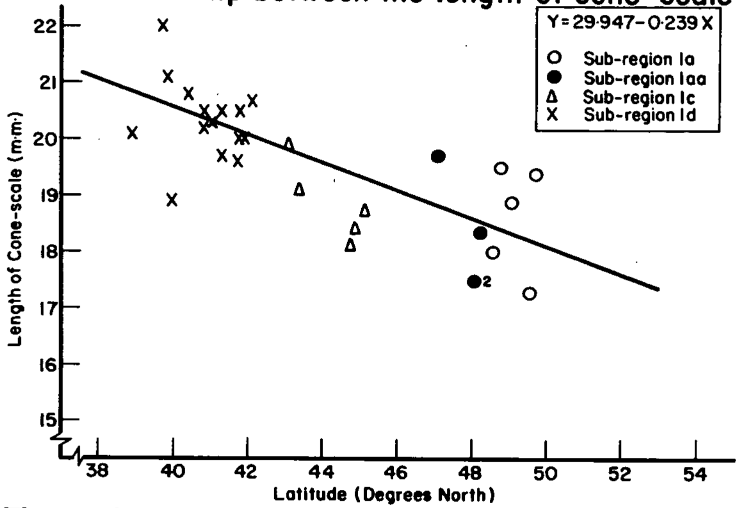

Figure 26· in region I·

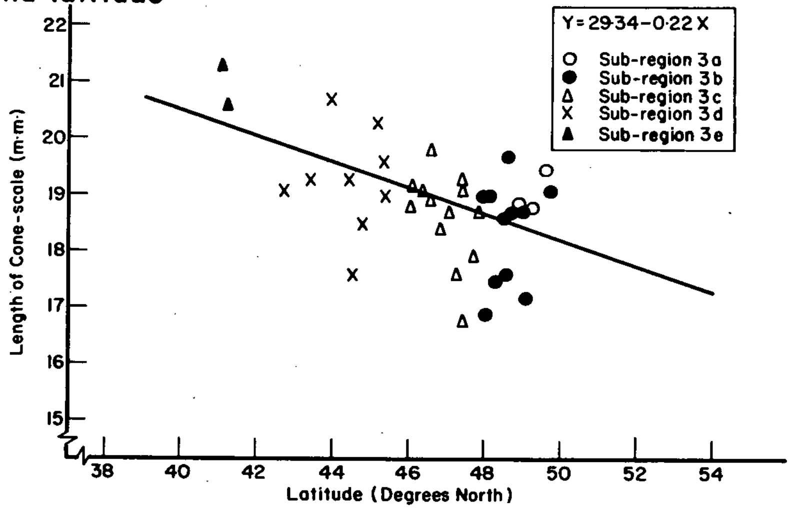

Figure 27· in region 3·

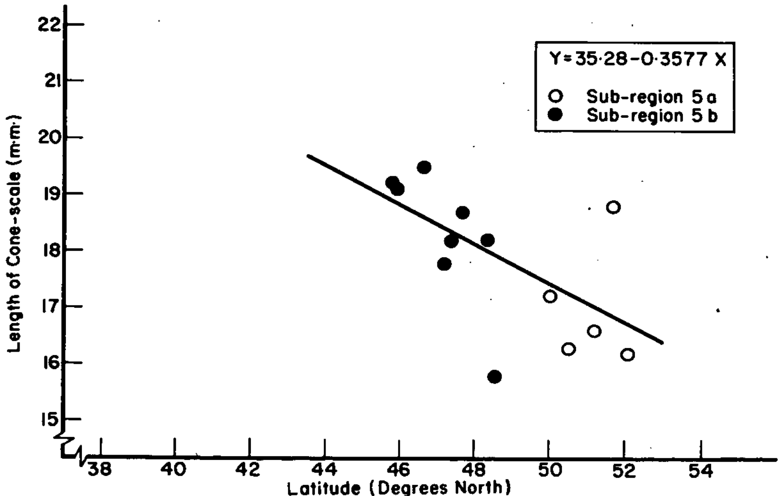

Figure 28· in region 5·

The relationship between the length of the 1st prong and latitude·

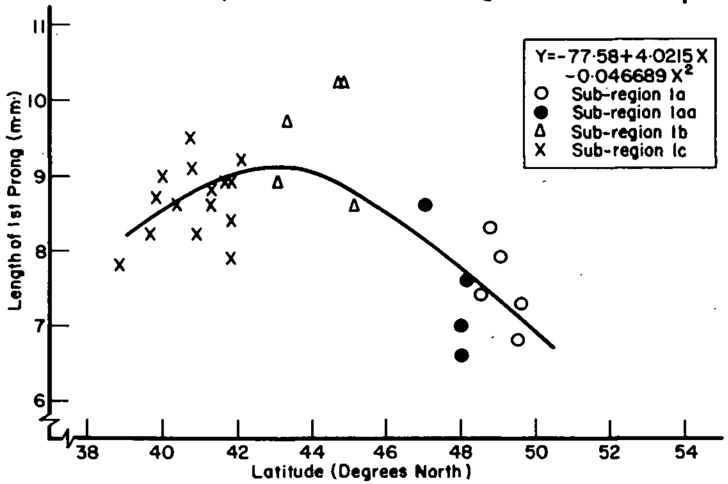

Figure 29· in region 1·

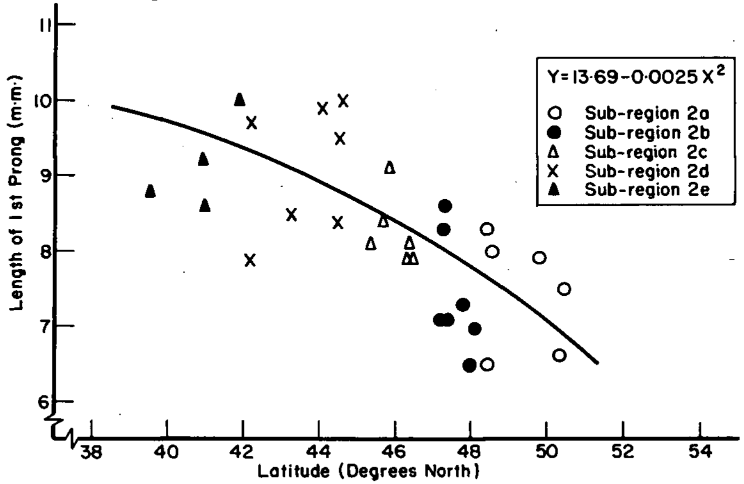

Figure 30· in region 2·

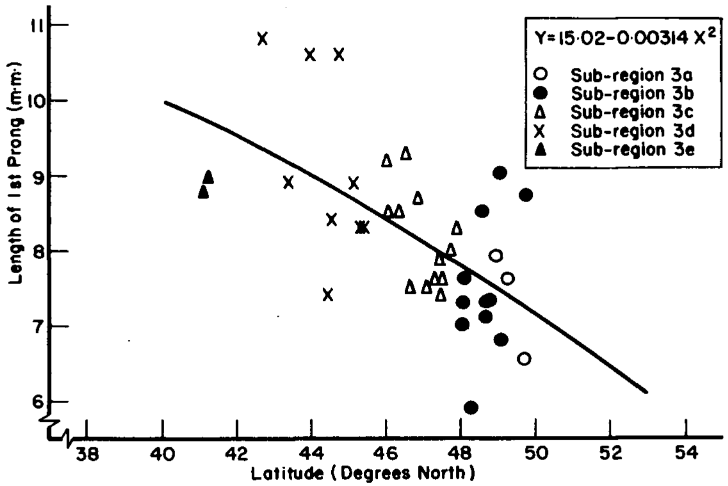

Figure 31· in region 3·

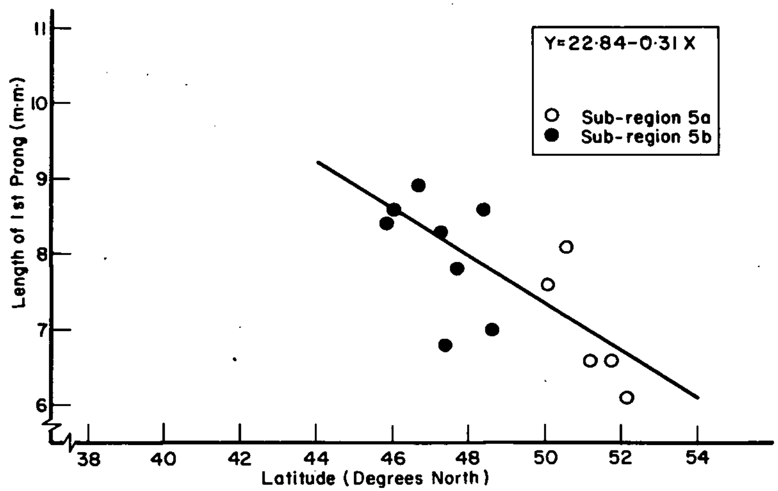

Figure 32· in region 5·

The relationship between the length of 2nd prong and latitude.

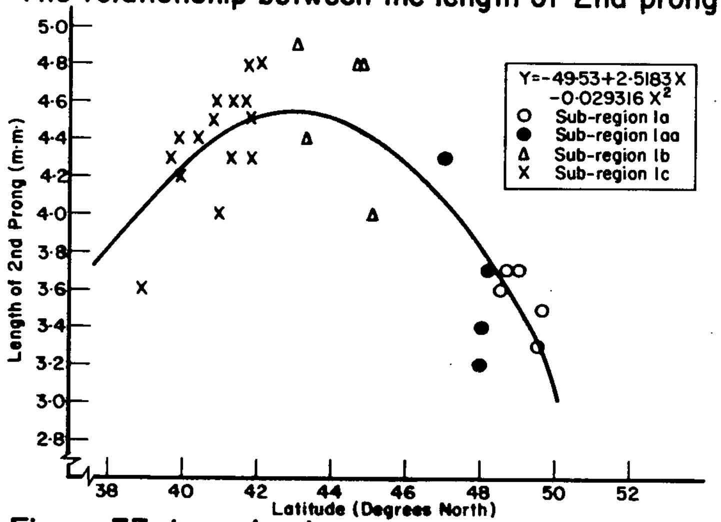

Figure 33· in region I·

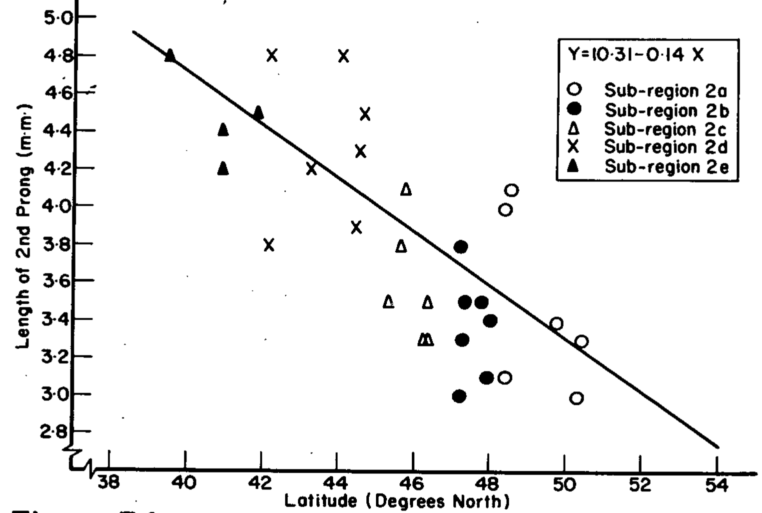

Figure 34· in region 2·

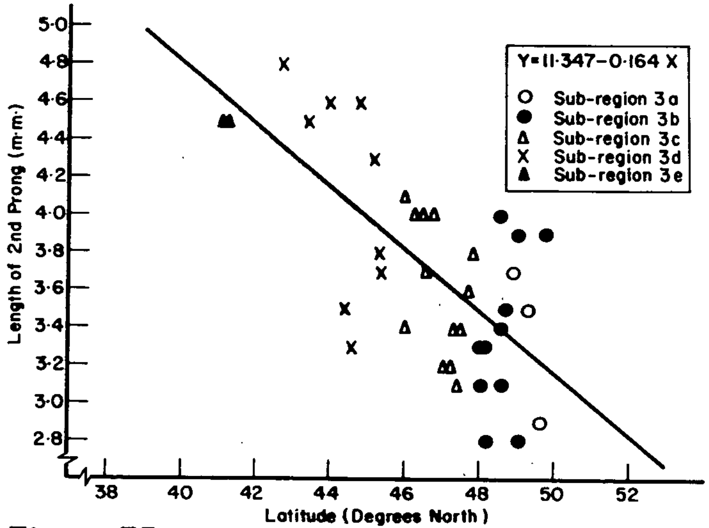

Figure 35· in region 3·

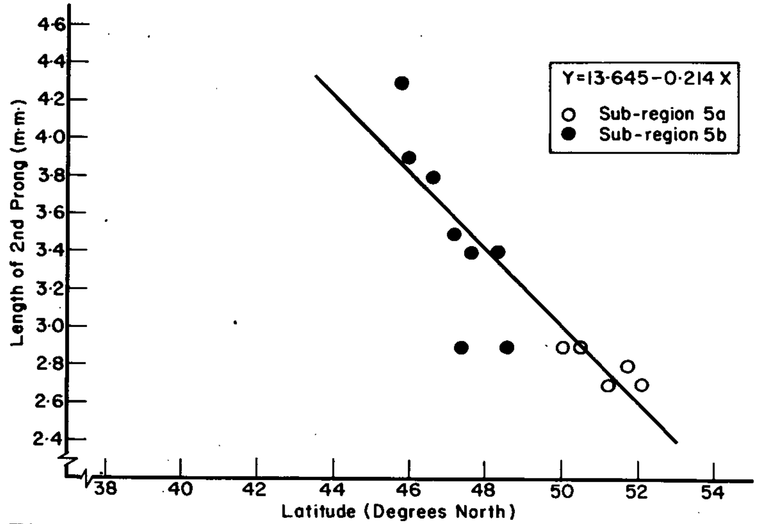

Figure 36· in region 5·

The relationship between the rating of bract and latitude·

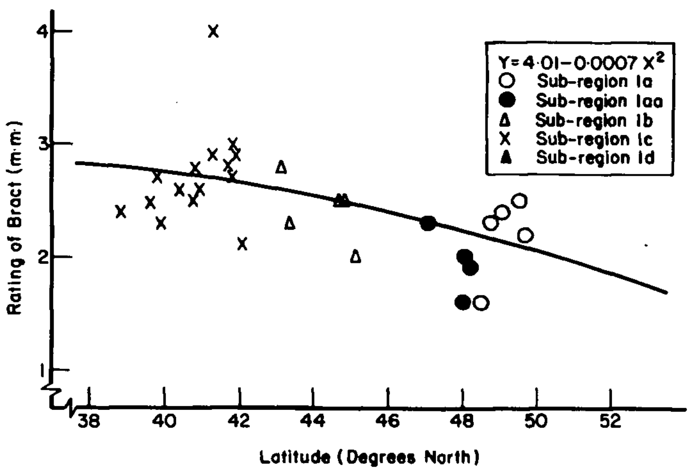

Figure 37· in region I·

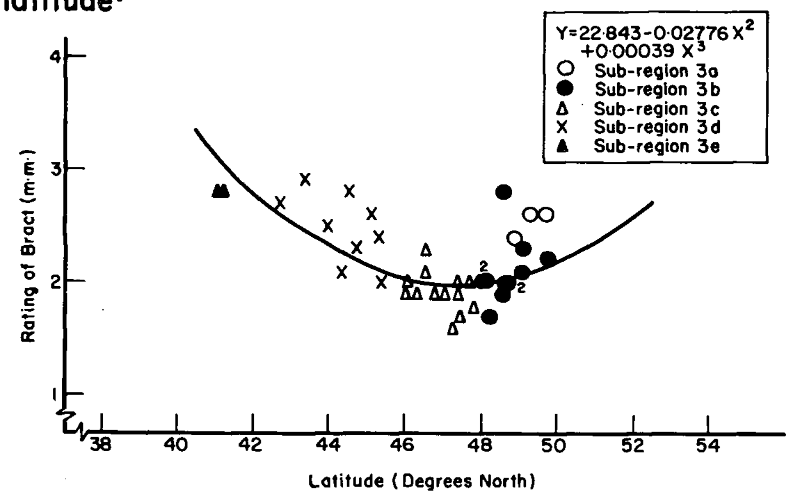

Figure 38· in region 3·

Table 7. Mean values and standard deviations of cone-scale characteristics by provenances in millimeters.

Prov. No.	W_1 Mean	W_1 ±SD	W_2 Mean	W_2 ±SD	L_1 Mean	L_1 ±SD	L_2 Mean	L_2 ±SD	L_3 Mean	L_3 ±SD	R Mean	R ±SD
1	20.43	1.55	4.59	.54	17.22	1.34	7.01	1.31	2.72	.43	1.90	.42
2	21 01	2 38	4.71	.51	16.79	1.75	7.29	0.81	2.76	.41	2.44	.35
3	23.98	1.57	5.32	.77	21.08	2.35	8.82	0.59	3.17	.80	3.00	.00
4	19.71	1.66	4.62	.51	17.33	1.47	6.61	0.79	2.74	.40	1.77	.65
5	20.80	1.96	4.65	.57	16.16	1.98	6.15	0.75	2.71	.44	1.87	.63
6	23.33	1.22	4.99	.91	19.09	1.33	7.47	0.89	3.43	.41	2.41	.77
7	22.46	2.07	5.01	.67	18.79	2.10	6.55	1.43	2.77	.38	2.63	.47
8	19.57	1.42	4.62	.71	16.70	1.55	6.60	1.15	2.46	.42	1.73	.74
9	21.27	2.55	5.05	.71	16.49	2.09	7.52	1.07	2.81	.59	2.21	.63
10	20.16	1.84	5.45	.63	16.51	1.55	7.91	0.87	3.19	.54	2.16	.50
11	20.31	1.89	4.99	.68	16.74	1.39	6.97	1.44	2.53	.34	2.33	.51
12	22.87	1.58	4.53	.37	17.98	1.34	7.53	0.84	3.33	.59	1.74	.61
13	20.09	2.34	4.39	.46	16.88	1.84	6.55	1.51	3.02	.95	2.26	.57
14	23.02	1.84	4.85	.45	19.74	2.34	7.44	1.44	3.37	.58	2.47	.67
15	20.91	1.38	4.94	.60	17.19	1.03	7.58	1.15	2.94	.50	2.48	.50
16	21.30	1.61	5.40	.72	16.72	1.73	8.11	1.41	2.87	.54	2.30	.72
17	20.85	1.74	5.24	.65	15.82	1.27	7.75	1.12	2.95	.50	2.40	.58
18	20.20	2.14	5.00	.54	16.67	5.56	8.42	1.46	2.86	.67	2.21	.78
19	22.28	2.15	5.50	.67	18.63	1.73	7.94	1.34	3.35	.69	1.78	.64
20	22.13	1.92	5.01	.65	19.46	2.07	6.60	0.98	2.93	.43	2.57	.55
21	21.83	0.87	5.19	.59	19.41	1.55	7.29	0.72	3.51	.59	2.19	.40
22	21 78	1.60	5.15	.45	18.77	1.88	7.63	1.13	3.49	.39	3.61	.44
23	23.01	1.89	5.22	.43	18.91	1.39	7.90	0.98	3.71	.66	2.32	.49
24	21.15	1.95	5.20	.63	17.31	1.51	6.83	0.82	3.55	.63	2.49	.50
25	22.35	1.49	5.13	.55	19.13	1.37	8.65	1.94	3.87	.55	2.15	.62
26	22.51	1.67	5.40	.59	18.66	1.97	8.97	1.43	3.87	.55	2.13	.52
27	21.88	1.79	4.85	.65	17.18	1.12	6.79	1.06	2.78	.58	2.33	.56
28	19.66	1.62	5.53	.55	16.48	1.23	8.44	0.89	3.34	.38	2.16	.49
29	22.77	1.27	5.37	.49	19.65	2.26	7.76	1.40	3.54	.47	2.21	.58
30	21.81	2.34	5.29	.60	16.54	1.77	6.46	1.55	3.15	.69	2.52	.51
31	23.33	2.31	5.27	.59	19.35	2.04	8.02	1.68	4.08	.65	2.41	.66
32	22.85	1.93	5.24	.41	19.46	1.49	8.31	1.26	3.66	.56	2.29	.66

Table 7. (Continued)

Prov. No.	W_1 Mean	W_1 ±SD	W_2 Mean	W_2 ±SD	L_1 Mean	L_1 ±SD	L_2 Mean	L_2 ±SD	L_3 Mean	L_3 ±SD	R Mean	R ±SD
33	21.94	2.39	5.35	.73	18.58	2.65	8.31	1.55	4.00	.66	2.10	.85
34	22.11	1.94	5.33	.64	19.02	1.74	7.04	1.13	3.37	.53	2.29	.69
35	22.11	2.52	5.11	.68	17.04	1.95	6.96	1.89	3.43	.73	1.97	.50
36	22.93	2.29	5.23	.73	17.96	1.80	7.42	1.10	3.58	.35	1.56	.58
37	21.88	2.01	5.06	.63	18.04	2.40	7.58	1.41	3.73	.40	1.85	.77
38	20.98	1.39	4.79	.58	16.89	1.42	7.28	1.50	3.26	.59	1.98	.74
39	23.30	2.30	4.74	.63	19.67	2.24	7.14	0.97	3.12	.37	2.02	.52
40	21.87	2.26	4.93	.78	17.51	2.22	5.85	1.10	2.87	.29	1.74	.51
41	21.17	1.98	4.74	.74	17.59	1.70	7.29	1.00	3.37	.38	1.81	.60
42	22.22	2.13	4.69	.76	18.97	2.04	6.96	0.98	3.09	.27	1.97	.63
43	22.05	1.56	5.23	.74	18.65	2.18	8.45	0.96	4.04	.41	1.94	.63
44	23.67	1.34	5.18	.45	18.99	1.75	7.60	1.19	3.30	.54	2.02	.58
45	22.24	1.78	4.87	.38	18.69	1.91	7.35	1.06	3.45	.50	1.03	.77
46	22.43	1.65	5.99	.98	18.17	2.13	8.57	1.60	3.45	.44	2.59	.41
47	20.23	1.37	5.24	.73	15.58	1.42	7.03	0.81	2.86	.38	2.37	.58
48	20.47	1.77	5.77	.76	17.36	2.22	8.32	1.41	3.17	.28	2.29	.66
49	21.86	2.08	5.46	.99	19.71	1.13	6.49	0.99	3.12	.41	1.64	.50
50	22.43	2.62	5.24	.24	18.29	2.06	7.38	1.21	3.51	.38	1.77	.60
51	22.75	1.44	5.14	.59	19.13	1.76	7.12	1.11	3.29	.53	1.62	.57
52	23.30	2.89	5.16	.57	18.86	1.47	8.65	1.92	3.50	.58	1.72	.59
53	23.75	1.42	5.04	.72	20.06	1.49	7.11	0.90	3.01	.42	2.32	.59
54	23.98	2.63	5.20	.73	19.61	1.50	8.33	1.48	3.81	.50	2.09	.62
55	21.89	1.61	5.18	.72	17.54	1.88	6.58	1.11	3.19	.39	1.64	.59
56	22.51	1.69	4.78	.74	17.61	1.46	7.55	1.12	3.25	.46	1.55	.67
57	21.17	1.55	4.96	.60	16.81	1.60	7.57	1.24	3.39	.39	1.71	.66
58	23.18	2.10	4.87	.61	19.26	2.16	7.85	1.04	3.42	.71	1.99	.57
59	22.95	1.92	4.40	.73	18.66	2.01	7.49	0.49	3.23	.45	1.92	.71
60	24.59	1.83	4.90	.45	19.07	2.04	7.41	0.66	3.12	.35	1.94	.47
61	22.87	2.25	5.39	.97	18.75	1.33	8.27	0.80	3.95	.53	1.83	.61
62	22.72	2.39	5.13	.82	17.62	2.41	8.00	0.94	3.55	.53	2.02	.56
63	22.41	1.83	4.58	.79	18.19	2.00	6.82	0.62	2.94	.27	2.17	.58
64	22.06	1.92	4.79	.64	17.78	2.07	8.29	1.67	3.53	.50	2.35	.52
65	23.63	2.51	5.14	.83	18.71	1.85	7.77	0.92	3.41	.69	2.75	.30

Table 7. (Continued)

Prov. No.	W1 Mean	W1 ±SD	W2 Mean	W2 ±SD	L1 Mean	L1 ±SD	L2 Mean	L2 ±SD	L3 Mean	L3 ±SD	R Mean	R ±SD
66	20.42	1.84	5.23	.84	16.29	1.43	7.80	0.78	2.86	.45	2.11	.52
67	24.19	2.23	4.97	.77	18.96	1.91	7.91	0.85	3.52	.56	1.65	.54
68	23.61	2.27	4.62	.78	18.19	1.99	7.78	0.94	3.31	.44	1.82	.45
69	23.67	1.12	5.13	.66	18.19	1.55	8.11	1.10	3.25	.45	1.71	.75
70	22.19	2.32	5.21	.78	19.09	2.41	8.54	1.41	4.01	.55	1.95	.63
71	22.82	1.48	5.30	.77	19.71	2.65	8.61	1.45	4.26	.83	2.33	.58
72	23.18	2.00	5.18	.49	18.76	1.58	9.16	1.59	4.07	.25	1.93	.69
73	24.20	1.49	5.15	.73	19.17	1.49	7.74	1.94	3.43	.66	1.96	.57
74	24.00	1.69	5.26	.82	18.42	1.42	8.67	1.35	4.03	.67	1.91	.69
75	23.86	1.99	5.41	.59	18.88	2.40	9.35	1.25	4.02	.64	2.12	.75
76	22.98	0.96	5.14	.68	19.79	1.36	7.51	1.07	3.66	.77	2.30	.50
77	22.81	2.36	5.24	.69	19.11	2.06	8.56	1.34	3.87	.58	2.51	.52
78	23.83	1.82	5.65	.65	19.49	1.85	8.91	1.37	3.79	.49	2.13	.77
79	24.59	1.84	5.23	.76	19.85	1.31	8.40	0.79	3.76	.47	2.01	.64
80	25.00	1.82	5.59	.83	19.20	2.10	8.41	1.10	4.34	.55	2.47	.54
81	23.54	1.53	5.21	.76	18.33	1.58	8.07	1.47	3.55	.90	1.07	.45
82	23.71	1.67	5.07	.42	18.73	2.23	8.57	1.31	3.96	.66	2.00	.63
83	23.60	2.48	5.29	.72	18.89	2.04	9.09	1.84	4.08	.79	2.09	.63
84	23.15	1.62	5.21	.68	18.97	1.64	8.35	1.31	3.73	.63	1.95	.53
85	24.94	1.02	5.49	.64	19.63	1.16	8.31	0.73	3.77	.64	2.37	.41
86	24.87	1.22	5.37	.55	20.30	1.25	8.93	0.82	4.31	.60	2.58	.35
87	24.17	1.31	5.04	.45	19.43	1.41	8.40	0.93	3.93	.54	2.07	.62
88	25.39	1.62	4.85	.56	19.34	1.43	8.90	0.90	3.43	.67	2.06	.62
89	23.74	2.07	5.44	.77	17.94	2.94	8.48	0.99	4.42	.69	1.84	.59
90	23.96	1.91	5.54	.71	19.86	1.33	8.94	1.56	4.94	.57	2.79	.32
91	22.35	2.60	5.01	.54	17.85	2.02	7.92	1.24	3.84	.55	2.22	.77
92	23.91	1.12	5.81	.80	19.97	1.09	10.04	1.81	4.46	.84	1.71	.87
93	23.33	1.19	5.84	.47	18.75	2.49	9.51	0.84	4.32	.51	2.03	.59
94	22.74	1.32	5.69	.50	19.75	1.47	9.93	0.90	4.84	.71	2.34	.34
95	22.12	1.04	5.53	.90	18.08	1.68	10.16	1.46	4.81	.80	2.52	.35
96	22.87	1.73	5.88	.51	18.41	1.53	10.18	1.29	4.80	.78	2.53	.39
97	22.39	2.06	5.31	.59	18.54	1.72	10.56	1.55	4.59	.89	2.32	.38
98	21.50	1.83	5.15	.39	17.65	2.35	8.42	0.47	3.28	.17	2.78	.28
99	22.64	1.70	5.64	.65	19.08	1.17	9.44	1.67	4.44	.76	2.35	.60

Table 7. (Continued)

Prov. No.	W_1 Mean	±SD	W_2 Mean	±SD	L_1 Mean	±SD	L_2 Mean	±SD	L_3 Mean	±SD	R Mean	±SD
100	21.94	2.00	5.95	.69	19.32	1.41	8.92	0.90	4.54	.39	2.89	.21
101	24.25	1.89	5.57	.73	20.74	2.16	10.59	1.82	4.62	.70	2.54	.44
102	21.94	1.94	5.21	.59	19.32	1.41	9.71	1.02	4.84	.66	2.64	.34
103	22.09	1.28	5.36	.56	20.74	2.16	10.75	0.84	4.82	.66	2.67	.47
104	24.31	1.90	5.65	.73	18.51	1.36	9.25	1.45	4.79	.73	2.31	.60
105	23.27	2.28	5.02	.57	19.15	1.99	9.95	1.36	4.49	.59	2.02	.68
106	23.79	2.04	5.28	.60	20.74	1.91	8.89	1.29	4.60	.90	2.79	.36
107	25.01	1.62	5.08	.49	19.05	1.59	8.77	1.48	4.27	.49	2.27	.10
108	24.61	2.07	5.67	.80	19.59	1.23	8.62	1.14	4.84	.73	2.75	.34
109	23.64	1.32	5.29	.52	20.53	0.81	8.89	1.27	4.32	.75	2.90	.21
110	23.72	2.12	4.98	.49	19.72	2.39	7.95	1.20	4.49	.78	2.87	.25
111	23.58	1.72	5.28	.29	20.49	1.47	8.43	1.80	4.51	.83	2.77	.40
112	24.57	1.73	5.18	.64	19.97	2.14	8.98	1.64	4.54	.57	2.77	.41
113	25.12	2.28	5.19	.61	19.99	1.65	8.85	1.54	4.17	.72	2.02	.65
114	22.44	2.19	5.10	.64	20.56	2.11	8.65	1.10	4.42	.61	1.92	.62
115	23.06	1.45	5.24	.45	21.34	3.00	9.21	1.57	4.61	.54	2.96	.10
116	26.06	1.46	5.21	.74	20.19	1.49	9.48	1.35	4.54	.54	2.51	.32
117	26.17	2.10	5.33	.35	20.30	2.30	9.09	1.04	4.61	.52	2.79	.30
118	24.94	2.58	5.06	.44	20.78	2.08	8.61	1.36	4.39	.56	2.56	.39
119	25.07	1.72	5.09	.38	20.28	1.62	8.21	0.97	4.01	.50	2.62	.44
120	22.48	1.06	4.90	.38	18.46	2.44	8.82	1.16	4.78	.49	1.44	.50
121	23.55	1.97	5.13	.60	18.94	1.37	9.04	0.88	4.20	.45	2.29	.70
122	24.96	2.32	5.35	.68	21.10	1.81	8.70	0.98	4.38	.77	2.70	.40
123	24.99	1.70	5.57	.54	22.05	2.47	8.21	1.71	4.25	.60	2.47	.60
124	24.13	2.08	4.93	.62	20.05	2.27	7.83	1.18	3.60	.65	2.45	.50

W_1 = cone-scale width.
W_2 = bract width.
L_1 = cone-scale length.
L_2 = 1st prong length.
L_3 = 2nd prong length.
R = rating of bract.

Table 8. Mean values and standard deviation of cone-scale characteristics by climatic regions in millimeters.

Region	Cone-scale width		Bract width		Cone-scale length		1st prong length		2nd prong length		Total No. of prov.
	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	Mean	±SD	
1a	22.3	2.06	5.2	.61	18.6	1.91	7.5	1.42	3.6	.70	5
1aa	22.2	2.06	5.2	.73	18.2	2.41	7.4	1.83	3.7	.82	4
1b	23.0	1.75	5.5	.74	18.7	1.77	9.9	1.68	4.5	.87	5
1c	24.6	2.19	5.3	.65	20.3	1.96	8.6	1.50	4.4	.82	15
2a	22.2	2.34	5.0	.76	18.0	2.20	7.5	1.92	3.5	.99	6
2b	22.9	2.43	5.2	.93	19.1	1.75	7.5	1.66	3.5	.64	7
2c	23.8	2.00	5.1	.80	18.7	1.97	8.2	1.39	3.6	.78	6
2d	23.2	2.11	5.4	.76	18.9	2.12	9.1	1.61	4.4	.91	7
2e	22.9	2.02	5.1	.58	18.8	1.84	9.2	1.54	4.4	.76	4
3a	22.2	1.77	5.2	.60	19.3	2.23	7.3	1.63	3.3	.69	3
3b	22.2	2.04	5.0	.71	18.4	2.09	7.5	1.75	3.4	.70	11
3c	23.1	2.16	5.1	.78	18.6	2.05	8.1	1.43	3.6	.73	13
3d	23.5	2.34	5.4	.78	19.4	2.12	9.2	1.76	4.2	.91	9
3e	24.9	2.10	5.2	.64	21.0	2.65	8.9	1.64	4.5	.80	2
4	22.6	2.21	4.9	.98	18.9	2.75	7.6	1.76	3.2	.72	4
5a	21.0	2.00	4.9	.77	17.1	1.98	7.0	1.93	2.8	.60	5
5b	22.8	2.39	5.3	.80	18.3	2.25	8.0	1.54	3.5	.78	8
6	20.1	1.76	4.6	.64	17.3	1.91	6.8	1.82	2.7	.68	2
7a	20.6	2.20	5.2	.72	16.4	1.87	7.9	1.77	2.9	.71	4
7b	20.2	2.20	5.5	.82	16.7	1.99	8.2	1.38	3.1	.58	3
8	20.3		5.0		16.8		7.0		2.5		1

Table 9/a. Relationship between cone-scale width and location of seed source.

Character	Elevation		Latitude		No.of Prov.
	R^2	r	R^2	r	
Region 1 Cone-scale width	0.66	0.81**	0.59	0.77**	29
Region 2 Cone-scale width	0.02	0.13NS	0.07	0.27NS	30
Region 3 Cone-scale width	0.11	0.34*	0.27	0.52**	38
Region 5 Cone-scale width	0.01	0.02NS	0.49	0.70**	13
Region 7 Cone-scale width	0.36	0.60NS	0.12	0.35NS	7

R^2 and r values in the above Table represent the relationships between cone-scale width and elevation (Figs. 13 and 14), and between cone-scale width and latitude (Figs. 23-25). Only the significant relationships were graphed.

R^2 = coefficient of determination.
r = correlation coefficient.
NS = not significant.
* = significant at 5% level.
** = significant at 1% level.

Table 9/b. Analysis of variance of cone-scale widths.

Source	DF	SS	MS	F
R	7	6872.0	681.7	4.06*
S/R	13	3145.0	241.9	6.28**
P/S/R	103	3967.0	38.5	3.73**
T/P/S/R	1701	1751.0	10.3	16.31**
Error	3649	2304.0	0.6	
Total	5473	33859.0		

R = region
S = sub-region
P = provenance
T = tree
* = significant at 5% level.
**= significant at 1% level.

Table 10/a. Relationship between bract width and location of seed source.

Character	Elevation		Latitude		No. of Prov.
	R^2	r	R^2	r	
Region 1 Bract width	0.01	0.11NS	0.01	0.10NS	29
Region 2 Bract width	0.07	0.27NS	0.03	0.17NS	30
Region 3 Bract width	0.03	0.17NS	0.01	0.28NS	38
Region 5 Bract width	0.01	0.09NS	0.19	0.44NS	13
Region 7 Bract width	0.69	0.83*	0.33	0.57NS	7

R^2 and r values in the above Table represent the relationships between bract width and elevation (Fig. 15), and between bract width and latitude. Only the significant relationship was graphed.

R^2 = coefficient of determination.
r = correlation coefficient.
NS = not significant.
* = significant at 5% level.
** = significant at 1% level.

Table 10/b. Analysis of variance of bract widths.

Source	DF	SS	MS	F
R	7	121.8	16.1	1.48NS
S/R	13	141.6	10.9	3.22**
P/S/R	103	348.6	3.4	2.66**
T/P/S/R	1701	2161.2	1.3	8.64**
Error	3649	536.3	0.2	
Total	5473	3300.1		

R = region
S = sub-region
P = provenance

T = tree
* = significant at 5% level.
**= significant at 1% level.

Table 11/a. Relationship between cone-scale length and location of seed source.

Character	Elevation		Latitude		No.of Prov.
	R^2	r	R^2	r	
Region 1 Cone-scale length	0.64	0.80**	0.52	0.72**	29
Region 2 Cone-scale length	0.01	0.10NS	0.03	0.18NS	30
Region 3 Cone-scale length	0.16	0.40*	0.25	0.50**	38
Region 5 Cone-scale length	0.01	0.10NS	0.41	0.64*	13
Region 7 Cone-scale length	0.02	0.15NS	0.10	0.32NS	7

R^2 and r values in the above Table represent the relationships between cone-scale length and elevation (Figs. 16-17), and between cone-scale length and latitude (Figs. 26-28). Only the significant relationships were graphed.

R^2 = coefficient of determination.
r = correlation coefficient.
NS = not significant.
* = significant at 5% level.
** = significant at 1% level.

Table 11/b. Analysis of variance of cone-scale lengths.

Source	DF	SS	MS	F
R	7	4956.0	708.0	4.21*
S/R	13	2186.0	168.2	5.24**
P/S/R	103	3306.0	32.1	3.30**
T/P/S/R	1701	16656.0	9.8	16.80**
Error	3649	2126.0	0.6	
Total	5473	29203.0		

R = region
S = sub-region
P = provenance
T = tree
* = significant at 5% level.
**= significant at 1% level.

Table 12/a. Relationship between 1st prong length and location of seed source.

Character	Elevation		Latitude		No.of Prov.
	R^2	r	R^2	r	
Region 1 1st prong length	0.14	0.37*	0.56	0.71**	29
Region 2 1st prong length	0.10	0.32NS	0.41	0.64**	30
Region 3 1st prong length	0.02	0.13NS	0.36	0.60**	38
Region 5 1st prong length	0.02	0.12NS	0.54	0.73**	13
Region 7 1st prong length	0.22	0.47NS	0.12	0.35NS	7

R^2 and r values in the above Table represent the relationships between 1st prong length and elevation (Fig. 18), between 1st prong length and latitude (Figs. 29-32). Only the significant relationships were graphed.

R^2 = coefficient of determination.
r = correlation coefficient.
NS = not significant.
* = significant at 5% level.
** = significant at 1% level.

Table 12/b. Analysis of variance of 1st prong lengths.

Source	DF	SS	MS	F
R	7	636.0	90.7	0.45NS
S/R	13	2600.6	200.0	7.87**
P/S/R	103	2621.3	25.4	4.66**
T/P/S/R	1701	9287.4	5.5	2.69**
Error	3649	7659.2	2.1	
Total	5473	22804.6		

R = region
S = sub-region
P = provenance

T = tree
* = significant at 5% level.
**= significant at 1% level.

Table 13/a. Relationship between 2nd prong length and location of seed source.

Character	Elevation		Latitude		No.of Prov.
	R^2	r	R^2	r	
Region 1 2nd prong length	0.29	0.54*	0.66	0.82**	29
Region 2 2nd prong length	0.05	0.23NS	0.52	0.72**	30
Region 3 2nd prong length	0.06	0.25NS	0.48	0.70**	38
Region 5 2nd prong length	0.04	0.20NS	0.75	0.87**	13
Region 7 2nd prong length	0.75	0.87*	0.08	0.28NS	7

R^2 and r values in the above Table represent the relationships between 2nd prong length and elevation (Figs. 19-20), and between 2nd prong length and latitude (Figs. 33-36). Only the significant relationships were graphed.

R^2 = coefficient of determination.
r = correlation coefficient.
NS = not significant.
* = significant at 5% level.
** = significant at 1% level.

Table 13/b. Analysis of variance of 2nd prong lengths.

Source	DF	SS	MS	F
R	7	815.2	116.5	1.97NS
S/R	13	767.1	59.0	10.02**
P/S/R	103	606.2	5.9	5.76**
T/P/S/R	1701	1739.3	1.0	4.05**
Error	3649	921.0	0.3	
Total	5473	4848.8		

R = region
S = sub-region
P = provenance
T = tree
* = significant at 5% level.
**= significant at 1% level.

Table 14/a. Relationship between rating of bract and location of seed source.

Character	Elevation		Latitude		No. of Prov.
	R^2	r	R^2	r	
Region 1 Rating of bract	0.31	0.56**	0.29	0.54**	29
Region 2 Rating of bract	0.00	0.00NS	0.02	0.15NS	30
Region 3 Rating of bract	0.41	0.64**	0.53	0.73**	38
Region 5 Rating of bract	0.09	0.30NS	0.14	0.38NS	13
Region 7 Rating of bract	0.14	0.37NS	0.01	0.11NS	7

R^2 and r values in the above Table represent the relationships between rating of bract and elevation (Figs. 21-22), and between rating of bract and latitude (Figs. 37-38). Only the significant relationships were graphed.

R^2 = coefficient of determination.
r = correlation coefficient.
NS = not significant.
* = significant at 5% level.
** = significant at 1% level.

Table 14/b. Analysis of variance of rating of bracts.

Source	DF	SS	MS	F
R	7	154.5	22.1	1.28NS
S/R	13	223.7	17.1	6.24**
P/S/R	103	283.9	2.8	2.95**
T/P/S/R	1701	1592.1	0.9	4.24**
Error	3649	805.0	0.2	
Total	5473	3059.3		

R = region
S = sub-region
P = provenance
T = tree
* = significant at 5% level.
**= significant at 1% level.

Table 15. Summary of average cone-scale characteristics for "coastal" and "interior" regions.

Character	Regions	
	Coastal	Interior
Cone-scale width (W_1)	23.14 mm	21.38 mm
Bract width (W_2)	5.22 mm	5.13 mm
Cone-scale length (L_1)	19.00 mm	17.38 mm
1st prong length (L_1)	8.24 mm	7.68 mm
2nd prong length (L_2)	3.84 mm	3.12 mm
Rating of Bract (R)	2.19 rating*	2.25 rating*

* for rating of bract see Figure 3/b page 18.

Relationship Between Thousand-Seed Weight and Cone-Scale Characteristics

Thousand-seed weight and cone-scale characteristics were found to vary greatly from provenance to provenance and were affected more strongly by latitude than elevation.

It is logical to examine the relatonships between 1000-seed weigth and cone-scale characteristics in each region to determine whether or not they agree with the findings shown previously.

Thousand-seed weight was associated with elevation in Regions 1, 2 and 3 and with latitude in Regions 1, 3, 5 and 7. Width of cone-scale was correlated with elevation in Regions 1, 3 and 7 and with latitude in Regions 1, 3 and 5, as mentioned earling. Figure 39 to 42 show that 1000-seed weigth was significantly correlated with width of cone-scale in Regions 1 and 3 (1% level), and in Regions 2 and 5 (5% level). Although 1000-seed weight was significantly correlated (5% level) with the width of cone-scale in Region 2 (Figure 40), the relationship was weak: the coefficient of determination (Table 16), R^2, was only 0.18, as compared with 0.66 in Region 1, which implied that in Region 2 the increasing 1000-seed weight was due more to environmental or other uncontrolled factors than to the width of cone-scale.

The 1000-seed weight was related to the length of cone-scale (Figures 43 to 45) in Regions 1, 3 (1% level) and in Region 5 (5% level), which agree with the previous findings. Ther was a clear trend that seed weight was directly correlated with the scale size, the larger cone-scale usually having heavier seed. Squillace (1957) reported that average weight of seed per cone was directly correlated with cone length and average cone-scale size in western white pine. Eliason and Heit (1940) found that cone size was related to seed size in Scots pine. Perry and Coover (1933) reported that larger cones generally yielded larger seeds in pitch pine, and that many small and medium-size cones contained not only more seed, but better filled seed than the larger cones in shortleaf pine. They also indicated that there was no relationship between cone size and vertical position of cone in pitch pine.

Seed weight is generally related to cone-scale size which in yurn depends on cone size. Although the relationship between seed weight and cone weight is not included in this study, it could be assumed that larger and heavier cones have heavier seed than smaller ones. In this connection, Simak and Gustaffsson (1954) reported that in Scots pine, increasing cone size and cone weigth increased not only seed production, but also the average seed weight per cone. Simak (1960) further noted that, in Scots pine, the number and the average size of seed per cone increased with larger cone weight. He concluded that these relationships appeared to be determined mainly by the tree's genotype, but were also strongly modified by environmental factors.

Figures 46 to 53 show that 1000-seed weight became heavier as 1st and 2nd prongs became longer. Furthermore, larger cone-scales were apparently accompained by longer prongs, but this relationship was not observed in Region 7.

Cone-scales with relatively shorter bracts generally yielded heavier seed in Regions 1 and 3 (Figures 54 and 55).

The relationships between 1000-seed weight and cone-scale characteristics existed in all regions except Region 7 (Table 16). The lack of relationship in Region 7 could perhaps be explained by inadequate sampling.

The relationship between 1000-seed weight and width of cone-scale.

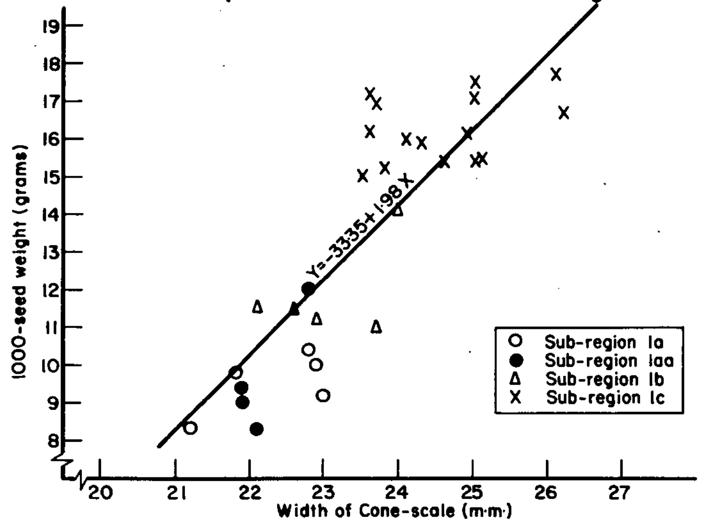

Figure 39. in region 1.

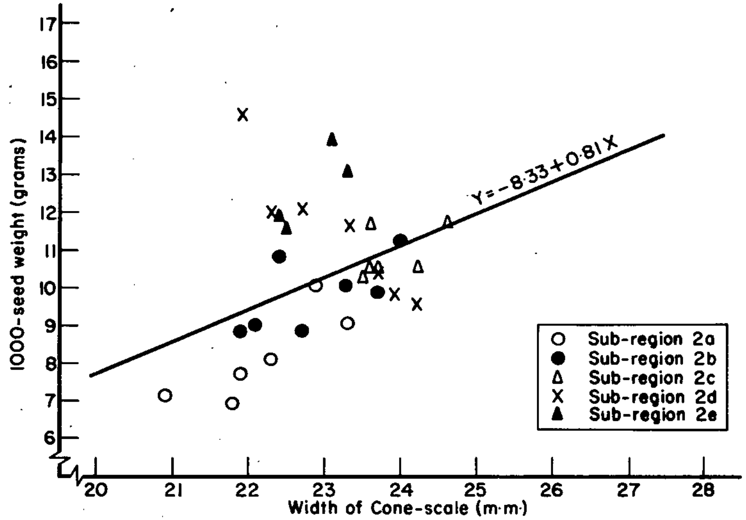

Figure 40. in region 2.

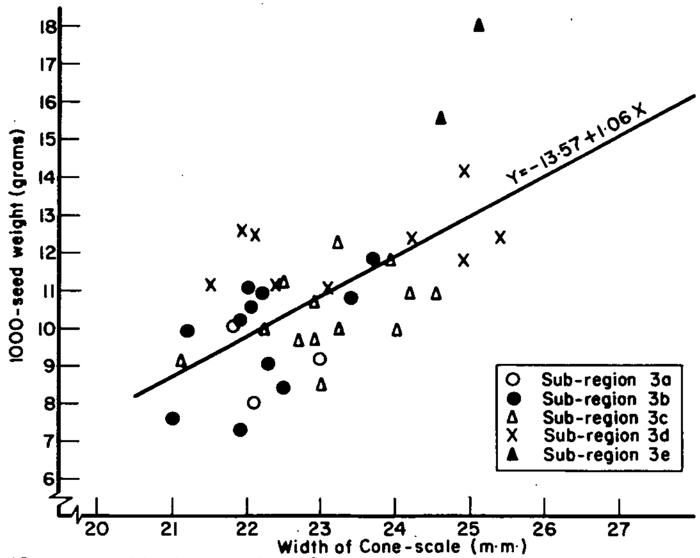

Figure 41. in region 3.

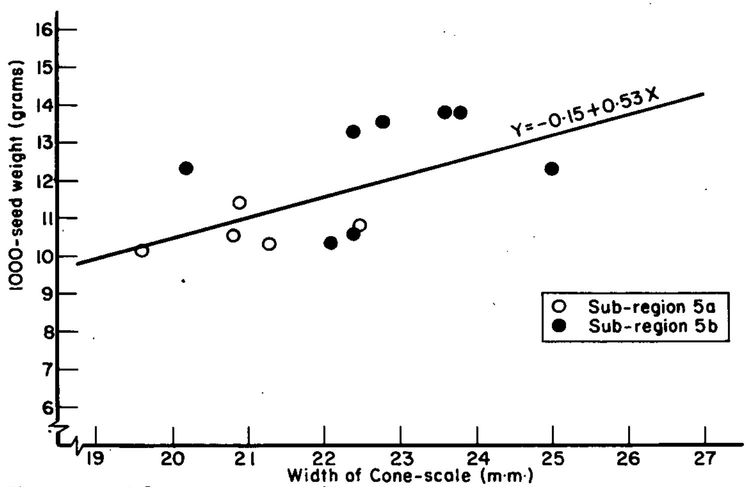

Figure 42. in region 5.

The relationship between 1000-seed weight and length of cone-scale.

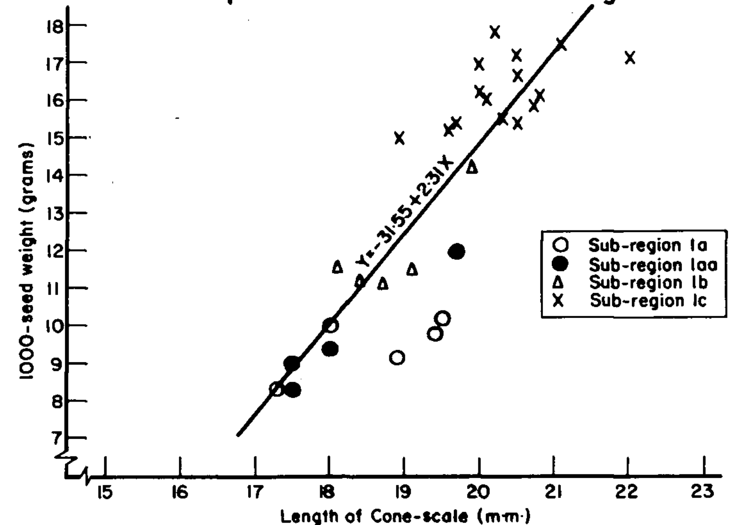

Figure 43· in region 1·

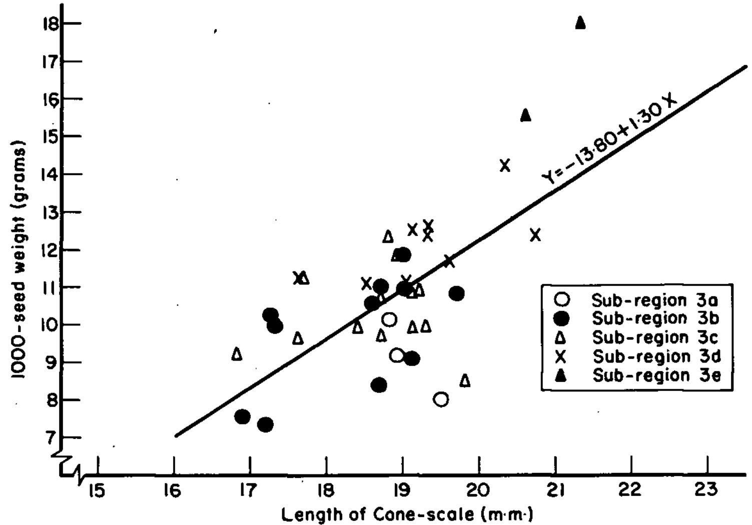

Figure 44· in region 3·

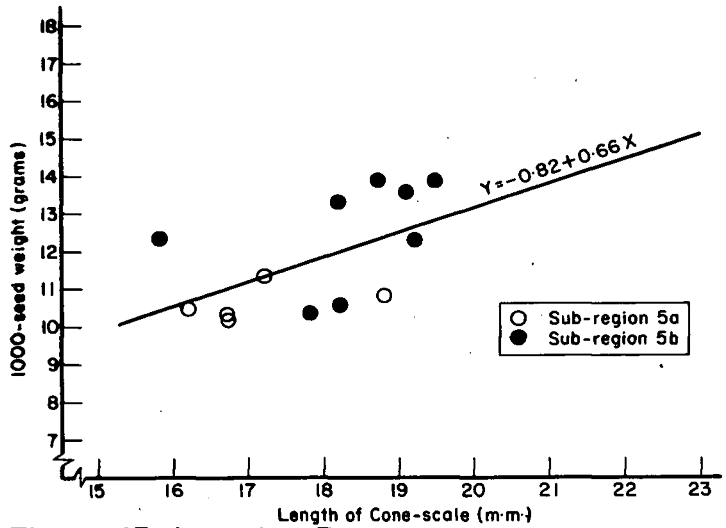

Figure 45· in region 5·

The relationship between 1000-seed weight and length of 1st prong·

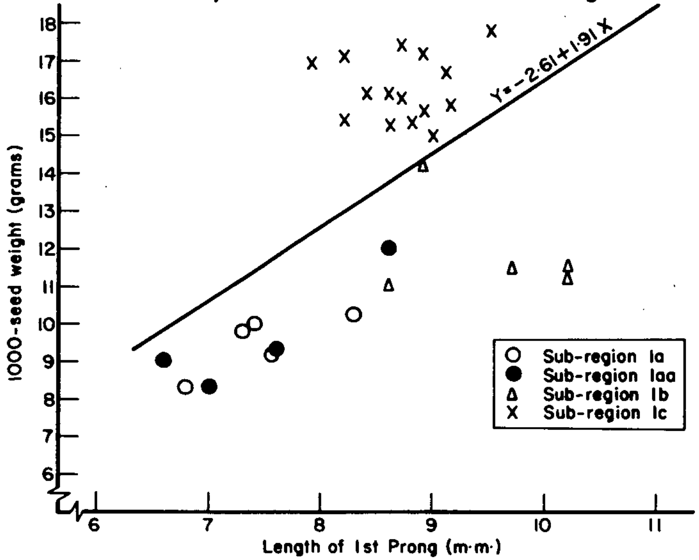

Figure 46· in region 1·

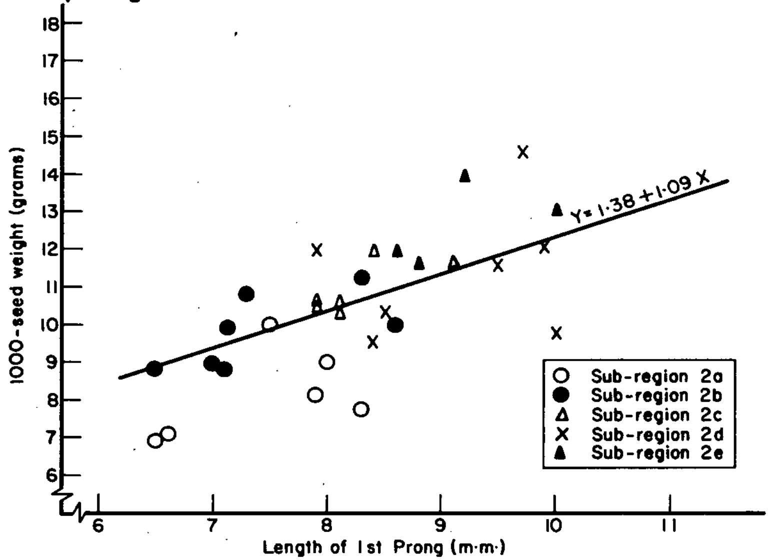

Figure 47· in region 2·

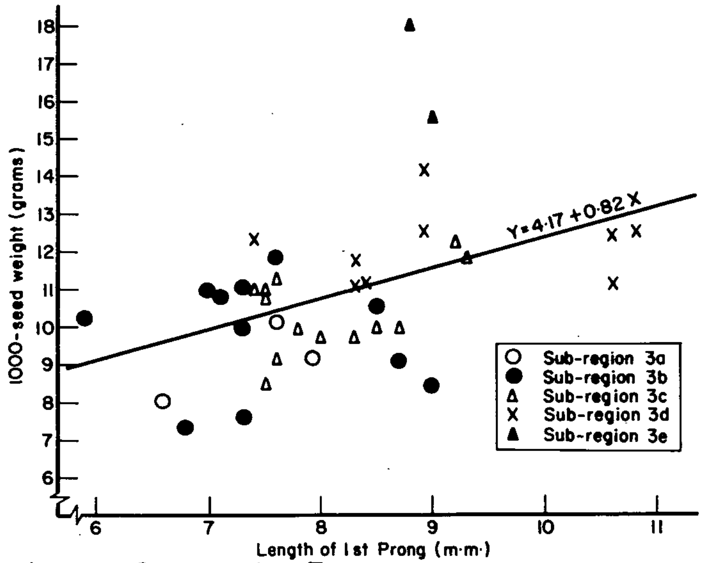

Figure 48· in region 3·

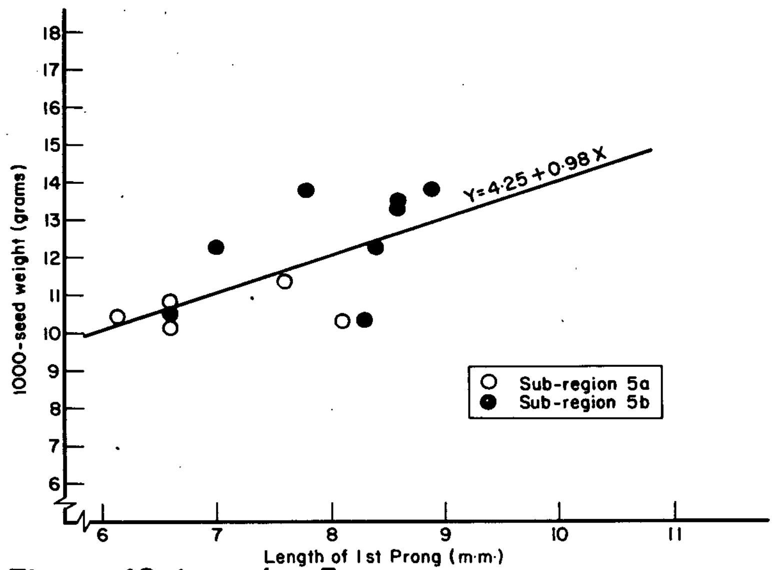

Figure 49· in region 5·

The relationship between 1000-seed weight and length of 2nd prong·

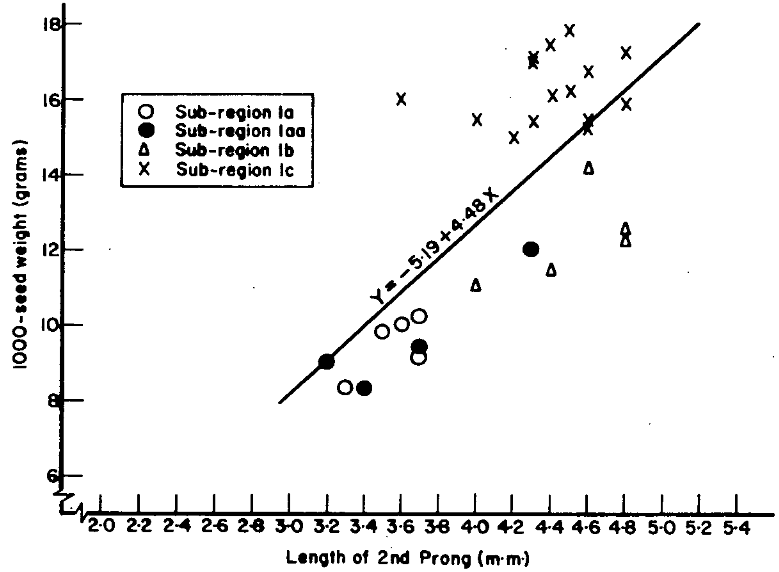

Figure 50· in region 1·

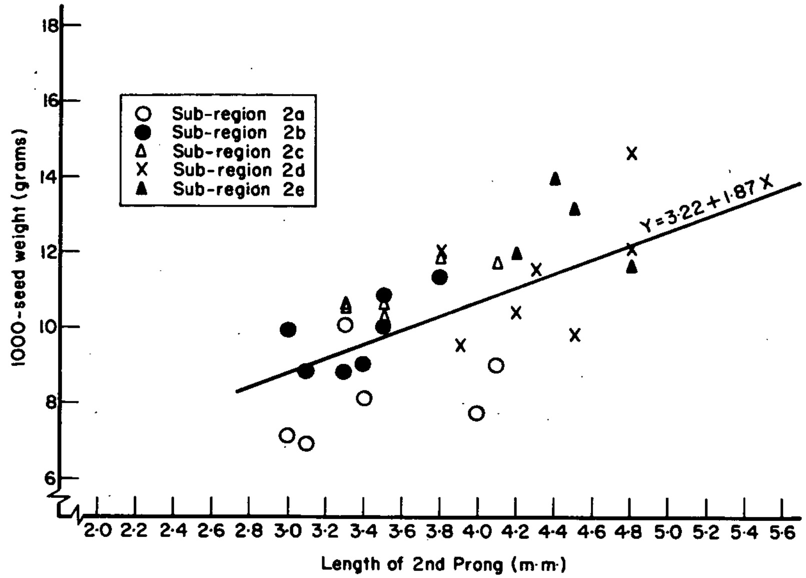

Figure 51· in region 2·

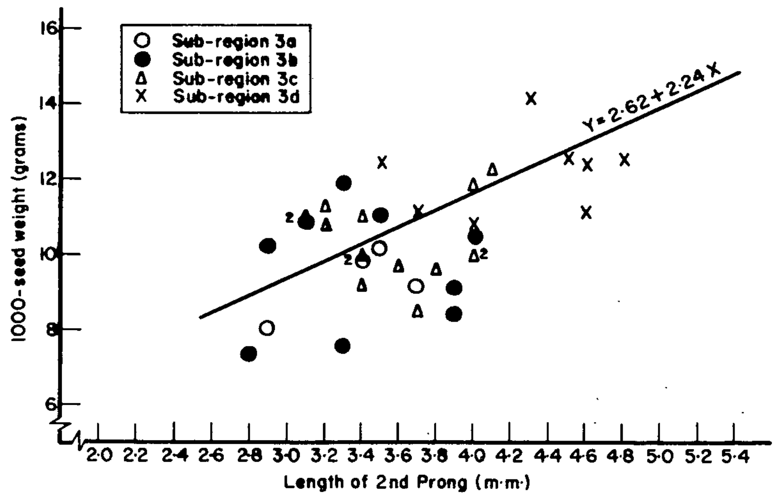

Figure 52· in region 3·

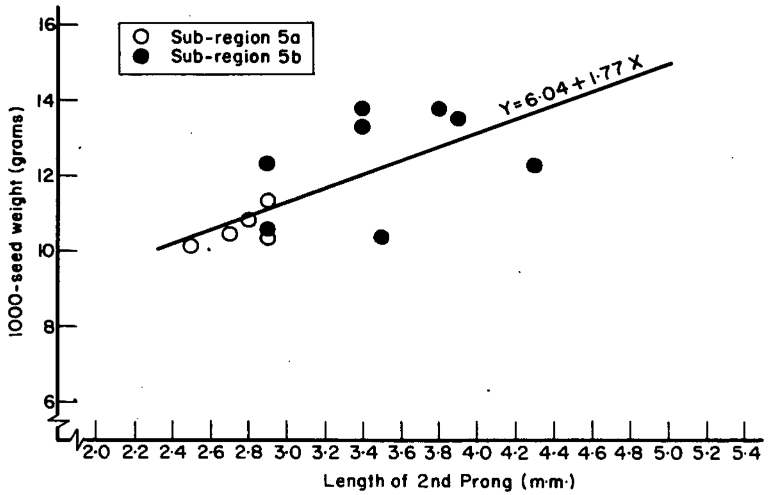

Figure 53· in region 5·

The relationship between 1000-seed weight and rating of bract·

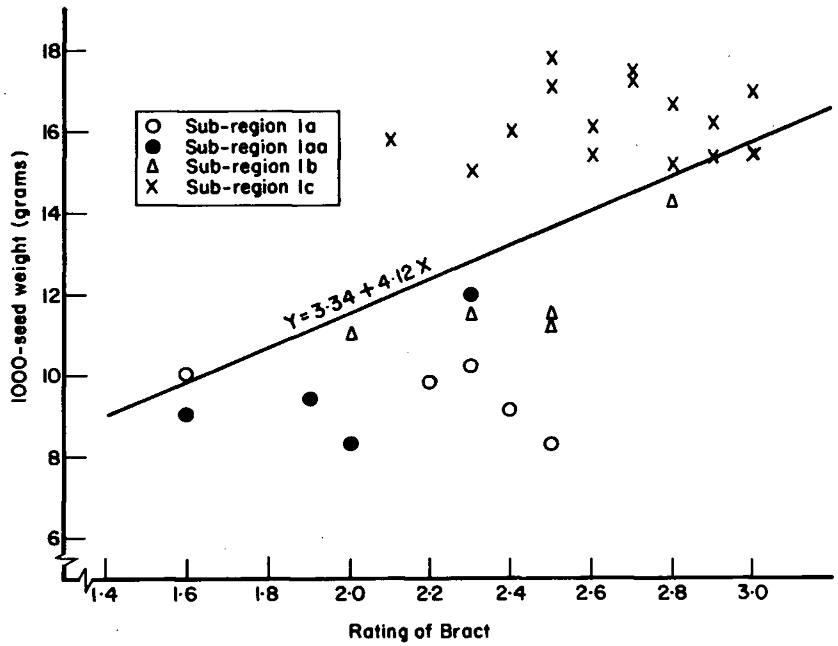

Figure 54· in region 1·

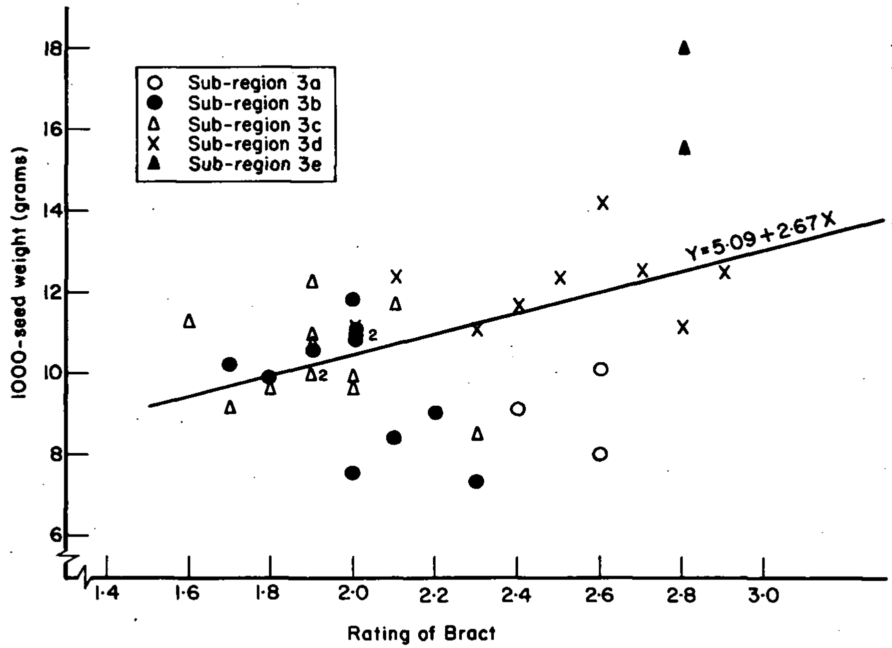

Figure 55· in region 3·

Table 16. Correlation between 1000-seed weight and cone-scale characteristics.

Character		1000-seed weight		No.of Prov.
		R^2	r	
Region 1	W_1	0.66	0.81**	29
	W_2	0.01	0.08NS	
	L_1	0.70	0.84**	
	L_2	0.28	0.53**	
	L_3	0.49	0.71**	
	R	0.36	0.60**	
Region 2	W_1	0.18	0.42*	30
	W_2	0.01	0.09NS	
	L_1	0.12	0.34NS	
	L_2	0.46	0.68**	
	L_3	0.39	0.63**	
	R	0.02	0.13NS	
Region 3	W_1	0.38	0.62**	38
	W_2	0.08	0.29NS	
	L_1	0.41	0.64**	
	L_2	0.19	0.43**	
	L_3	0.33	0.58**	
	R	0.24	0.49**	
Region 5	W_1	0.32	0.57*	13
	W_2	0.01	0.10NS	
	L_1	0.31	0.56*	
	L_2	0.39	0.63*	
	L_3	0.44	0.66*	
	R	0.24	0.48NS	
Region 7	W_1	0.04	0.20NS	7
	W_2	0.03	0.17NS	
	L_1	0.01	0.06NS	
	L_2	0.07	0.26NS	
	L_3	0.05	0.21NS	
	R	0.04	0.19NS	

R^2 and r values in the above Table represent the relationship 1000-seed weight and cone-scale characteristics from Figs.39 to 55. Only the significant relationships were graphed.

W_1 = cone-scale width
W_2 = width of bract
L_1 = cone-scale length
L_2 = 1st prong length
L_3 = 2nd prong length
R = rating of bract

R^2 = coefficient of determination.
r = correlation of coefficient.
NS = not significant.
* = significant at 5% level.
** = significant at 1% level.

Seed germination test

Regression analysis was carried out between germination percent and latitude, longitude and elevation of seed source firstly on sub-regions and regions. No significant relationships could be established, so the regression analysis was then based on 114 out of 124 provenances in this experiment.

An analysis of the data 36 days after sowing indicated that germination percent was significantly affected by latitude (Figure 56). However, it was shown that the coefficient of determination, R^2, is 0.14, which implies that only 14 per cent of the variation in germination percent can be explained by latitude. The effect of this factor disappeared 50 days after sowing the seeds. There was no significant relationship between germination percent and either latitude or longitude.

The lowest germination percent (Table 17) of 11.6 (36 days after sowing) was obtained from seeds collected in Castle Rock, Washington (Prov. No.70, lat. 46°19', long. 122°52') and the highest, 61.9 percent was collected from Tatla, B.C. (Prov. No.7, lat. 51°44', long. 124°44').

The lowest germination percent (Table 17) of 41.8 (92 days after sowing) was found in Sook, B.C. (Prov. No.33, lat. 48°24', long. 123°44') and the highest, 85.6 percent, seeds were collected from Pine Grove, Oregon, (Prov. No.86, lat. 45°06', long. 121°23').

The range in the germination percent within each sub-region is presented in Table 18. As can be observed there was a considerable difference among provenances within a sub-region;

for example, at end of the germination period, sub-region 3d had the highest range between minimum and maximum germination percent, i.e., from 44.5 to 84.3%, while sub-region 7b had a relatively smaller range from 73.7 to 78.6%. These two sub-regions are located in Washington State.

In some sub-regions, for example, samples from sub-regions 2b, 2d, 4, 6 and 7a (Table 18) with the highest and lowest germination percent remain the highest and lowest throughout the entire duration of the experiment.

The data showed that the provenances with the lowest and highest germination percent in sub-regions 1aa, 2b, 3e, 4, 5a, 5b, 6 and 7a appeared to have the most consistent germination patterns when compared with the other sub-regions in Table 18.

The difference in the germination percent of seeds from the following four provenances: northern (Prov. No.1, Stoner, B.C., lat. 53°37', long. 122°40'), easthern (Prov. No.11, Golden, B.C., lat. 51°23', long. 177°00'), westhern (Prov. No.12, Jeune Landing, B.C., lat. 50°27', long. 127°27') and southern (Prov. No.122, Covel, California, lat. 39°48', long. 122°56') are shown in Table 19. The analysis of variance showed statistically significant differences at 1% level among these four provenances 36 days after sowing. The greater variation of germination percent at 36 days after sowing found between northern and southern provenances when compared with westhern and easthern provenances is clearly shown in Figures 57 to 60. These results can be confirmed in Figure 56 that latitudinal factor affects the germination percent more than longitudinal factor. No significant differences among these four provenances were observed after

50 days from sowing.

The intra-provenance variation in germination percent can also be observed from these four provenances. The range among trees within provenances (Figures 57 to 60, Table 19) was greater in westhern and northern provenances than in easthern and southern provenances. This may indicate that Douglas-fir moved gradually northwards after the ice age. Stronger selection pressure in the interior eliminated the individuals not adapted to the new conditions and reduced the variability within population (Figure 60). Coastal provenances exhibit a much wider range of variation (Figure 59).

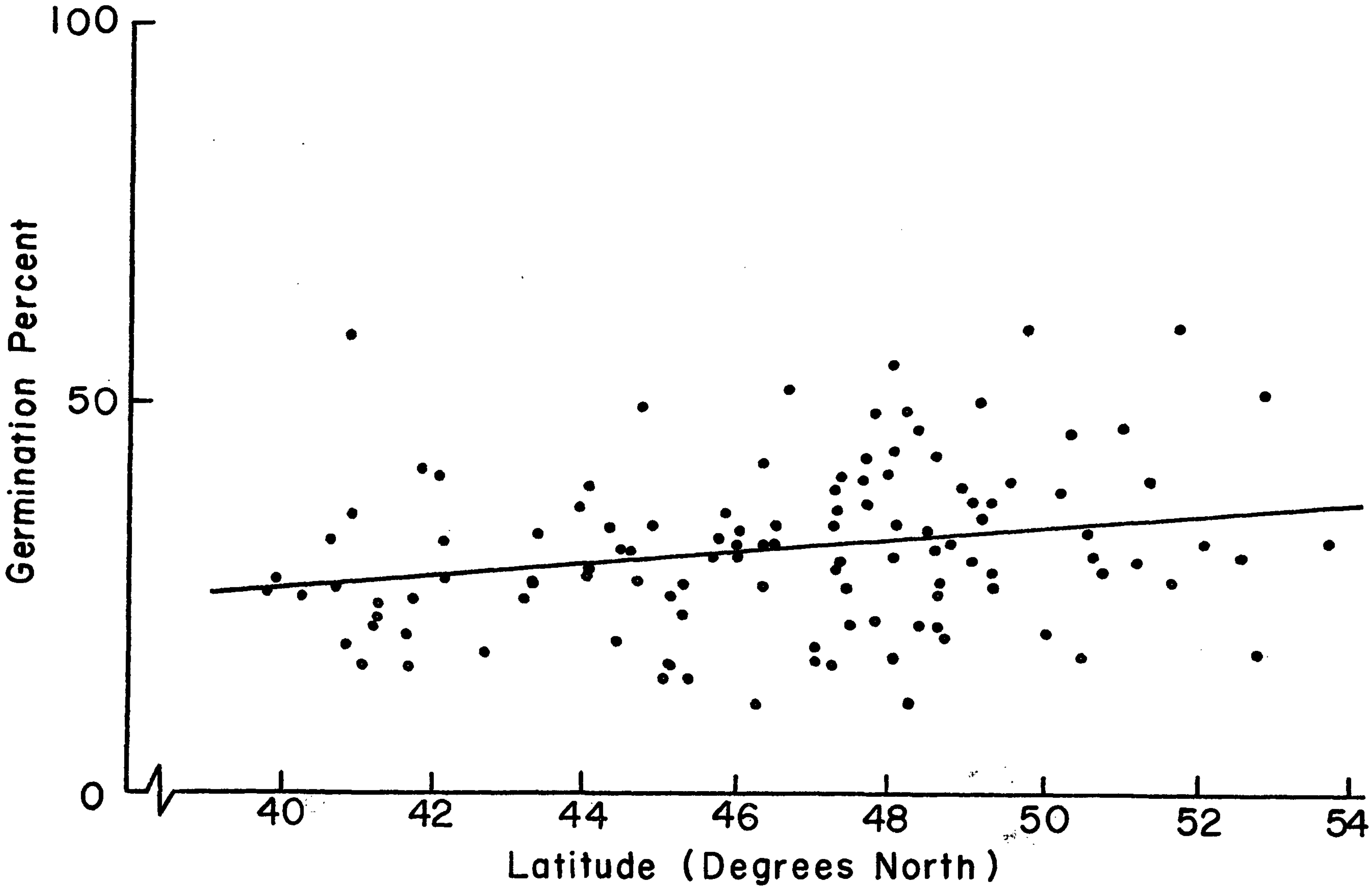

Figure 56. The correlation between average germination percent (36 days after sowing) and latitude in Douglas-fir.

Cumulative germination percent of 12 trees within provenance·

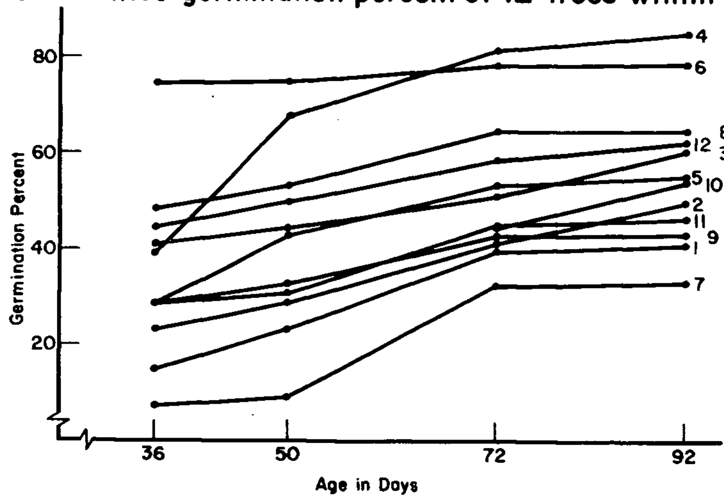

Figure 57· Provenance No· 1, Stoner, B·C·

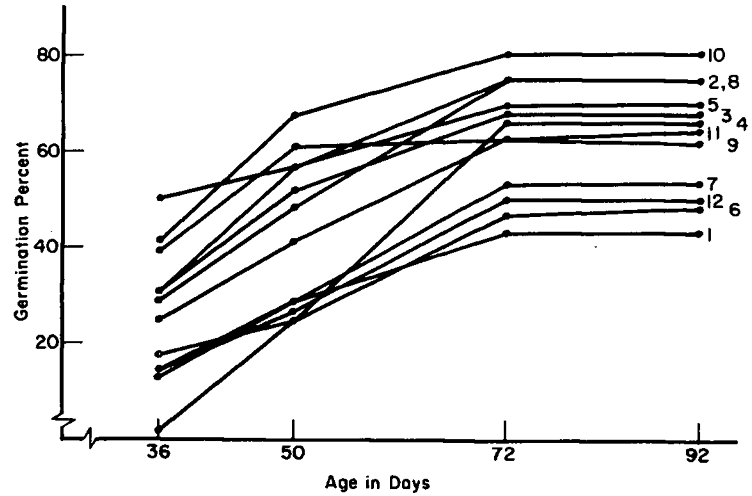

Figure 58· Provenance No· 122, Covelo, California·

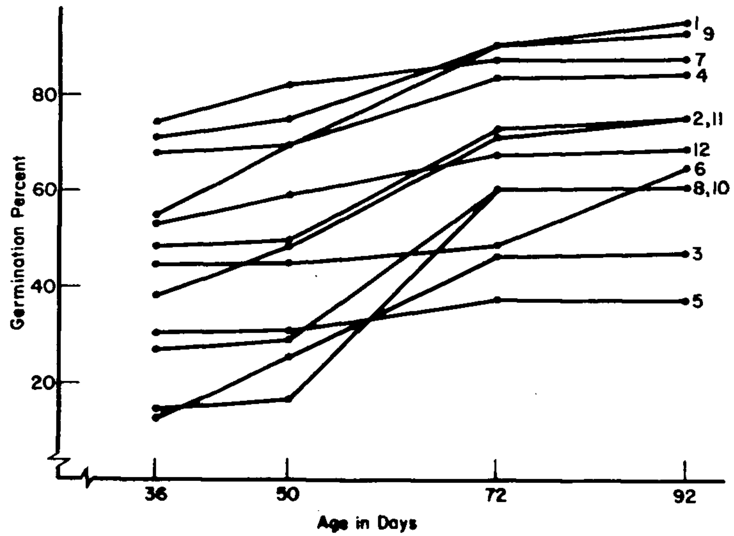

Figure 59· Provenance No· 12, Jeune Landing, B·C·

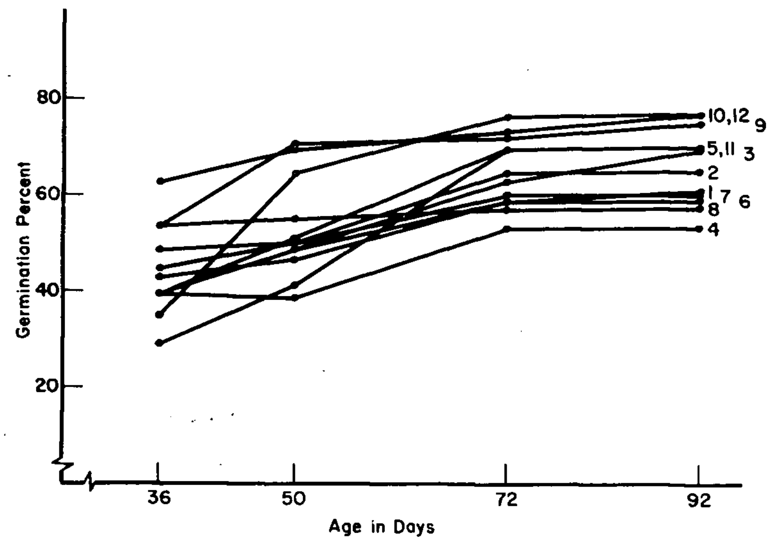

Figure 60· Provenance No· 11, Golden, B·C·

Table 17. Germination percent of 114 Douglas-fir provenances.

Prov. No.	Germination percent days after sowing 36	50	72	92
1.	33.8	41.7	53.6	57.8
2.	52.8	68.8	81.8	81.6
4.	19.4	32.3	48.7	48.7
5.	33.2	45.8	53.9	54.1
7.	61.9	67.4	70.5	75.0
8.	30.8	50.0	65.7	66.0
9.	28.0	50.2	65.7	66.1
10.	48.4	61.8	72.8	72.8
11.	44.2	53.3	64.3	66.0
12.	44.8	49.8	68.3	70.0
13.	47.6	50.0	64.2	64.2
14.	40.0	54.5	74.3	74.3
15.	21.8	29.8	44.7	44.7
16.	18.5	32.4	57.8	59.4
17.	31.6	47.8	61.6	61.6
18.	31.0	48.1	68.3	69.8
20.	41.1	46.9	60.9	62.2
21.	25.0	42.3	64.6	65.5
22.	38.3	47.6	62.7	62.7
23.	38.1	43.6	65.8	67.7
24.	27.3	34.7	63.4	65.7
25.	60.0	68.5	82.8	84.0
26.	30.4	36.8	63.0	66.9
27.	51.8	55.4	72.0	72.6
28.	48.9	62.2	78.6	78.6
29.	39.9	49.4	74.4	75.9
31.	44.0	49.6	71.8	73.4
32.	33.6	45.5	70.6	71.3
33.	22.6	27.0	39.2	41.8
34.	33.7	39.0	66.2	66.2
35.	31.3	39.3	63.9	63.9
36.	34.6	45.4	72.6	72.6
37.	20.1	30.8	61.5	65.1
38.	17.9	24.3	56.9	56.9
39.	26.9	37.8	68.8	68.8
40.	12.2	19.0	59.9	61.3
41.	26.5	38.1	69.5	70.2
42.	45.0	55.5	77.4	77.4
43.	32.2	48.1	76.7	77.2
44.	35.3	48.9	64.6	65.6
45.	24.7	38.7	68.2	71.6
46.	48.0	61.5	79.2	79.8
47.	21.9	38.4	57.2	60.4
48.	51.0	63.0	72.2	73.7
49.	42.0	47.8	67.7	70.1
50.	49.7	54.0	73.3	74.8

Table 17. (Continued)

Prov. No.	36	50	72	92
51.	36.6	41.7	68.5	70.2
52.	39.0	43.7	63.3	63.3
53.	35.6	38.6	59.7	62.9
54.	17.0	27.1	58.7	58.7
55.	56.3	59.7	72.3	73.3
56.	29.5	43.2	68.6	68.6
57.	22.2	36.6	67.6	68.5
58.	31.4	41.7	63.0	64.1
59.	17.1	26.2	43.1	44.5
60.	27.5	43.5	63.0	63.0
61.	34.9	46.8	73.0	73.8
62.	44.1	51.1	62.8	63.9
63.	41.5	55.2	72.6	73.5
64.	36.2	50.0	64.2	66.8
65.	40.6	52.2	73.5	75.0
66.	38.9	62.7	78.0	79.5
67.	43.9	54.8	73.7	73.7
68.	27.6	33.1	47.6	50.6
69.	32.3	42.7	69.2	69.2
70.	11.6	19.3	53.8	54.8
71.	19.8	32.8	59.7	60.0
72.	31.3	41.7	67.0	67.7
73.	34.5	41.3	62.2	63.7
74.	33.2	39.5	69.2	72.3
75.	35.1	49.0	70.7	70.7
76.	32.9	44.4	70.1	84.3
77.	32.2	53.6	78.9	78.9
78.	53.4	71.6	83.2	83.2
79.	30.7	46.3	68.5	70.5
80.	37.1	62.4	81.3	81.3
81.	27.5	42.0	60.8	61.8
82.	16.5	30.7	58.8	60.1
83.	33.4	45.7	76.5	78.4
84.	14.8	33.7	64.9	66.8
85.	22.9	30.1	47.6	48.1
86.	25.6	57.9	85.6	85.6
87.	20.1	31.7	56.1	56.3
88.	35.3	52.4	70.9	72.2
89.	25.4	41.4	68.6	69.5
91.	32.7	42.1	62.7	62.7
92.	31.5	45.3	70.7	72.8
93.	31.9	46.4	63.7	64.5
94.	29.8	50.0	71.9	72.0
95.	26.8	43.5	75.2	75.2
96.	34.3	47.8	73.0	73.0

Table 17. (Continued)

Prov. No.	36	50	72	92
97.	50.5	66.4	84.1	84.5
99.	36.8	58.8	81.9	81.9
100.	33.5	42.0	55.1	55.1
101.	36.9	58.2	81.3	81.3
102.	27.9	53.9	75.8	76.2
103.	18.0	50.3	75.0	75.0
104.	41.1	56.3	76.4	76.4
105.	45.0	57.0	78.0	78.9
106.	20.7	66.0	66.7	67.4
107.	26.7	42.9	68.8	68.8
108.	22.8	35.0	61.2	61.9
109.	16.7	32.8	57.3	58.6
110.	25.6	48.0	74.3	76.2
112.	21.6	44.5	69.8	70.4
113.	16.2	30.4	58.5	59.1
114.	36.2	49.8	66.6	66.6
115.	59.8	64.5	79.4	79.7
116.	32.4	52.7	73.2	74.4
117.	27.7	46.0	64.9	66.7
118.	25.9	41.3	70.9	70.9
119.	19.2	36.2	60.7	60.7
121.	27.4	43.2	70.2	71.0
122.	25.5	44.1	62.4	62.7

Table 18. Minimum And Maximum Germination Percent 36, 50, 72 And 92 Days After Sowing within A Climatic Region

Region	Total No. of Prov.	36 days after sowing					50 days after sowing				
		Prov. No.	Min.	Prov. No.	Max.	Mean	Prov. No.	Min.	Prov. No.	Max.	Mean
1a	5	21	25.0	23	38.1	31.7	24	34.7	32	45.5	42.3
1aa	4	71	19.8	55	56.8	31.8	37	30.8	55	59.7	40.8
1b	4	82	16.5	96	34.3	26.1	82	39.7	99	58.8	45.1
1c	12	109	16.7	104	41.1	25.9	109	32.8	106	66.0	45.4
2a	4	33	22.6	13	47.6	39.8	33	27.0	13	30.0	50.0
2b	7	54	17.0	50	49.7	36.2	54	21.1	50	54.0	41.7
2c	6	68	27.5	67	43.9	32.5	68	33.1	67	54.8	44.1
2d	7	87	20.1	91	32.7	28.4	87	31.7	102	53.9	44.4
2e	3	114	36.2	115	59.8	47.0	114	49.8	115	64.5	57.1
3a	3	22	38.3	20	41.1	39.5	20	46.9	29	49.4	47.9
3b	11	40	12.2	25	60.0	30.0	40	19.0	25	68.5	42.8
3c	13	70	11.6	62	44.7	29.7	70	19.4	62	51.5	40.4
3d	6	84	14.8	101	36.9	28.2	85	30.1	101	58.2	45.7
3e	2	113	16.2	112	21.6	19.8	113	30.4	112	44.5	37.5
4	2	14	40.0	2	52.8	46.4	14	54.5	2	68.6	61.6
5a	5	16	18.5	7	61.9	33.2	15	26.8	7	67.4	45.1
5b	8	47	21.9	78	53.4	33.8	47	38.4	78	71.6	55.6
6	2	4	19.4	1	33.8	26.6	4	32.3	1	41.7	37.0
7a	4	18	31.0	10	48.4	34.9	17	47.8	10	61.8	51.9
7b	3	66	38.9	43	51.0	46.3	28	62.2	48	68.0	62.6

Table 18. (Continued)

Region	Total No.of Prov.	72 days after sowing					92 days after sowing				
		Prov. No.	Min.	Prov. No.	Max.	Mean	Prov. No.	Min.	Prov. No.	Max.	Mean
1a	5	24	63.4	36	72.6	67.4	21	65.5	36	72.6	68.6
1aa	4	71	59.7	55	72.3	64.3	71	60.0	55	73.3	65.5
1b	4	82	58.8	99	81.9	72.2	82	60.1	99	81.9	72.5
1c	12	109	57.3	104	76.4	67.2	109	58.6	104	76.4	67.9
2a	4	33	39.2	12	68.3	60.9	33	41.8	31	73.4	62.5
2b	7	54	58.7	50	73.3	65.3	54	58.7	50	74.8	66.6
2c	6	68	47.6	83	76.5	60.1	68	50.6	83	78.4	67.4
2d	7	87	56.1	102	75.8	66.9	87	56.3	102	76.2	67.7
2e	3	114	66.6	115	79.4	74.6	114	66.6	115	79.7	75.0
3a	3	20	60.9	29	74.4	60.0	20	62.2	29	75.9	66.9
3b	11	38	56.9	25	82.8	69.1	38	56.9	25	84.0	70.2
3c	13	39	43.1	61	73.0	64.2	59	44.5	76	84.3	66.2
3d	6	85	47.6	86	85.6	67.6	85	48.1	86	85.7	68.2
3e	2	113	58.5	112	69.8	64.2	113	59.1	112	70.4	64.6
4	2	14	74.3	2	81.2	77.9	14	74.3	2	81.6	78.6
5a	5	15	44.7	7	70.5	58.5	15	44.7	7	75.0	59.8
5b	8	47	57.2	78	83.2	73.8	47	60.4	78	83.2	74.9
6	2	4	48.7	1	53.6	51.8	4	48.7	1	57.8	53.3
7a	4	17	61.6	10	72.8	67.2	17	61.6	10	72.8	67.6
7b	3	48	72.1	28	78.6	76.2	48	73.7	28	78.6	77.3

Table 19. Variation of germination percent from four different provenances throughout four observed stages. (The value presented in the Table is percent %)

Location	days after sowing	Tree No. 1	2	3	4	5	6	7	8	9	10	11	12	A.V.
Northern	36	14.3	23.2	41.1	39.3	28.6	75.0	7.2	48.2	28.6	28.6	28.6	44.7	33.8
Prov. No.1	50	23.2	28.6	44.7	67.9	42.9	75.0	9.0	53.6	32.2	42.9	30.4	50.0	41.7
Stoner, B.C.	72	39.3	41.1	51.8	81.9	53.6	78.6	32.2	64.3	42.9	53.6	44.7	58.9	53.6
Lat. 53°37'	92	41.1	50.0	60.8	85.7	55.4	78.6	33.4	64.3	42.9	54.1	46.5	62.4	57.8
Long. 122°40'														
Eastern	36	42.9	44.7	39.3	39.3	39.3	42.9	48.3	53.6	53.6	62.5	29.0	35.0	44.2
Prov. No.11	50	46.4	50.0	48.3	39.3	51.8	48.2	50.0	54.7	70.8	69.7	41.4	64.3	53.3
Golden, B.C.	72	58.9	64.3	62.5	53.6	69.7	58.9	60.0	57.2	71.5	73.3	69.7	76.8	64.7
Lat. 51°23'	92	60.7	64.3	69.7	53.6	69.7	58.9	60.0	57.2	75.0	76.8	69.7	76.8	66.0
Long. 117°00'														
Western	36	67.9	48.2	12.5	55.4	30.4	44.7	75.0	14.3	71.4	26.8	39.3	53.4	44.8
Prov. No.12	50	69.7	49.6	25.0	69.7	30.4	44.7	82.2	16.1	75.0	28.6	48.2	59.1	49.8
Jeune Land-	72	91.1	73.3	46.5	83.9	37.5	48.3	87.5	60.7	91.1	60.7	71.1	67.9	68.3
ing, B.C.	92	94.8	75.0	46.5	84.2	37.5	64.3	87.5	60.7	92.9	60.7	75.0	69.7	70.7
Lat. 50°27'														
Long. 127°27'														
Southern	36	12.5	30.4	30.4	1.8	50.0	17.9	14.3	28.6	39.3	41.4	25.0	14.3	25.5
Prov. No.122	50	28.6	56.4	53.6	25.0	57.2	25.0	28.6	58.7	60.7	67.9	41.1	26.8	44.1
Covelo, Calif.	72	42.9	75.0	67.9	66.1	69.7	46.4	53.6	75.0	61.4	80.4	60.4	50.0	62.4
Lat. 39°48'	92	42.9	75.0	67.9	66.1	69.7	48.2	53.6	75.0	61.4	80.4	64.3	50.0	62.7
Long. 122°56'														

SUMMARY AND CONCLUSIONS

Geographic variation and relationship between 1000-seed weights and cone-scale morphology and the relationship between these factors and germination percent have been reported for Douglas-fir from within its natural range. One hundred and twenty four provenances representing eight regions from British Columbia to California (lat. 38°50' to 53°37', long. 117°00' to 127°27') were collected in 1966 and 1968 by IUFRO, Section 22.

Each region was divided into several sub-regions according to geographic factors and soil and climatic conditions.

The studies of 1000-seed weights and cone-scale morphology were based on all provenances, while germination tests were based on only 114.

Seeds extracted from cone samples were then identified as "filled" or "empty" using X-ray fluoroscopy and separated by hand. Seed lots were weighed with a balance reading to 10^{-4} grams, and average 1000-seed weight was computed for each provenance.

The cone-scale characteristics of cone-scale widths and lengths, bract widths and 1st and 2nd prong lengths were measured in millimeters.

Regression analyses between 1000-seed weights and cone-scale characteristics, and the latitude and elevation of seed sources were carried out for each region.

Seed germination for each provenance was tested under nursery conditions. Regression analyses showed no relationship between germination percent and elevation, latitude and longitude within each region, and further regression analyses were therefore based on combined provenances.

Some results are summarized as follows:

1. <u>Thousand-Seed Weight</u>

   a. Thousand-seed weight varied among trees, provenances, sub-regions and regions.

   b. Thousand-seed weight had a clinal variation increasing from low to high elevation, observed mainly in coastal regions, and a clinal increase from north to south in both coastal and interior regions. Latitude appeared to affect seed-weight more than elevation.

2. <u>Cone-Scale Characteristics</u>

   a. Cone-scale characteristics differed significantly among trees within provenances, among provenances within sub-regions and among sub-regions. However, only cone-scale widths and lengths had significant variances among regions.

   b. Cone-scale widths and lengths were significantly related to elevation in only two regions and to latitudes in three regions.

   c. 1st prong length was significantly related to elevation in one region, and to latitude in four regions.

   d. 2nd prong length was significantly related to elevation in two regions, and to latitude in four regions.

   e. A significant relationship between bract width and elevation was found in only one region. Bract width was not related to latitude in any region.

   f. A significant number of cone-scale and bract measurements had a definite clinal variation increasing from low to high elevation and from north to south in some regions.

g. The average values of cone-scale characteristics in "coastal" regions were greater than in "interior" regions.

3. Relationship Between Thousand-Seed Weight and Cone-Scale Morphology

Thousand-seed weight was strongly correlated with cone-scale size, larger cone-scales producing heavier seeds in all but one region. This region may have had an insufficient number of provenances sampled.

4. Germination Percent - Seed Source Relationship

Germination percent was significantly affected by latitude some 36 days after sowing, but this effect seemed to disappear at about 50 days after sowing. Elevation and longitude appeared not to affect germination percent.

In Region 2, generally, the cone-scale sizes were not related to their seed source. These results indicate that further investigation is needed to prove that cone-scale size is influenced by either environmental effects such as moisture and relative humidity, or genetic effects, or a combination of the two.

Clinal variation of cone-scale characteristics did not exist universally, but only in certain regions. This and larger overall tree-to-tree variation within provenances indicate that, in future seed collections for provenance tests and artificial regeneration, careful attention should be given to intra-provenance variation.

LITERATURE CITED

Allen, G. S. 1957. Better handling of a scarce commodity. B.C. Lumberman 41 (7): 32-36

__________, 1958. Factors affecting the viability and germination behavior of coniferous seed. III. Commerical processing and treatments similar to processing, Pseudotsuga menziesii (Mirb.) Franco, and other species. For. Chron. 34 (3): 266-298.

__________, 1960. Factors affecting the viability and germination behavior of coniferous seed IV. Stratification period and incubation temperature. Pseudotsuga menzieaii (Mirb.) Franco. For. Chron. 36 (1): 18-29.

__________, 1961. Testing Douglas-fir seed for provenance. Proc. Int. Seed Test. Ass. 26 (3): 388-403

Andersson, E. 1965. Cone and seed studies in Norway spruce (Picea abies (L.) Karst) Stud. for. suec. Skogshogsk, Stockn, No. 23, 286 pp.

Baker, K. F. 1957. The U.C. System for Procucing Healthy Container-Growth Plants. University of Calif., Division of Africulture Sci., Agricultural Experiment Station-Extension Service. 331 pp.

Baldwin, H. I. 1942. Forest tree seed of the north temperate region with special reference to North America. Chronice Botanica Co. 240 pp.

Barner, H. 1966. Circular letter of April 20, 1966 of Working Group on Procurement of Seed for Provenance Research. I.U.F.R.O. Section 22. 10 p.

Buck, J. M., R. S. Adams, J. Cone, M. T. Comkle, W. J. Libby, C. J. Eden and M. J. Knight. 1970. California Tree Seed Zones. Calif. Region Forest Service, U. S. Dept. of Agri. San Francisco, Calif.. 5 pp.

Ching, K. K. and D. Bever. 1960. Provenance Study of Douglas-fir in the Pacific Northwest Region. 1. Nursery Performance. Silvae Genetica 9: 11-17.

Eliason, D. J. and C. E. Heit. 1940. The size of Scots pine cones as related to seed size and yield. J. For. 38: 65-66

El-lakany, M. H. and O. Sziklai. 1971. Intraspecific Variation in Nuclear Characteristics of Douglas-fir. Paper presented at the Working Group Meeting at Gainesville, Florida. Mar. 14-20, 1971. 12 pp.

Hegg, E. A. 1954. How to open pond pine cones. J. For. 52: 770.

Haddock, P. G. 1962. Douglas-fir in Canada: Seed collection zones based on geographic variation of population as influenced by climate. U.B.C. Faculty of Forestry. Mimeographed. 17 p.

__________ and O, Sziklai. 1966. Seed collection zone for Douglas-fir in Canada. Sixth World Forestry Congress. Madrid. 6 CFM/E/C. T. 1?15. 16 pp.

Iljin, A. I. 1955. Influence of the size of Scots pine seed on their quality. For. Abstr.. 16: 255.

Irgens-Moller, H. 1958. Genotypic variation in the time of cessation of height growth in Douglas fir. For. Sci.. 4: 325-330.

__________, 1962. Genotypic variation in photoperiod response of Douglas fir seedlings. For. Sci. 8: 360-362.

Kocharj, N. T. 1952. Correlation of field germination of *Pinus sylvestris* seed with size of cone. For. Abstr. 13: 384.

Larsen, G. S. 1937. Genetics in silviculture. Translated by H. L. Anderson. 1956. Oliver and Boyd Edinburgh. 224 pp.

Lines, R. 1967. Standardization of methods for provenance research and testing. I.U.F.R.O. XIV Kongress. Munchen 1967. Section 22. III: 672-718.

Mirov, N. T. 1936. A note on germination methods for coniferous species. J. For. 34: 719-723.

__________, 1946. Viability of pine seed after prolonged cold storage. J. For. 44: 193-195.

__________, J. W. Duffield and A. R. Liddicoet. 1952. Altitudinal races of *Pinus ponderosa* -- a 12 year progress report. J. For. 50: 825-831.

Peace, T. R. 1948. The variation of Douglas fir in its native habitat (*Pseudotsuga taxifolia* Brit. syn. *Pseudotsuga douglasii* Carr.). Forestry 22: 45-61.

Perry, G. S., and C. A. Coover. 1933. Seed source and quality. J. For. 31: 19-25.

Robinson, B. A. 1963. Variation in seed characteristics of Douglas-fir in British Columbia. B.S.F. Theses, Faculty of Forestry, U.B.C. Vancouver, 68 pp.

Roche, L. 1966. Spruce provenance research in British Columbia. Tenth Meeting of the Committee on Forest Tree Breeding in Canada, Univ. of B.C., Vancouver B.C. Sept. 7-10. Progress Report.

Rogmeder, E. 1942. Germination with <u>Ulmus</u> <u>montana</u> (With.) For. Abstr. 164.

Simak, M. 1960. Influence of cone size on the seed produced (<u>Pinus</u> <u>silvestris</u> L.). Medd Skogsforskn,. 49: 16 pp.

__________, 1967. Seed weight of larch from different provenances (<u>Larix</u> <u>decidua</u> Mill.). Forestalia Suecia, Nr. 57, Studia For. Suec. Skogshogskolan, Stockn, 25 pp.

__________, and A. Gustafsson. 1954. Frobeskaffenheten hos modertrad och ymper av tall. (Seed properties in mother trees and grafts of Scots pine). Medd Skogsforskn., Stockholm 44: 73 pp.

Squillace, A. A. 1957. Variation in cone properties, seed weight in western white pine when pollination is controlled. School of Forestry. Montana State University. Missoula, Montana. Bulletin No. 5, 16 pp.

Stebbins, G. J. 1957. Variation and evolution in plants. Columbia University Press, N.Y. 643 pp.

Stone, E. C. 1957. The effect of seed storage on seedling survival of sugar pine. J. For. 55: 816-820.

Sweet, G. B. 1965. Provenance Differences in Pacific Coast Douglas-Fir. Silvae Genetica 14: 46-56.

Sziklai, O. 1964. Variation and inheritance of some physiological and morphological traits in <u>Pseudotsuga</u> <u>menziesii</u> (Mirb.) Franco var. menziesii. Ph.D. Thesis. Faculty of Forestry, U.B.C. 136 pp.

__________, 1967. Variation of Douglas-fir in its native habitat. Paper presented at International Scientific Conference, Zvolen, Czechoslovakia, 11 pp.

__________, 1969. Preliminary notes on the variation in cone and seed morphology of Douglas-fir (<u>Pseudotsuga</u> <u>menziesii</u> (Mirb.) Franco. Second World Consulation on Forest Tree Breeding. FO-FTB-69-6/9, 11 pp.

Toole, E. H., <u>et al</u>. 1956. Physiology of seed germination. Annual Review of Plant Physiol. 7: 299-324.

Toumey, J. W., and G. F. Korstian. 1948. Seeding and Planting in the Practics of Forestry. John Wiley and Sons Inc., N.Y.

Tusko, F. F. 1963. A study of variability in certain Douglas-fir populations in British Columbia. Ph.D. Thesis, Dept. of Biol. and Bot., U.B.C. 173 pp.

Van Deusen, J. L., and L. D. Beagle. 1970. Some Cone and Seed Characteristics of Black Hills Ponderosa Pine. Rocky Mountain Forest and Range Exp. Sta. U.S.D.A. For. Serv. Note RM - 179. 7 pp.

Western Forest Seed Council. 1966. Tree seed zone map for Washington and Oregon. Meeting of W.F.T.S.C. April, 1966. Portland, Oregon.

Willis, C. P., and J. V. Hoffmann, 1915. A study of Douglas-fir seed. Soc. Amer. Foresters Proc. 10: 141-164.

Willett, S. V. H. 1963. Variation in cone characteristics of Douglas-fir in British Columbia. B.S.F. Thesis, Faculty of Forestry, U.B.C. 65 pp.