ficant differences existing between the regional means. The regions identified were:

- Region A. Northern Scandinavia in the vicinity of the Arctic Circle.
- Region C. Central and Southern Scandinavia.
- Region G. Northeastern Germany and Czechoslovakia.
- Region H. Western Germany, eastern France and Belgium.
- Region I. England.
- Region J. Yugoslavia.
- Region K. Northeastern Greece (Macedonia).
- Region L. Scotland.
- Region M. South central mountains of France.
- Region N. Northern and central Spain.
- Region T. North central Turkey.

Comparisons were made of the regional grouping based on the parental measurements and a regional grouping based on juvenile characters in an associated 122-origin provenance study in a uniform environment in East Lansing, Michigan, reported by WRIGHT and BULL (1963). The groupings were nearly identical. In other words, it is possible to delimit a race or variety of Scotch pine nearly as well by studying parental specimens collected in Europe as by growing their progenies in this country. However, it was not possible to forecast a race's performance in Michigan from a study of the parental cones and leaves.

Literature Cited

CARLISLE, A.: A guide to the named variants of Scots pine *(Pinus silvestris* LINNAEUS). Forestry 31: 203–224 (1958). — CRITCHFIELD, W. B.: Geographic variation in *Pinus contorta.* Harvard Univ., Cambridge, Mass. Maria Moors Cabot Foundation Publication No. 3, 118 pp. (1957). — CVRKAL, H.: Príspevek k vozlisovani odrud borovice leshi *(P. sylvestris* L.). (Distinguishing varieties of *P. sylvestris.)* Sborn. Esl. akad. zemed. (lesn.) 4: 213–228 (1958). — EDLIN, H. B.: A modern sylva or a discourse on forest trees. Quart. Jour. Forestry 56: 110–120 (1962). — FIELDING, J. M.: Variations in Monterey pine. Forestry and Timber Bureau, Canberra, Bull. No. 21, 43 pp. (1953). — GERHOLD, H. D.: Seasonal variation of chloroplast pigments and nutrient elements in the needles of geographic races of Scotch pine. Silvae Genetica 8: 113–123 (1959). — KING, J. P.: Seed source × environment interactions in Scotch pine. I. Height growth. II. Needle length and color. Silvae Genetica 14: 105–115, 141–148 (1965). — MIROV, N. T.: Composition of gum turpentines of pines. Pacific Southwest For. and Range Expt. Sta., USDA, FS. Tech. Bul. No. 1239, 1961. — PAULEY, S. S., KHAILIL, M. A. K., and CROMELL, W. H.: NC-51 Scots pine seed source tests in Minnesota. Minn. Forestry Notes 1965. — SHAW, G. R.: The genus *Pinus.* Cambridge, Mass., Arnold Arboretum Pub. No. 5, 96 pp. (1914). — SCHJENIKE, R. E., RUDOLPH, T. D., and SCHANTZ-HANSEN, T.: Characteristics in a Jack pine seed source plantation. Univ. Minn., Forestry Note 76, 1959. — STASZKIEWICZ, J.: Zmienność współczesnych i kopalnych szyszek sosny zwyczajnej *(Pinus silvestris* L.). (Variation in recent and fossil cones of *Pinus silvestris* L.) Floristica et Geobotanica 7 (1): 97–160 (1960). — STASZKIEWICZ, J.: Biometric studies on the cones of *Pinus silvestris* L., growing in Hungary. Acta Botanica 7: 451–466 (1961). — STASZKIEWICZ, J.: Recherches biometriques sur la variabilite des cones du Pin sylvestre *(Pinus silvestris* L.) du Massif central en France. (Badania biometryczne nad zmiennoscia szyszek sosny zwyczajnej *[Pinus silvestris* L.] wystepujacej w Masywie Centralnym we Francji.) Floristica et Geobotanica 9 (2): 175–187 (1962). — STEINBECK, K.: Foliar mineral accumulation by several Scotch pine *(Pinus sylvestris* L.) provenances. Michigan State University, Ph. D. Thesis, 1965. — STOVER, E. L.: Varying structure of conifer leaves in different habitats. Bot. Gaz. 106: 12–25 (1944). — THOR, E., and BROWN, S. J.: Variation among six Loblolly pine provenances tested in Tennessee. Jour. Forestry 10: 476–480 (1962). — VIDAKOVIĆ, M.: Investigation on the intermediate type between the Austrian and the Scots pine. Silvae Genetica 7: 12–19 (1958). — VIDAKOVIĆ, M.: Značenje češera, sjemenki i nijhovih krilaca za sistematika i za odredivanje proveniencije crnog bora. (Significance of cones, seeds and their scales for taxonomy and determination of *Pinus nigra* provenances. In Yugoslavian with English Summary.) Annales pro Experimentis Foresticis XIV: 383–437 (1960). — WRIGHT, J. W.: Genetic variation among 140 half-sib Scotch pine families derived from 9 stands. Silvae Genetica 12: 83-89 (1963). — WRIGHT, J. W., and BCLL, W. I.: Geographic variation in Scotch pine. Silvae Genetica 12: 1–25 (1963).

Patterns of Height Growth Initiation and Cessation in Douglas-fir

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Introduction

Although studies of patterns of growth initiation or bud burst in Douglas-fir (Pseudotsuga *menziesii* [MIRB.] FRANCO) have been reported earlier (for a review see SWEET, 1965) the genetic variation in this characteristic continues to attract attention because the relative time of bud burst often determines the success or failure of Douglas-fir introduced into areas with late frosts or widely fluctuating weather conditions during spring such as in northwestern Europe. This short paper also reports on the relationship between the relative time of bud burst and cessation of terminal growth and, in addition, adds some details of local variation.

Methods and Results

The observations reported here were made in a breeding arboretum near Corvallis, Oregon, containing plants from throughout the natural range of the species. The experimental design is that of complete randomization at a spacing of 12 by 12 feet. Observations were made during the second to eighth year after planting before any crown competition occurred. Time of bud burst was defined as thc time when any bud, regardless of position in crown had opened to expose the new needles. Observations were made at three to five days intervals.

Growth Initiation

Plants originating along an east-west transect across western Oregon were first selected for study. The earliest of these selected trees in bud burst each year were those originating from the vicinity of Corvallis (Fig. 1) while those from the Oregon Coast Range only 20–40 miles west of Corvallis and 100–200 ft. higher in elevation were the latest. The earliness of the Corvallis plants and those from Sweet Home is in accordance with the conclusions drswn by MUNGER et al. (1936) that Douglas-fir from broad, open valleys are early. The lateness of the Coast Range plants is more difficult to explain since no weather data are available from that area. However, the area around Corvallis

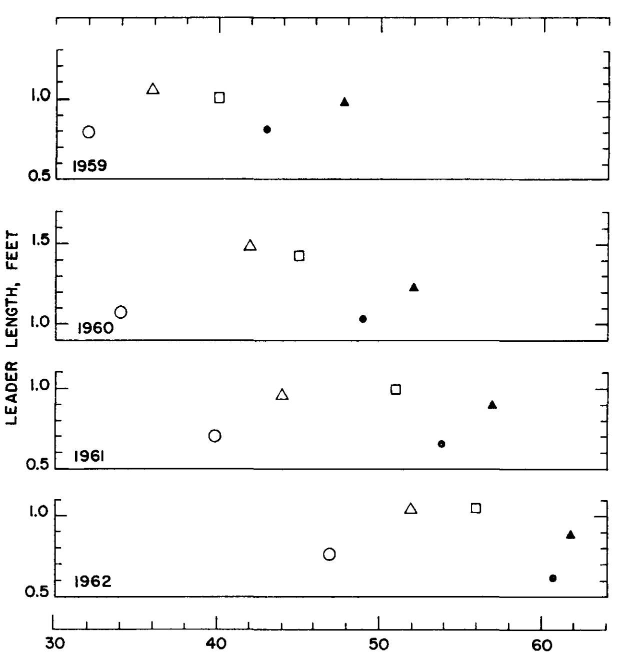

Figure 1. — Times of bud burst and length of leader growth in Douglas-fir plants from five localities along an east-west transect across western Oregon when grown at Corvallis, Oregon, averages of 44—100 plants per source. Standard errors of means for time of bud burst and leader length do not exceed 1 5 days and .15 feet, respectively. Open circle: Corvallis; open triangle: Sweet Home; open square: Coast; black circle: Santiam Pass; black triangle: Coast Range.

is characterized by early and severe summer droughts accentuated by severe grass competition and it is possible that such conditions have permitted only plants which start and stop growth early to survive in that area. Trees from the east side of the Willamette Valley near the town of Sweet Home were slightly later than those from the west-side (Corvallis) possibly reflecting the slightly higher precipitation there, (60 versus 40 inches). The lateness of the Santiam Pass plants no doubt reflects the shorter growing season there and possibly also a lack of sufficient winter chilling during the winters at the planting site of Corvallis. Santiam Pass plants have been shown to require a longer period of chilling at 40° F than plants from the valley (Wommack, 1964) for normal growth.

The relative time of bud burst for plants from all sources became progressively later during the first four years of observation *(Fig. 1)*. There was no correlation between this and weather conditions. It is a common observation in the forest that young trees are earlier than older trees and the progressively later bud burst in the plantation with increasing age appears to reflect this fact. However, in 1965 bud burst in the test plantation was as early as in 1959 and the differences between the five groups became very small. This may reflect a somewhat warmer spring that year, but is more likely due to the change in microclimate in the plantation created by the larger size of the trees which decreased air movements and increased air temperature near the ground. This is indicated by the fact that in all trees it was the buds on the lower branches one-two feet above ground and on the south side of the trees which opened first.

Sweet (1965) has reported on the time lag in bud burst between the lateral and terminal buds in two-year old Douglas-fir in New Zealand. He found significant positive correlations between the size of this time lag which varied from two to more than 20 days and the length of frost-free season, the mean, temperature of the coldest month, and, therefore, also a negative correlation with the altitude of origin. No such correlation could be found in the present material at the age of eight years. The average time lag for each group varied from seven to nine days.

As is evident from *Figure 1* there was no correlation between time of bud burst and amount of leader growth. The leader growth of the earliest plants was each year as small as those from Santiam Pass which were next to the latest in bud burst.

The observations on bud burst described above were confined to plants originating west of the Cascades. On April 6, 1965 observations were made in a three-year old part of the arboretum containing plants from the Rocky Mountains and eastern Washington and Oregon as well as plants from west of the Cascades in an effort to compare plants from continental and coastal origins. Only five percent of the plants from western Washington and Oregon had started growth as opposed to 73 percent of plants from eastern Washington and Oregon and 80 percent of plants from New Mexico and Arizona based on samples of 73 to 186 plants per source.

Growth Cessation

During 1961 weekly measurements of leader growth was made in an attempt to determine by interpolation the time when 90 percent of the height growth was completed *(Figure 2)*. The Corvallis plants ceased height growth earlier than those from the remaining four sources. The period of growth between 10 and 90 percent completion of height growth was about the same for all sources with the exception of those from Santiam Pass which had a six to eight day shorter period no doubt reflecting the short growing season at the place of origin.

From *Figure 2* it appeared that there might be a correlation between the time of terminal bud burst and the time of height growth cessation. Statistically significant correlations were indeed found for plants from four of the areas along the east-west transect and for plants from Vancouver Island. However, the correlations varied greatly from .85 for the Vancouver Island plants, .40—.60 for the plants from the Coast, Coast Range and Sweet Home, to none for the Corvallis plants and a negative correlation for the Santiam Pass plants (—.33). The biological meaning, if any, of this variation remains obscure.

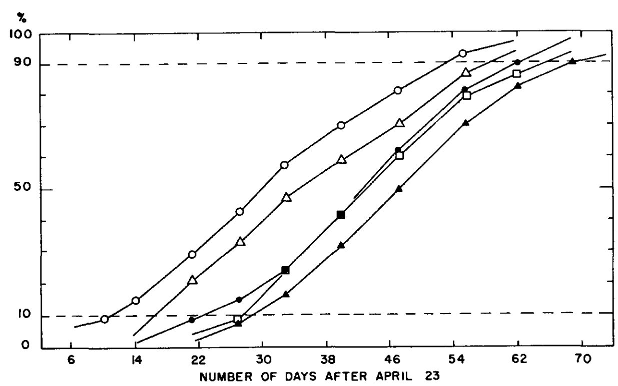

Figure 2. — Time-course of leader growth of Douglas-fir plants (four years old) from five localities along an east-west transect across western Oregon when grown at Corvallis, Oregon. Averages of 44—68 plants. Symbols as in *Figure 1.*

Discussion

The difference in time of bud burst of 15 to 18 days found between plants originating from areas separated by only 20—40 miles is of considerable importance in the selection of a seed source. Of equal importance is the lack of relationship between the time of bud burst and amount of growth since this permits selection of late types without necessarily also selecting for poor growth. However, this is true only when considering trees native to the area west of the Cascades. Continental sources from areas east of the Cascades and the Rocky Mountains are considerably earlier and also more slow growing. In any selection for early or late types recognition should be given to the obvious age dependency of the relative time of bud burst with younger plants being earlier. The great variability in time of bud burst indicates that the genetic control probably is multifactorial. The differences among the plants from the various sources with regard to the relationship between the times of initiation and cessation of height growth need further observations, including plants from other sources, before the possible biological meaning of these differences can be understood in terms of the environments of their native habitats.

Literature Cited

Munger, Thornton T., and Morris, W. G.: Growth of Douglas-fir trees of known seed source. U. S. D. A. Tech. Bul. 537 (1936). — Sweet, G. B.: Provenance differences in Pacific Coast Douglas-fir. Silvae Genetica 14: 46—56 (1965). — Wommack, D. E.: Temperature effects on the growth of Douglas-fir seedlings. Ph. D. thesis, Oregon State University, Corvallis (1964). — U. S. D. A. Yearbook of Agriculture, Climate and man, 1941.

Effects of Temperature on the Growth and Wood Formation of Ten Pinus resinosa Sources

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Red pine (*Pinus resinosa* Ait.) is often considered an extremely homogeneous species. The literature on the extent of red pine variability has been comprehensively reviewed and critically evaluated by Fowler (1964). On the basis of this literature survey and results of his own experiments, Fowler reached the following conclusion: "Red pine, regardless of its origin, was observed to be morphologically uniform. With few exceptions, the variation observed could be attributed more easily to environmental than to genetic differences. A survey of the literature revealed that, although genetic differences undoubtedly do occur among red pines from different origins, the magnitude of these differences is not great."

Results of the present study, conducted during the 1962 growing season on 3-year-old red pine seedlings, agree in some respects with those of Fowler. Although statistically significant differences among sources were found in the characteristics examined, no meaningful relationship could be established between any of these growth characteristics and geographic origin of the seed. On the contrary, source differences in vegetative growth characteristics, such as terminal elongation and needle size, suggested a random distribution that may be attributed to the variability among local populations. However, source differences in most wood growth characteristics appeared to be more closely associated with certain aspects of vegetative growth and varied accordingly.

Material and Methods

Red pine seedlings, representing seed collections from 10 widely separated natural stands, were used as test material. The 10 sources selected for this study were fairly representative of the original 77 collections used by Wright *et al.* (1963) and extend across the natural range of the species (*Table 1*). Procedures for seed collection and for sowing and rearing in the nursery have been previously described (Wright *et al.*, 1963).

In the fall of 1961, after two growing seasons in the nursery, the seedlings were transplanted to clay pots and placed in a cold room maintained at about 5° C. After approximately 5 months of cold exposure, 20 seedlings of each source were randomly divided into lots of 5 and transferred to 4 growth rooms. The growth rooms were maintained on identical daylengths but different temperature regimes.

In each room 48 eight-foot fluorescent lamps supplemented with incandescent lamps provided a total light intensity of about 3500 foot-candles at plant height. The daylength was adjusted to correspond, as closely as possible, to that prevailing at Rhinelander, Wisconsin (approximately 45° N. latitude). Thus, the daylength increased from 12-3/4 hours at the start of the experiment to 15-3/4 hours at mid-season, and then decreased. In addition, a standard ½-hour "twilight" of about 250 foot-candles intensity was added to the beginning and end of each day.

The following temperature schedule was maintained throughout the experiment:

	Day °C	Night °C
Room 1	23.8 (75° F)	12.8 (55° F)
Room 2	18.3 (65° F)	12.8 (55° F)
Room 3	29.2 (85° F)	18.3 (65° F)
Room 4	23.8 (75° F)	18.3 (65° F)

The daily changes in temperature coincided with the changes in daylength. All changes in temperature and daylength were controlled automatically by preset time clocks.

Since the rooms were not provided with humidity controls, humidity tended to vary with temperature. For example, the high temperature Room 3 was more humid following watering, but also dried out somewhat faster than the lower temperature rooms. However, by watering the trees in all rooms twice daily, soil moisture and atmospheric humidity were maintained at acceptable levels.

Height growth and needle elongation were measured weekly on every seedling. Three needles to be measured

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