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Nursery Temperature as a Factor in Root Elongation of Ponderosa Pine Seedlings*

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ABSTRACT: Greenhouse and nursery studies suggest that graphs of "effective" day and night temperatures provide a convenient method to compare nursery sites and to evaluate the effects of temperature on seedling root growth. Comparisons of root response under different natural temperature regimes should provide information useful for the production of higher quality nursery stock and for interpretation of the more detailed studies in controlled-temperature chambers.

Planting trials over a great many years in California have shown that soil moisture is the most critical environmental factor in the initial establishment of tree seedlings. There appear to be at least two possibilities for favoring establishment. One is to conserve soil moisture by cultural practices to remove all vegetation which competes for the limited supply of soil moisture (Buck 1959). The other possibility is to develop a seedling with an actively elongating root system which would continue to tap new sources of moisture.

Greenhouse studies with ponderosa pine seedlings have shown the importance of temperature in controlling root growth (Stone and Schubert 1959a, 1959b). These studies, reviewed briefly in this note indicated that each nursery site had an individual optimum period for lifting the trees from nursery beds. During this optimum period, root response was at its highest, both in numbers of new roots and in total length of new root production. Differences in root growth response from the greenhouse findings suggested that the nursery climate may have had a strong influence on the root growth potential. Subsequent studies indicated that differences in root response were related to night temperatures at nurseries, and suggested comparison of nursery sites in terms of "effective temperature."

METHODS AND MATERIALS USED IN GREENHOUSE STUDIES

The previous experiments (which provided the basic growth data for the inferences on "Effect of Nursery Temperatures") consisted of measuring root initiation and root elongation on ponderosa pine seedlings from two proveniences and two nurseries of different climatic regimes. Root responses were measured on seedlings,

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lifted at monthly intervals throughout the year from each nursery, after they were allowed to grow for one month in soil containers set in thermostatically controlled water baths maintained at 10°C., 15°C., 20°C., and 25°C. The air temperature in the greenhouse did not drop below 20°C. at night, and with few exceptions, did not exceed 35°C. in the daytime. Thus, the resulting root growth responses could be related to the seed provenience, the date of lifting, and the temperature of the soil containers in the greenhouse.

The seedlings which were studied were produced from seed collected in seed collection zones III and V (fig. 1). These collection zones occupy the mid-elevation belt of similar site quality on the west slope of the Sierra Nevada (Fowells 1946). This mid-elevation belt was subdivided into Zone III to the north and Zone V to the south to reduce the amount of climatic variation correlated with latitude.

The seedlings were grown at the Mt. Shasta and Placerville Nurseries (fig. 1). These nurseries are operated by the U. S. Forest Service and are in two different climatic zones. Although there is only a difference of about 600 feet in elevation, Mt. Shasta Nursery is located about 200 miles farther north than the Placerville Nursery. Mt. Shasta is located in Zone I, which is characterized by the colder east slope mountain climate; Placerville is in Zone II, which is influenced by the warm to hot climate of the Sacramento Valley. The average frost-free period at Mt. Shasta is about 140 days compared to 184 days at Placerville.

RESULTS FROM GREENHOUSE STUDIES

Measurements of the elongation of lateral roots on stock from the two nurseries illustrate the differences in response by nurseries, greenhouse soil temperatures, and lifting dates. The great difference between nurseries in number of roots that elongated is most striking. The Placerville stock had nearly seven times as many roots that elongated as Mt. Shasta stock (table 1). Although the Mt. Shasta stock came from Zone V seed and the Placerville stock came from Zone III seed, this seed-source difference does not negate the effect of nursery site. For example, in the study of stock from four different seed sources all grown at Mt. Shasta Nursery, the trees from Zone III seed produced about 90 percent as many new roots as stock from Zone V seed (Stone and Schubert 1959a). Observations of stock from different seed sources grown at the California State nurseries also indicate that the seedlings produced from Zone III seed tend to be smaller than those from Zone V seed.

Soil temperature in the greenhouse also had a definite effect. The lowest number of root elongations occurred at 10° C. (table 1). The root response was progressively better at higher temperatures up to 20° C., but dropped slightly at 25° C. With one exception, the differences in root response were statistically significant between each root temperature for the seedlings grown at each nursery. The response did not differ significantly between Placerville seedlings at 20° and 25° C. soil temperature.

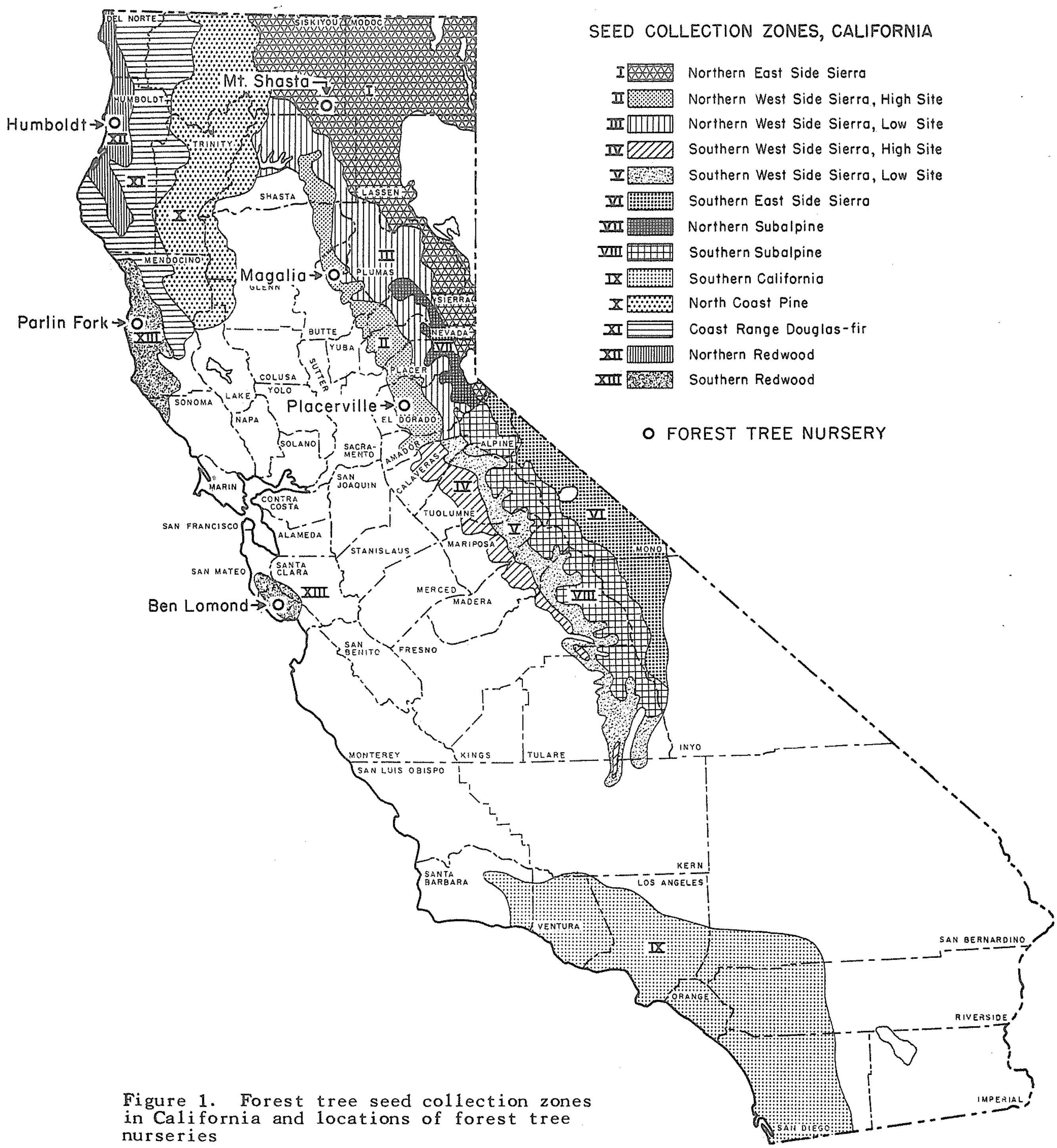

Figure 1. Forest tree seed collection zones in California and locations of forest tree nurseries

Table 1. *Number of lateral roots that elongated within one month after transplanting into constant-temperature soil in the greenhouse*[1,2]

Nursery	Soil temperatures (degrees C.)				
	10	15	20	25	Total
	Number[3]				
Mt. Shasta	80	587	1,364	1,032	3,063
Placerville	2,052	4,886	6,560	6,542	20,040
Total	2,132	5,473	7,924	7,574	23,103

[1]Mt. Shasta stock produced from Zone V seeds; Placerville from Zone III seed; no storage period, 1-1 stock. Each statistic is the sum of measurements from 20 seedlings lifted in each of the 12 months in one year (total, 240 seedlings).

[2]Data from Stone and Schubert (1959b).

[3]A difference of 288 for Mt. Shasta and 856 for Placerville between any two temperatures is significant at the 95 percent level of probability.

Table 2. *Amount of lateral root elongation of roots that grew 0.5-inch or more within one month after transplanting to constant temperature soil in the greenhouse*[1,2]

Nursery	Soil temperatures (degrees C.)				
	10	15	20	25	Total
	Inches[3]				
Mt. Shasta	0.6	71.1	226.1	406.5	705.3
Placerville	5.6	275.4	1,443.3	2,897.4	4,621.7
Total	6.2	346.5	1,669.4	3,303.9	5,326.0

[1]Basis: 240 seedlings for each soil temperature from each nursery.

[2]Data from Stone and Schubert (1959b).

[3]A difference in root length of 156 for Mt. Shasta and 172 for Placerville between soil temperatures is significant at the 95 percent level of probability.

In terms of root length, the results closely parallel those for number of root elongations except that a substantially greater length was produced in soil at 25° C. than at 20° C. (table 2). The total amount of root growth (0.5 inch and longer) at 25° C. was about 2 times that at 20° C., 6 to 10 times that at 15° C., and 500 to 600 times that at 10° C.

The effect of lifting date on root growth for the seedlings grown at the two nurseries is illustrated in figure 2. Among the seedlings

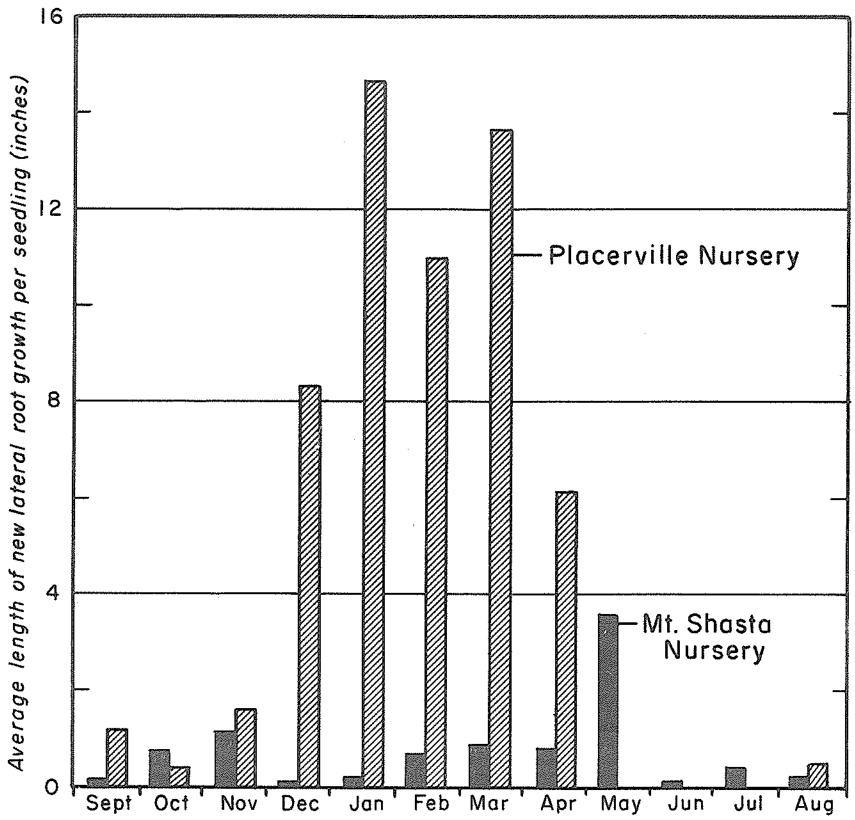

Figure 2. Average amount of lateral root growth per ponderosa pine seedling that occurred within one month after planting in the greenhouse by lifting dates for warm and cold climate nurseries.

from the warmer nursery (Placerville, mean annual temperature 15.2° C.) root growth was greatest during the months of December to April. During this period the average increase in root length exceeded 6 inches per seedling. But among seedlings from the colder nursery (Mt. Shasta, mean annual temperature 9.6° C.) root growth was low during all months except May when the average increase in root length was less than 4 inches per seedling.

EFFECT OF NURSERY TEMPERATURE

The physiological condition of the trees as measured by root growth suggested a pronounced root activity response to nursery temperature. To pursue this lead, a recording thermograph was placed in each nursery. The 2-year record of temperatures is presented in figure 3 for the Placerville and the Mt. Shasta nurseries. Day temperatures (mean maximum temperatures) at these two nurseries were quite similar during these years (fig. 4). The main difference occurred in night temperatures (mean minimum temperatures).

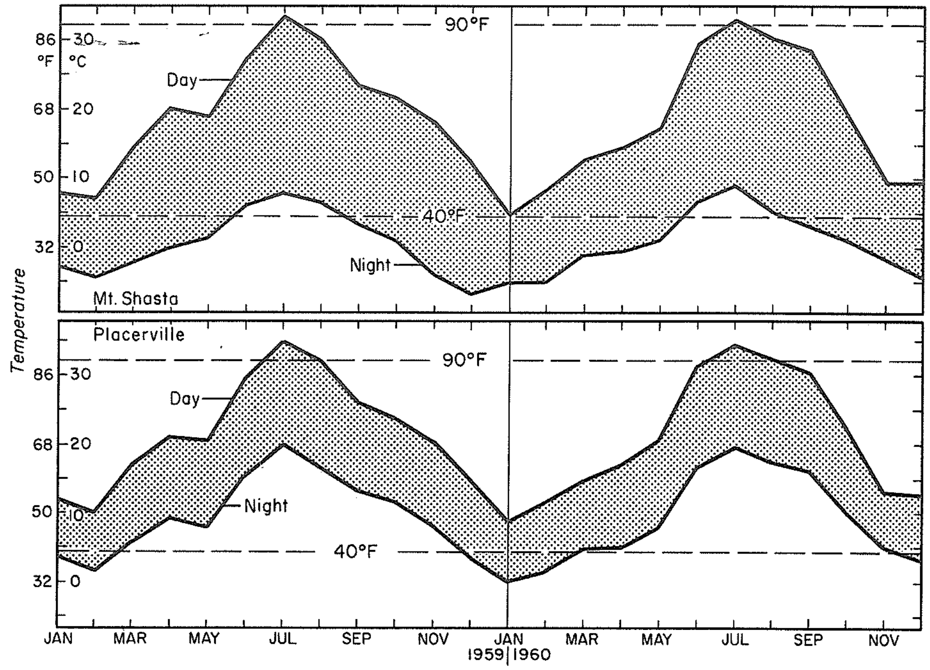

Figure 3. Average day-night air temperature at the Mt. Shasta and Placerville Nurseries during 1959 and 1960.

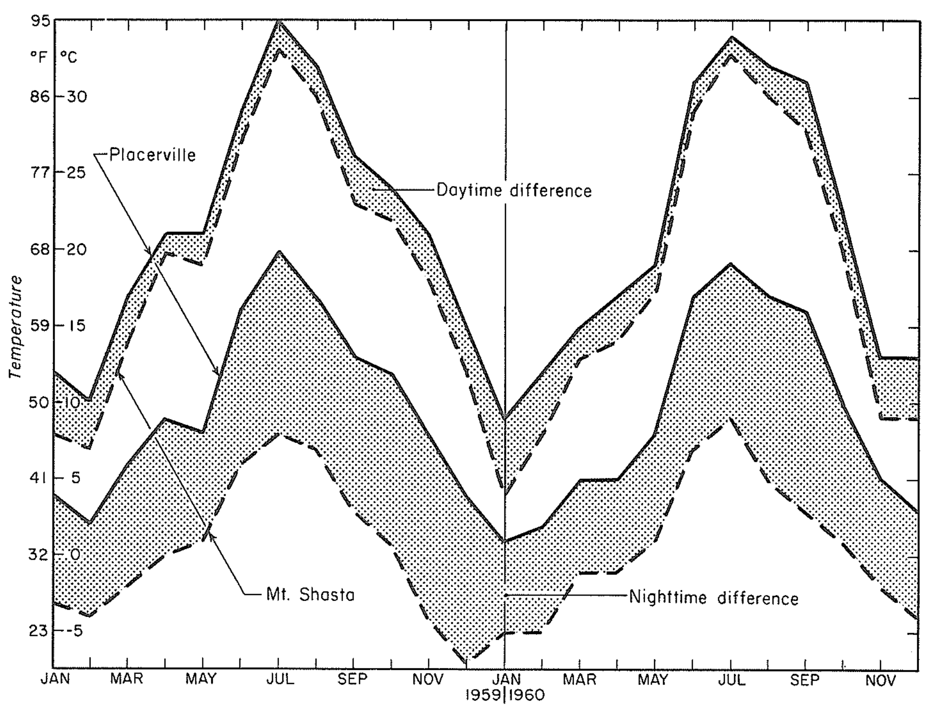

Figure 4. Difference in day and night temperatures at the Mt. Shasta and Placerville Nurseries during 1959 and 1960.

Therefore, the differences in root response of seedlings from these two nurseries appears to be directly related to night temperatures and not to day temperatures. Results with the constant-temperature soil containers (Stone and Schubert 1959b) indicated a strong positive relationship between temperature and root activity.

Trees from Placerville nursery, which had the higher night temperatures, had a much higher degree of root activity during the winter (fig. 2) than trees from the Mt. Shasta nursery. Unpublished data also indicate a direct influence of nursery climate on the physiological condition of stored nursery stock.[2] Since the top layer of soil is often frozen at Mt. Shasta from December to March, part of the difference in root activity of seedlings lifted during the winter months may have been due to lifting damage.

DISCUSSION

Various methods have been used to summarize temperature data (Bates and Zon 1922; Deasy 1941; Hellmers and Ashby 1958; Kimball and Brooks 1959; Went 1953; Zon 1914). These methods usually resort to a fixed base temperature and disregard extremes and above-optimum temperatures which may retard growth or kill the plant (Kramer 1957; Paine 1960; Went 1953; Zon 1914).

The importance of considering day and night temperatures separately has been borne out by work in controlled-environment chambers (Hellmers and Ashby 1958; Hellmers and Sundahl 1959; Kramer 1957). Kramer (1957) found that the best growth on loblolly pine seedlings was made when day and night temperatures differed by 12° or 13° C., and the least growth when the day and night temperatures were the same. Hellmers and Sundahl (1959) reported similar results with redwood.

Recently a method has been proposed to determine "effective" day and night temperatures (Kimball and Brooks 1959; Went 1957). This method recognizes the importance of maximum and minimum temperatures. The effective day temperature is computed as half way between the daily mean and the daily maximum, and the effective night temperature as half way between the daily mean and the minimum. The annual growth cycle is characterized by computing monthly effective temperatures.

The effective day and night temperatures are presented for Mt. Shasta and Placerville Nurseries in figure 5. The difference in the temperature regimes is quite apparent. Knowing the plant response at the two nurseries, it should be possible to predict plant response at other locations by comparing their effective day-night temperature graphs with those from the study areas.

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[2]Schubert, Gilbert H., Stone, Edward C., Baron, Frank J., and Benseler, Rolf. Nursery sites determine planting stock storage schedules. (Unpublished report on file at Pacific Southwest Forest and Range Expt. Sta., Berkeley, Calif., 1961.)

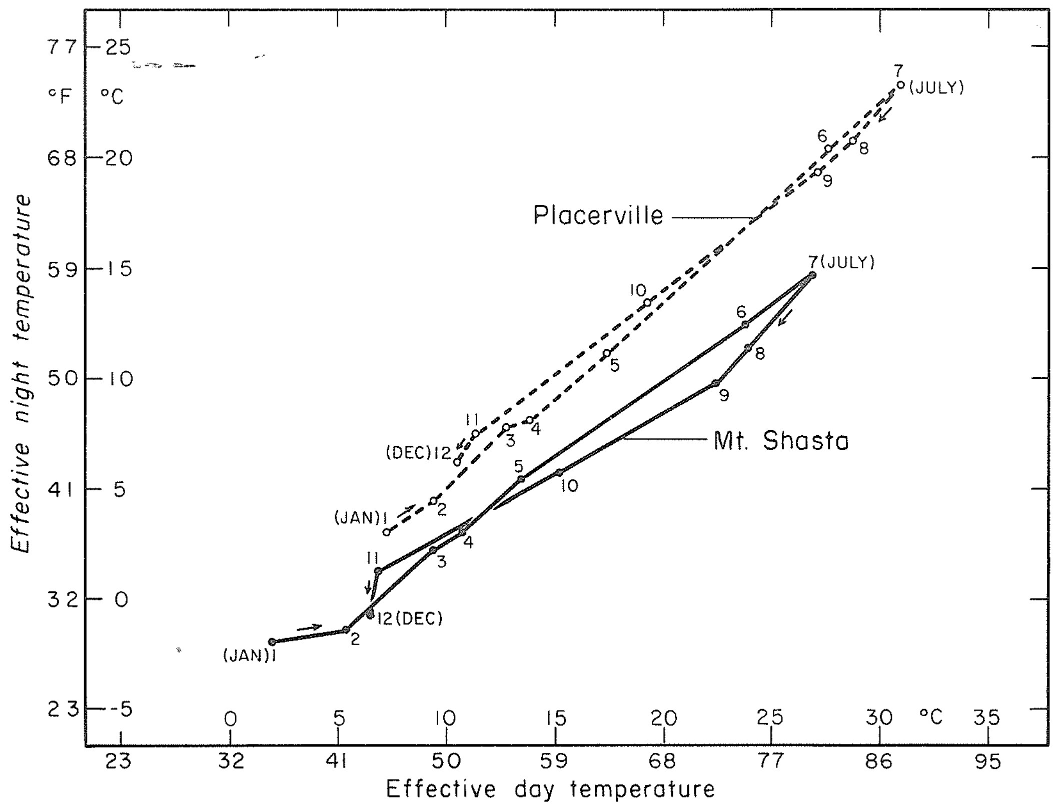

Figure 5. Effective monthly temperatures at the Mt. Shasta and Placerville Nurseries--1960.

Best growth in our studies with ponderosa pine occurred at the Placerville Nursery, where the diurnal range between day and night temperatures was 10° to 14° C. and mean minimums were above 5° C. during the spring growing season (fig. 4). Root growth response was greatly depressed on stock from Mt. Shasta Nursery, where night temperatures were substantially lower (at or near 0° C.). These results suggest that higher night temperatures, about 10° to 14° C. below day temperature with an average minimum temperature above 5° C., may prove to be a valuable criteria in the selection of nursery sites.

The temperature regime of existing or proposed nurseries can be determined from official weather data. The data collected at the nurseries were found to agree very closely with data reported for nearby Weather Bureau Stations. Some workers have questioned the validity of using "official" air temperature (at 4.5 feet above the ground surface) for predicting plant growth. It is true that soil temperatures have been measured at a relatively few locations, but sufficient data exist to suggest that average or long-term air temperatures are closely correlated with soil temperatures at different depths for soils of similar texture (Fowells 1948; Frazer 1957; Shanks 1956).

CONCLUSIONS

Root growth response of ponderosa pine transplants, grown at constant soil temperatures was greatest in number of root elongations at 20° C. and highest in total length at 25° C.

Fluctuating temperatures of the diurnal cycle can be considered in the concept of "effective" day and night temperatures, and used to prepare graphs for comparison of the growth potentials of different nursery sites.

The root productivity cycle at a nursery with warm nights differed markedly from that at a nursery with cold nights, although their day temperatures were similar.

For ponderosa pine, a night temperature greater than 5° C. and averaging 10° to 14° C. cooler than the day temperature seems to yield optimal root production.

A system of grouping temperature data, such as that prepared by Went (1957) has shown promise for agricultural crops, and also offers a convenient basis for ecological evaluation of nursery locations and planting sites.

Because forest tree nurseries have individual climates and are fairly uniform in other environmental characteristics, nurseries offer excellent field locations to evaluate the effects of temperature on seedling root development. Comparisons of root response under different natural temperature regimes will provide information useful not only for the production of higher quality nursery stock, but also for interpretation of the more detailed studies in controlled-environment chambers.

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