MATCHING SPECIES TO SITE

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RECOGNIZING THE PRODUCTIVE POTENTIAL of an area and selecting well-adapted species for planting are two of the forester's most difficult problems. These problems are intensified by the West's mountainous topography. Even when we think we know the problems in one area, we find our experience counts little elsewhere. And sometimes elsewhere is only a few miles away!

My colleagues and I have applied, for the last 6 years, an ecological and physiological approach to studying interactions between plants and environment in the Siskiyou Mountains of southwestern Oregon. I will present some of the theory behind this approach and give examples that illustrate how we can recognize and predict the productive potential of different environments.

WHAT IS ENVIRONMENT?

Environment is "something that surrounds", but what does the environment surround? For our purposes, the environment surrounds a plant. Because plants are inseparable from their environment, there may be merit in using them not only to determine what we should measure, but also as an aid in interpreting our measurements.

Many of the environmental variables that affect us have little direct significance to plants. Unlike man, plants cannot identify the direction of slope, the elevation, or even the soil type. Plants respond to the environment because of its action rather than origin. That is, plants can respond to moisture, but they can not identify the source as snow, rain, or seepage.

Accordingly, then, the elements of the physical environment that interact, but cannot be substituted for one another, can be classified as moisture, chemicals, temperature, light, and mechanical forces. And to these elements of its environment, a plant responds (2, 4, 9).

CHOICE OF REFERENCE PLANTS

To interpret environment, we selected plants with wide distribution for reference. Then, as suggested by Mason and Langenheim (5), we measured environment in a sequence that related to the development and sensitivity of these plants. Douglas-fir and Shasta red fir made good reference species in the Siskiyous because their combined distribution extended over all forested environments.

Sampling from seedlings was convenient and desirable because small plants have greater sensitivity to their environment than large ones. The cambial activity of Douglas-fir and Shasta red fir from 1 to 2 meters tall served to define the growing season at each of the stands described in Table 1. All environmental data were interpreted in sequence to plant development rather than calendar date.

ENVIRONMENTAL MEASUREMENTS AND INTERPRETATION

Measurements were taken around or upon reference plants from 1 to 2 meters tall, according to diurnal and seasonal moisture stress of the plant; shoot and root temperatures; daily light energy in the photosynthetic spectrum (400-700 nm); soil fertility and foliar nutrition; and estimates of mechanical stress from snow creep and ice breakage.

Portable instruments, today, permit the direct determination of moisture stress within twigs of vascular plants (6,8). Moisture stress usually increases during the day and reaches a minimum during the night. The stress during the night reflects the availability of soil moisture to the root system. The increase during the day is attributed to atmospheric conditions such as vapor pressure, radiant energy, and wind speed. Different species of conifers may have slightly different patterns of diurnal stress that are related to their stomatal response (Hinckley, T., Plant Moisture Stress: a Dynamic System as Seen Through the Response of an Organism to its Environment. Manuscript in preparation. 1968). At night, however, sampled conifers show similar values for stress after their root systems are equally well established.

Different seasonal patterns in the minimum stress in sampled Douglas-fir characterize different environments (Figure 1). In an Engelmann spruce stand,

Table 1. Description of Stands in the Siskiyou Mountains.

Stand	Elevation	Slope	Aspect	Parent material	Vegetation
	Feet	*Percent*			
1	4,900	25	W	Granite	White fir, ponderosa pine, Douglas-fir
2	5,500	60	W, NW	Granite	White fir, Douglas-fir
3	2,600	45	N	Granite	Douglas-fir, black oak, ponderosa pine
4	6,300	65	SE	Ultrabasic	Jeffrey pine, incense cedar, western white pine
5	5,600	65	SE	Ultrabasic	Jeffrey pine, incense cedar
6	6,700	35	NNE	Granite	Mountain hemlock, Shasta red fir
7	6,300	20	N	Granite	Shasta red fir
8	4,200	40	SW	Granite	Ponderosa pine, Douglas-fir
9	5,100	55	NNW	Metavolcanic	White fir, sugar pine, Shasta red fir
10	5,700	55	N	Metavolcanic	Brewer spruce, Shasta red fir, mountain hemlock
11	4,500	35	SW	Granite	Ponderosa pine, shore pine, white fir, Douglas-fir
12	5,200	70	WSW	Green schist	Ponderosa pine, Douglas-fir
13	4,400	20	W	Green schist	Douglas-fir, ponderosa pine, sugar pine, white fir
14	5,200	45	E	Green schist	Douglas-fir, white fir
15	6,600	10	NE	Mica schist	Mountain hemlock
16	6,200	40	SW	Mica schist	Shasta red fir
17	6,000	10	E	Metavolcanic	Shasta red fir
18	7,000	30	NE	Granite	Mountain hemlock
19	4,100	70	W	Mica schist	Douglas-fir, shore pine, white fir
20	2,500	70	NNW	Mica schist	Douglas-fir, Pacific yew
21	1,800	75	N	Metavolcanic	Douglas-fir, black oak, Oregon white oak
22	4,800	50	N	Metasedimentary	Douglas-fir, white fir
23	4,600	10	N	Granite	Engelmann spruce, Douglas-fir, white fir
24	6,700	45	NNE	Metavolcanic	Mountain hemlock
25	5,700	5	SE	Ultrabasic	Jeffrey pine, white fir, incense cedar, Douglas-fir
27[1]	3,700	55	NW	Granite	Douglas-fir, black oak, ponderosa pine
28[1]	4,200	45	N	Granite	Douglas-fir, white fir, ponderosa pine
29[1]	6,000	50	N	Granite	Shasta red fir, white fir

[1]Supplementary stands to verify precision of original data.

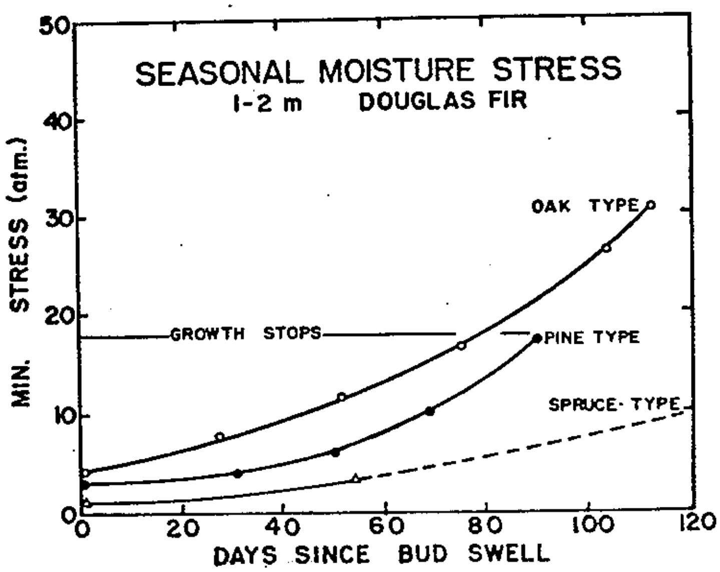

Figure 1. Seasonal patterns in the minimum stress of Douglas-fir from 1 to 2 meters tall.

stress remained low, but in a stand dominated by ponderosa pine, critical levels were reached during the growing season. In an oak stand, moisture stress of Douglas-fir reached such high values toward the end of the growing season that no recovery took place at night. In a region such as the Siskiyous, we obtained a good index to the seasonal patterns of moisture stress by comparing minimum stress at all environments near the peak of drought (usually in September).

Records of daily temperature from all the stand environments were analyzed and interpreted as they affect the growth of Douglas-fir seedlings (3). The temperature-related growth potential was 50 percent less in the Engelmann spruce stand than in the oak stand. A temperature index was derived for each stand environment by summing the fractions of growth possible each day during the growing season a determined by experiments with Douglas-fir in a growth room (Lavender, D. P., Some Effects of Air and Soi Temperatures upon the Growth of Douglas-Fir Manuscript in preparation. 1968). The index wa expressed as "Optimum Temperature Days". In some environments, 2-3 days were required to accumulate th growth potential of one Optimum Temperature Day

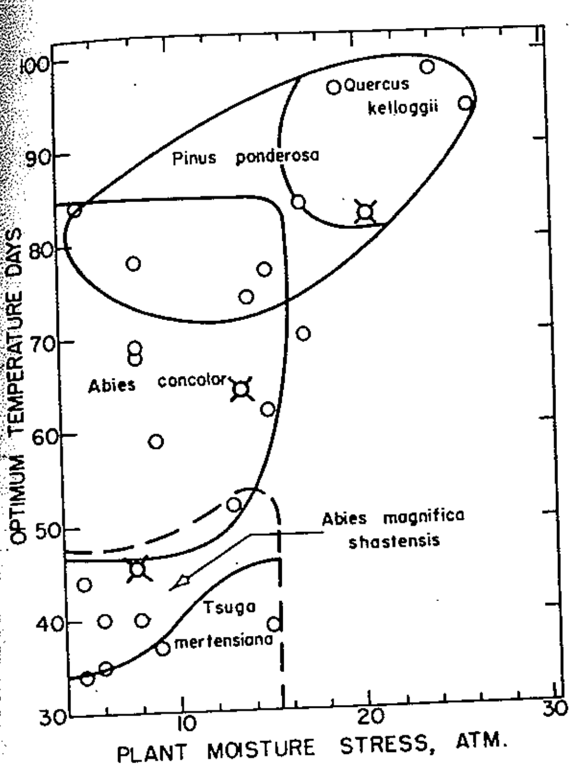

Figure 2. Distribution of natural regeneration in relation to gradients of moisture and temperature. Starred data points indicate supplementary stands to verify precision of original data.

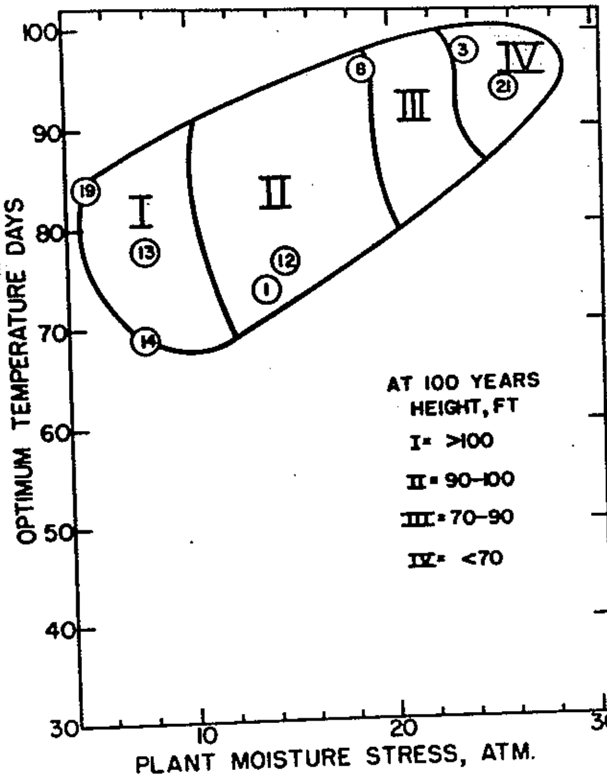

Figure 3. Relation of site index for ponderosa pine to gradients of moisture and temperature.

Conveniently, the highest values approached 100 for the growing season. Thus, the temperature-related growth-potential of each environment studied was a percentage of the maximum possible under the most favorable regimes of temperature, with the assumption that there were no other limiting factors.

The distribution of natural regeneration in relation to effective gradients of temperature and moisture stress is presented in Figure 2. Oak is restricted to the hot and dry sites. Ponderosa pine has a wider distribution and achieves its greatest productivity on sites with low moisture stress (Figure 3). Without fire or other disturbance, however, it is limited to drier sites where its competitor, the shade-tolerant white fir, is unadapted. Pine requires an average of 10 percent of full sunlight (of 400-700 nm wavelengths) throughout the day to just survive. But white fir continues terminal growth with less than 1 percent of full sunlight (1).

White fir, Shasta red fir, and mountain hemlock occur on progressively cooler sites with adequate soil moisture. That is not to say the true firs and hemlock never experience moisture stress. If stands are opened too much, the regeneration may experience transpirational stress that may be sufficient to force closure of leaf stomata, which prevents photosynthesis. Generally, clear cutting will slightly increase the temperature index and, for reasons just mentioned, favor species adapted to high moisture stress. In the high-elevation types, Jeffrey pine, usually restricted to only the most infertile soils derived from ultrabasic rocks, may be a desirable species to plant to provide a cover for the subsequent regeneration of Shasta red fir.

Figure 4 presents productivity of Douglas-fir in relation to the gradients of moisture and temperature. Again, as with ponderosa pine, productivity of Douglas-fir increases as moisture stress decreases. When moisture is adequate (less than 10 atmospheres' stress), temperature exerts a noticeable influence upon productivity. This general trend in productivity is demonstrated with all the tree species (Figure 5). Near timberline on very cool sites, the effect of wind, snow, and ice breakage also contributes to decreased productivity.

The distributions of other species are illustrated in Figures 6, 7, and 8. Western white pine, although most frequent on moist, cool sites, is nutritionally adapted to extend into both drier and warmer habitats if infertile soils, such as those derived from ultrabasic rocks, are

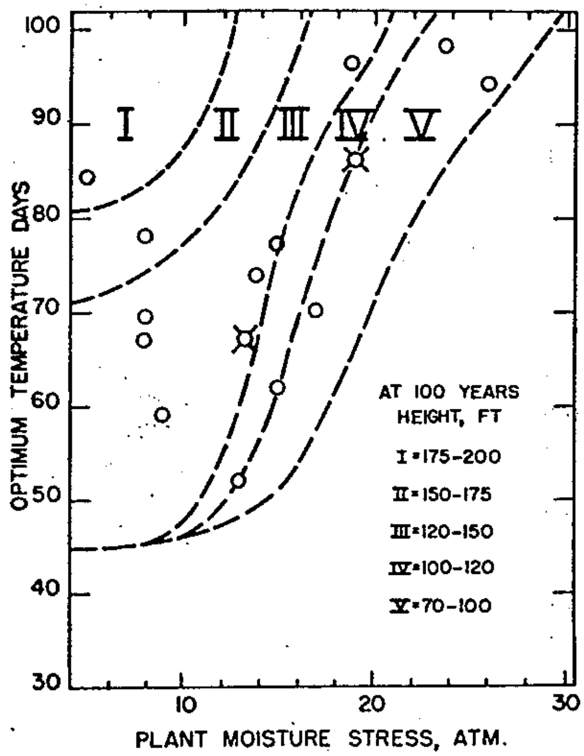

Figure 4. Relation of site index for Douglas-fir to gradients of moisture and temperature. Starred data points indicate supplementary stands to verify precision of original data.

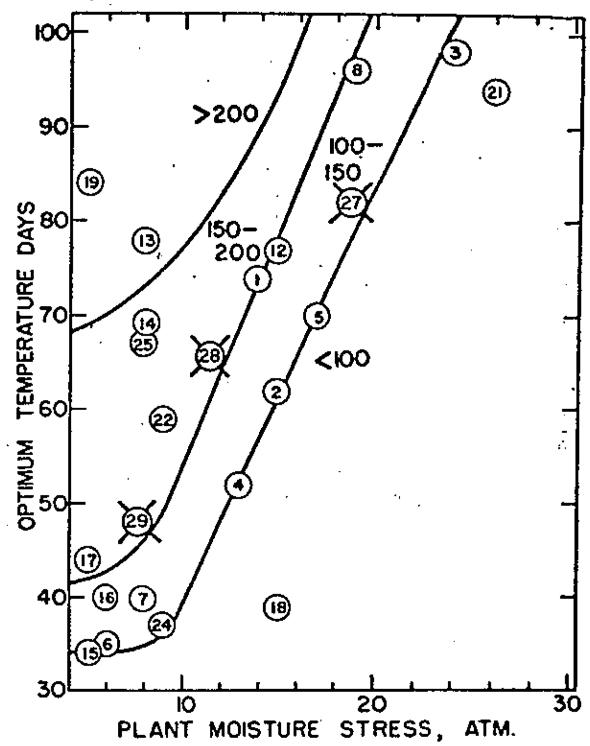

Figure 5. Relation of maximum height in feet of trees to gradients of moisture and temperature. Starred data points indicate supplemental stands to verify precision of original data.

available. Shasta red fir and mountain hemlock appear to lack this ability.

As a group, the hardwoods are restricted to the warmer sites, partly because of their brittleness to ice and snow. Bigleaf maple and black oak are, however, clearly separated, according to their distribution along the moisture gradient.

Knowledge of the limited distributions of many lesser species such as poison-oak, gray manzanita, and mountain heliotrope can be useful in identifying the environment's growth potential even after the forest has been removed (9).

APPLICATIONS

The approach presented here, and the actual data, have wide applications, particularly in forest genetics and other fields when direct comparisons between regions are desired. Within a region, once the environmental distributions of trees and other species are known, maps can be constructed from aerial photographs and ground checks that classify all forest environments in relation to such factors as moisture, temperature, and soil fertility. With knowledge of the most critically limiting environmental factor and the present growth potential of each site, the forester can compare the relative returns of various alternatives in management. Also, the results of past experiences from planting selected genetic stock, adding fertilizers, or thinning can all be re-evaluated.

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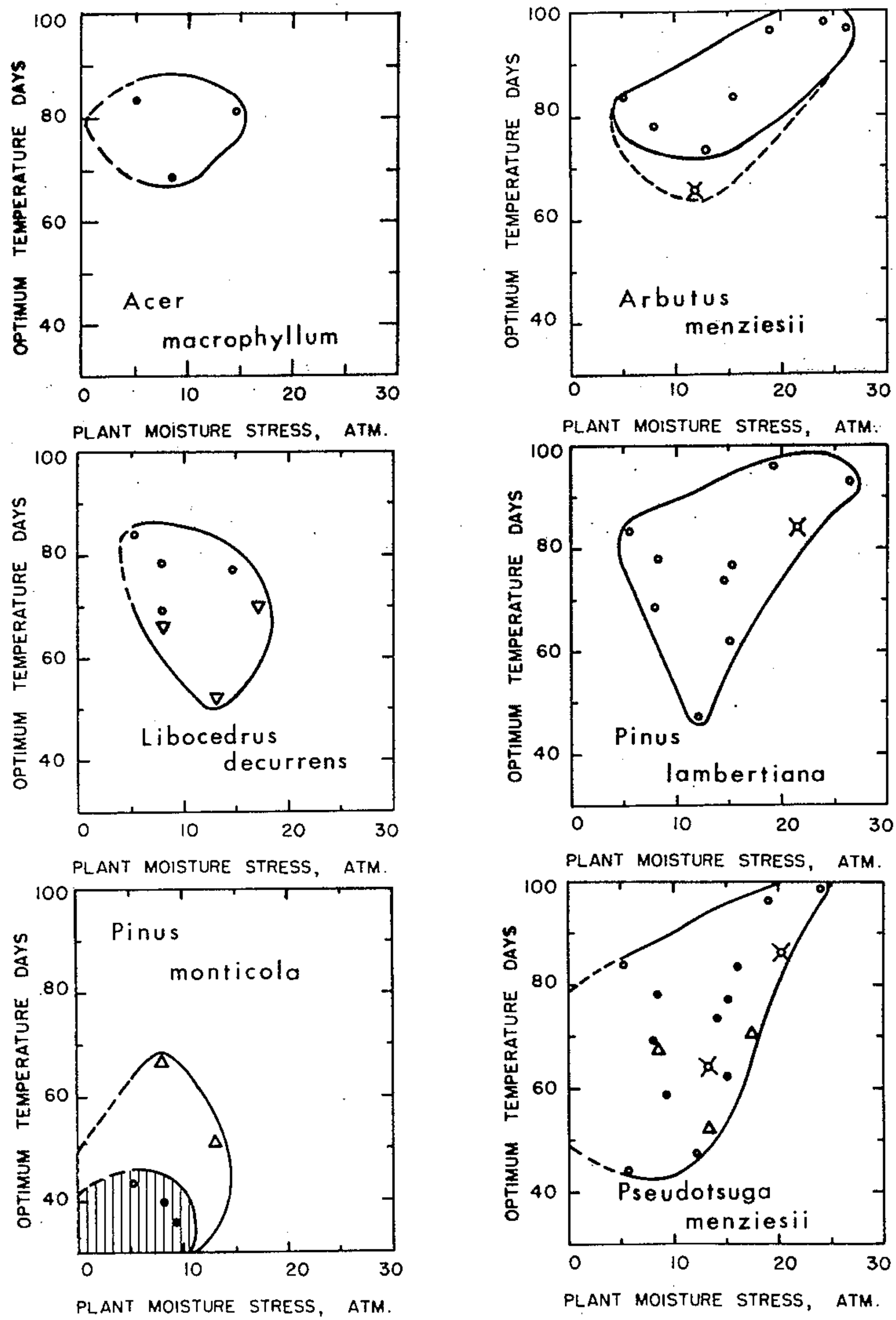

Figure 6. Distribution of tree regeneration in relation to gradients of moisture and temperature. Triangles represent stands on soils from ultrabasic material. Shading indicates frequencies greater than 50 percent. Starred data points indicate supplementary stands to verify precision of original data. Dotted lines indicate appropriate correction where there was disagreement with original data.

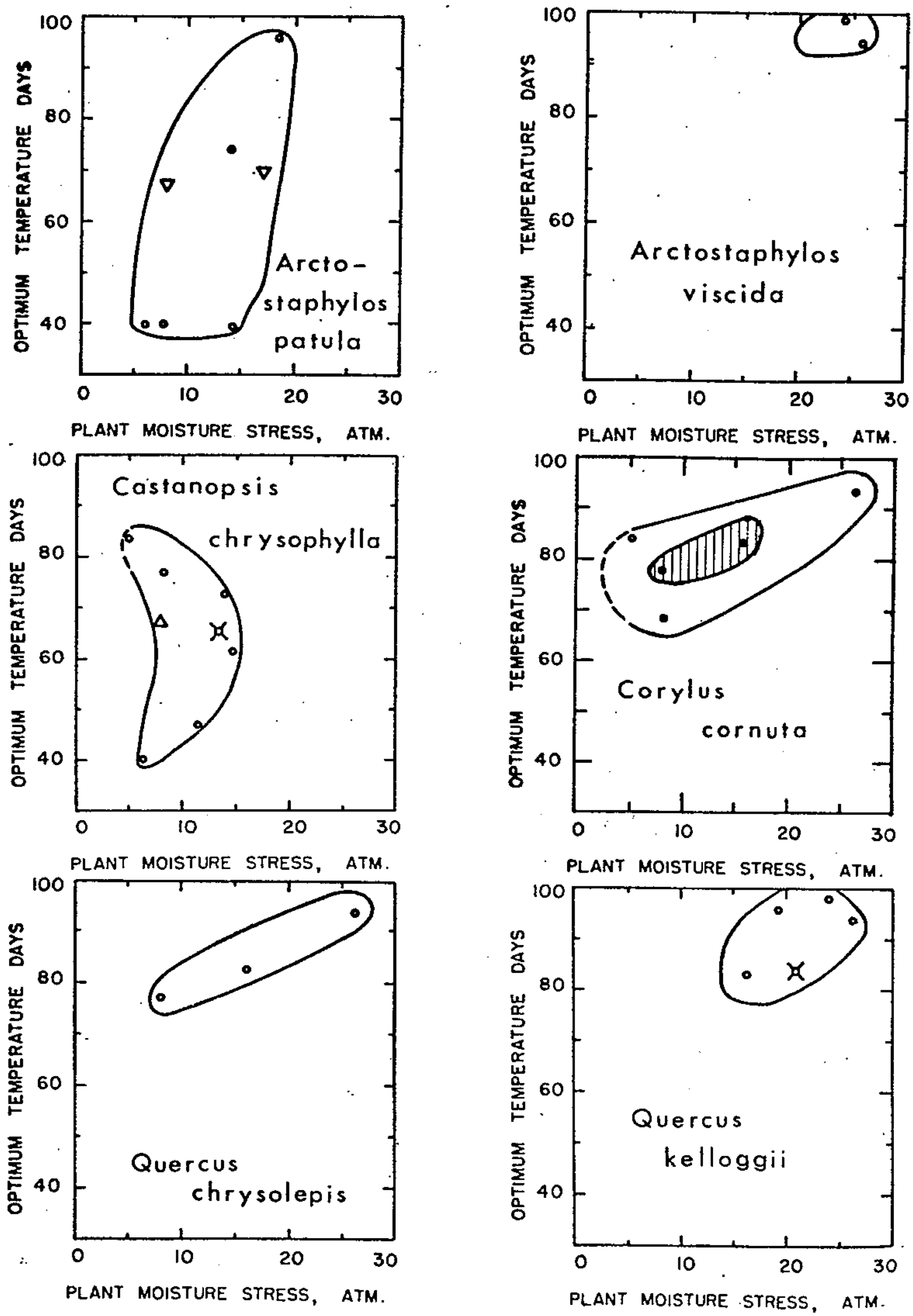

Figure 7. Distribution of selected tree and shrub species in relation to gradients of moisture and temperature. Triangles represent stands on soils from ultrabasic material. Shading indicates frequencies of 50 percent or more. Starred data points indicate supplementary stands added to verify original data.

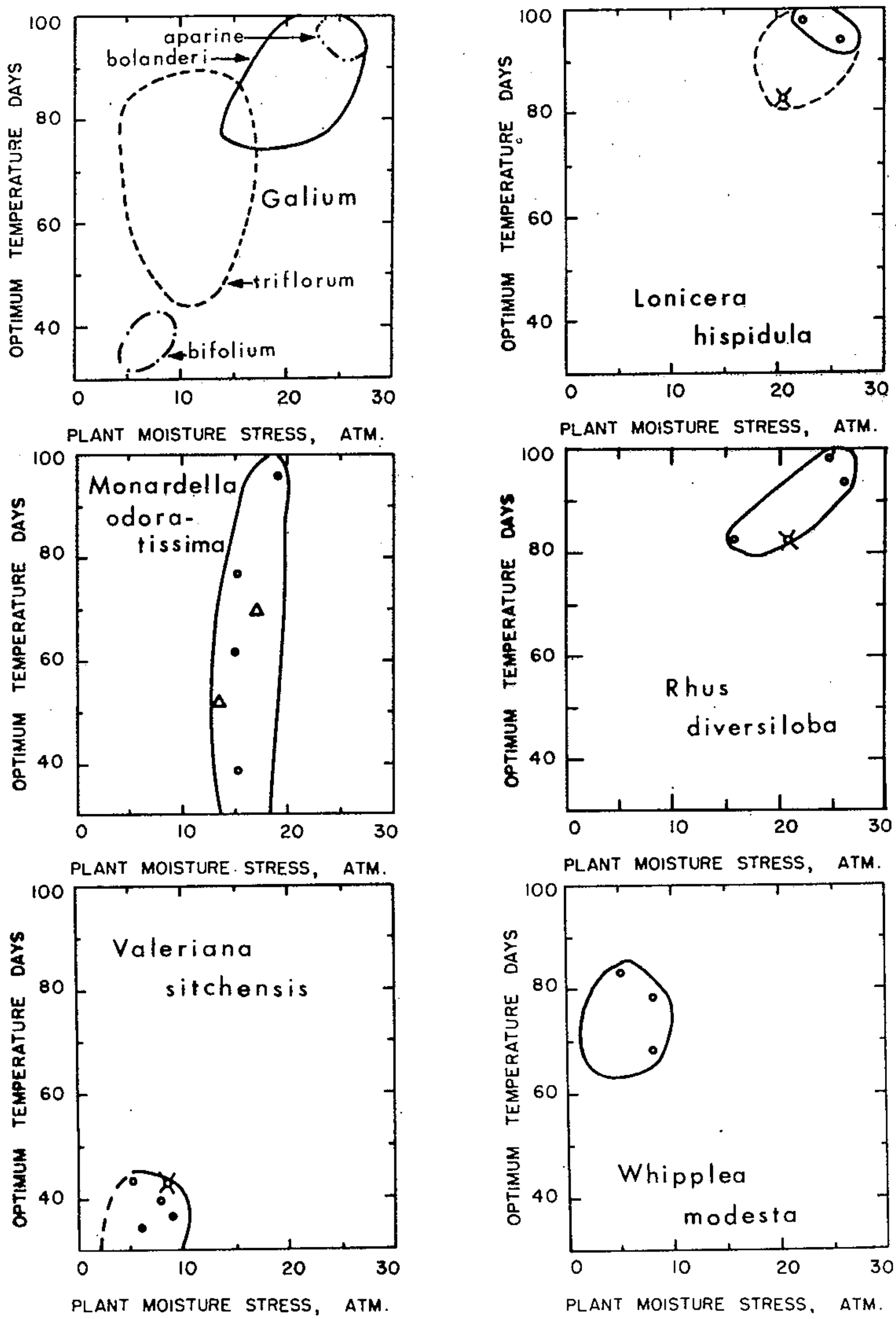

Figure 8. Destribution of selected half-shrubs and herbs in relation to gradients of moisture and temperature. Triangles represent stands on soils derived from ultrabasic material. Starred data points indicate supplementary stands added to verify original data. Dotted lines indicate appropriate correction where there was disagreement with original data.

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CHECKLIST OF PLANTS

Common Name	Scientific Name
Cedar, incense	*Libocedrus decurrens* Torr.
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco
Fir, Shasta red	*Abies magnifica* Murr. var. *shastensis* Lem.
Fir, white	*A. concolor* Lindl.
Heliotrope, mountain	*Valeriana sitchensis* Bong.
Hemlock, mountain	*Tsuga mertensiana* (Bong.) Sarg.
Manzanita, gray	*Arctostaphylos viscida* Parry
Maple, bigleaf	*Acer macrophyllum* Pursh
Oak, black	*Quercus kelloggii* Newb.
Oak, Oregon white	*Quercus garryana* Dougl.
Pine, Jeffrey	*Pinus jeffreyi* Murr.
Pine, ponderosa	*P. ponderosa* Laws.
Pine, sugar	*P. lambertiana* Dougl.
Pine, western white	*P. monticola* Dougl.
Poison-oak	*Rhus diversiloba* T. and G.
Spruce, Brewer	*Picea breweriana* Wats.
Spruce, Engelmann	*P. engelmannii* (Parry) Engelm.
Yew, Pacific	*Taxus brevifolia* Nutt.