CLIMATES

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The broad range of aspen in North America is evidence of its equally broad tolerance of wide variations in climate (Fowells 1965). Given open space for establishment and not too severe competition from other plants, aspen can survive from timberline on the tundra's edge to very warm temperate climates, and from the wet maritime climates of the coasts to very severe and often quite dry continental climates of the interior. Therefore, to describe the climates typical of this species' range is extremely difficult, especially in the mountainous West, where climates vary greatly. However, aspen grows much better and competes more successfully under some climatic regimes than under others. Ecotypes of aspen have developed that perhaps are best adapted to the climatic regime in which they are growing (see the GENETICS AND VARIATION chapter).

It is difficult to relate climate measured at a standard weather station to optimum or limiting conditions for aspen growth and development. Topography markedly influences climate. There often is a large difference in climate from the point of measurement at an instrument shelter or raingage to the effective climate at the nearest aspen sites.

In the West, it is unusual for weather measurements to be taken at the actual site where aspen stands are common. Therefore, an assumption usually is made that measurements taken at the nearest station are representative of conditions in the aspen forest. This seldom is true in mountainous terrain. Under average conditions in Utah, for example, a 1,000-foot (300-m) change in elevation is roughly equivalent to a 20-day change in the length of the growing season. These changes may be much more rapid or even reversed within the air inversion zone of mountain valleys.

Differences in precipitation isohyets also are found in mountainous terrain. Depending on the synoptic pattern producing the precipitation, the same isohyet may be as much as 1,000 feet (300 m) higher on the leeward side of mountains than on their windward side.

Even more important than these major variations of climate with elevation are the local microclimate differences in available soil moisture that are associated with topography and soil characteristics. Available soil moisture may be much greater than measured precipitation in a swail or canyon site and much less on a rocky ridge or hillside. Aspect also is critical. Temperature and available soil moisture on a southwest facing slope will be quite different from those at the same elevation on a north facing slope. (See the EFFECTS OF WATER AND TEMPERATURE chapter for a discussion of the effects of these climatic factors on aspen.)

Despite data interpretation difficulties, climatic descriptions are presented here for selected sites within the range of quaking aspen in the western conterminous United States. Similar descriptions for Alaska and Canada were not attempted.

A Representative Climate

Price and Evans (1937) described climates along an elevational gradient on the west front of the Wasatch Plateau, in central Utah. The lowest station cited, at 7,660 feet (2,350 m), represents the elevational zone dominated by Gambel oak (*Quercus gambelii*). The Gambel oak zone in Utah and western Colorado occupies a position equivalent to that of ponderosa pine (*Pinus ponderosa*) in other areas—intermediate between pinyon-juniper below and aspen or mesophytic conifers such as Douglas-fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*) above. The second station, at 8,850 feet (2,700 m), represents the zone of extensive aspen dominance. This station, in the midst of the aspen forest, probably provides the best available characterization of the climates of major aspen areas in Utah and western Colorado. Those climates have been compatible with, and perhaps conducive to, the most widespread aspen dominance in the West. The third station, at 10,100 feet (3,100 m), was near the mountain top, in the spruce-fir zone, above any extensive stands of aspen. All three stations were in forest openings.

Based upon 20 years of record, there was little difference between the aspen station and the spruce-fir station in amount or monthly distribution of precipitation. Both received between 28 and 30 inches (71 cm and 76 cm) average annual precipitation, with two-thirds falling largely as snow between November and April. Growing season precipitation at the aspen station was greatest in May (2.4 inches (6 cm)), least in June (0.8 inch (2 cm)), and averaged 1.8 inches (5 cm) in each of the following four months. Both locations received much more precipitation than the oak station, especially in winter. Snowfall comprised 60% of the total precipitation at the oak station, 70% at the aspen station, and 80% at the spruce-fir station.

Snow cover usually began before November 1 at all three stations, and remained on the average until April 18 at the oak station, May 6 at the aspen station, and May 26 at the spruce-fir station. Even though the winter pack had melted, almost one-half the precipitation in May fell as snow at the aspen station. Average snow depths there were 14 inches (36 cm) on December 1, 28 inches (71 cm) on January 1, and a peak of 48 inches (122 cm) on April 1.

Summer temperatures at the aspen station were moderate. The average hours per day above 70°F (21°C) were 1 in May, 3 in June, 4 in July, 3 in August, and 1 in September. About twice as many hours per day above 70°F (21°C) were recorded at the oak station; whereas, at the spruce-fir station, no month had more than 1 hour per day above 70°F (21°C). The hours above 32°F (0°C) were more alike among the stations. At both the oak and aspen stations, more than 18 hours per day were above 32°F (0°C) from May through September. July and August continuously remained above 32°F (0°C).

The overall picture of aspen climate in this area is of cool summers with modest rainfall, and of long, snowy winters that are only moderately cold. However, the details vary from place to place in Utah and western Colorado, and differ substantially in other parts of the West.

Precipitation

Strain (1964) reported data from a weather station at 10,150 feet (3,100 m) elevation in southern California that illustrates a very dry aspen site, perhaps an extreme. For 10 years there, the annual precipitation averaged only 12.5 inches (32 cm), with 10 inches (25 cm) falling as snow. Aspen was abundant in the vicinity, although it grew poorly.

Most aspen areas, however, receive at least 15 inches (38 cm) of precipitation a year. Table 1 shows the average monthly and annual precipitation at several stations with aspen growing nearby at similar elevations. The locations of these stations are shown in figure 1, on which monthly precipitation of selected stations also has been noted to illustrate the geographic variation in seasonal distribution of moisture.

There are marked seasonal differences in precipitation across the West. In a south-to-north transect through Arizona, Utah, and Idaho, winter precipitation generally increases and summer precipitation decreases from south to north. This pattern may reflect the distance from major sources of summer rainfall, (i.e., the Gulf of California and the Gulf of Mexico) (Green and Sellers 1964, Hales 1974), and position relative to major winter storm tracks. In Colorado and New Mexico, the most notable south-north trend is in spring precipitation. Spring is exceedingly dry in southern New Mexico but is the wettest season in northern Colorado. Further north, in Montana for example, the spring wet season occurs later, in May and June.

Mountain barriers concentrate precipitation on the windward sides of mountains, and local topographic features funnel moist air. This causes marked variability in precipitation within relatively small geographic areas. This phenomenon is illustrated in northern Utah, where the west side of the Wasatch Range gets heavy orographically enhanced snowfall, while winter precipitation is greatly reduced on the east side. The November-April precipitation at Silver Lake Brighton (8,740 feet (2,650 m) elevation) on the western slopes is 30.27 inches (77 cm), compared to only 21.80 inches (55 cm) at Park City Summit (9,270 feet (2,800 m)), and only 8.03 inches (20 cm) at Moon Lake (8,150 feet (2,500 m)) on the east side.

Such contrasts are not unique to the Wasatch. Even more extreme is the contrast between two southern Colorado stations only 25 miles apart, on opposite sides of the San Juan crest. Wolf Creek Pass 4W (9,425 feet (2,850 m)) averages 45.55 inches (116 cm) per year, and Santa Maria Reservoir (9,706 feet (2,950 m)) averages only 15.37 inches (39 cm) per year. Winter averages (November-April) are 29.45 inches (75 cm), and only 5.71 inches (15 cm), respectively.

Ives (1941a) pointed out that precipitation varies fairly consistently among locales in the Rocky Mountains because of interactions of topography and local as well as large-scale air movements. The same presumably is true elsewhere in the mountainous West.

There is a sparsity of weather stations in the West at the higher elevations occupied by aspen. Because of large precipitation variability in these uplands, precipitation records from stations in the valleys, even a few miles away, do not accurately describe the climate of most aspen stands. Therefore, for most higher elevations in the West, an estimate of annual or seasonal precipitation at any point is best made using large-scale precipitation maps.[1]

Monthly precipitation sometimes may be of interest. Equations for estimating monthly precipitation are available in Jones (1971a) for the southern Rocky Mountains. They are based on relationships of precipitation with several physiographic variables.

In addition to usual forms of precipitation, heavy rime sometimes accumulates in the crowns of trees when supercooled winter clouds move through the forest (fig. 2). From a 3-year study in the Sangre de Cristo Mountains of New Mexico, Gary (1972) estimated that rime collection in the canopy of a dense stand contributed at least 1 inch (3 cm) of water per year to the moisture regime. Grover[2] reported a similar phenomenon on the west slopes of the central Wasatch Mountains in Utah.

Temperature

In the interior West, high elevation weather stations with fairly long periods of temperature records are even more sparse than are locations with precipitation records. Table 2 lists several stations with long-term temperature records within or near elevations where aspen grows. Station locations are shown in figure 3.

[1]Summer (May-September), winter (October-April), and annual precipitation maps are variously available from: (Arizona) University of Arizona, Room 102, West Stadium Building, Tucson, Ariz. 84721; (Colorado) Colorado Water Conservation Board, 215 State Services Building, 1525 Sherman Street, Denver, Colo. 80203; (New Mexico) State Engineer Office, State Capitol Building, Santa Fe, N. Mex. 87501; (Utah) State Engineer Office, State Capitol Building, Salt Lake City, Utah 84101. The isohyets are drawn on topographic maps with scales of 1:500,000. The maps were prepared by the Water Supply Forecast Unit of the USDA Soil Conservation Service in cooperation with the State Climatologists' Offices of the U.S. Department of Commerce Weather Bureau.

[2]Personal communication from Dr. Ben Grover to E. Arlo Richardson, both with Utah State University, Logan.

Table 1.—Precipitation (in inches) at some stations with aspen nearby at a similar elevation. Stations are listed in north-south order within states and are number-coded to map locations (figure 1).[1]

Station	Elev. (feet)	Months												Total annual	Class[2]
		J	F	M	A	M	J	J	A	S	O	N	D		
MONTANA															
1 Babb 6NE	4,300	0.79	0.84	0.97	1.47	2.79	4.44	1.60	1.65	1.93	1.01	0.81	0.82	19.12	1
2 Whitefish 5NW	3,080	2.33	1.81	1.38	1.53	2.36	3.38	1.18	1.55	1.61	1.69	2.15	2.18	23.15	3
3 Lewistown AP	4,145	0.68	0.59	0.71	1.00	3.08	4.08	1.62	1.70	1.64	1.00	0.71	0.66	17.47	2
4 Ovando	4,109	1.71	1.04	0.85	0.83	1.98	2.47	1.00	0.99	1.22	1.18	1.47	1.69	16.43	3
5 Red Lodge	5,575	1.20	1.00	2.09	3.50	3.42	3.49	1.25	1.18	2.22	1.35	1.57	0.94	23.21	2
6 Lakeview	6,710	1.70	1.19	1.60	1.48	2.58	3.28	1.22	1.43	1.48	1.45	1.55	1.56	20.52	2
IDAHO															
7 McCall	5,025	4.04	2.81	2.53	2.04	2.47	2.39	0.44	0.82	1.43	2.34	3.18	3.69	28.18	3
8 Ashton	5,260	1.85	1.80	1.30	1.22	1.87	2.21	0.64	1.04	1.15	1.29	1.86	2.04	18.27	3
9 Willow Flat	6,100	4.34	4.13	3.53	4.01	2.68	2.52	0.92	1.07	1.89	2.21	3.52	4.08	34.90	2
WYOMING															
10 Moran 5WNW	6,798	2.81	2.10	1.82	1.72	2.03	1.85	0.88	1.30	1.46	1.40	2.32	2.69	22.38	1
11 Kendall	7,645	1.65	0.98	1.24	1.09	1.93	2.05	1.03	1.33	1.39	1.00	1.26	1.57	16.52	1
12 Foxpark	9,065	1.37	1.37	1.71	1.68	1.55	1.57	1.68	1.49	1.16	0.97	1.11	1.03	16.69	3
UTAH															
13 Red Butte No. 6	7,200	4.06	3.82	3.92	4.89	3.02	2.14	0.78	1.34	1.87	2.95	3.02	3.93	35.74	2
14 Silver Lake Brighton	8,740	5.35	4.80	5.53	4.50	2.87	2.65	1.28	1.95	1.74	3.05	4.75	5.34	43.81	2
15 Moon Lake	8,150	1.20	1.00	1.29	1.53	1.63	1.85	1.24	2.23	1.64	1.54	1.25	1.76	18.16	3
16 Timpanogos Div. No. 4	8,140	4.90	4.41	3.50	3.97	2.33	2.06	0.70	1.82	2.14	2.94	4.26	5.47	38.50	1
17 Ephraim GBRC HQ	8,800	2.83	3.51	3.55	4.13	2.33	1.41	1.07	1.84	1.77	2.42	2.66	3.16	30.68	1
18 Ephraim Alp. Mead.	9,850	3.80	4.36	4.56	4.78	2.77	1.73	1.17	2.01	1.88	2.91	3.24	3.94	37.15	3
19 Beaver Canyon PH	7,275	1.75	1.97	2.38	2.13	1.49	1.05	1.58	1.88	0.99	1.30	1.28	1.63	19.43	1
20 Bryce Canyon NPHQ	7,915	1.28	1.21	1.42	1.19	0.85	0.73	1.30	2.41	1.50	1.50	1.05	1.39	15.83	1
COLORADO															
21 Longs Peak	8,956	1.34	1.26	2.33	2.89	2.76	2.03	2.36	2.35	1.50	1.39	1.06	0.69	21.96	3
22 Silver Lake	10,200	1.81	2.46	3.03	3.37	3.42	2.36	2.91	2.42	1.54	1.73	1.72	1.54	28.31	2
23 Winter Park	9,058	2.24	2.42	2.84	3.35	2.88	1.70	2.29	2.07	1.33	1.88	2.00	1.86	26.86	3
24 Dillon	9,065	1.43	1.55	2.08	2.17	1.71	1.20	1.89	1.63	1.17	1.11	1.18	1.30	18.42	3
25 Leadville	10,200	1.32	1.51	1.71	1.83	1.44	1.13	2.73	2.11	1.35	1.11	1.07	1.17	18.48	2
26 Crested Butte	8,800	2.68	2.56	2.36	1.73	1.31	1.43	1.95	2.27	1.66	1.43	1.52	2.10	23.00	1
27 Fremont Exp. Stn.	8,900	0.51	0.82	1.64	2.41	2.96	2.33	3.27	3.08	1.47	0.99	0.78	0.46	20.72	2
28 Pitkin	9,200	1.45	1.36	1.41	1.41	1.15	0.91	1.86	1.82	1.23	1.00	0.89	1.19	15.68	1
29 Knott Ranch[3]	9,300	2.48	2.23	2.68	1.85	1.21	1.01	1.57	2.18	1.35	1.52	1.69	2.43	22.20	1
30 Trout Lake	9,700	2.48	2.51	2.86	3.00	1.89	1.24	2.62	3.07	2.26	2.35	1.59	1.87	27.74	3
31 Rio Grande Reservoir	9,495	1.54	1.06	1.44	1.68	1.63	1.17	1.96	2.55	2.17	2.43	1.26	1.25	20.14	1
32 Rico	8,840	2.46	2.46	2.49	2.23	1.61	1.19	2.39	2.80	2.49	2.40	1.66	2.31	26.49	2
33 LaVeta Pass	9,200	1.75	1.73	2.42	3.02	2.56	1.14	1.63	1.72	1.22	1.60	1.62	1.08	21.49	2
34 Terminal Dam	8,300	2.17	1.58	1.81	1.51	1.35	1.02	2.21	2.65	2.43	2.05	1.15	1.92	21.85	2
35 Wolf Creek Pass 4W	9,425	6.08	4.64	5.77	4.06	2.13	1.25	2.79	3.60	3.02	3.31	3.64	5.26	45.55	3
36 North Lake	8,800	0.92	1.14	1.76	2.30	2.53	1.38	2.95	2.98	1.43	1.26	0.92	0.77	20.34	3
37 Cumbres Pass	10,000	3.76	4.17	3.94	3.45	1.74	1.23	2.45	3.45	2.19	2.11	2.93	2.89	34.31	1
NEW MEXICO															
38 Red River	8,676	1.07	1.10	1.35	1.60	1.80	1.24	2.56	3.07	1.49	1.47	0.98	0.93	18.66	2
39 Bateman Ranch	8,900	1.94	1.98	2.18	1.56	1.82	1.18	2.48	3.05	2.16	1.81	1.24	1.61	23.01	1
40 Chacon	8,500	1.11	0.78	1.07	1.22	1.82	1.46	2.97	3.73	1.75	1.29	0.90	0.91	19.01	2
41 Wolf Canyon	8,135	1.64	1.77	1.90	1.50	1.45	1.04	2.91	3.28	2.14	1.62	1.16	1.51	21.92	2
42 Elk Cabin	8,500	1.21	1.37	1.70	1.47	1.46	1.42	3.49	3.61	1.61	1.54	1.24	1.42	21.54	1
43 Sandia Crest	10,680	1.74	1.72	2.26	1.23	0.92	0.96	3.19	3.40	1.73	2.06	1.34	2.17	22.72	1
44 Cloudcroft	8,827	1.59	1.69	1.44	0.80	1.11	1.61	4.56	4.77	2.78	1.48	1.30	1.45	24.58	3
ARIZONA															
45 Jacob Lake	7,920	1.45	1.01	2.07	1.48	1.06	0.79	2.38	2.47	1.10	1.87	1.34	2.01	19.03	3
46 Fort Valley	7,347	2.32	2.27	1.92	1.52	0.69	0.76	2.65	3.65	1.83	1.52	1.14	2.07	22.34	2
47 Maverick Fork	9,050	2.52	2.26	2.30	1.53	0.82	1.16	4.80	4.31	2.20	2.75	1.82	3.49	29.96	1
48 Alpine	8,020	1.60	1.38	1.24	0.78	0.54	0.80	3.10	3.87	2.10	1.61	0.92	1.27	19.21	1
49 Rustlers Park	8,400	3.05	1.80	2.06	0.77	0.43	1.10	6.45	6.34	2.62	1.96	1.74	2.03	30.35	3

[1] *These data come from several sources; most are from the National Weather Service and its predecessors under the U.S. Department of Commerce, the U.S. Department of Agriculture and the U.S. Army.*

[2] *Class 1 = aspen type is prominent in locale;*
Class 2 = a fair amount of aspen;
Class 3 = some aspen, may be largely mixed with conifers.

[3] *Also known as Sapinero 9W.*

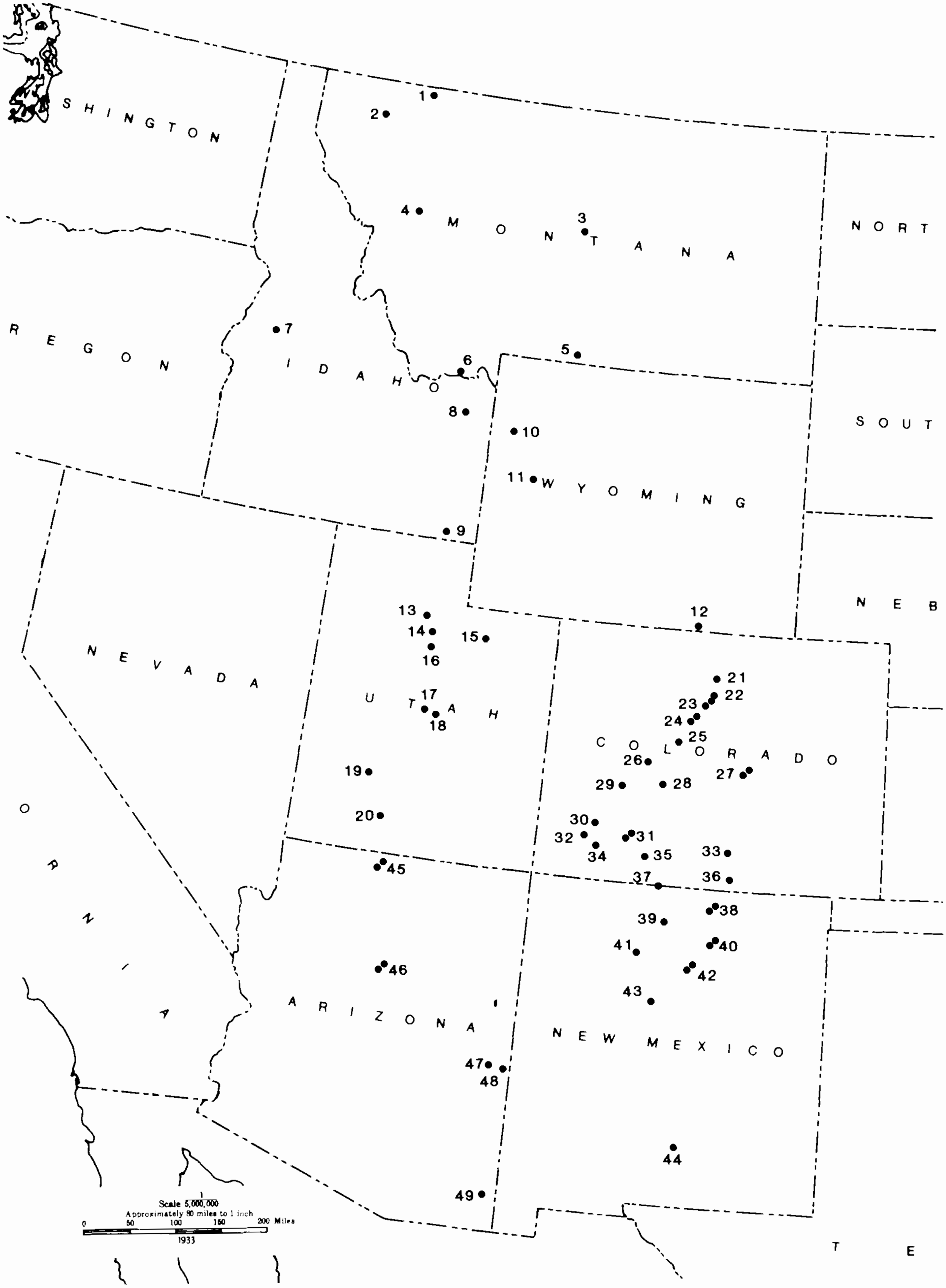

Figure 1.—Precipitation stations listed in table 1.

The temperatures listed are average maximums for each month, not the average monthly temperatures commonly reported. Most weather stations at aspen elevations are in valley bottoms and are not representative of aspen terrain. These valley locations commonly have severe temperature inversions at night, with much lower minimum temperatures than those on the nearby slopes that are covered with aspen. Daily high temperatures are affected less by the topography than are the minimums or the daily averages.

The temperatures in table 2 have little relationship to aspen growth and development (see the EFFECTS OF WATER AND TEMPERATURE chapter). Usually the limiting temperatures are the extreme minimums at the actual aspen site. The values listed should be used for comparative purposes only in terms of general climate.

Winter temperatures within the zone of aspen forest, as expected, decrease northward from southern New Mexico to Wyoming or Montana. Perhaps more important is the decline of spring (April-June) temperatures northward (fig. 4), because these determine when aspen begins its annual growth. The longer growing season in the Southwest may contribute to the large sizes attained by aspen in that region. By contrast, July and August temperatures are not very different in aspen forests from Wyoming to Arizona.

Summer temperatures at the intermediate- and low-elevation aspen sites in the north are often higher than on typical aspen sites further south. For example, Lyon (1971) described the climate at two stations in south-central Idaho, at about 6,500 feet (2,000 m) elevation, where patches of aspen were often associated with mesic microsites. Precipitation at the two stations was 14 and 17 inches (36 cm and 43 cm) per year, and summer temperatures reached or exceeded 90°F (32°C) on 7 and 15 days per year, which is appreciably warmer than the higher elevation sites in Utah described by Price and Evans (1937).

Figure 2.—Rime on aspen crowns, Sangre de Cristo Mountains, New Mexico (Gary 1972).

Other aspects of climate related to temperatures at a given site are length of the frost-free period and temperature extremes. Throughout much of the range of western aspen, particularly from Wyoming southward, 90°F (32°C) air temperatures are rare; therefore, critically high temperatures seldom are reached. Conversely, 0°F (−18°C) is common in winter, the period of dormancy when the aspens are most hardy. Extreme temperatures tend to be greater in aspen areas of the northern Rockies. South of Canada, one of the coldest temperatures experienced by aspen now living was near Rogers Pass, Montana where it dropped to −70°F (−57°C) on January 20, 1954. At the same latitude, aspen near Lewistown, Mont. have experienced summer air temperatures of 105°F (41°C).

Marr (1961) provided an example of an extreme climate in which aspen can grow in the West. He collected temperature data in a scrub stand, in the forest-tundra transition of northern Colorado, probably above 11,000 feet (3,350 m) in elevation. Although the data were collected for only 1 year, the most striking feature was the late beginning of the growing season. In May, temperatures fell below freezing every day but one; and the mean daily high was only 39°F (4°C). In July, the warmest month, the average daily high temperature was 61°F (16°C); the warmest temperature recorded during the year was only 70°F (21°C).

The length of the freeze-free season is especially influenced by topography. The weather station at Fort Valley, Arizona is in the forest, on a plain at 7,347 feet (2,250 m). At night, cold air flows down the slopes of the adjacent San Francisco Mountains and spreads across the plain, causing rapid cooling. Aspen there have experienced air temperatures as low as −37°F (−38°C). The average frost-free season lasts only 61 days. Fraser, Colo., at 8,560 feet (2,600 m) in the cold-air trap of a high mountain valley, has an average of only 24 days (June 24 to July 18) between 28°F (−2°C) air temperatures. In contrast, the Cloudcroft Ranger Station in New Mexico lies at 8,650 feet (2,650 m), with no high mountains nearby to intensify nocturnal cooling. The coldest temperature recorded there has been −15°F (−26°C), with a frost-free season of 147 days, more than twice as long as at Fort Valley and six times longer than at Fraser.

Aspen forest affects the microclimate. Miller (1967) studied temperature profiles within an aspen sapling stand in which the trees were large enough that a foliage-free "bole space" had developed beneath the canopy. On a sunny day, leaf temperatures measured near the top and bottom of the canopy did not get warmer than about 4°F to 7°F (2°C to 4°C) above air temperature. Within the central part of the canopy, temperatures of individual leaves generally were within 8°F (4°C) of air temperature. On a partly cloudy day, leaf temperatures responded somewhat to temporary shade from clouds. When the sun dropped behind the ridge in late afternoon, leaves sharply cooled to below air temperature. Because this typical aspen canopy was not dense, cold air settled through from the radiating surfaces of the upper canopy at night, so that the lowest night temperatures were at the top of the canopy and at ground level. On an August night with frost in the adjacent meadow, however, there was no frost beneath the aspen.

Gary (1968) compared soil temperatures beneath aspen and Douglas-fir in northern New Mexico. The soils froze earlier and deeper and stayed frozen longer under Douglas-fir (fig. 5). The difference was especially great on south slopes, where the snow under aspen received much more sunlight than under Douglas-fir. The upper few inches of aspen soils there were as warm in April as Douglas-fir soils were in June. At 1 to 2 feet (31 cm to 61 cm), south-slope aspen soils warmed about 1 month before Douglas-fir soils.

Table 2.—Mean daily high temperatures (°F) at some stations with aspen nearby at a similar elevation. Stations are listed in north-south order within states and are number-coded to map locations (fig. 3).[1]

	Elev.						Months							
Station[2]	***(feet)***	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Class**[3]
MONTANA														
1 Babb 6NE	4,300	31.4	32.7	38.6	51.7	61.1	66.1	76.8	75.0	65.7	56.0	43.0	35.6	1
2 Lewistown AP	4,132	32.1	34.9	40.6	55.7	65.5	71.0	82.9	80.5	70.3	59.9	44.6	36.7	2
3 Ovando 1SW	4,109	27.0	33.1	41.1	57.0	65.5	71.3	82.2	80.6	71.1	60.0	41.2	30.8	3
4 Red Lodge	5,575	32.3	34.4	39.4	51.7	60.9	67.3	78.4	76.6	66.8	56.7	43.0	36.7	2
5 Lakeview	6,800	19.3	26.3	31.9	47.3	58.2	63.9	75.8	75.7	66.4	52.9	33.8	23.8	3
IDAHO														
6 McCall	5,025	28.6	33.7	40.2	50.6	61.6	68.1	80.7	79.3	69.4	56.9	40.1	31.5	2
7 Ashton 1S	5,100	27.6	33.0	39.5	55.3	67.9	73.8	83.4	81.9	73.4	61.3	41.6	31.9	2
WYOMING														
8 Moran	6,740	24.5	30.2	36.4	47.8	58.9	62.0	77.1	75.3	66.8	54.9	37.3	28.3	1
9 Kendall	7,645	25.0	28.4	33.9	45.8	57.3	65.6	74.7	73.5	66.0	54.7	37.6	28.4	1
10 Pole Mt. Nursery	8,530	27.4	29.6	34.5	44.6	55.7	67.2	75.1	73.0	64.9	51.8	37.1	30.9	2
11 Foxpark	9,065	26.4	28.9	33.6	43.3	52.8	63.6	72.5	71.4	63.2	51.4	36.7	29.5	3
UTAH														
12 Silver Lake Brighton	8,740	29.9	32.2	36.1	45.1	53.6	62.1	71.7	70.6	63.8	51.8	39.9	33.5	2
13 Moon Lake	8,150	30.8	32.3	37.6	48.9	59.3	66.9	76.0	74.2	66.8	54.7	41.3	33.7	3
14 Bryce Canyon NP	8,213	34.2	38.9	43.7	55.1	64.8	73.1	80.8	78.0	73.3	59.9	44.8	36.9	1
COLORADO														
15 Longs Peak	8,956	32.7	33.2	36.6	45.8	55.0	65.8	72.4	70.8	63.5	53.8	41.0	36.5	3
16 Dillon	9,065	31.8	35.0	39.6	49.4	60.0	69.4	74.7	73.4	68.4	57.6	42.0	34.8	3
17 Leadville	10,200	30.7	33.2	36.7	45.8	56.1	67.0	73.3	71.4	65.2	54.2	39.9	32.9	2
18 Crested Butte	8,800	28.9	32.5	38.1	49.1	60.8	71.2	77.7	76.2	69.4	59.5	42.4	32.5	1
19 Fremont Exp. Stn.	8,900	35.5	36.5	39.8	46.4	53.4	66.3	71.8	68.1	63.1	54.4	43.8	37.6	2
20 Knott Ranch[4]	9,300	29.4	33.2	40.0	48.1	58.4	67.6	73.7	71.8	65.1	54.3	41.4	33.3	1
21 Silverton 2NE	9,400	32.9	35.6	39.2	47.7	57.0	66.4	72.4	70.4	64.9	54.8	42.8	35.6	1
22 Cumbres Pass	10,000	28.3	29.8	32.3	43.6	53.0	63.7	68.7	67.1	62.3	51.5	38.2	31.6	1
NEW MEXICO														
23 Red River	8,676	35.6	37.9	43.3	53.7	62.2	72.5	76.8	75.0	69.8	59.4	45.6	38.4	2
24 Lee Ranch	8,691	34.1	37.3	42.6	52.5	62.1	72.1	75.5	73.2	65.9	56.6	45.1	38.0	2
25 Cloudcroft 1	8,650	40.9	42.9	48.0	56.1	64.5	72.6	72.5	71.3	67.6	59.7	50.8	44.3	3
ARIZONA														
26 Bright Angel RS	8,400	36.2	38.3	43.6	52.3	63.0	72.8	77.9	75.3	70.9	58.3	47.1	39.7	1
27 Fort Valley	7,397	40.1	42.0	48.0	56.9	66.2	75.8	80.5	77.5	73.0	62.5	51.0	43.4	2
28 Alpine	8,000	44.9	46.3	50.4	60.9	68.8	77.2	78.6	75.8	72.8	64.9	55.2	47.5	1

[1]*These data come from several sources; most are from the National Weather Service and its predecessors under the U.S. Department of Commerce, the U.S. Department of Agriculture, and the U.S. Army.*

[2]*Some of these stations are at slightly different locations from stations in table 1 that have the same or similar names.*

[3]*Class 1 = aspen type is prominent in locale;*
Class 2 = a fair amount of aspen;
Class 3 = some aspen, may be largely mixed with conifers.

[4]*Also known as Sapinero 9W.*

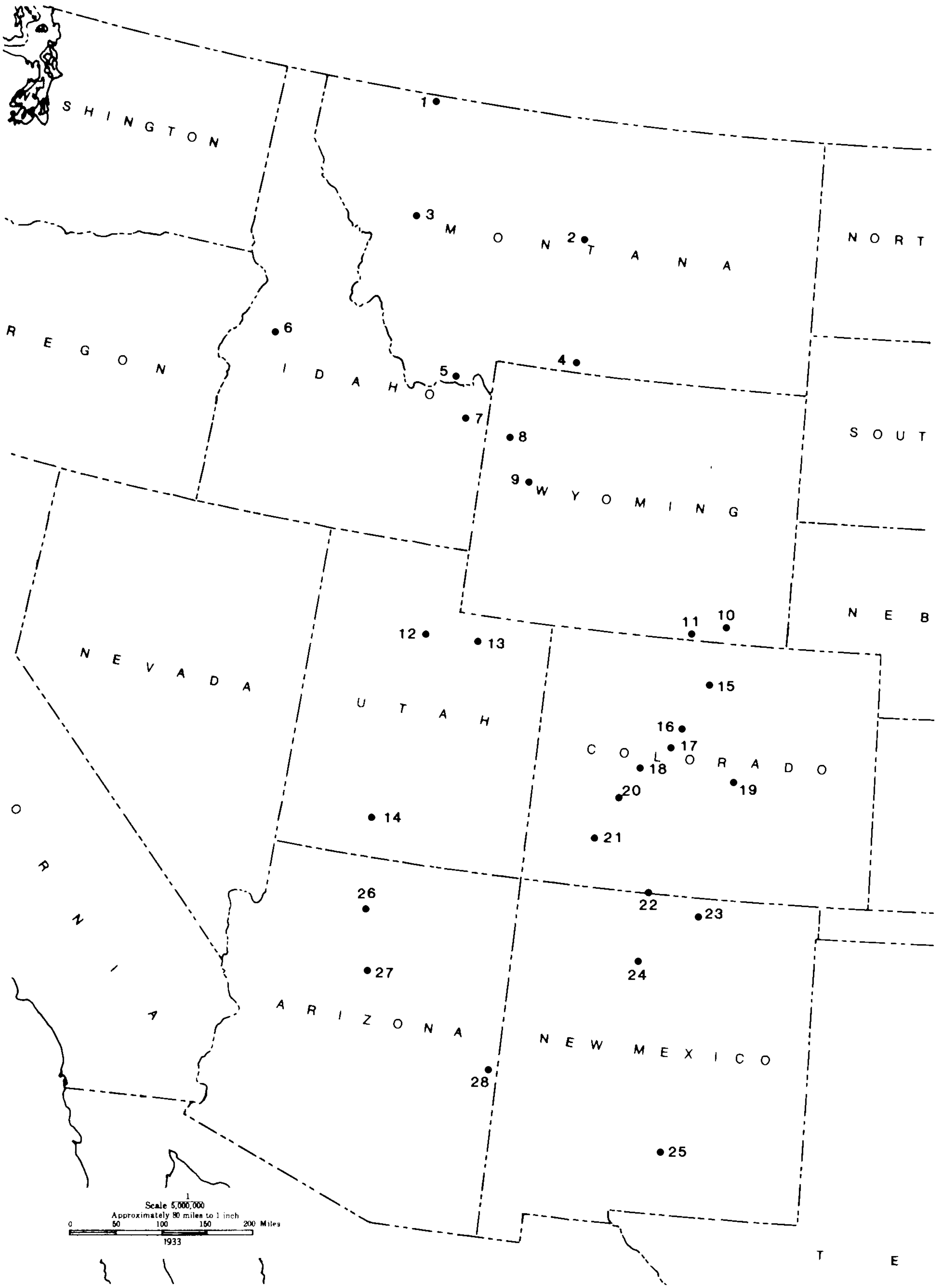

Figure 3.—Temperature stations listed in table 2.

Summary

Where there is adequate water, as in the eastern portion of its range, it appears that the southern boundary of aspen is near the 75°F (24°C) mean July isotherm. In the central Rocky Mountains, the lower elevational limit roughly coincides with a mean annual temperature of 45°F (7°C). Such relationships may not have a physiological basis, but are related to isolines that can be drawn on maps.

The range of aspen in the interior West, where much of the climate is semiarid, appears to be limited by water availability to satisfy the heavy evapotranspirational demands of the species rather than by any discernible temperature extreme or average. An average annual water runoff isopleth of at least 1 inch (3 cm) best describes the lower boundary in the mountainous West just as it does the western limits of aspen on the Great Plains (Perala, in press). Another isoline, the upper boundary, probably is best described by a combination of factors that limit the length of the growing season (temperatures, snowpack depths, radiation, etc.) and by wind.

The range of aspen probably is limited by a combination of factors; and, at any given site, it likely is limited by one or two critical climatic factors. Limits of soil moisture and extreme temperatures should be investigated first, when determining climatic restrictions to expansion of the range.

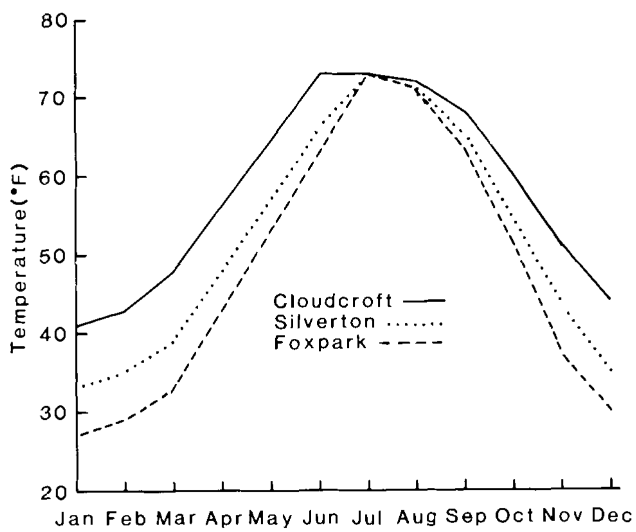

Figure 4.—Graph of average daily high temperatures for each month at stations at three different latitudes: Cloudcroft 1, New Mexico (32°58′N); Silverton 2 NE, Colorado (37°48′N); and Foxpark, Wyoming (41°05′N). The horizontal line at 56°F (13°C) is a hypothetical threshold temperature showing different lengths of growing seasons despite almost identical mid-summer temperatures.

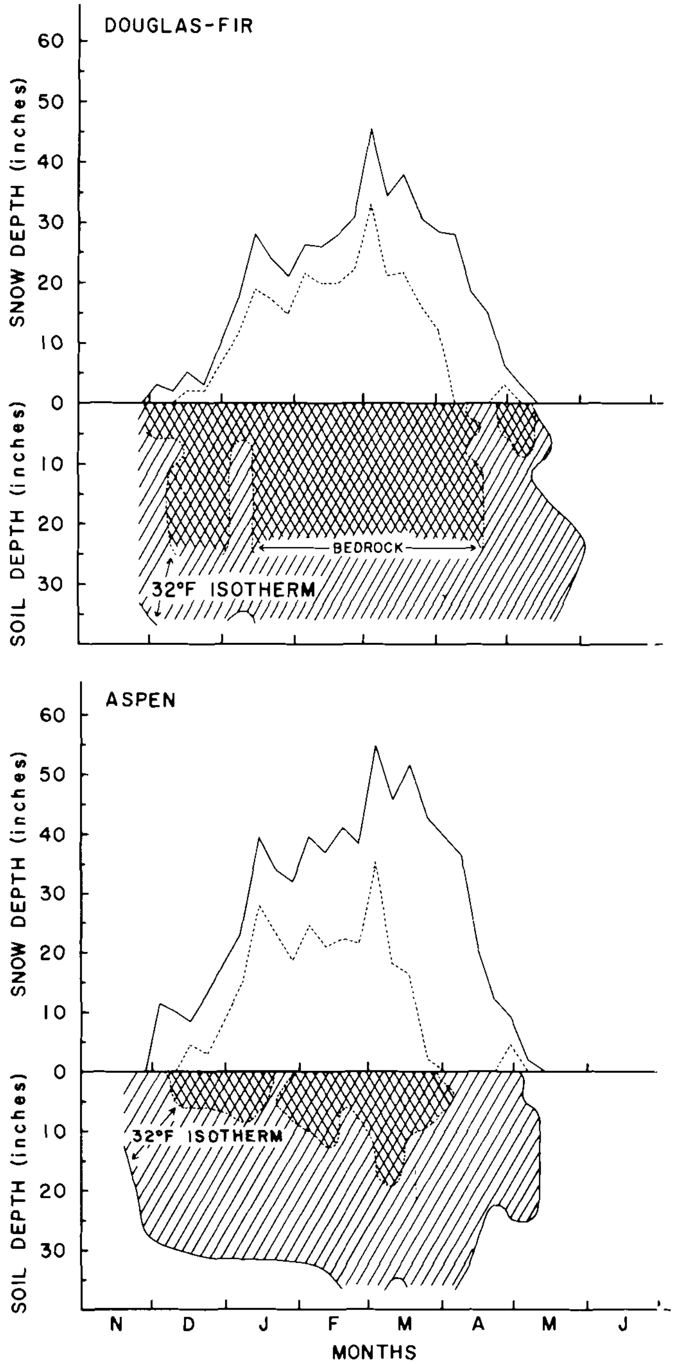

Figure 5.—Snow depth and 32°F (0°C) isotherms in the first 3 feet (1 m) of soil under aspen and Douglas-fir cover types on north and south aspects in northern New Mexico (Gary 1968).