# *Picea sitchensis* (Bong.) Carr. Sitka Spruce

## Pinaceae Pine family

**A. S. Harris**

Sitka spruce *(Picea sitchensis),* known also as tideland spruce, coast spruce, and yellow spruce, is the largest of the world's spruces and is one of the most prominent forest trees in stands along the northwest coast of North America. This coastal species is seldom found far from tidewater, where moist maritime air and summer fogs help to maintain humid conditions necessary for growth. Throughout most of its range from northern California to Alaska, Sitka spruce is associated with western hemlock *(Tsuga heterophylla)* in dense stands where growth rates are among the highest in North America. It is a valuable commercial timber species for lumber, pulp, and many special uses *(15,16).*

## Habitat

### Native Range

Sitka spruce (fig. 1) grows in a narrow strip along the north Pacific coast from latitude 61" N. in south-central Alaska to 39" N. in northern California. The most extensive portion of the range in both width and elevation is in southeast Alaska and northern British Columbia, where the east-west range extends for about 210 km (130 mi) to include a narrow mainland strip and the many islands of the Alexander Archipelago in Alaska and the Queen Charlotte Islands in British Columbia (24). North and west of southeast Alaska, along the Gulf of Alaska to Prince William Sound, the range is restricted by steep mountains and piedmont glaciers edging the sea. Within Prince William Sound, the range again widens to about 105 km (65 mi) to include many offshore islands. Westward, the range again narrows. It extends across Cook Inlet to Cape Kubugakli and across Shelikof Strait to the islands of the Kodiak Archipelago where the range continues to advance to the southwest.

In southern British Columbia, the range includes a narrow mainland strip and offshore islands, but the best development occurs on the northern tip and west side of Vancouver Island. On the east side of Vancouver Island and on the mainland south to Washington, the range tends to be restricted to sea-facing slopes and valley bottoms.

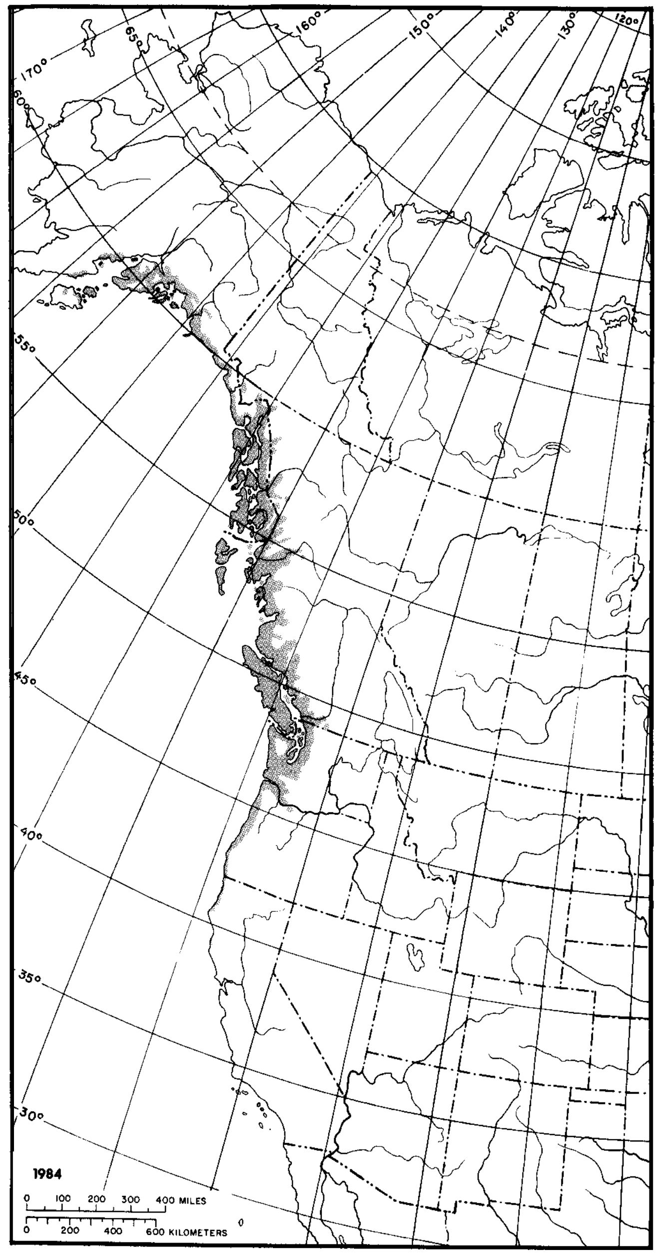


**Figure** ***l-The*** *native range of Sitka spruce.*

In Washington, the range includes a narrow mainland strip along the Strait of Georgia, around Puget Sound, up valleys to the east, and on the Olympic Peninsula. On the west side of the Olympic Peninsula, the range broadens to include the extensive

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coastal plain and seaward mountain slopes. It narrows southward along the Washington and Oregon coast but extends inland for several kilometers along the major rivers. In northern California, the range is more attenuated and becomes discontinuous. A disjunct population in Mendocino County, CA, marks the southern limit of the range.

## Climate

Sitka spruce is restricted to an area of maritime climate with abundant moisture throughout the year, relatively mild winters, and cool summers. Summer temperatures decrease northward and lack the extremes found in more continental locations. In terms of growing degree days, annual heat sums (based on a threshold of 5" C or 41" F) range from 2511" C (4,552" F) at Brookings, OR (lat. 41" 03' N.) to 851" C (1,564" F) at Cordova, AK (lat. 60" 30' N.) (8). The number of frost-free days varies locally but generally declines northward; averages range from about 294 days at Brookings, OR, to 111 days at Cordova, AK.

Annual precipitation varies within the range of Sitka spruce and is influenced greatly by local topography. Annual precipitation of 2950 mm (116 in) at Forks, WA, and 5615 mm (221 in) at Little Port Walter, AK, contrasts with 635 mm (25 in) at Anacortes, WA, and 660 mm (26 in) at Skagway, AK. Summer precipitation is greater toward the north, where light drizzle and fog are frequent. At Cordova, AK, from June to September, at least a trace of precipitation occurs during 22 to 24 days each month. In contrast, at Otis, OR, a trace or more of precipitation occurs on only 8 to 15 days each month. Toward the south, fog and moist maritime air are important in maintaining moisture conditions needed for growth; most winter precipitation is in the form of rain. Depth of snowfall increases northward. Average annual snowfall at sea level is 1 cm (0.5 in) at Brookings, OR; 58 cm (23 in) at Quatsino, BC; and 340 cm (134 in) at Cordova, AK.

## Soils and Topography

Sitka spruce grows on Entisols, Spodosols, Inceptisols, and Histosols, on soils derived from a wide variety of parent material. The species requires relatively high amounts of available calcium, magnesium, and phosphorus, and grows best where soils are derived from rocks rich in calcium and magnesium *(19)*. Best development is on deep, moist, well-aerated soils. Drainage is an important factor, and growth is poor on swampy sites. Sitka spruce commonly occupies alluvial soils along streams, sandy or coarse-textured soils, or soils having a thick accumulation of organic material. Soils are usually acidic, and pH values of 4.0 to 5.7 are typical. Spruce is an early pioneer on immature soils recently exposed by glacial retreat or uplift from the sea. It is more tolerant of ocean spray than are associated trees and often occupies a prominent position on exposed headlands and beaches along the outer coast (2). In Oregon and Washington, spruce follows lodgepole pine *(Pinus contorta)* in succession on coastal sand dunes as they become stabilized by vegetation. On highly disturbed sites, it frequently becomes established concurrently with red alder *(Alnus rubra)* or Sitka alder *(A. sinuata)*, gradually succeeding the alder as stands are eventually overtopped.

Sitka spruce grows from sea level to treeline in Alaska, at elevations ranging from 910 m (3,000 ft) in southeast Alaska to 300 m (1,000 ft) in Prince William Sound. High mountains of the coast ranges lie close to the sea, forming a barrier to moist, onshore winds and providing abundant moisture during the growing season. Spruce is limited in elevation by the short growing season at treeline. South of northern British Columbia, spruce is restricted to low elevations near the sea where moist maritime air and fog help provide moisture during summer. For the most part, high mountains that otherwise might offer suitable habitat lie farther inland where more continental conditions of summer drought and warmer temperatures are unsuitable for growth. Exceptions are on the Olympic Peninsula and in valleys in the Cascade Range off Puget Sound in Washington, and on isolated peaks in Oregon. On the Olympic Peninsula, Sitka spruce rarely grows above 610 m (2,000 ft) in elevation *(1)*.

## Associated Forest Cover

Sitka spruce is commonly associated with western hemlock throughout most of its range (fig. 2). Toward the south, other conifer associates include Douglas-fir *(Pseudotsuga menziesii)*, Port-Orford-cedar *(Chamaecyparis lawsoniana)*, western white pine *(Pinus monticola)*, and redwood *(Sequoia sempervirens)*. Shore pine *(P. contorta* var. *contorta)* and western redcedar *(Thuja plicata)* are also associates that extend into southeast Alaska. Toward the north, conifer associates also include Alaska-cedar *(Chamaecyparis nootkatensis)*, mountain hemlock *(Tsuga mertensiana)*, and subalpine fir *(Abies lasiocarpa)*—trees that are usually found only at higher elevations toward the south. In central and northern British Columbia and Alaska, however, these species are found with Sitka spruce from sea level to timberline. White spruce *(Picea glauca)* is also associated with Sitka spruce in Alaska, and hybrids occur. The most important hardwood associates are red alder and bigleaf maple *(Acer macrophyllum)* in the south and red alder and Sitka alder toward the north. Black cottonwood *(Populus trichocarpu)* is an associate throughout the range.

Stands stocked with at least 80 percent Sitka spruce are identified as the forest cover type Sitka Spruce (Society of American Foresters Type 223) *(6)*. Sitka spruce is also a component of 10 other forest cover types:

221 Red Alder
222 Black Cottonwood-Willow
224 Western Hemlock
225 Western Hemlock-Sitka Spruce
227 Western Redcedar-Western Hemlock
228 Western Redcedar
229 Pacific Douglas-Fir
230 Douglas-Fir-Western Hemlock
231 Port-Orford-Cedar
232 Redwood

**Figure 2**—*Sitka spruce about 200 years old in an even-aged western hemlock—Sitka spruce stand near Ketchikan, AK. Average diameter of spruce is 91 cm (36 in); average diameter of hemlock, 56 cm (22 in).*

Sitka spruce usually grows in mixed stands, less often in pure stands. Pure stands usually occur in early successional situations and as tidewater stands influenced by salt spray. The most extensive pure stands are found on the Kodiak-Afognak Archipelago at the extreme west extension of the range. Sitka spruce is the only conifer present on this group of islands. A relatively recent invader there, spruce is expanding its range to the southwest, invading a tundra complex at the rate of about 1.6 km (1 mi) per century *(14)*.

In Oregon and Washington, common understory species associated with Sitka spruce include swordfern *(Polystichum munitum)*, Oregon oxalis *(Oxalis oreganu)*, false lily-of-the-valley *(Maianthemum dilatatum)*, western springbeauty *(Montiu sibiricu)*, three-leaved coolwort *(Tiarella trifoliutu)*, evergreen violet *(Viola sempervirens)*, stream violet *(V. glabella)*, Smith fairybells *(Disporum smithii)*, red huckleberry *(Vaccinium purvifolium)*, and rustyleaf menziesia *(Menziesiu ferrugineu)*. On drier sites, salal *(Guultheriu shallon)*, Pacific rhododendron *(Rhododendron mucrophyllum)*, and evergreen huckleberry *(Vaccinium ovutum)* are common. On wetter forest sites, the previously mentioned species are found, along with devilsclub *(Oplopunax horridurn)*, ladyfern *(Athyrium filix-femina)*, deerfern *(Blechnum spicunt)*, mountain woodfern *(Dryopteris uustriucu)*, and Pacific red elder *(Sumbucus callicarpa) (11)*.

In Alaska, the more common understory plants include devilsclub, skunkcabbage *(Lysichitum americanurn)*, ovalleaf huckleberry *(Vaccinium ovulifolium)*, red huckleberry, Alaska blueberry *(V. alaskaense)*, rustyleaf menziesia, salmonberry *(Rubus spectubilis)*, five-leaf bramble *(R. pedutus)*, thimbleberry *(R. parviflorus)*, bunchberry *(Cornus cunudensis)*, stink currant *(Ribes bructeosum)*, and trailing black currant *(R. laxiflorum) (32)*. Cryptogams are abundant throughout the range of Sitka spruce. The Olympic Peninsula is especially noted for mosses, many of which occur as epiphytes on living trees.

In Oregon and Washington within the Sitka spruce forest zone, important plant communities include *Tsugu heterophyllu-Piceu sitchensis /Gaultheria shallon / Blechnum spicunt, Tsugu-Piceu / Oplopunux horridum /Athyrium filix-femina,* or *Tsugu-Piceu /Polystichum munitum–Oxalis oregunu (11)*. Similar communities can be found in southern British Columbia within the "fog western hemlock/Sitka spruce subzone" (23). In Alaska, some of the more common communities include *Picea sitchensis / Oplopanax horridum–Rubus spectabilis / Cornus canadensis, Picea sitchensis-Tsuga heterophylla / Lysichiton americanum / Sphagnum* spp., and *Tsuga heterophylla-Picea sitchensis–(Thuja plicata) / Vaccinium ovalifolium–V. alaskaense / Rhytidiadelphus loreus (32).*

## Life History

### Reproduction and Early Growth

**Flowering and Fruiting-Individual** Sitka spruce may occasionally produce cones before 20 years of age, but cone bearing in stands usually does not begin until ages 20 to 40 (24). Sitka spruce is monoecious; female strobili (cones) are usually produced at the ends of primary branches near tops of trees; male strobili are usually produced at the ends of secondary branches lower in trees. Both may be on the same branch. Reproductive buds are initiated in early summer of the year preceding pollination and seed ripening, and heavy cone crops have been explained in terms of early summer drought the preceding year. Cones ripen in the year they were pollinated. Pollen is shed from the last week in April in the southern portion of the natural range through early June in the extreme northwest part of the range. Time of flowering is mainly related to temperature.

**Seed Production and Dissemination-Seeds** of Sitka spruce are small, averaging 463,000/kg (210,000/lb) (26). Seeds ripen in southeast Alaska during late August or early September, and dispersal usually begins in October. Cones open during dry weather, release seed, and reclose during wet weather. One study showed that 73 percent of the seed was released within 6 weeks of the first dispersal date, and the remainder was released over 1 year *(15).* Good crops occur at 3- to 5-year intervals in the southern part of the range and at 5- to 8-year intervals in Alaska. Cone and seed production in seed orchards can be increased by treating trees with gibberellin *(31).* Dispersal distance depends on several factors, including height and location of the seed source, local topography, and wind conditions. Reported dispersal distances range from 0.8 km (0.5 mi) when a seed source was on high ground, to 30 m (100 ft) when seed was released from the edge of a clearcut area *(15).*

**Seedling Development-Under** natural conditions, seed germinates on almost any seedbed, but survival may be low. Germination is epigeal (26). A mineral soil or mixed mineral and organic soil seedbed is usually considered best for germination, especially under light shade, as long as drainage is adequate and the soil provides sufficient nutrients for tree growth. Fine-textured soils combined with a high water table are suitable for germination but may be unsuitable for seedling establishment because of frost heaving. Coarse-textured mineral soils in unshaded conditions may dry out excessively but may improve after invasion by hair mosses that bind the soil surface and provide shade. Organic seedbeds are suitable in shade but are unsuitable in the open if subject to severe moisture fluctuations. On alluvial sites having high water tables and subject to frequent flooding, where competition from brush is severe, rotten wood may be the only suitable seedbed.

**Vegetative Reproduction-Asexual** reproduction by layering occurs under natural conditions and in plantations, but layering is most likely to occur on very moist sites at the edges of bogs or near timberline. Asexual propagation can be done by air-layering or rooting of stem cuttings. Clones differ in their ability to root or graft, and clones that graft easily do not necessarily root easily and vice versa. Cuttings from shoots of the current year root more easily than cuttings from older branches *(15).*

### Sapling and Pole Stages to Maturity

**Growth and Yield-Height** growth is slow for the first few years but increases rapidly thereafter (fig. 3). On average sites in southeast Alaska, trees can be expected to reach about 27 m (90 ft) in height within 50 years after attaining breast height (7). Average site index at elevations near sea level varies inversely with latitude, declining from 48 m (158 ft) at base age 100 years in Lincoln County, OR, to 33 m (108 ft) in southeast Alaska, at the rate of about 1 m (3 ft) per degree of latitude *(8).* Observations within the natural range of spruce show that growth rate also declines with increasing elevation.

Height growth of Sitka spruce and western hemlock are nearly equal during the period of most rapid growth, but spruce grows more rapidly in diameter. Consequently, thinning from below tends to favor spruce. Spruce continues to maintain height growth longer than hemlock and lives longer. Few hemlock live more than 500 years; Sitka spruce may live to 700 or 800 years. Very old spruces eventually assume a dominant position in old-growth hemlock-spruce stands.

Sitka spruce trees often attain great size. In Alaska, mature trees near sea level may exceed 61 m (200 ft) in height and 3 m (10 ft) in d.b.h. In Oregon, a tree 87 m (286 ft) tall was reported (24). The largest tree on record is located near Seaside, OR. It is 5.1 m (16.7 ft) in d.b.h. and 65.8 m (216 ft) tall and has a crown spread of 28 m (93 ft) *(17).*

Stands in which Sitka spruce is a major component tend to be dense, and yields are high *(21,30).* Stand volumes can be impressive. One plot in a 147-year-old hemlock-spruce stand in coastal Oregon contained, on an area basis, 188 spruce and 32 hemlock/ha (76 spruce and 13 hemlock/acre). Total volume was 2380 $m^3$/ha (34,000 $ft^3$/acre). Spruce averaged 64 m (210 ft) in height and 86 cm (34 in) in d.b.h., and hemlock averaged 44 m (144 ft) in height and 46 cm (18 in) in d.b.h (24).

**Figure** *S-Natural regeneration of Sitka spruce 10 years after a western hemlock-Sitka spruce stand was clearcut in Maybeso Valley, southeast Alaska.*

**Rooting Habit-Roots** will grow where moisture, fertility, aeration, and mechanical soil properties are favorable. Consequently, there is great variability in root form-from flat platelike roots to deep, narrow-spreading roots *(12).* Where soils are shallow, soil temperature and fertility low, and water tables high, shallow rooting is by far the most common form. Deeper rooting does occur, however, where soils have good drainage and depth to water table. Rooting to depths of 2 m (6 ft) has been reported *(5).*

Sitka spruce commonly produces long lateral roots with few branches and rapid elongation (20). Annual elongation rates of 42 to 167 cm (16 to 66 in) have been reported *(3).* Lateral roots up to 23 m (75 ft) in length have been observed in Alaska *(15).* Root grafting occurs between roots of the same tree and between adjacent trees. It is fairly common to find living stumps sustained by root grafts from adjacent trees. Adventitious roots develop on trees growing along streams where alluvium is deposited by periodic flooding. Roots are vulnerable, however, to compaction and lack of aeration. Spruce are frequently killed by permanent flooding caused by beavers, and often valuable ornamental and roadside trees are killed when landfill is deposited around them. Containerized nursery stock has been successfully inoculated with the mycorrhizal fungi, *Laccaria laccata* and *Cenococcum geophilum (29).*

**Reaction to Competition—**Sitka spruce is more tolerant of shade than Douglas-fir but less tolerant than hemlock. Depending on latitude, Sitka spruce has been described as being in the tolerant and intermediate shade-tolerant classes. Overall, it probably can most accurately be classed as tolerant of shade. Since reproduction under mixed stands is predominantly hemlock, there is a tendency for this more tolerant species to eventually dominate the site. Few climax stands proceed to pure hemlock, however; in time, small openings, usually caused by blowdowns, develop, allowing reproduction of spruce. The combination of greater stature, greater longevity, and occasional stand disturbance is enough to assure a scattering of spruce in the overstory of most climax hemlock-spruce stands (fig. 4).

Sitka spruce is one of the few conifers that develop epicormic branches along the stem. Production of these sprouts is related to light intensity, and roadside trees often develop dense new foliage from base to crown. Thinning stimulates epicormic branching and could decrease the quality of the wood, although this is not a problem in production of pulp or dimension lumber. In deep shade, lower limbs soon die, decay, and break off, but the resinous branch stubs remain for many years.

**Damaging** Agents-Blowdown is probably the most serious damaging agent of Sitka spruce, but the species is attacked by a number of pests-insects, disease organisms, and animals. In general, problems tend to be more severe toward the south. The white pine weevil *(Pissodes strobi)* is the most serious insect pest in Oregon, Washington, and southern British Columbia; weevil damage has been the most serious deterrent to management of Sitka spruce in the southern part of its range. Damage is most severe on young trees 3 to 6 m (10 to 20 ft) tall. The weevil is not a problem on the Queen Charlotte Islands or in Alaska, possibly because there is insufficient summer heat to allow its development (22). The spruce aphid *(Elatobium abietinum)* feeds on Sitka spruce from California to Alaska and is a pest of ornamental trees. Epidemics are sporadic and short lived. A root-collar weevil *(Steremnius carinatus)* girdles 1- and 2-year-old seedlings, causing some losses. The spruce beetle *(Dendroctonus rufipennis)* periodically damages stands throughout the range and is a major pest of spruce in British Columbia. In addition, damage from a number of defoliators and other insects is common (13).

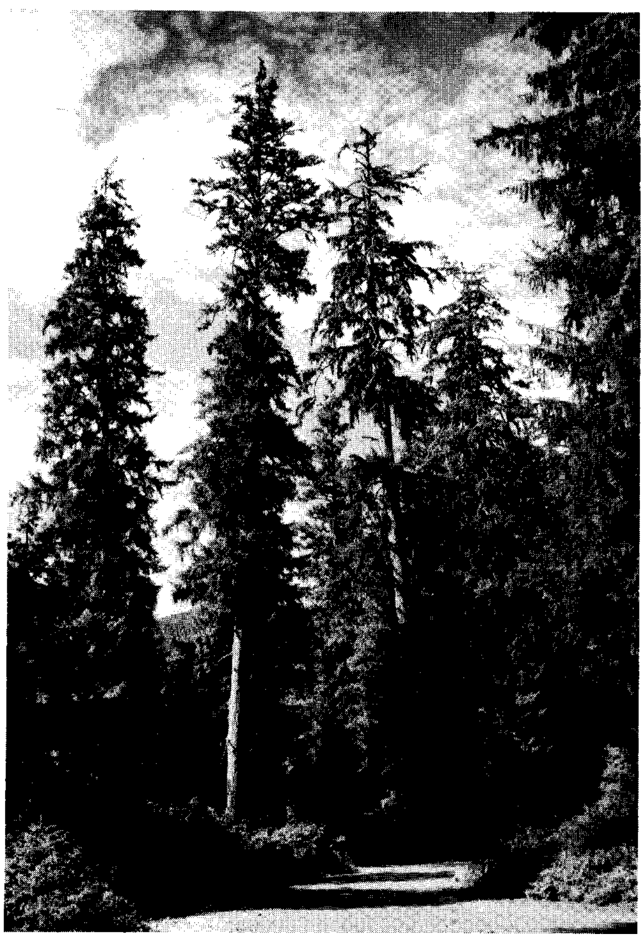

**Figure 4**—*Sitka spruce trees, north of Ketchikan, AK, 46 m (150 ft) tall and 1.8 to 2.1 m (6 to 7 ft) in d.b.h.*

Sitka spruce is highly susceptible to decay when injured (18). In the past, most emphasis has been on studies of decay in old-growth stands, but currently interest is shifting to young, managed stands. Some of the organisms causing decay in old growth (for example, *Heterobasidion annosum* and *Armillaria mellea)* can also cause root rot in young stands. *Heterobasidion annosum* infects freshly cut stump surfaces, and in Europe the tendency for plantation-grown Sitka spruce to develop *H. annosum* butt rot is well known.

Foliage and stem diseases are usually of minor importance. Several rusts cause occasional light to moderate defoliation, witches' brooms, or loss of cones. Seed and seedling diseases are probably most important in production of containerized seedlings in greenhouses.

Sitka spruce is damaged at various locations by animals such as elk, bear, deer, porcupines, rabbits, hares, and squirrels. In general, these problems are more serious in the southern part of the range. Deer are generally more troublesome in the southern part, porcupines in the northern part (25). Spruce is often less damaged than its associates.

Few growth abnormalities have been reported, although large tumorlike growths on stems have been reported in Washington, and they occur in Alaska as well. The causal agent is not known.

## Special Uses

High strength-to-weight ratio and resonant qualities of clear lumber are attributes that have traditionally made Sitka spruce wood valuable for specialty uses, such as sounding boards for high-quality pianos; guitar faces; ladders; construction components of experimental light aircraft; oars, planking, masts, and spars for custom-made or traditional boats; and turbine blades for wind energy conversion systems.

## Genetics

In addition to the clinal latitudinal difference in growth rate, cone characteristics such as size, length-to-width ratio, angle of sterigma, and phylotaxy also vary with latitude (4).

Variation in wood characteristics has been reported by provenance, region, site, and individual trees. Although no comprehensive heritability studies have been completed, Sitka spruce shows considerable variation in wood density, tracheid length, and grain angle. Improvement in these characteristics through breeding appears feasible. Selection for vigor tends to favor trees of lower-than-average specific gravity but has no effect on tracheid length *(15).*

Provenance studies show that-at a given planting site-northern, inland, and high-elevation sources are the first and the most variable in breaking dormancy. Dormancy appears to be influenced by photoperiod, and northern provenances are the first to enter dormancy. Total seasonal height growth is positively correlated with the time interval between flushing and dormancy. When moved north, introduced southern sources make better height growth, but they may be subject to frost damage if moved too far or planted on exposed sites. Once dormant, Sitka spruce is able to endure very low temperatures without damage. Sitka spruce from northern provenances may be more resistant to freezing than those from southern provenances. Dormant leaves from a Bellingham, WA, source withstood temperatures to -30" C (-22" F), whereas a Juneau, AK, source withstood temperatures to -40" C (–40° F). Twigs of the two sources withstood temperatures to -40" C and –60° C (–40° F and -76" F), respectively *(27).*

Only limited data are available on genetic variation between individual trees. Assessment of first-year characteristics of progeny from a diallel cross among six trees showed that characters affecting tree form were inherited in a predominantly additive fashion; characters reflecting tree vigor were under "additive, dominance, and maternal control" (28). Self-pollinated progeny showed growth depression caused by inbreeding (28).

### Population Differences

Biochemical variation between populations of Sitka spruce from various parts of its natural range has been studied for polyphenols, isoenzymes, and terpenoids. Differences in polyphenol concentrations have been found between different origins, and a high degree of variation in monoterpene concentrations has been shown between trees in stands and by stand origin. Polyphenol, isoenzyme, and terpenoid analyses have been used in studying the introgression between Sitka spruce and white spruce (9).

Variation is known to occur within the cell nucleus. The length of the haploid complement and the nuclear volume increase with latitude of seed origin. Seeds from northern sources have more DNA per cell than those from southern provenances. Supernumerary (B) chromosomes have been found in seeds from eight provenances *(15).*

Genetic tree improvement programs are progressing in Britain and in Denmark. In North America, efforts toward tree improvement have been concerned primarily with developing procedures for control of indiscriminate transfer of seeds and plant materials. Efforts are being made to locate plus-trees, primarily by private industrial forest organizations, and seed orchards are being established.

### Hybrids

A natural hybrid between Sitka spruce and white spruce ***(Picea x lutzii*** Little) occurs in the Skeena River Valley, BC, and on the Kenai Peninsula, AK. The hybrid shows some resistance to the white pine weevil. Sitka spruce is also known to cross with Yezo spruce ***(Picea jezoensis),*** Serbian spruce *(P. omorika),* and Engelmann spruce *(P. engelmannii)* ***(33).*** The cross black spruce ***(Picea mariana*** x Sitka spruce) on black spruce strobili has yielded viable seed. Crossability averaged 5 percent; this low average suggests that black spruce does not share the same phylogenetic relationship with the more easily crossed Sitka, white, and Engelmann spruces *(10).*

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