# *Taxus brevifolia* Nutt. Pacific Yew

**Taxaceae Yew family**

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Pacific yew *(Taxus brevifolia)*, also called western yew, is a coniferous tree associated with several conifer and hardwood tree species on a variety of sites. Pacific yew tolerates shade, and in undisturbed stands is usually found as an understory tree. Growth of such trees is slow, but where the overstory has been removed or thinned, diameter growth on undam aged yew trees may increase considerably. Pacific yew rarely exceeds 60 cm (24 in) in d.b.h., and 15 m (49 ft) in height. The largest on record is 142 cm (56 in) in d.b.h., and 18 m (60 ft) in height (28). The wood is hard, heavy, and resistant to decay. Although not of great interest to the forest products industry, it has many special uses. The bark of Pacific yew contains a drug, taxol, that is being used in cancer research, so demand for yew bark by the National Cancer Institute has increased dramatically in recent years (9).

## Habitat

### Native Range

Pacific yew (fig. 1) grows in forests from the southern tip of southeast Alaska-including Annette and Prince of Wales Island-south through the Pacific Coast region of British Columbia, Vancouver and the Queen Charlotte Islands, and the Olympic Peninsula of Washington. It is rare in the Coast Range south of the Olympic Peninsula in Washington and north of the Umpqua River in Oregon, but occurs with greater frequency in the Coast Range in southern Oregon and northern California. Isolated occurrences are found as far south as Marin and San Mateo Counties in California. Yew occurs in scattered localities in the valleys between the Coast Range and Cascade Ranges of Oregon and Washington. In the Cascade Range, it is fairly common at low to moderate elevations, and on some sites in southern Oregon it is abundant. Pacific yew extends south through the Klamath Mountains of California, then southeasterly to the western slopes of the Sierra Nevada. Its southern limit is in Calaveras County. Farther inland, it grows on the western slopes of the Rocky Mountains in British Columbia, south into northern Idaho and western Montana, the Lewis Range in Montana, and isolated areas in eastern Washington and northeastern Oregon. In the South Fork of the Clear-water River basin in Idaho, Pacific yew deviates from its role as a minor forest component and becomes a dominant on about 16 000 hectares (40,000 acres) *(8,19,20,27,30,31,35,40,42,43, 44,47,49)*.

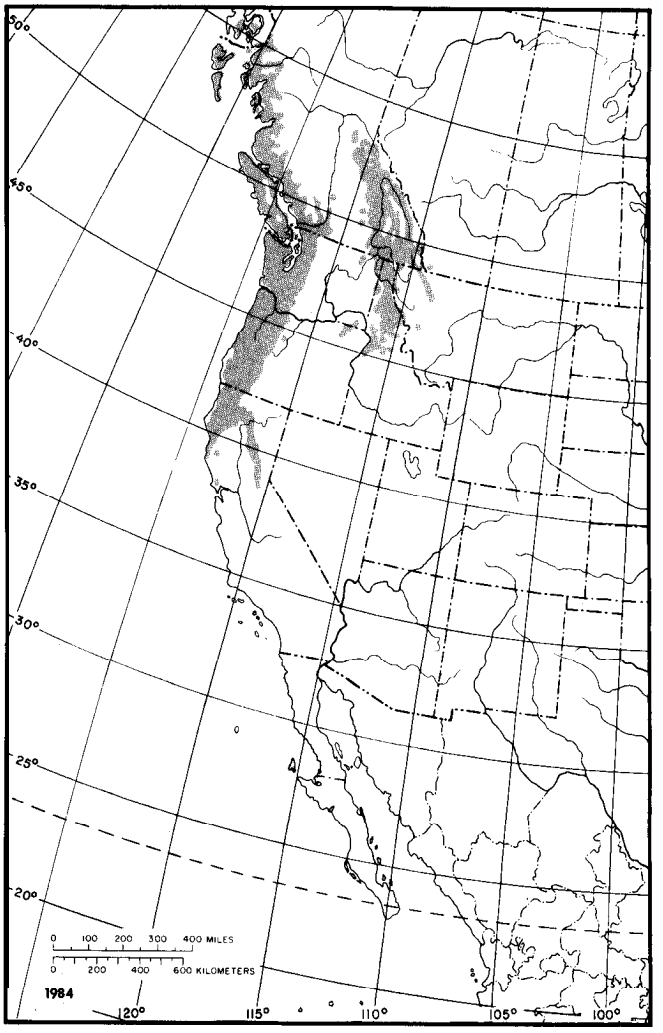


**Figure** *1-The native range of Pacific yew.*

### Climate

Pacific yew is found over a wide range of moisture and temperature conditions *(8,11,19,35,40,44)*. In dry, subhumid areas with an average annual precipitation as low as 470 mm (19 in), it is confined to

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**Figure 2**—*Understory of Pacific yew trees, Wind River Research Natural Area near Carson, WA.*

streamside areas and the lower third of north-facing slopes. Some large specimens can be found in such environments; for example, the largest known yew tree in Idaho-848 cm (33.4 in) d.b.h. and 8.5 m (28 ft) tall-is at the bottom of Hell's Canyon in an area that receives about 500 mm (20 in) of precipitation annually *(21).* On the Queen Charlotte Islands, Pacific yew is confined to the borders of inlets *(44).* Throughout much of its range within humid and superhumid forests (precipitation of 1400 to 4000 mm [55 to 157 in]), it can be found on all slopes, benches, and ridgetops. For example, a large yew tree in Oxbow County Park near Troutdale, Oregon (precipitation about 1450 mm [57 in]), is on the highest point in the park, a 210-m (690-ft) ridge overlooking the Sandy River 168 m (550 ft) below *(3).* Pacific yew is found from sea level in coastal areas to 2440 m (8,000 ft) in the Sierra Nevada. Length of growing season ranges from 60 to 300 days, with annual minimum temperatures from -15" to -12" C (5° to 10" F) *(4,8,11,24,25,35,45).*

### Soils and Topography

Pacific yew grows best on deep, moist or rich, rocky or gravelly soils. In dry interior forests, the species develops best along mountain streams, and in shady canyons, ravines, and coves. Within the moist maritime climate of the Pacific Northwest, it grows most abundantly in drier, warmer environments. A partial list of soils on which Pacific yew grows includes those in the orders Ultisols, Alfisols, and Inceptisols *(4,11,20,24,25,27,30,37,45,50).*

### Associated Forest Cover

Pacific yew commonly occurs as an understory species (fig. 2) in several forest cover types. It is a major component in some stands, but in most it is minor to rare. In some types, it tends to be found mostly on microsites. Some examples: In stands of ponderosa pine *(Pinus ponderosa),* grand fir *(Abies grandis),* and western larch *(Larix occidentalis)* in the drier interior forests, yew is found in moist areas near streams and springs (but on well drained soil); on wet, hummocky sites west of the Cascades, yew can be found in Oregon white oak *(Quercus garryana)*—Oregon ash *(Fraxinus latifolia)* stands (ash occupies the low, wet spots and yew grows with the oak on slightly raised hummocks); scattered large yew trees grow along the Clackamas River in northwest Oregon on berms and banks between first and second bottomlands in stands of black cottonwood *(Populus trichocarpa),* red alder *(Alnus rubra),* hawthorn *(Crataegus* spp.), crab apple (*Malus* spp.), and willow (*Salix* spp.) *(3,47).* By far, Pacific yew is most common in dense conifer forests. Among the major Society of American Foresters (16) cover types in which Pacific yew is found are: Engelmann Spruce-Subalpine Fir (206), Interior Douglas-Fir (210), White Fir (211), Grand Fir (213), Black Cottonwood-Willow (222), Western Hemlock (224), Western Redcedar-Western Hemlock (227), Western Redcedar (228), Pacific Douglas-Fir (229), Douglas-Fir-Western Hemlock (230), Port-Orford-Cedar (231), Redwood (232), Oregon White Oak (233), Douglas-Fir-Tanoak-Pacific Madrone (234), Sierra Nevada Mixed Conifer (243), and Pacific Ponderosa Pine-Douglas-Fir (244) *(4,8,11,17,24,25,35,45,47).*

In western Oregon, Douglas-fir was present on 89 percent of the forest inventory plots in which yew was tallied. A list of plants found most frequently with Pacific yew on these plots (table 1) indicates the broad range of conditions to which the species can adapt.

## Life History

### Reproduction and Early Growth

**Flowering and Fruiting-Pacific yew** is dioecious. Male strobili are stalked, budlike, pale yellow, and composed of 6 to 12 filamentous stamens, each with 5 to 9 anthers. They are abundant on the un-

**Table** l-Plants frequently found on plots with Pacific yew present, western Oregon.

| Species | Percentage of plots | Indicator value [1/] |
|---|---|---|
| *Pseudotsuga menziesii* | 89 | Common |
| *Berberis* nervosa | 75 | Common |
| *Polystichum munitum* | 75 | Mesic, common |
| *Acer circinatum* | 70 | Common |
| *Tsuga heterophylla* | 59 | Cool, common |
| *Gaultheria shallon* | 59 | Warm, mesic to dry |
| *Corylus* cornuta var. *californica* | 43 | Warm, dry |
| *Acer macrophyllum* | 39 | Warm |
| *Vaccinium parvifolium* | 39 | Warm, common |
| *Thuja plicata* | 36 | Moist, common |
| *Alnus rubra* | 36 | Warm, moist |
| *Rhododendron macrophyllum* | 34 | Cool, mesic |
| *Cornus nuttallii* | 32 | Warm, dry |
| *Holodiscus discolor* | 27 | Hot, dry |
| *Linnaea borealis* | 27 | Mesic |
| *Arbutus menziesii* | 25 | Warm, dry |
| *Abies grandis* | 23 | Warm, dry |
| *Xerophyllum tenax* | 23 | Cool, dry |
| *Rhus diversiloba* | 20 | Hot, dry |
| *Oxalis* oregana | 20 | Warm, moist |

"Based on information from 4.24, and 45.

derside of branch sprays and usually appear in May or June. Female strobili are less abundant, greenish, and composed of several scales. They also are borne on the underside of branches. The fruit is an ovoid-oblong seed about 8 mm (0.3 in) long, partially enveloped by a fleshy, berrylike, scarlet, cup-shaped disk called an aril. Pollen is dispersed by wind in the spring *(6,11,19,22)*.

**Seed Production and Dissemination-Fruits** ripen from August to October of the same year that flowering occurs. Fruits either drop to the ground or are taken from trees by birds or rodents. Birds devour the fleshy arils and void the seeds which remain viable. Chipmunks and squirrels often take only the seeds. Rodents and some birds-nuthatches, for example-cache yew seeds, thus creating the clusters of yew seedlings observed in some areas *(11)*. The seed is about 6 mm (0.24 in) long with a depressed hilum, bony inner coat, and membranous outer seedcoat. Pacific yew is a prolific seeder *(19,43)*. Seeds average about 33,100/kg (15,000/lb) after cleaning (39). The frequency of good seed crops is unknown.

**Seedling Development-Seeds** of Pacific yew germinate slowly and require stratification. Germination tests indicate that 30" C (86" F) day and 20" C (68" F) night temperatures are desirable *(11,19,43)*. Germination is epigeal, and usually in heavy organic matter. In a study in Idaho, wild yew seedlings were distributed in seedbeds as follows *(11)*:

| Type of seedbed | Percentage of seedlings |
|---|---|
| Forest litter | 61 |
| Decaying wood | 20 |
| Bird and rodent caches | 16 |
| Mineral soil | 3 |
| | 100 |

Yew seeds sown in nursery beds in late spring require mulching. Beds require shading during the summer and again in December. Some seeds do not germinate until the second spring after sowing (39).

**Vegetative Reproduction-Pacific yew** is capable of layering and often sprouts from stumps or rootstocks after the top has been killed or the tree cut *(3,11,23,44)*. Layering usually occurs after branches or tree tops have been pressed to the ground for a prolonged period by large fallen trees or limbs (11), although occasional old yew trees can be found surrounded by a ring of well rooted branches that were apparently held down only by their own weight and the weight of snow in the winter.

Although Pacific yew is sensitive to heat *(11,26,44)*, sprouts that originated from the bases of burned stumps were reported from the Rogue River National Forest in southern Oregon (23). Young yew trees that originated by layering and sprouting were observed in a sunny, south-facing clearcut on the Mount Hood National Forest in northern Oregon. From one cut yew tree with a stump diameter of 30 cm (12 in), seven new trees had originated by layering before cutting, and a clump of vigorous stump sprouts had originated after cutting. Sprouts emerged from one side of the 36-cm-high (14 in) stump (the opposite side had been debarked during logging) from ground level to the top. The layers were 1.0 m to 2.5 m (3 ft to 8 ft) from the stump. Most of the layers had been damaged by logging and lacked the vigor of the stump sprouts (3).

### Sapling and Pole Stages to Maturity

**Growth and Yield-Pacific yew,** unlike most woody plants that grow in heavily shaded forest understories, often has a straight bole (see fig. 2). Although yew trees are reported to have typically fluted, ridged, and asymmetrical trunks, often with tightly spiraled grain *(6,11,23,37,44)*, yew cutters in southwest Oregon reported that many yew trunks were round and unfluted above the base section, and

straight-grained (7). Large limbs are common in the mid and upper bole. The crown tends to be ragged and lopsided. Pacific yew "reaches" for light by way of limbs that may be as long as the tree is tall. Young trees often have an umbrella-shaped crown of flat branches, and old trees have long drooping spraylike branches. Pacific yew is sometimes shrublike, forming dense thickets. In western Montana, parts of Idaho, northeastern California, the Blue Mountains of eastern Oregon and southeastern Washington, and at high elevations throughout its range, the shrub form of yew often occurs in the absence of tree-size specimens *(3,8,10,11,20,27,30,31,35,44,49,50)*. In other areas, large tree-size yews may occasionally be found in or near yew shrub thickets (3). Whether the differences in size and form are genetic traits or the results of environment and stand history is not known.

The needles of Pacific yew are dark green on the underside, two ranked, and spirally arranged on twigs. The bark is purplish, papery thin, and scalelike. New bark is rose red *(6,19,22,40)*. The wood is fine grained, hard, and heavy: at 712 kg/m$^3$ (about 44 lb/ft$^3$) (8 percent moisture content), it is the heaviest of U.S. conifers, comparable in weight to high-density hardwoods such as ash, oak, and hard maple (46). Heartwood is red to brownish red, and sapwood is whitish yellow to bright yellow.

Pacific yew grows slowly, taking about the same time to grow to 30 cm (12 in) in d.b.h. as other conifers in the same stand take to grow to several times that size. Height growth is correspondingly slow. Trees larger than 50 cm (20 in) in d.b.h. and taller than 12 m (40 ft) are rare within most of the species' range: they account for less than 2 percent of the yew trees tallied on inventory plots on non-Federal land in California, Oregon, and Washington. The following tabulation shows average height by diameter class as determined from 55 Pacific yew trees randomly selected in Oregon and Washington **(47):**

| D.b.h. | Total height |
|---|---|
| 10 cm (4 in) | 6 m (20 ft) |
| 20 cm (8 in) | 8 m (26 ft) |
| 30 cm (12 in) | 10 m (31 ft) |
| 40 cm (16 in) | 11 m (37 ft) |
| 50 cm (20 in) | 13 m (43 ft) |
| 60 cm (24 in) | 15 m (49 ft) |

Because of the slow growth of individual trees and because the species is typically found as an occasional tree in stands of other tree species, volumes and yields of Pacific yew are low. Stands with 125 yew trees/ha (50/acre) that are 20 cm (8 in) in d.b.h. and larger have been observed, but always in association with other species (3). The theoretical volume of yew wood in such stands could be as much as 140 m$^3$/ha (2,000 ft$^3$/acre), including the volume in main stems from ground level to tip. The greatest volume of Pacific yew found in randomly located plots on non-Federal land in California, Oregon, and Washington was 28 m$^3$/ha (400 ft$^3$/acre) (47). These are gross volume estimates. Because heart rot is prevalent in large yew trees, net volume would be considerably less.

In Idaho, analyses of increment cores and stem sections of yew trees from mature stands showed annual growth in diameter at 15 cm (6 in) above ground to range from 0.05 cm (0.02 in) to 0.25 cm (0.10 in). The following tabulation shows diameters by age class *(11)*:

| Age in years | Diameter at 15 cm (6 in) above ground |
|---|---|
| 25 | 2.5 cm (1.0 in) |
| 50 | 5.0 cm (2.0 in) |
| 75 | 11.4 cm (4.5 in) |
| 100 | 15.2 cm (6.0 in) |
| 125 | 22.9 cm (9.0 in) |

The largest known Pacific yew tree is found in a cool, moist valley in western Washington (28). Large yew trees are, however, more prevalent on somewhat drier sites with warm, moist winters. Forty-seven percent of all the yew trees larger than 30 cm (12 in) tallied on inventory plots on non-Federal land in California, Oregon, and Washington were in a 4-county area in southwestern Oregon at mid to low elevations in the drier interior valleys and slopes between the Cascade and Coast Ranges, and in the Klamath Mountains (47).

Although Pacific yew is sometimes damaged by heat, frost, and wind, especially after overstory trees have been removed *(10,11,35,44)*, it can sometimes respond to release. On permanent plots in western Oregon measured 12 years apart, diameters of undamaged yew trees left after removal of overstory trees grew an average of 0.18 cm/yr (0.07 in/yr) and trees under dense overstories grew 0.06 cm (0.02 in) *(47)*.

The adaptation of Pacific yew to overstory removal is made possible through morphological changes in the needles-length, cuticle thickness, and deflection from the horizontal-and development of epicormic twigs *(10,11)*.

**Rooting Habit-The** root system of Pacific yew is deep and wide-spreading (22).

**Reaction to Competition-Pacific yew** is very tolerant of shade *(1,11,44)*. It appears to require shade for establishment and can grow and develop under heavy forest canopies. On many sites, it is able to adapt to overstory removal (10,11), and large, old

trees can be found that have been in the open much of their lives (3).

**Damaging** Agents-Pacific yew is sensitive to damage from fire, and, where the overstory has been removed, it is sometimes damaged by exposure to the sun, wind, and cold *(10,11,26,35,44)*. It resists damage from sulfur dioxide and was the least sensitive of 12 coniferous species to smelter fumes at Trail, British Columbia (26). Diseases of Pacific yew seedlings have not been studied, but ***Rhizoctonia solani, Phytophthora cinnamoni,*** and ***Pythium sp.*** have caused damping-off and seedling root rot in yews in the East. No serious leaf diseases have been reported. Snow blights-Neopeckia ***coulteri*** and ***Herpotrichia juniperi-have*** caused localized damage, and four needle blights are caused by ***Macrophoma taxi, Mycosphaerella taxi, Phoma hystrella,*** and ***Sphaerulina taxi.*** A stem canker is caused by ***Diplodia taxi,*** and twig blights by ***P. hystrella*** and ***Physalopspora gregaria.*** *Two root diseases—**Armillaria ostoyae** (obscura)* and ***Phaeolus schweinitzii***—have been reported on Pacific yew in Idaho (26).

Although seasoned heartwood of Pacific yew is extremely durable, large living Pacific yew trees often have hear-trot or hollow boles *(11,23)*. Many of the yew trees over 50 cm (20 in) d.b.h. tallied on non-Federal land in California, Oregon, and Washington could not be bored to determine age because of rotten or hollow trunks (47). Heartrot fungi infecting Pacific yew include ***Phellinus nigrolimitatus, P. pini, P. robustus,*** and ***Fomitopsis rosea (26).***

Several insects cause damage to yews in the eastern United States, including ***Lecanium fletcheri*** (called Fletcher scale or taxus lecanium), ***Pseudococcus comstocki*** (Comstock mealybug), ***Dysmicoccus wistariae, Pseudococcus maritimus*** (grape mealybug), and ***Maladera castanea*** (Asiatic garden beetle) (2). No damage to Pacific yew in forested settings has been confirmed. Reported damage to Pacific yew foliage by budworms ***(Choristoneura*** spp.) in areas of heavy budworm infestation is thought to be heat or frost damage resulting from the defoliation of the overstory *(5,41)*.

## Special Uses

The wood of Pacific yew has been used for archery bows, canoe paddles, tool handles, gunstocks, boat decking, furniture, musical instruments, carved figurines, and miscellaneous novelty items. (In a recent western State gubernatorial election, campaign buttons were made of yew wood.) Japanese have used Pacific yew for ceremonial "Toko" poles, which they place next to entrances of their homes *(6,19,23,29,44)*. Pacific yew's resistance to decay makes it useful for fenceposts. Of seven northwest species tested for use as untreated fenceposts, Pacific yew was the second most durable, with an average service life of 25 years (33). In the mid-1980's Japanese purchasers paid $3,600 per thousand board feet (Scribner scale) for Pacific yew logs, mostly for wood carvings. In 1989, Japanese buyers agreed to pay $4,150 per thousand for grade 1 yew logs, and a Taiwanese buyer paid $6,100 (7).

Among Native Americans, Saanich Tribal women used Pacific yew to remove underarm hair; Okanagans made a red paint from ground yew wood mixed with fish oil; several tribes smoked dried yew needles, which was said to cause dizziness; Haidas believed that women who ate yew berries would not conceive. Yew was valued as an item of trade and used in making instruments for hunting, fishing, and warring; tools, such as mauls and splitting wedges; household utensils, such as bowls and spoons; and medicine for a broad range of ailments *(23,29,44)*.

Pacific yew is again being used for medicinal purposes. In the late 1960's, taxol-a complex compound extracted from yew bark-was identified as a possible anticancer agent *(18,48)*. The National Cancer Institute (NCI) has found taxol to be one of the most promising of more than 120,000 plant compounds tested for anticancer properties. Tax01 appears to be effective against a wide range of tumors, and good responses have been obtained in the treatment of refractory ovarian cancer *(9,38)*.

In 1988, the NCI acquired 27 700 kg (60,000 lb) of dried Pacific yew bark, collected from trees cut down in southwestern Oregon. On average, one yew tree yielded 18 kg (40 lb) of green bark, which weighed about 9 kg (19 lb) dried (7). From the 27 700 kg of dried bark, about 4 kg (9 lb) of dry, crystalline taxol was extracted. Clinicians in several locations across the country have asked for increased supplies of taxol to expand tests to a broader range of cancer types. In January 1989, the NCI solicited another 27 700 kg of yew bark (9).

The 27 700 kg of yew bark already collected and the second 27 700 kg ordered represent 6,000 to 7,000 trees. Most of these trees were cut or will be cut on Federal forest land where yew has not been inventoried. On non-Federal lands in California, Oregon, and Washington, where inventories have been made, there are an estimated 700,000 Pacific yew trees 28 cm (11 in) d.b.h. and larger, the size of most trees cut for bark collection. Almost all the yew trees on non-Federal land are survivors of logging operations that removed the old-growth overstory (47). On Federal land where old-growth forests still exist, many more yew trees are thought to be

present, but trees of the size needed to produce large quantities of bark are not abundant in most areas. An unknown but unquestionably significant percentage of the original yew resource has already been destroyed in logging. In the process of harvesting Douglas-fir and other timber species, mostly by clearcutting, yew trees were either cut or knocked over and broken up by machinery. Yew trees were seldom taken in primary logging operations, but some yew wood was later salvaged by firewood cutters and gleaners gathering wood for specialty products. Most of the yew trees that existed in logged areas were burned in slash-disposal fires. In many logged areas, the rootstocks have survived and resprouted, so, although the wood and bark of many yew trees were destroyed, there seems to have been little threat to the existence of the yew germ plasm.

Continued or increased demand for yew bark for taxol production could further decrease a resource that has already been greatly reduced. Attempts to synthesize taxol in the laboratory have failed, and prospects for success in the future are considered to be poor. The only known source of taxol now is yew bark. Tax01 has been found in most of the several other species of *Taxus* that exist, but Pacific yew is the only one that is considered to be a practical source of quantities sufficient for clinical use *(9,12)*. At least one private organization has begun to investigate alternative ways of producing taxol, through tissue culture and by growing vegetatively propagated seedlings in a controlled environment (7).

The several species of yew in both the western and eastern hemispheres are thought to have poisonous seeds and foliage. Incidents of livestock poisoning by yew have been reported in Europe and North America. Conversely, in both Europe and North America, domestic and wild animals are known to browse yew foliage without ill effects. If and under what conditions yew foliage is poisonous are not known *(13,14,22,32)*. Pacific yew is browsed by moose in the South Fork of the Clear-water River basin in Idaho, where the tree is considered critical to the animals' survival (36). Pacific yew is also browsed heavily by elk and occasionally by deer in Oregon and Washington *(20,23,30)*.

Sprouts and epicormic branches that form in response to stand disturbance are favored by browsing animals. Repeatedly browsed yews in clearcut areas sometimes develop compact bushy crowns resembling the yew topiary of English gardens. Some limited use of *T. brevifolia* as an ornamental indicates it also has potential as a shade tree, for hedges, and for topiary *(23,44)*.

## Genetics

Pacific yew occurs in nature as a shrub or a tree, but whether the two forms are distinct subspecies, races, or varieties is not known. Three cultivars have been reported: cv *erecta*, a columnar form; cv *nana*, a dwarf form; and *cv nutallii*, a drooping form. A hybrid between *Taxus brevifolia* and *T. cuspidata* (Japanese yew) has been reported, but has no botanical standing. Pacific yew was originally classified as a variety of *T. baccata* (European yew), which it closely resembles; some botanists grouped all seven of the currently recognized species of *Taxus* worldwide as varieties of *T. baccata.* Where different species grow near each other, interspecific hybrids frequently occur, lending support to the view that there is but one species *(13,22,23,34,44)*. Further evidence of the close similarity of the species of *Taxus* is provided by bark analyses which show that most species contain taxol *(9)*, and by an analysis of heartwood constituents of *T. baccata, T. brevifolia, T. cuspidata,* and *T. floridana*: the four species were found to be "chemically almost indistinguishable" *(15)*

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