

Taxaceae—Yew family

Taxus L.

yew

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Growth habit. The yews—members of the genus *Taxus* of the family Taxaceae—are non-resinous evergreen gymnosperms that are widely distributed throughout the moderate zone of the Northern Hemisphere (table 1). They grow primarily in the understory of moist, forested habitats in cool, temperate to subtropical climates (Price 1990). The growth form may be a tree or a shrub. In the understory, the yew's sprawling branchiness and spreading crown enable it to capture light gaps in the canopy. The tree may convert to shrub form if the main shoot is injured or declines and is replaced by lateral branches or new growth. Shrubiness may also be sustained by frequent browsing. Crowns of these shrubby forms may attain as much as 24 m in diameter (Bugala 1978). The main stem of the yew tree can become quite stout in proportion to its height. Often the large diameter is attained by multiple stems that have fused over time. English yew has reached great age (1,000+ years) and girth, especially those planted in country churchyards (Lewington and Parker 1999).

Cultivated for centuries, the many English yew cultivars show distinct morphological differences in growth form and habit and in needle form and color (Krüssman 1983). Since the 1920's, cultivars of *T. Hmedia* Rehder (a hybrid of English and Japanese yews) have increased the number and variety of these commercially important ornamental shrubs (Chadwick and Keen 1976). The height of most yew species ranges from 6 to 12 m, although open-grown English yew may reach heights of 12 to 25 m and grow extremely thick trunks up to 17 m in girth

(Krüssmann 1983; Lewington and Parker 1999). Florida yew is a small, broad tree, about 1 to 5 m in height at maturity (Redmond 1984). Pacific yew trees growing in the wild may reach diameters as large as 6 m and heights up to 18 m under favorable conditions (Bolsinger and Jaramillo 1990). A shrubby form of the Pacific yew is common east of the Cascade Divide (Arno and Hammerly 1977).

Occurrence. There are 7 to 9 recognized species of yews (Krüssmann 1983; Rehder 1951) (table 1). English, Japanese, and Himalayan yews occur in Europe and Asia (Bugala 1978; Voliotis 1986) and Honduran, Florida, Canada, and Pacific yews occur in North America (Little 1971) (table 1). Chinese yew, considered a separate species in Chinese flora, is found in the mountainous regions of China up to about 3,000 m (Lee 1973; Zhang and Jia 1991). *Taxus mairei* (Lemee et Level.) S.Y. Hu ex Liu; *T. yunnanensis* Cheng and L.K. Fu; and *T. celebica* (Warburg) Li may also be identified as sub-species or varieties of *T. chinensis* (Krüssman 1983). Species classification within the genus is disputed and its phylogeny is not well understood (Bugala 1978; Voliotis 1986).

Of the 4 species native to the North American continent, 3 of them—Pacific, Canada, and Florida yews—occur in the United States. Honduran yew ranges from Honduras to southern Mexico. Of the species growing in the United States, Pacific yew has the most widespread range (table 1), and Florida yew, which is confined to the Appalachian River bluffs in northwest Florida, the most restricted. Although distinct geographic races have not been fully established, allozyme evaluation of 54 Pacific yew populations from 174 geographic areas indicate that Sierra Nevada populations were genetically distinct from Idaho, Montana, and northeast Oregon populations (Doede and others 1993). Six geographic seed zones established by the Oregon State Department of Forestry divide Oregon into north coast, south coast, Willamette valley, south valley, north Cascades, south Cascades; and an elevation band in the Cascades separated at 762 m (Randall 1996).

Use. *Taxus* is the only genus of the yew family of economic importance (Price 1990). For centuries, indigenous people have used yew species in traditional utensils and medicines (Hartzell 1991). North American indigenous people used yew for implements, including bows and dip-net and drum frames, as well as for medicines (Alaback and others 1994). In Europe and Asia the wood of the tree was once prized for making bows and is still valued for its quality in making fine musical instruments, cabinets, and utensils (Ambasta 1986; Hartzell 1991). Yew has

gained additional importance in recent years for a unique class of diterpenoid alkaloids, or taxanes, contained in its needles, bark and seeds (Miller 1980). These taxanes are the source of a chemotherapeutic drug (taxol) used to treat cancer (Rowinsky and others 1990). The fruit-like arils are eaten by birds, and birds and small mammals eat the seeds. Although rabbits (*Sylvilagus* spp.), deer (*Odocoileus* spp.), and elk (*Cervus canadensis*) feed on foliage, leaves, and shoots of the Pacific yew, the European yew is reportedly toxic to horses and cattle but apparently not to white-tailed deer (Nisley 2002; Smith 1989; Veatch and others 1988).

Flowering and fruiting. Almost all yew species are dioecious; however, Canada yew is monoecious. Nevertheless, a small percentage of unisexual plants have been observed in this species (Allison 1991). Cosexuality has been reported in Pacific yew—fruits and seeds have been observed on branches of male trees (DiFazio and others 1996; Owens and Simpson 1986). Cosexuality and sex reversion have also been reported in other taxa (Chadwick and Keen 1976).

Yew flowers are small and solitary and arise from axillary buds. Female buds consist of single ovules surrounded by bracts. Anthesis is indicated by the appearance of the micropylar opening in the exposed ovule, which eventually develops into a seed. Male buds usually cluster along the underside of the previous season's branches. The male flower at anthesis is a stalked, globose head on which are 14 stamens, each with 5 to 9 microsporangia or pollen sacs. The pollen is shed between February and May (table 2). Dry pollen grains are yellow, indented spheroids, lacking sacci; diameters range from 19 to 26 μm (Owens and Simpson 1986).

The fruit, which ripens from late summer through autumn, consists of a scarlet fleshy, cup-like aril (figure 1) bearing a single, hard, ovate seed up to 6 mm long (figures 2 and 3). The mature seed has a greenish brown to brown seed coat and is filled with white megagametophyte tissue (rich in lipids) that surrounds a small embryo 1 to 2 mm long. Times of flowering, fruit ripening, and seed dispersal for each species are listed in table 2.

Little information is available on the frequency of good seedcrops among the yews, but most species produce some seeds almost every year (Chadwick and Keen 1976; Harlow and Harrar 1958). Flowering and seed production was found for Pacific yew in western Oregon to be related to overstory openness and tree vigor (DiFazio and others 1997; Pilz 1996a). However, predation of fruit on trees in the open was higher, limiting seed production (DiFazio and others 1998). For Japanese yew, good crops are reported every 6 to 7 years (Rudolf 1974). English yew begins to produce seeds at about 30 years of age (Dallimore and Jackson 1967). Comparable

information for the other species is lacking. For dioecious species, good seed crops are produced where there is a good intermixture of male and female trees. Pollen may limit seed production in some populations of Canada yew where deer browse has created widely spaced plants that produce little pollen (Allison 1990). Although pollination was found limiting, it was not the primary factor limiting seed production in Pacific yew trees examined in western Oregon (DiFazio and others 1998). Yew seeds have been found to survive in a soil seedbank for several years (Minore and others 1996). Although seeds will germinate under mature overstories in canopy gaps, seedlings may be abundant following disturbance such as burning and overstory removal. However, Crawford (1983) noted that in Idaho, most abundant yew seedlings were found growing in forest litter and decaying wood.

Collection of fruits. The maturation of seeds and ripening of arils (full expansion and orange-red coloration) may occur over a span of months. Over this time, losses to birds and small mammals such as chipmunks (*Eutamias* spp.) can be considerable (DiFazio 1995). To prevent losses to predation, yew fruits should be picked frequently from the branches, beginning when individual fruits first ripen. To ensure that adequate amounts of seeds are collected in specific seed collection areas, bagging branches of desirable trees well before fruit ripens is recommended so that fruits are not lost or destroyed by squirrels (*Citellus* spp.) and other predators (DiFazio and others 1998). If returning repeatedly to individual trees is impractical, harvesters can bag branches in July with light-weight mesh bags and then collect the fruits in late fall.

When collecting seed in Oregon and Washington differences in phenology were noted in nursery-grown yews from seed collected in the Coastal and Cascade Ranges (Randall 1996). Seed zones that have been identified should be used for collecting; ideally seed should be collected from the approximate area where the yew trees will be grown.

Extraction and cleaning. Seeds should be extracted from the fruit shortly after harvest, as storage with fruit promotes mold. Extract seeds by macerating the fleshy arils in water. A blender with the blades covered by rubber tubing (Munson 1986) and set at low speed will efficiently and quickly separate seed from arils without damaging seeds. Light, unfilled seeds float to the top and can be easily removed. In some species the membranous, outer seedcoat is partially destroyed during extraction; in others, it remains tightly fixed to the bony inner coat. After extraction, excess moisture should be dried from seeds. Seeds can then be

weighed, sown, cold stored, or stratified as soon as possible. The number of cleaned seeds per weight is listed in table 3. Purity of seedlots generally ranges from 96 to 100%, and soundness, from 78 to 99% (Rudolf 1974).

Storage. Yew seeds are orthodox in storage characteristics and, if kept at low moisture content, may be successfully stored frozen for years without losing viability. The viability of yew seeds can be maintained for 5 or 6 years if they are dried just after extraction at room temperature for 1 or 2 weeks and then stored in sealed containers at 1 to 2 EC (Heit 1967). If seeds are dried to 15 to 25% relative humidity (moisture content of 2 to 3%), seedlot viability of greater than 90% can be maintained for weeks at 25 EC. Pacific yew seeds have a high lipid content (megagametophyte lipid content is about 71% of the dry mass); therefore, long-term storage conditions should maintain seeds at 14% relative humidity and subzero temperatures (Walters-Vertucci and others 1996). Analysis of seeds for cryopreservation indicates that they can be stored at ! 18 to ! 20 EC without losing viability, provided that they have reached sufficient maturity, and that they probably will remain viable for decades under these conditions (Walters-Vertucci and others 1996). Yew seeds can be held for several months in cold stratification without losing viability. Reasonably good viability of English yew seeds was maintained for up to 4 years by storing them in moist sand or acid peat at low temperatures (Rudolf 1974).

Pregermination treatments. Yew seeds are slow to germinate; natural germination usually does not take place until the second spring after seedfall (Suszka 1978). Viable yew seeds of Pacific yew have been found in soil seedbanks for several years (Minore 1994). Although a variety of birds and small mammals eat, digest, and disperse yew seeds (Bartkowiak 1978), germination does not appear to be hastened by their passing through the alimentary canal of birds. Yew seeds have a strong but variable dormancy that can be broken by warm-plus-cold stratification (Suszka 1978). One recommendation is to hold the seeds for 150 to 210 days at 16 to 18 EC, then for 60 to 120 days at 2 to 5 EC (Heit 1967, 1969). The ISTA rules specify prechilling yew seeds for 270 days at 3 to 5 EC. Steinfeld (1993a) reported on 2 groups of seeds collected in the fall in Oregon that were stratified during the fall and winter. One group was chilled for 1 month and the other was kept at warm temperatures for 5 months and then chilled for 2 months. The seeds were sown in bareroot beds covered with mulch the following spring. Germination was negligible for the cold-treated seeds and about 5% for the warm/cold-treated

seeds; however, in the following spring, the germination rate of the remaining seeds combined with that of the previous spring exceeded 95%. No difference in total germination between the 2 treatment groups was detected by the second year.

Germination and seed viability tests. Germination of yew seeds is epigeal (figure 4). Because of the deep dormancy of the seeds, germination will be sporadic over the course of several years. Germination percentages after the first year do not indicate the potential of the seeds to germinate, for germination will continue in the following year (Heit 1969; Pilz 1996b). Official testing rules recommend tetrazolium staining as the first choice in testing, followed by germination in sand at 30 EC for 28 days after 270 days of stratification (ISTA 1993). Cutting tests are also recommended for rapid viability checks. After a seed is carefully split in half with sharp knife or scalpel, the embryo and megagametophyte tissue can be examined. If an embryo is opaque and developed, with visible cotyledon buds, and gametophyte tissue is white and fills the seed cavity, the seed should be considered mature and viable. A tetrazolium test for viability requires cutting seeds to expose tissue, staining for about 24 to 48 hours, then cutting out the embryos. A seed is considered viable if all of the embryo and endosperm is stained (Edwards 1987). Removing embryos from Pacific yew seeds and culturing them on nutrient medium with an energy source such as 2% sucrose has resulted in germination of 70 to 100%. Cleaned, mature seeds showed high germination whether seeds were fresh, cold stored, or stratified (Vance 1995). Embryo germination was shown to improve with a 14-hour photoperiod and up to 50 days of cold treatment in *in vitro* germination tests of embryos from English and Japanese yews (Flores and others 1993). Test results for 3 species are given in table 4.

Nursery practices. Freshly collected yew seeds can be sown in late summer or early fall of the year of collection, whereas stratified seeds can be sown in the spring of the year following collection. The seeds should be covered with about 1 to 2 cm (.4 to .8 in) of soil, and mulching the seedbed is beneficial (Steinfeld 1993a). Beds should be shaded during the summer. Even with these treatments many seeds often will not germinate until the second spring (Heit 1969; Steinfeld 1993a). Seedlings should be shaded after they emerge the first spring and summer. Rabbits have been observed feeding on Pacific yew seedlings in the bareroot beds at the USDA Forest Service's J. Herbert Stone Nursery at Central Point, Oregon (Steinfeld 1993b). Birds eat seeds, and germinants may be susceptible to damping-off fungi (*Fusarium* spp.). Although most ornamental yews are propagated by cuttings, seedlings of the Japanese yew

cultivar 'Capitata' are germinated from seeds after 3 months of warm stratification (20 EC) followed by 4 months at 5 EC (Hartmann and others 1990). Seedlings are grown 2 to 3 years in seedbeds in a poly house, followed by 2 to 3 more years in liner beds, then 3 or 4 years in a nursery field before they are of salable size (Hartmann and others 1990; Shugert 1994). In the first 3 years, 55% shade is used from mid-June until November to reduce stress (Shugert 1994). Young yew plants are susceptible to root weevils. Commercial preparation of nematodes that are effective against weevil larvae can be applied in early spring when soil temperatures reach 7 EC.

All yew species can be successfully propagated by rooting cuttings, and most commercial cultivars are produced this way. Successful stecklings from Pacific, Canada, Florida, and Honduran yews were obtained by rooting cuttings in a greenhouse under shaded conditions, on benches that had bottom heat of about 21 EC, an overhead mist system to maintain high humidity, and cool air temperatures (Hartmann and others 1990; Suszka 1978). On 1 to 2-year-old stems, from healthy branch tips, cuttings should be clipped at an angle and needles removed from the clipped end. Cutting length varies depending on the branch but may range from 10 to 20 cm (Chadwick and Keen 1976). The clipped tip should be dipped in a solution containing a root-promoting compound such as indole B-indolebutyric acid (IBA) or α -naphthalenacetic acid (NAA) and a fungicide, then stuck to a depth of about 3 cm (1.2 in) in rooting medium. Using 5,000 to 10,000 ppm of IBA dissolved in 50% ethanol and dipping cuttings quickly achieves satisfactory rooting (Hartmann and others 1990). The medium should hold the cuttings, maintain a high moisture content, and be well drained. A mixture of sphagnum peat moss, coarse vermiculite, and perlite or sand will enhance rootability and promote a desirable root system (Copes 1977). If Pacific yew cuttings are stuck in the winter, rooting may begin to occur within 4 to 6 weeks, depending upon species and cultivar but may also take up to 3 or more months. Rooting ability varies widely by clone or cultivar and by the time of year that yews are propagated. Clonally propagated plants should only be used where genetic selection for desired traits is needed in a cultivated setting. Seedlings are preferred over rooted cuttings for reforestation because seedlings have genetic variation that more nearly approximates wild populations.

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Table 1—*Taxus*, yew: nomenclature and occurrence

| Scientific name & synonym(s) | Common name | Occurrence |
|---|--|--|
| <i>T. baccata</i> L. <i>T. baccata</i> ssp. <i>eubaccata</i> Pilger. | English yew, common yew | Throughout Europe & Algeria, N Iran & the Himalayas |
| <i>T. brevifolia</i> Nutt. <i>T. baccata</i> ssp. <i>brevifolia</i> Pilger. | Pacific yew | From SE Alaska S to N California & central Nevada; E to coastal Oregon & Washington to W Montana |
| <i>T. canadensis</i> Marsh. <i>T. baccata</i> ssp. <i>canadensis</i> Pilger. | Canada yew, eastern yew, & ground hemlock | E from Ontario into E Canada, S to Virginia & Tennessee |
| <i>T. chinensis</i> (Pilg.) Rehder <i>T. celebica</i> (Warburg) Li. <i>T. mairei</i> S.Y. Hu ex Liu. <i>T. yunnanensis</i> Cheng & L.K.Fu. | Chinese yew, Maire yew, & Yunnan yew | Central & W China from Yunnan to Guangxi |
| <i>T. cuspidata</i> Sieb. & Zucc. <i>T. baccata</i> ssp. <i>cuspidata</i> Pilger. | Japanese yew | Throughout Japan & in E China |
| <i>T. floridana</i> Nutt. ex Chapman <i>T. baccata</i> ssp. <i>floridana</i> Pilger. | Florida yew | Along Appalachian River bluffs in N Florida |
| <i>T. globosa</i> Schltldl. <i>T. baccata</i> ssp. <i>globosa</i> Pilger. | Honduran yew, Guatemalan yew, & Mexican yew | From NE Mexico to Guatemala & El Salvador |
| <i>T. wallichiana</i> Zucc. <i>T. baccata</i> ssp. <i>wallichiana</i> Pilger. | Himalayan yew | Himalayan Mtns from E Afghanistan & N India, E to Tibet, Burma & the Philippines |

Sources: Krüssman (1983), Rehder (1971), Rudolf (1974), Voliotis (1986).

Table 2—*Taxus*, yew: phenology of flowering and fruiting

| | | | | | Species | Loc |
|----------------------|-----------------------|----------|----------|----------|---------|-----|
| <i>T. baccata</i> | W Europe | Mar–May | Aug–Oct | Aug–Oct | | |
| <i>T. brevifolia</i> | Washington & Oregon | Mar–May | July–Oct | July–Oct | | |
| <i>T. canadensis</i> | Minnesota & Wisconsin | Apr | Aug–Sept | Aug–Sept | | |
| <i>T. cuspidata</i> | Japan | Apr–June | Sept–Oct | Oct | | |
| <i>T. floridana</i> | NW Florida | Jan–Mar | Aug–Oct | Aug–Oct | | |

Sources: Allison (1990), Chadwick and Keen (1976), Redmond (1984).

Table 3—*Taxus*, yew: seed yield data

| Species | Place collected | Range | | Average | | Samples |
|----------------------|-------------------------------|---------------|---------------|---------|--------|---------|
| | | /kg | /lb | /kg | /lb | |
| <i>T. baccata</i> | Western Europe | 13,900–18,000 | 6,300–8,200 | 17,000 | 7,700 | 14 |
| | NE US | 13,200–15,000 | 6,000–6,800 | 14,100 | 6,400 | 3 |
| <i>T. brevifolia</i> | Carson & Skamania Cos., WA | 32,400–36,200 | 14,700–16,500 | 33,100 | 15,000 | 2 |
| | S Cascades, OR | 23,800–25,900 | 10,800–11,800 | 24,950 | 11,300 | 10 |
| | Central Cascades, OR | 26,330–39,950 | 12,000–18,200 | 31,077 | 14,100 | 4 |
| <i>T. canadensis</i> | Upper Midwest | 33,000–62,400 | 15,000–28,400 | 46,300 | 21,000 | 4 |
| | Minnesota & Wisconsin | 35,700–38,460 | 16,200–17,500 | 37,000 | 16,800 | 4 |
| <i>T. cuspidata</i> | Japan | 24,700–43,000 | 11,200–19,500 | 31,300 | 14,200 | 7 |
| | NE US | 14,840–19,300 | 6,700–8,800 | 16,300 | 7,400 | 3 |

Sources: Allison (1995), Heit (1969), Rudolf (1974), Vance (1993), Yatch (1957).

Table 4—*Taxus*, yew: stratification periods, germination test conditions, and results

| Species | Germination test conditions | | | | | Germinative capacity | | Samples |
|----------------------|-----------------------------|------|-----------|-------|--------------------|----------------------|--------------|---------|
| | Stratification (days) | | Temp (EC) | | Interval (days) | Avg (%) | Range (%) | |
| | Warm | Cold | Day | Night | | | | |
| <i>T. baccata</i> | — | — | 16 | 10 | — | 67 | 47–70 | 12 |
| <i>T. baccata</i> | 120 | 365 | 10–16 | 10–16 | 60 | 47 | — | 1 |
| <i>T. brevifolia</i> | — | — | 30 | 20 | 60 | 55 | 50–99 | 3 |
| <i>T. cuspidata</i> | 120 | 365 | 10–16 | 10–16 | 60 | 68 | — | 1 |

Source: Rudolf (1974).