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*Pinus patula* Schiede and Deppe, known as patula pine, spreading-leaved pine, or Mexican weeping pine (19, 31) in English and pino patula, pino china, or ocote in Spanish (6, 31), is one of the four closed-cone pines (division *Oocarpae*, sensu Little and Critchfield) native to Central America. These trees can reach 20 to 40 m in height, are notable for their reddish, flaky, paperlike bark on the upper stem and branches and for their large, persistent, serotinous cones (fig. 1) (20, 21). Although it has a very restricted natural range, patula pine has been extremely successful in industrial plantations throughout the tropics and subtropics, noted for its good form, fast growth, and large size (4, 31). There is debate over whether a species first identified as *Pinus tecunumanii* (Schwerdtf.) Eguluz and Perry may in fact be a subspecies, *Pinus patula* Schiede and Deppe ssp. *tecunumanii* (Eguluz and Perry) Styles (22, 27, 28). The second nomenclature, including silvicultural information on *P. patula* ssp. *tecunumanii* where available, will be used in this paper.

## HABITAT

### Native Range

Patula pine occurs naturally in the Mexican States of Querétaro, Hidalgo, Mexico, Puebla, and Veracruz (21) (fig. 2). Subspecies *tecunumanii* ranges naturally from southern Mexico to western Nicaragua (5). Collectively, patula pine ranges in scattered pockets within latitudes 13° to 24° N. and longitude 85° to 100° W. Patula pine has been widely planted outside its range throughout the tropics and temperate zones since the 1940's, including southern Africa, the Indian subcontinent, South America, and Australia (16, 31). Patula pine has done well in these locations and has most likely naturalized in at least some of them; e.g., India and southern Africa. It presently grows successfully at many sites as far as 40° S. and N. latitudes.

### Climate

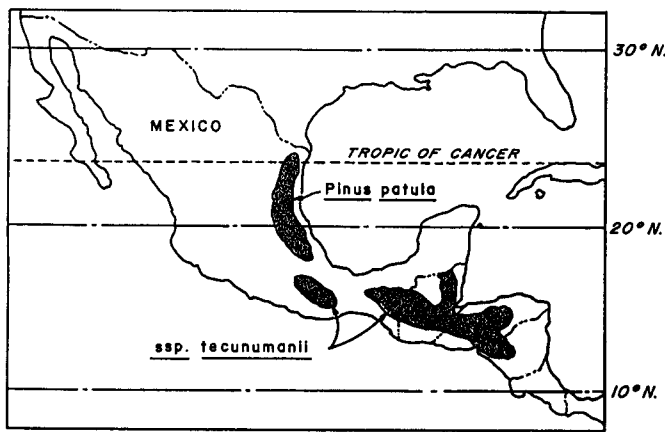
In its natural range, patula pine is generally found in the warm to cool regions, often in moist upper mountain valleys (11, 20, 31). Mean annual rainfall ranges from 500 to 2000 mm/yr (20) with most rain occurring in the summer (June to October) and a zero- to 3-month dry season from December to February (31). Mean annual temperatures range from 12

to 18 °C, with mean maximum and minimum temperatures in the hottest and coldest months of 20 to 29 °C and 6 to 12 °C, respectively. Patula pine thrives as an exotic in frost-free areas where rainfall is at least 750 mm, falling mostly in the summer, as well as in areas subjected to a monsoonal two-peak rainfall distribution with most of the rain coming in the cooler season (31) and on sites located within high-elevation mist belts (25). Patula pine may not thrive on sites where dry periods exceed 3 months and soils are too shallow or too friable to hold moisture, or where maximum or minimum mean monthly temperatures are outside the zero -to- 28-°C range (31). *Pinus patula* ssp. *tecunumanii* is native to slightly wetter areas, with mean annual precipitation between 1200 and 2400 mm (12) and mean annual temperatures of 15 to 23 °C.



**Figure 1.**—*Patula pine* (*Pinus patula*) growing in Puerto Rico.

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**Figure 2.**—Native range of patula pine (*Pinus patula*) and *Pinus patula* ssp. *tecunumanii* in Mexico and Central America.

### Soils and Topography

Patula pine grows successfully on a wide variety of soils, preferring moist, deep, acidic soils, usually sandy loam (20) to sandy clay (31), and at elevations ranging from 1400 to 3200 m above mean sea level (30). *Pinus patula* ssp. *tecunumanii* grows naturally down to 1000 m and prefers acidic soils (pH 4.5 to 5.5) (11, 30). Patula pine does best in ravines and on flats with deep, loamy, moist soils, and is replaced by other pine species on shallow, moisture-deficient soils (31). As an exotic, patula pine has grown successfully on young volcanic soils as well as on old, leached, infertile soils—in fact, on any soil sufficiently acidic and moist throughout the year. Patula pine has been grown at lower elevations, but the trees often culminate height growth early (31) and become coarse and unthrifty (4). *Pinus patula* ssp. *tecunumanii* does very well at low altitudes down to near sea level (4). However, optimal growth probably occurs between 1000 and 2000 m (31).

### Associated Forest Cover

Patula pine can occasionally be found in pure, dense stands (31) but is more often associated with other pines; e.g., *P. teocote* Schlect and Cham., *P. greggii* Engelm., *P. montezumae* Lamb., *P. pseudostrobus* Lindl., and *P. lawsonii* Roehl. In addition, it associates with various other softwoods such as *Taxus globosa* Schlect, *Podocarpus reichei* Buchh. and Gray, *Abies religiosa* (H. B. and K.) Schlect and Cham., and *Cupressus* spp., as well as hardwoods such as *Fagus* spp., *Tilia* spp., *Cercis* spp., *Acer* spp., *Liquidambar* spp., *Quercus* spp., and *Alnus* spp., (31). *Pinus patula* ssp. *tecunumanii* is often found associated with several pines including *P. oocarpa* Schiede, *P. ayacahuite* Ehrenb., *P. maximoi* H. E. Moore, *P. pseudostrobus* Lindl., *Abies guatemalensis* Rehder, *Cupressus lusitanica* Mill., *Quercus* spp., and *Liquidambar styraciflua* L. (11, 28).

## LIFE HISTORY

### Reproduction and Early Growth

**Flowering and Fruiting.**—Male and female flowers occur separately on the same plant. Male (staminate) cones are yellow and occur in crowded clusters on new shoots (20), usually in the lower crown (31). Female (pistillate) conelets are purplish, have a deciduous prickle, and appear singly or in groups, generally lateral but rarely subterminal (20), and in the upper crown (31). Throughout its natural range, patula pine flowers between January and April, but with the flowering period on any one site much less than 4 months (31). In plantations, flowering generally occurs in a spring flush (3), but there can be two flowerings (spring and late summer) (31). Flowering has occurred on plants as young as 2 years when grown in nurseries; flowering in outdoor plantations is common by age 3 and heavy annual cone production is common by age 8 and 10 (31). Male flower production or synchronization of male and female flowers may be poor at lower elevations, which may lead to poor seed set and low seed production (3, 17, 31). Impaired male flower production at lower elevations in Colombia was stimulated by fertilizing with nitrogen and boron (17).

Mature cones are long-conical, tapering towards the apex, generally sessile but rarely subsessile, reflexed asymmetrical, slightly curved, glossy gray to brown, borne in groups of three to six, and average 4 to 12 cm in length and 2.5 to 4 cm in width (31, 20). Scales are hard, 2 cm long by 1 cm broad, apophysis rhomboidal, flat and slightly protruding, dark umber, with a deciduous prickle (31, 20). The cones take from 22 to 30 months to mature, thereafter persisting for up to 2 years in a serotinous condition with little loss in viability before slowly and symmetrically opening. In Madagascar, seed stands with a stocking of 500 to 700 trees per hectare yield 1.0 to 1.5 tonnes per hectare of cones. Cones weigh about 50 g each, which reduces to an average of 40 cones per tree (31). Seeds are small (3 mm), light brown to black, with brown (13 mm) wings (20).

**Seed Production and Dissemination.**—Seed set varies greatly, probably due to variation in pollen production and the weather conditions at the time of fertilization. Estimates from southern Africa indicate an average of 200 seeds per mature cone, of which 35 to 80 seeds were fertilized and thus viable (31). Seed weights reported from Mexico, southern Africa, and Australia ranged from 97,000 to 166,000 seeds per kilogram (0.0103 to 0.006 grams per seed). Seeds are generally collected by collecting the closed cones, either by climbing, pruning, or felling the tree (31). The cones open readily with heat, either from direct sunlight or in a kiln. It may be difficult to reopen cones that have opened and then closed again (31). The seeds store readily, up to 1 year at room temperature in open bins, to several years when dried and sealed in airtight jars (31), and up to 21 years in cold storage (15). Seed production has been unsatisfactory in seed orchards at elevations below 1500 m in South Africa (31) and below 2000 m in Colombia (18).

**Seedling Development.**—Germination capacities of 75 to 90 percent are reported for patula pine (31). In Rhodesia, germination energy averaged 13 percent after 14 days,

rising to 90 percent after 27 days (31). Other reported germination periods in southern Africa range from 15 to 70 days (31). Patula pine is known to regenerate naturally and prolifically, with up to 25,000 stems per hectare in the seedling stage reducing to 1,500 to 2,000 stems per hectare at middle age (20, 31). However, natural regeneration is not the method of choice in countries using patula pine in industrial plantations; the gains in growth obtained from planting nursery stock are generally considered economically worthwhile (31).

Several pretreatments have been described for breaking dormancy and preparing patula pine seeds for sowing, including soaking in water, soaking in hydrogen peroxide, and stratification (31). However, the consensus seems to be that pretreatment is generally neither necessary nor desirable (31, 30). Seedlings grow best in lightly acidic soils with good drainage. Seed beds raised 15 cm and filled with 7 to 8 cm of 50:50 mix of sieved forest soil and sand, 2 to 3 cm of unsieved forest soil, and 5 cm of broken stone and rubble are used in eastern Africa (31). Seeds should be sown on the surface or under no more than 6 mm of soil, preferably watered by a mist spray to prevent excessive seed movement. Seeds can be planted in pots or beds, and generally require 6 to 12 months in the nursery before reaching outplanting size (15–20 cm). The South African Pulp and Paper Industries located their nursery 600 to 1200 m lower in elevation than the sites where the trees will be planted. At this warmer, lower altitude they produce trees ready for outplanting in 6 to 12 months (31, 30). Seedlings may need to be partially shaded when grown in areas of intense sun; e.g., equatorial Africa. Patula pine seedlings are susceptible to a variety of damping-off fungi including *Pythium*, *Rhizoctonia*, and *Fusarium*, which can be controlled by appropriate fungicides (31). Patula pine will benefit from infusion with an appropriate pine-associated ectomycorrhizae inoculum; e.g., *Pisolithus* or *Rhizopogon* (29); early failures of patula pine in southern Africa are blamed on failure to inoculate the seedlings with mycorrhizae (31).

The root system is less robust than in other pines; individual containers are preferred for raising seedlings. Seedlings grown in containers should not be allowed to grow much more than 20 cm in height. Plants grown too large in containers may suffer long-term root damage (9, 31). Common sizes for individual containers range from 10 to 20 cm in height and from 6 to 10 cm in diameter. Seedlings grown in beds must be lifted with extreme care (31), and root wrenching may be required to put the seedlings into a dormant state ("conditioning") before outplanting (8, 9).

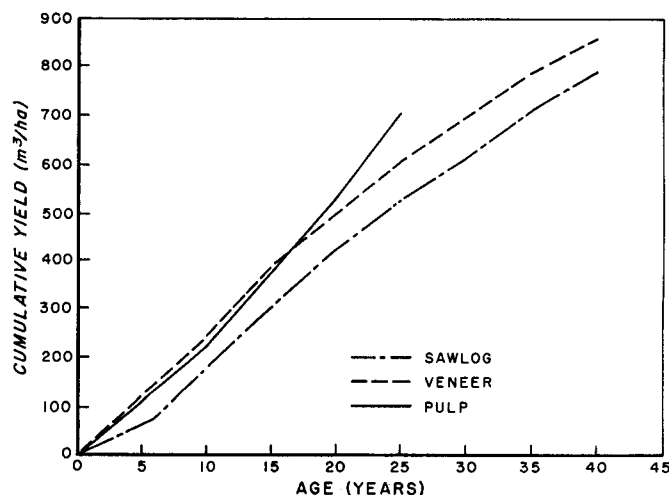
Seedlings are planted at spacings ranging from 2.40 to 2.75 m, preferably just after the start of the rainy season (in seasonal climates) to give the seedlings the maximum amount of time to become established before the next dry season. Deep planting (planting the root collar 10 cm below the surface) is used in drier areas or areas with friable soil that tends to hold less moisture. Long taproots should be trimmed if necessary to avoid root kinking or 'J-root' systems. The need for site preparation varies, being most necessary on dry sites where other plants will compete for moisture. Direct seeding has been successful on clean, moist sites, but the faster growth obtained from nursery stock has generally been considered to be worth the cost (31, 14). First-year height growth averages 0.9 to 1.5 m (25).

**Vegetative Reproduction.**—Vegetative reproduction of patula pine may be possible, but has not been reported in the literature. Coppicing and basal shoots (shoots arising from the root collar of established trees) are common for *P. patula* ssp. *tecunumanii* but not for patula pine (26).

### Sapling and Pole State to Maturity

**Growth and Yield.**—Patula pine is probably one of the fastest growing and largest tropical pines. Mature trees are generally 20 to 30 m tall, occasionally 40 m, and can reach up to 1 m in diameter. The population of *P. patula* ssp. *tecunumanii* can be divided into high-elevation and low-elevation provenances, with low-elevation trees growing to sizes similar to patula pine but the high-elevation trees reaching 50 m in height and 1.5 m in diameter (10). Patula pine tends to have a good form, with up to 50 percent of the bole clear of branches. Height growth culminates at around 25 years (20, 31).

Mean annual volume increments reported in the literature vary widely, depending on the site quality and stand management. On good sites with no excessively dry season, well-managed stands can yield gross mean annual increments of 35 m<sup>3</sup>/ha/yr and utilizable mean annual yields of 27 m<sup>3</sup>/ha/yr on a 30-year rotation if large (>40 cm) timber is not required. Larger timber requires both longer rotations (35–40 years) and lower stand density to obtain trees larger than 50 cm in diameter. On sites with dry seasons longer than 3 months, gross yields are probably more like 20 m<sup>3</sup>/ha/yr or less. Mean annual increment in plantations generally culminates at 14 to 18 years of age. Yields depend upon the ultimate use of the timber; thinning options may leave from 15 to 40 m<sup>2</sup>/ha residual basal area, and will greatly affect the timing and diameter distribution of yields (31). Volume and yield tables are available for patula pine (1, 2, 7, 13, 24, 31). Average cumulative yields under several management regimes in South Africa are illustrated in figure 3. No volume or yield tables were found in the literature for *P. patula* ssp. *tecunumanii*, but provenance trials indicate that the subspecies (particularly in high-elevation



**Figure 3.**—Expected yields (sawlog, veneer, and pulp, in m<sup>3</sup>/ha) of patula pine (*Pinus patula*) from average quality sites in South Africa, based on standard management regimes as reported in Wormald (appendix II) (31).

provenances) may outperform patula pine (10). Four provenances of *P. patula* ssp. *tecunumanii* included in an international provenance trial of *P. oocarpa* sponsored by the Oxford Forestry Institute in the early 1970's (22) consistently outperformed *P. oocarpa* (5).

**Rooting Habit.**—Patula pine forms a taproot with well-distributed lateral roots and readily increases rooting depth in search of moisture when soil conditions permit (31). It will form ectomycorrhizal relationships when the inoculum is present in the soil and requires mycorrhizae for health growth (29, 31). Patula pine does not normally form buttresses (31).

**Reaction to Competition.**—Patula pine is shade intolerant and sensitive to competition for water during extended droughts. When planted in tall vegetation or potentially dry areas, site preparation should include some clearing. The need for and timing of weeding will vary depending on the site; patula pine is sensitive to competition in its early years. Both mechanical and chemical weeding have been successful in southern Africa (31). Because of the fast growth of patula pine, seedlings planted at a 2.4-m spacing can often fully occupy a site after 2 years, necessitating a precommercial thinning at age 6 or so but eliminating the need for subsequent periodic cleanings (31).

**Damaging Agents.**—Patula pine is susceptible to wind damage, which results in broken tops and branches rather than uprooting. It is also susceptible to drought damage when planted on sites subjected to long (>3 months) dry seasons in shallow soils or soils that do not retain moisture. Trees are thin barked and thus very susceptible to scorching damage by fire. Patula pine is somewhat frost resistant for a tropical pine, able to withstand brief frost and snow spells, provided the tree is in a dormant state. *Pinus patula* ssp. *tecunumanii* appears to be less frost resistant than patula pine but more frost resistant than *P. oocarpa* (26).

Patula pine is susceptible to a variety of pathogens, including damping-off fungi and diseases of the foliage, stem, cone, root, and heart. Among the more serious diseases are *Diplodia pinea*, which acts as a wound pathogen and causes canker and tip dieback, and the root diseases *Armillariella mellea* and *Heterobasidion annosum*. Patula pine is also susceptible to attack from a variety of insect pests, the most serious pests being defoliating insects, especially certain families in the order *Lepidoptera* (31) and black aphids (4). In general, however, patula pine has proved remarkably free of damage by insects and diseases throughout the many parts of the world where it has been planted (31).

Domestic and feral pigs damage trees by digging and browsing on roots. Patula pine appears to be less susceptible to pig damage than does *P. patula* ssp. *tecunumanii* (26). Browsing animals can damage plantations by feeding on new shoots (31).

## SPECIAL USES

Patula pine has generally been planted as a fast-growing, high-yield industrial species. The timber is lower in density and strength than many temperate conifers, but suitable for general construction. The wood is white to yellowish white, with pinkish heartwood, and often has a strong contrast between lighter early wood and darker late wood. Wood

strength and density increase markedly from pith outward, so that the outer wood is suitable for general structural work while the inner juvenile wood is more suited to box or crate manufacture, shingles, and cheap joinery. The wood is easily treatable, relatively nonresinous with little odor, and is suitable for both particle board and pulp (6, 31).

There is no literature on the wood qualities of patula pine from its native range. Physical and mechanical properties of patula pine grown in plantations in southern Africa range from specific gravity of 0.40 to 0.52 at 12-percent moisture content; modulus of rupture, 41 to 83 Newtons/mm<sup>2</sup>; modulus of elasticity, 5860 to 9660 Newtons/mm<sup>2</sup>; compression along the axial plane, 29.4 to 44.8 Newtons/mm<sup>2</sup>; side hardness (Janka method), 1352 to 2523 Newtons; radial and tangential cleavage, 8.0 to 10.5 mm and 12.2 to 13.3 mm, respectively; and radial, tangential, and volume shrinkage of 2.8 to 4.1 percent, 3.9 to 8.8 percent, and 7.3 to 13.9 percent, respectively (6, 31).

## GENETICS

Botanical synonyms are *P. subpatula* Roehl. ex Gord., *P. oocarpa* var. *ochoterenai* Martinez, *P. patula* var. *longipedunculata* (*longepedunculata*) Looock ex Martinez, and *P. patula* var. *zebrina* Milano (now known as *P. patula* cv. "Zebrina"). In addition, there is currently debate over whether patula pine formerly (but incorrectly) identified as *P. tecunumanii* Schwerdt. is actually a separate species *P. tecunumanii* (Schwerdt.) Eguiluz and Perry (11, 12), or if this species is in fact a subspecies of patula pine, *P. patula* Schiede and Depp ssp. *tecunumanii* (Eguiluz and Perry) Styles (4, 28).

Patula pine is currently the subject of an international provenance trial begun in 1982 by the Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFA) of Mexico (23).

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