

Araucaria Juss.

araucaria

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Growth habit, occurrence, and use. The araucarias, consisting of 15 species, are evergreen coniferous trees that are generally confined to the Southern Hemisphere. They are found in South America, Australia, New Guinea, New Caledonia, the New Hebrides Islands, and Norfolk Island under tropical, subtropical, and temperate climates (Dallimore and Jackson 1954; Howcroft 1978a, b; Ntima 1968; Record and Hess 1943; Veblen and Delmastro 1976; Webb and others 1984). They are noted for their long, straight, clear boles, and symmetrical crowns; many are useful for timber and some are cultivated as ornamental trees (Streets 1962).

Several species have been introduced to California, Oregon, Washington, Florida, Hawaii, Puerto Rico, the U.S. Virgin Islands, Guam, American Samoa, and other U.S. territories in the Pacific Basin (table 1) (Francis 1988; Walters 1974). *Araucaria* species are generally found on sites at elevations from sea level to 2,100 m, with 1,200 to 2,400 mm of rainfall and well-drained soils. Cook-pine and Norfolk-Island-pine have been widely planted in Hawaii (Menninger 1964; Walters 1974). The botanical identities of these 2 species are often confused, and no one, not even visiting foresters from Australia, is absolutely sure which species is which! Recipients of araucaria seeds shipped out of Hawaii should be made aware of this confusion. All data on phenology and methods reported here are based on information obtained from the areas of natural occurrence. Norfolk-Island-pine is also a very common ornamental tree in Florida, California, Puerto Rico, and the U.S. Virgin Islands.

Flowering and fruiting. Araucarias generally begin to flower and set seed between the age of 15 to 20 years. Most hoop-pine trees begin producing female flowers and fruits when they are between 10 and 12 years old and 6 to 10 m tall. Flowering and fruiting is very intermittent from year to year, and pollen production begins when trees are between 22 and 27 years old and are about 20 m tall (Haines and Nikles 1987). Male and female flowers are generally found on different parts of the same tree. Male flowers usually appear at the base of the crown in young trees and the female flowers at the top. As the tree grows older, the male and female flowers come closer to each other. Bisexual flowers are also found. After pollination the female flowers develop slowly, with the cones maturing in about 2 years (Ntima 1968). The mature cones are ovoid or almost spherical, ranging in size from 10 by 5 cm for hoop-pine to 30 by 20 cm for bunya-pine (Ntima 1968). In natural stands, seedlots collected from hoop-pines are rarely more than 65% viable (Haines and Nikles 1987).

Upon maturing, cones turn from green to brown (Ntima 1968; Walters 1974). Cones

disintegrate on the tree or they fall to the ground and disintegrate. The brown seeds are kite-shaped and have papery wings on either side (figures 1 and 2) or are thick and heavy with much endosperm. Araucaria seeds may be carried a short distance from the mother tree by wind, but generally the seeds fall within the periphery of the crown (Ntima 1968). Animals and birds that prey on the seeds are the most effective natural dispersers of the heavy seeds. The time of flowering, seed development, and seed dispersal, as well as seed crop intervals are listed for 5 species in table 2.

Collection, cleaning, and storage. Most of the seeds of hoop-pine collected for planting are grown in seed orchards (Haines and Nikles 1987). Collection of cones should begin when the first trace of brownness is observed on the cone. In natural stands, the second-year cones are generally picked by climbing or felling trees (Howcroft 1978; Ntima 1968; Walters 1974). Cone collection must be timed correctly to get the highest proportion of mature and fertile seeds. A method for timing cone maturity is to pick a cone and measure the time it takes to disintegrate; ripe cones spontaneously disintegrate within 7 days. Collected cones should be spread on shelves in single layers for drying and turned daily. The cones normally will begin to disintegrate within a few days. Cones that fail to disintegrate within 10 days should be discarded, as they are considered too immature (Ntima 1968; Walters 1974). The average number of seeds per weight ranges from 77/kg (35/lb) for bunya-pine to 4,400/kg (1,995/lb) for hoop-pine (table 3) (Howcroft 1986; Walters 1974).

Most araucaria are recalcitrant (that is, intolerant of desiccation). Their seeds have short viability under atmospheric conditions and normally should be sown within a month of collection (Ntima 1968). If the seeds cannot be sown immediately, they should be stored under cold, moist, and airtight conditions at a temperature of 3 °C (Ntima 1968; Walters 1974). Klinki-pine seeds can be stored for at least 6 months with 32% moisture at a temperature of 3.5 °C (Willan 1991). Damp storage at 4 to 7 °C was best for monkey-puzzle-tree seeds. After 3 months of storage, these seeds began to germinate after 21 days at 25 to 30 °C and reached 70 to 90% germination after 7 days (Swindells 1980). Hoop-pine seeds appear to be orthodox (that is, tolerant of desiccation); air-dried seeds stored at temperatures ranging from 1.7 to -15 °C showed little reduction in germination percentage for 17 months of storage (46 to 50% germination), but decreased significantly between 17 and 100 months of storage. However, after 100 months of storage, germination still ranged from 25 to 44% (Shea and Armstrong 1978). Tompsett (1984) found that seeds of monkey puzzle, parana-pine, klinki-pine, and bunya-pine could not be safely dried below 25 to 40% moisture content; seeds of cook-pine and 2 other araucarias (*A. nemorosa*, and *A. scopulorum*) cannot be dried below 12%; and seeds of hoop-pine could be dried to 2% without damage. Seeds in the second 2 groups dried to moisture contents just above the critical levels can be stored at -18 °C and thus appear to be orthodox. Parana-pine, monkey-puzzle-tree, and bunya-pine seeds are classified as recalcitrant (Farrant and others 1989; Ramos and others 1988). Plastic bags are good containers (Ntima 1968). Seeds of hoop-pine can be stored up to 8 years (Shea and Armstrong 1978).

Germination. No pregermination treatments are needed for araucaria seed (Ntima 1968; Walters 1974). Under suitable moisture and temperature (21 to 30 °C) conditions, germination (which is cryptogeal in this genus) may begin about 10 days after sowing. Germination is delayed by cooler temperatures, sometimes taking 50 days or more (Ntima 1968). Seed quality varies from year to year; if sufficient pollen is available to the parent trees, seed quality is generally good (Walters

1974).

Twenty-nine and 45% of a large number of hoop-pine and klinki-pine seeds germinated within 9 weeks in a germination test (Thong 1974). Klinki-pine seeds are pregerminated (incubated until the radicle begins to show) before sowing into containers. In a test with 3 replications of 1,200 seeds each, germination averaged 85% in 22 days. Of those seeds not germinating, 54% were dead, 30% were rotten, and 16% had not germinated yet. Survival of seedlings in containers to outplanting size was 88%. Broadcasting seeds on the surface of wet sawdust with a second shadedcloth a few centimeters above the bed gave better germination than covering seeds with sawdust or germinating them without the second shadedcloth covering (Howcroft 1974). Tompsett (1984) obtained 80 to 100% germination of 6 species tested when seed moisture contents were optimal.

Nursery practice. Araucarias can be grown under high shade or low shade. For both types of shade, seeds are sown during spring. Norfolk-Island-pine seeds are placed on a bed of sandBsoilBpeat mix to germinate with the pointed end of the seed slightly embedded. About 70% of fresh seed germinate in 4 to 12 days (Logsdon 1973). Seeds should be treated with a fungicide to prevent damping-off. Fungi pathogenic to seedlings can be isolated from seed collected from the ground and even from seed extracted from cones collected from trees (El-Lakany and others 1981). *Rhizoctonia solani* Kühn the fungal species causing most of the cases of pre- and post-emergence damping-off was one of the most commonly isolated fungi from *Araucaria* seed (Kamara and others 1981). Control of seedborne and soilborne fungi should be undertaken before planting. With high shade, the seeds of all species except bunya-pine are sown in flat-bottomed drills about 1.25 cm (2 in) deep and then covered with the same amount of softwood sawdust (fungicide-treated hardwood sawdust may also be suitable).

Bunya-pine seeds are sown in drills 7 to 10 cm (3 to 4 in) deep or on shaded, moist media. A few months after sowing, fusiform radicles, called Atubers® (see chapter x, page xx), are formed. The seedbeds are re-dug, and these Atubers® are collected and then either planted directly into containers or stored at room temperature until required for planting. Exposure of the Atubers® to sunlight before re-planting breaks their dormancy, and the plants begin to grow. Almost every seed produces a Atuber® and all of these develop into plants (Walters 1974).

With low shade, the seeds are broadcast on well-prepared nursery beds and covered with about 2 cm (: in) of sawdust. The aim in both types of sowing is to have a stocking of 130 to 180 plants/m² (12 to 17/ft²) (Ntima 1968; Walters 1974).

Newly sown beds should be given full overhead shade within several days of sowing. Best shoot development occurs when the seedbeds are given 75% shade for the first few months and 5% shade for the next 3 months (except for hoop-pine). Shading should be removed in 2 steps after this shading treatment to give full exposure 2 weeks before transplanting to containers. Full light is not admitted until nearly 1 year after sowing hoop-pine. When 75% of the seedlings are 15 to 22 cm (6 to 9 in) tall, the seedlings should be transplanted. Lifting and planting need to be done carefully to minimize damage to the roots. Transplanting should be done about 5 months before field planting. The seedlings should be spaced 5 by 20 cm (2 to 8 in) apart (stem to stem) and given full shade. The shade should be gradually removed to give full sunlight to the seedlings for at least a month before transferring them to the planting site (Ntima 1968). About 50 to 60% of the seeds will develop into plantable seedlings. Seedlings are generally outplanted when 2 years old (Ntima 1968). Norfolk-

Island-pine seedlings grown in nursery beds or containers will be 15 to 20 cm (6 to 8 in) tall in 1 year and 60 to 76 cm (24 to 30 in) tall in 2 years (Logsdon 1973).

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Table 1C *Araucaria*, araucaria: nomenclature, occurrence, and heights attained

Scientific name & synonym	Common name	Occurrence		Maximum height (m)	
		Native	US		
<i>angustifolia</i> (Bertol.) Kuntz	Parana-pine candelabra tree, Brazilian-pine	Brazil, Argentina, & Paraguay	Hawaii & Puerto Rico	36	A.
<i>A. araucana</i> (Molina.) K. Koch. <i>A. imbricata</i> Par.	monkey-puzzle-tree, monkey puzzle,	Chile & Argentina Arauco-pine	California, Oregon, & Washington	50	
<i>A. bidwillii</i> Hook.	bunya-pine, bunya-bunya	Australia	California, Florida, Hawaii, & Puerto Rico	43	
<i>A. columnaris</i> (Forster) Hook. <i>A. excelsa</i> (Lamb.) R. Br.	Cook-pine, columnar araucaria	New Caledonia	Hawaii, Florida, & Puerto Rico	60	
<i>A. cunninghamii</i> Aiton ex D. Don)	hoop-pine	New Guinea, & Australia	California, Hawaii, & Puerto Rico	60	
<i>A. heterophylla</i> (Salisb.) Franko	Norfolk-Island-pine	Norfolk	California, Florida,	60	Island
<i>A. hunsteinii</i> K. Schum. & Hollrung <i>A. schummaniana</i> Warb.) <i>A. klinkii</i> Laut.	Klinki-pine	New Guinea	Hawaii & Puerto Rico	80	

Sources: Dallimore and Jackson (1954), Walters (1974).

Table 2C *Araucaria*, araucaria: time of flowering, seed development and dispersal, and seed crop intervals

Species	Flowering dates	Seed ripening dates	Seed dispersal dates	Crop intervals (yrs)
<i>A. angustifolia</i>	C	AprBMay	MayBAug	1
<i>A. bidwillii</i>	SeptBOct	JanBFeb	JanBFeb	1B2
<i>A. columnaris</i>	Dec.Jan	DecBFeb	DecBFeb	3B4
<i>A. cunninghamii</i>				
Early flowering races	DecBJan	Dec	Dec	4B5
Late flowering races	AprBMay	C	C	C
<i>A. heterophylla</i>	Sept	Apr	AprBMay	3B4

Source: Walters (1974).

Note: Information for all species is based on their natural ranges.

Table 3C *Araucaria*, araucaria: seed data (number of cleaned seeds per weight)

Species	Range		Average	
	/kg	/lb	/kg	/lb
<i>A. angustifolia</i>	C	C	108	50
<i>A. bidwillii</i>	66B88	30B40	77	35
<i>A. columnaris</i>	1,980B2,640	900B1,200	2,200	1,000
<i>A. cunninghamii</i>	3,300B6,600	1,500B3,000	4,400	2,000
<i>A. heterophylla</i>	550B620	250B280	573	260
<i>A. hunsteinii</i>	2,000B2,500	900B1,100	C	C

Sources: Howcroft (1986b), Walters (1974).