Pinaceae—Pine family

PINUS L. Pine

by Stanley L. Krugman [1] and James L. Jenkinson [2]

Growth habit, occurrence, and use.—The genus *Pinus*, one of the largest and most important of the coniferous genera, comprises about 95 species and numerous varieties and hybrids. Pines are widely distributed, mostly in the Northern Hemisphere from sea level *(Pinus contorta* var. *contorta)* to timberline *(P. albicaulis)*. They range from Alaska to Nicaragua, from Scandinavia to North Africa, and from Siberia to Sumatra. Some species, such as *P. sylvestris*, are widely distributed—from Scotland to Siberia—while other species have restricted natural ranges. *Pinus canariensis*, for example, is found naturally only on the Canary Islands, and *P. torreyana* numbers only a few thousand individuals in two California localities (table 1) (*49*).

Forty-one species of pines are native to the United States. These species are also the most widely planted in the United States. Planting has extended the range of a number of them, including *P. strobus, P. banksiana, P. radiata, P. ponderosa* var. *scopulorum, P. resinosa,* and *P. virginiana* (*71, 266*). Many of the native eastern pines, especially those from the southern States, do not do well in the western States. The same appears to be true for many western pines when they are planted in the eastern States (*120, 201*).

Many introduced pines have been planted and grown successfully in the United States. Four of these—*P. sylvestris, P. thunbergiana, P. densiflora,* and *P. nigra*—have become naturalized in parts of New England and the Lake States (*264, 270*).

Many other pine species have been successfully planted outside their native range. These include *P. patula* in South Africa; *P. radiata* in South Africa, New Zealand, Australia, and South America; *P. insularis* in East Africa; *P. elliottii* var. *elliottii, P. taeda, P. pinaster,* and *P. palustris* in South Africa, New Zealand, and Australia; *P. ponderosa* in Australia and New Zealand; *P. canariensis* in North Africa and South Africa; *P. caribea* in South Africa and Australia; *P. halepensis* in South America; *P. muricata* in New Zealand and Australia; *P. sylvestris, P. strobus, P. contorta,* and *P. nigra* in Europe; *P. merkusii* in Borneo and Java *128, 152, 169, 266*).

The pines are evergreen trees of various heights, often very tall but occasionally shrubby (table 3). Some species, such as *P. lambertiana, P. monticola, P. ponderosa,* and *P. strobus,* grow to more than 200 feet tall, while others, as *P. cembroides* and *P. pumila,* may not exceed 30 feet at maturity.

Pines provide some of the most valuable timber and are also widely used to protect watersheds, to provide habitats for wildlife, and to construct shelterbelts. The bulk of naval stores still comes from pines, and the seeds of some species are a valuable food source. Increasingly, pines are planted to improve man's environment.

Sixty-five species and varieties which are now being planted or which have a potential in the United States are listed in table 1; included are 40 species and varieties native to the United States, one to Mexico, one to the Caribbean region, 11 to Europe, Africa and the near east, and 12 to Asia.

Geographic races and hybrids.—The importance of planting seeds or seedlings from the proper source cannot be stressed to strongly. Seed origin is extremely important in determining the ability of a species to grow and succeed in a given environment. Many pines with an extensive range, as well as some of limited natural range, have developed geographic races that are morphologically and physiologically distinct (*32*). These differences make each race best suited for growing in certain environments. As a general rule, seeds from sources in moist regions are smaller and produce faster growing and less deeply rooted seedlings than seeds from sources in drier regions. Southern seed sources commonly differ from northern sources by being faster growing, capable of growing longer in a season, more susceptible to damage by winter

[1] Timber Management Research, USDA Forest Service.

[2] Pacific Southwest Forest and Range Exp. Stn.

freezes, less susceptible to late spring and early autumn frosts; and having seed dormancy that can often be overcome with a shorter presowing treatment (*122, 218, 260, 266*).

For many of the pines, detailed data about geographic races are not available. In some cases our understanding of races of pines native to the United States comes from plantings in other countries. When appropriate, this information is included in the following species summaries:

Pinus attenuata—From morphological and nursery studies, knobcone pine in California can be separated into two major groups, one north and the other south of the Monterey-San Luis Obispo County line. Seed weight tends to increase from north to south, and seeds of northern origins require a longer stratification period (3 weeks or more) than seeds of southern origin (less than 3 weeks). Seedlings from northern sources tend to be more frost resistant than those from southern sources. These differences among sources appear to be clinal and reflect the latitudinal distribution of the species (*175*).

Pinus balfouriana—Seeds of northern origin (Lake Mountain, California) are longer than those of southern origin (Mineral King, California) and have persistent seed wings compared to the detachable wings of southern sources (*154*).

Pinus banksiana—Sources differ in seed size, growth, form, and susceptibility to insect and disease damage. Seeds tend to be larger from the warmer parts of the range (*71*). In Minne-

TABLE 1.—*Pinus: nomenclature, occurrence, and uses; data compilers*

Scientific names and synonyms	Common names	Occurrence	Uses[1]	Data compilers for the species
P. albicaulis Engelm.	**whitebark pine**	Subalpine in the northern Rocky Mountains and Coast Mountains of British Columbia through the Cascade Range to the southern Sierra Nevada.	T, W, E	R. J. Steinhoff.
P. aristata Engelm. *P. balfouriana* var. *aristata* (Engelm.) Engelm.	**bristlecone pine,** foxtail pine, hickory pine.	Small, scattered subalpine areas in California, Nevada, Utah, Arizona, and New Mexico.	H, E	G. H. Schubert.
P. armandii Franch.	**Armand pine**	Moderate-high elevations from central and southwestern China to northern Burma and southeastern Tibet; Taiwan and Hainan.	T, E	P. O. Rudolf.
P. attenuata Lemm. *P. tuberculata* Gord.	**knobcone pine**	Rocky slopes and ridges from southwestern Oregon and California to northwestern Baja California.	W, E	S. L. Krugman.
P. balfouriana Grev. & Balf.	**foxtail pine,** Balfour pine.	Subalpine in Klamath Mountains and southern Sierra Nevada, California.	H, W	Do.
P. banksiana Lamb. *P. divaricata* (Ait.) Sudw.	**jack pine,** scrub pine, banksiana pine, black pine, gray pine.	Canada, from the Mackenzie River and Alberta to Nova Scotia and south into the Great Lakes region and New England States.	T, H, W, S, E.	D. H. Dawson.
P. brutia Ten. *P. halepensis* var. ***brutia*** (Ten.) Elwes & Henry	**Calabrian pine**	Crete, Cyprus, and Lebanon north through Turkey.	S, E	S. L. Krugman.
P. canariensis C. Smith	**Canary Island pine,** Canary pine.	Dry, exposed slopes of the central and western Canary Islands.	T, W, E	P. O. Rudolf.
P. caribaea Morelet *P. bahamensis* Griseb. *P. hondurensis* Loock	**Caribbean pine**	Bahama Islands, western Cuba, Isle of Pines, and Central America from British Honduras to Nicaragua.	T, E	S. L. Krugman.

TABLE 1.—*Pinus: nomenclature, occurrence, and uses; data compilers*—Continued

Scientific names and synonyms	Common names	Occurrence	Uses[1]	Data compilers for the species
P. cembra L. *P. montana* Lam.	**Swiss stone pine,** cembran pine, arolla pine.	High elevations in the Alps and Carpathian Mountains of central Europe.	T, W, E	P. O. Rudolf.
P. cembroides Zucc.	**Mexican pinyon,** nut pine, pinyon.	Semiarid mountain regions in Mexico, southeastern Arizona, southwestern New Mexico, and southwestern Texas.	W, E	S. L. Krugman.
P. clausa (Chapm.) Vasey	**sand pine,** spruce pine.	Sandy plains of central and coastal Florida and the southern tip of Alabama.	T, H	L. Jones.
P. contorta Dougl. var. ***contorta***	**shore pine,** lodgepole pine, beach pine, coast pine.	Low elevations on the Pacific Coast from southeastern Alaska to California.	W, E	S. L. Krugman.
P. contorta var. ***latifolia*** Engelm.	**Rocky Mountain lodgepole pine.**	Rocky Mountains, from Canada to Utah and Colorado, and the Black Hills.	T, H, W, S	J. E. Lotan.
P. contorta var. ***murrayana*** (Grev. & Balf.) Engelm.	**Sierra Nevada lodgepole pine.**	High elevations in the Cascade Range-Sierra Nevada chain from southwestern Washington to Baja California.	T, H, W	S. L. Krugman.
P. coulteri D. Don	**Coulter pine,** nut pine, big-cone pine.	Coastal mountains from central California south to northern Baja California.	H, E	Do.
P. densiflora Sieb. & Zucc.	**Japanese red pine.**	Midelevation in the mountains of Japan and Korea north to eastern Manchuria and adjacent U.S.S.R.	E	S. L. Krugman and P. O. Rudolf.
P. echinata Mill.	**shortleaf pine,** southern yellow pine.	Coastal plain of southeastern United States to eastern Oklahoma and eastern Texas.	T, H, W	J. M. McGilvray.
P. edulis Engelm. *P. cembroides* var. *edulis* (Engelm.) Voss	**pinyon,** Colorado pinyon pine, nut pine.	Semiarid regions in Utah, Colorado, Arizona, and New Mexico.	T, H, E	G. H. Schubert.
P. elliottii var. ***densa*** Little & Dorman.	**South Florida slash pine.**	Southern and central Florida, and Lower Florida Keys.	T, E	R. L. Barnes.
P. elliottii Engelm. var. ***elliottii*** *P. caribaea* Morelet	**slash pine,** swamp pine, pitch pine, yellow slash pine.	Coastal Plains from South Carolina to central Florida and southeastern Louisiana.	T, H, E	Do.
P. engelmannii Carr. *P. latifolia* Sarg. *P. apacheca* Lemm.	**Apache pine,** Arizona longleaf pine.	Mountains of southeastern Arizona and southwestern New Mexico south through the Sierra Madre Occidental, Mexico.	T, E	G. H. Schubert.
P. flexilis James	**limber pine,** Rocky Mountain white pine.	Subalpine in the Rocky Mountains and southern Sierra Nevada.	T, W, S, E	R. J. Steinhoff.
P. gerardiana Wall. *P. aucklandii* Lodd. *P. chilghoza* Ehh.	**chilgoza pine,** Gerard pine.	Mountains of eastern Afghanistan, northern Pakistan, Kashmir, and northern India.	T, H, E	P. O. Rudolf.
P. glabra Walt.	**spruce pine,** cedar pine.	Coastal Plains from South Carolina to northern Florida and west to southeastern Louisiana.	T, H	J. P. Barnett.

TABLE 1.—*Pinus: nomenclature, occurrence, and uses; data compilers*—Continued

Scientific names and synonyms	Common names	Occurrence	Uses[1]	Data compilers for the species
P. halepensis Mill. *P. alepensis* Poir.	**Aleppo pine,** Jerusalem pine.	Mediterranean region, from Spain and Morocco to Turkey and Jordan.	T, W, E	P. O. Rudolf.
P. heldreichii Christ *P. heldreichii* var. *leucodermis* (Ant.) Markgr. *P. leucodermis* Ant. *P. nigra* var. *leucodermis* (Ant.) Rehd.	**Heldreich pine,** Balkan pine, Bosnian pine, graybark pine.	High elevations from central Yugoslavia to northern Greece and in southern Italy.	W, E	Do.
P. insularis Endl. *P. khasya* Royle	**Khasi pine**	High elevations from eastern India to South Vietnam, and mountains of northern Luzon, Philippines.	S, E	S. L. Krugman.
P. jeffreyi Grev. & Balf. *P. ponderosa* var. *jeffreyi* (Grev. & Balf.) Engelm.	**Jeffrey pine**	Mountains of southwestern Oregon, California, western Nevada and northern Baja California.	T, H, W, E	Do.
P. koraiensis Sieb. & Zucc.	**Korean pine,** cedar pine.	Mountains from southeastern Siberia to South Korea; central Honshu, Japan.	T	P. O. Rudolf.
P. lambertiana Dougl.	**sugar pine,** pino real.	Mountains from western Oregon through California to western Nevada and northern Baja California.	T, W	S. L. Krugman.
P. leiophylla var. ***chihuahuana*** (Engelm.) Shaw *P. chihuahuana* Engelm.	**Chihuahua pine,** yellow pine, pino real.	Mountains of central Arizona and southwestern New Mexico south through the Sierra Madre Occidental in northern Mexico.	T, E	W. J. Rietveld.
P. merkusii Jungh. & de Vriese	**Merkus pine,** Tenasserim pine.	Mountains of southeastern Burma to North and South Vietnam; western Sumatra; Luzon and Mindoro in the Philippines.	T, E	S. L. Krugman.
P. monophylla Torr. & Frém. *P. cembroides* var. *monophylla* (Torr. & Frém.) Voss	**singleleaf pinyon,** nut pine, pinyon.	Semiarid mountains from southeastern Idaho through the Great Basin ranges to central and southern California and northern Baja California.	H, W, E	A. L. Roe.
P. monticola Dougl.	**western white pine,** Idaho white pine, silver pine.	Southern British Columbia to western Montana, northern Idaho and northeastern Oregon; south in the Cascade Range, Klamath Mountains and Sierra Nevada to central California.	T, W	R. T. Bingham.
P. mugo Turra *P. montana* Mill.	**Swiss mountain pine,** Mugho pine, dwarf mountain pine.	Subalpine in the Pyrenees, Alps, Carpathian and Balkan Mountains of central and southern Europe.	W, E	P. O. Rudolf.
P. muricata D. Don *P. remorata* Mason	**bishop pine,** prickle-cone pine, Santa Cruz Island pine.	Coastal California and northern Baja California; Santa Rosa, Santa Cruz, and Cedros Islands.	H, E	S. L. Krugman.
P. nigra Arnold *P. laricio* Poir.	**Austrian pine,** black pine, European black pine.	Southern Europe, northern Morocco, Sicily, and Cyprus.	T, W, S, E	P. O. Rudolf.

TABLE 1.—*Pinus: nomenclature, occurrence, and uses; data compilers*—Continued

Scientific names and synonyms	Common names	Occurrence	Uses [1]	Data compilers for the species
P. palustris Mill. *P. australis* Michx. f.	**longleaf pine,** southern pine, longstraw pine	Coastal Plains from southeastern Virginia to central Florida and west to eastern Texas.	T, H, E	J. M. McGilvray.
P. parviflora Sieb. & Zucc. *P. pentaphylla* Mayr *P. himekomatsu* Miyabe and Kudo	**Japanese** white pine.	Mountains throughout Japan from southern Kyushu north to southern Hokkaido; Korean Island of Utsuryo.	E	P. O. Rudolf.
P. patula Schiede and Deppe	**Mexican weeping pine.**	Eastern Mexico from Tamaulipas south to Oaxaca.	T, W	S. L. Krugman.
P. peuce Griseb. *P. excelsa* var. *peuce* (Griseb.) Beissn.	**Balkan pine,** Macedonian pine, Greek stone pine.	High mountains of western Bulgaria, southern Yugoslavia, eastern Albania, and northern Greece.	T, E	P. O. Rudolf.
P. pinaster Ait. *P. maritima* Poir.	**maritime pine,** cluster pine, pinaster pine.	Coastal areas in Morocco, Portugal, Spain, southern France, western Italy, Corsica, Sardinia, and northeastern Algeria.	T, W, S	Do.
P. pinea L.	**Italian stone pine,** umbrella pine, stone pine.	Portugal, Spain, and north shores of the Mediterranean Sea to Lebanon; northeastern Turkey; Ibiza, Sardinia, Sicily, Crete, and Cyprus.	T, H, S, E	Do.
P. ponderosa var. ***arizonica*** (Engelm.) Shaw *P. arizonica* Engelm.	**Arizona pine,** Arizona ponderosa pine, Arizona yellow pine.	Extreme southwestern New Mexico and southeastern Arizona through the Sierra Madre Occidental to Durango.	T, H, W	W. J. Rietveld.
P. ponderosa Laws. var. ***ponderosa***	**ponderosa pine,** bull pine, rock pine, western yellow pine, blackjack pine.	Southern British Columbia south to central Idaho, and through the Cascade Range, Coast Ranges, and Sierra Nevada to southern California.	T, S, E	R. J. Boyd.
P. ponderosa var. ***scopulorum*** Engelm.	**Rocky Mountain ponderosa pine,** western yellow pine, blackjack pine.	Rocky Mountains from Montana south to New Mexico, Trans-Pecos Texas and northern Mexico; west to eastern Nevada and east to central Nebraska.	T, H, W, S, E.	J. L. VanDeusen.
P. pumila Regel *P. cembra* var. *pumila* Pall.	**Japanese stone pine,** dwarf Siberian pine.	Eastern Siberia south to northern Mongolia, Manchuria, Korea, and through the Kuril Islands to central Honshu, Japan.	E	S. L. Krugman.
P. pungens Lamb.	**Table Mountain pine,** hickory pine, mountain pine.	Appalachian Mountain region from Pennsylvania to northeastern Georgia.	T, H, W, E	S. Little.
P. quadrifolia Parl. *P. cembroides* var. *parryana* Voss	**Parry pinyon,** nut pine, pinyon.	Semiarid mountains of extreme southern California and northern Baja California.	W, E, H	S. L. Krugman.
P. radiata D. Don *P. insignis* Dougl.	**Monterey pine,** radiata pine, insignis pine.	Coastal central California and northern Guadalupe Island, Mexico.	T, S, E	Do.
P. resinosa Ait.	**red pine,** Norway pine, hard pine, pitch pine.	Great Lakes region from southeastern Manitoba and Minnesota east to Newfoundland, Nova Scotia and New Jersey.	T, H, W, E, S.	D. H. Dawson.

TABLE 1.—*Pinus: nomenclature, occurrence, and uses; data compilers*—Continued

Scientific names and synonyms	Common names	Occurrence	Uses [1]	Data compilers for the species
P. rigida Mill.	**pitch pine,** hard pine, bull pine.	Northeastern United States and the Appalachian Mountain region, from Lake Ontario and Maine to western Kentucky and northern Georgia.	T, H, W, E	S. Little.
P. roxburghii Sarg. *P. longifolia* Roxb.	**Chir pine,** longleaf Indian pine.	Monsoon belt of the outer Himalayas, from northeastern West Pakistan to Bhutan.	T, S, E	P. O. Rudolf.
P. sabiniana Dougl.	**Digger pine,** gray pine.	Low-elevation dry sites in the Coast Ranges and Sierra Nevada, California.	T, H	S. L. Krugman.
P. serotina Michx. *P. rigida* var. *serotina* (Michx.) Loud.	**pond pine,** marsh pine.	Coastal Plains from southern New Jersey to central Florida and west to central Alabama.	T	B. Benson.
P. sibirica Du Tour *P. cembra* var. *sibirica* Loud.	**Siberian stone pine.**	Ural Mountains east through western and central Siberia to northern Mongolia.	T, E	P. O. Rudolf.
P. strobiformis Engelm. *P. flexilis* var. *reflexa* Engelm. *P. reflexa* (Engelm.) Engelm.	**southwestern white pine,** border limber pine, Mexican white pine.	Mountains of southwestern Colorado, Arizona, and New Mexico south in the Sierra Madre Occidental and Oriental to central Mexico.	T, H, W	W. J. Rietveld.
P. strobus L.	**eastern white pine,** northern white pine, white pine, soft pine, Weymouth pine.	Newfoundland and Nova Scotia west to southeastern Manitoba, south through the Great Lakes and Appalachian Mountain regions to Iowa, western Kentucky, and northern Georgia.	T, H, W, S, E.	R. E. Graber.
P. sylvestris L.	**Scotch pine,** Scots pine.	Eurasia, from Scotland and Spain to Finland and Turkey, across U.S.S.R. to the Sea of Okhotsk and Manchuria.	T, S, E	R. S. Walters.
P. taeda L.	**loblolly pine,** oldfield pine.	Coastal Plains and Piedmont from Delaware to central Florida to eastern Texas, southern Arkansas, and southern Tennessee.	T, H, W	B. F. McLemore.
P. thunbergiana Franco *P. thunbergii* Parl.	**Japanese black pine.**	Maritime in South Korea and in Japan from northern Honshu south to northern Ryukyu Islands.	T, W, S, E	P. O. Rudolf.
P. torreyana Parry	**Torrey pine,** Soledad pine, Del Mar pine.	Santa Rosa Island and low coastal bluffs in San Diego Co., California.	E	S. L. Krugman.
P. virginiana Mill.	**Virginia pine,** scrub pine, Jersey pine.	Appalachian Mountain and Piedmont regions, from Long Island south and west to central Alabama, western Tennessee, and southern Indiana.	T, W	S. Little.
P. wallichiana A. B. Jacks. *P. excelsa* Wall. *P. griffithii* McClelland *P. nepalensis* de Chambr.	**blue pine,** Bhutan pine, Himalayan pine.	Mid- and high-elevations in the Himalayas, west to eastern Afghanistan and east to southern China and northern Burma.	T, E	P. O. Rudolf.

[1] T: timber production, H: habitat or food for wildlife, W: watershed, S: shelterbelt, E: environmental forestry.

sota there is a change in cone serotiny from closed cones in the north to predominantly open cones in the south (*197*). Winter coloration of needles is less in seedlings from lower latitudes than in those from higher latitudes (*222*). In Canada, height growth was greater for sources from areas with longer growing seasons; selections moved north made better height growth than selections moved south (*104*).

Pinus brutia—Several varieties have been described in the Black Sea region. The var. *pithyusa* is found along the northern and northeastern shores of the Black Sea, and var. *eldarica* is found in the central Transcaucasus (*152*). In northern California, an Afghanistan source related to var. *eldarica* is out-growing var. *pithyusa* and appears to be both frost and drought hardy and of good form (*90, 122*).

Pinus canariensis—This pine is found naturally only in the Canary Islands where it ranges from 2,100 to 7,200 feet above sea level (*152*). Seedlings of several sources from the various islands and elevations, when exposed to low winter temperatures in the Institute of Forest Genetics' nursery at Placerville, California, showed marked differences in cold hardiness. Seedlings from 4,000 feet showed more cold damage than seedlings from 6,200 feet on Tenerife Island. Seedlings from 6,200 feet on Palma Island were badly damaged, suggesting that sources from different islands may also differ in susceptibility to low temperature (*122*).

Pinus caribaea—Three geographic variants are recognized. The var. *caribaea* native to Cuba and the Isle of Pines has persistent seed wings, while the other two varieties do not. In tests in South Africa, var. *caribaea* showed better growth than var. *hondurensis* from the mainland of Central America. The var. *hondurensis* has the largest seeds; var. *bahamensis* from the Bahama Islands has the smallest (*150*).

Pinus cembra—A number of cultivars of this species have been reported (*51, 180*).

Pinus cembroides—Two varieties have been described. The var. *remota* found on the Edwards Plateau in southwestern Texas has very thin seedcoats. The var. *bicolor* is found in southwestern New Mexico and southeastern Arizona (*137*).

Pinus clausa—In central Florida, this small pine has closed cones. But in western Florida it has an open-cone variety, var. *immuginata*—Choctawhatchee sand pine, whose cones ripen in September and shed seeds during October (*29, 138*).

Pinus contorta—Four varieties are recognized though only three are listed in the tables. The fourth, var. *bolanderi*, has a restricted range on the northern California coast—the Mendocino White Plains—and has serotinous cones like those of the Rocky Mountain variety, var. *latifolia*. The other varieties have cones which open at or soon after maturity; the open cones of var. *contorta* persist indefinitely while those of var. *murrayana* do not (*44*). In tests in northern Europe, seedlings of var. *contorta* grew faster, and were more branchy and less winter hardy than those of var. *latifolia* from interior British Columbia and the Rocky Mountains (*64*). The var. *murrayana* has the largest seeds. At temperatures of 50° to 68° F. the var. *latifolia* germinates twice as fast as coastal sources (*44*).

Differences between sources also are found within a given variety. Seeds from high elevations in central British Columbia germinated faster at 68° F. than at other temperatures, and seed from low elevations germinated faster at temperatures above 68° F. (*84*). Commonly, the southern sources grow faster than the northern sources of a given variety.

Pinus coulteri—This pine is endemic to California and Baja California. No races have been described, even though it grows in isolated stands from 500 to 7,000 feet and on fertile to very poor soil types. Mount Diablo sources are considered to have the poorest form, with greater branching than any other source (*273*).

Pinus densiflora—A number of cultivars have been described (*180*). This pine is widely planted and hardy in the Lake States, New England, and southern Ontario (*264*).

Pinus echinata—Ten-year results in a range-wide test suggest that in the southern United States the southernmost sources from east of the Mississippi River are superior to northern sources in both survival and growth (*260*). Seeds from northern sources should be used in the northern extremities of the range (*144, 260, 262*). In an Oklahoma test, an Arkansas seed source showed the best performance, even surpassing a local source (*183*).

Pinus edulis—A single leaf variety, var. *fallax*, is found in the mountains at 6,000 feet in central and eastern Arizona, and in the Grand Canyon and parts of New Mexico. Its seeds tend to be larger and have a thicker seedcoat than the more common variety, var. *edulis*. In contrast to var. *edulis*, var. *fallax* seldom produces seeds in quantity (*137*).

Pinus elliottii—Two varieties are recognized. The var. *densa* is found only in south Florida. Compared to typical slash pine, var. *elliottii*, the var. *densa* germinates faster, has a grasslike seedling stage with crowded needles, and has heavy wood with very wide summer rings (*139, 140, 216*). Sources of var. *elliottii* in northeastern Florida appear to be the poorest, as they are susceptible to ice damage and are less drought resistant than northern and western sources (*216, 260*).

Pinus flexilis—Seedlings from southern stands are faster growing than seedlings from northern stands (*219*).

Pinus halepensis—In Israel at least two elevational ecotypes are recognized, and others can be expected in other parts of the range (*118, 152*).

Pinus heldreichii—*Pinus heldreichii* var. *leucodermis*, considered by some to be a timberline tree, commonly is found on drier sites and often on soils formed on limestones (*51*). The var. *heldreichii* forms open forests in the mountains at elevations between 3,000 and 5,000 feet (*180*).

Pinus insularis—In tests in northern Rhodesia, trees from seed of Philippine origin were more vigorous and had better form than those from India, Burma, or Vietnam origins (*152, 200*).

Pinus jeffreyi—Evidence for distinct geographic races is lacking, but differences in seed origin are still important. Generally, trees from seed collected east of the Sierra Nevada are slower growing, more drought resistant, and less susceptible to cold damage (*85*). Also trees from high-elevation sources tend to be slower growing than those from lower elevations (*33*).

Pinus koraiensis—The Siberia, China, and Korea sources most likely should be considered a geographic race distinct from that in Japan.

Pinus leiophylla var. *chihuahuana*—Two distinct forms have been found. One has poor form with a short, crooked bole and many branches; the other has good form and grows to heights of 80 feet (*152*).

Pinus merkusii—At least two distinct races are recognized, one on the Asian mainland and the other on the island of Sumatra. Seeds of mainland origin are larger than those from Sumatra. Trees from mainland origins pass through a grasslike stage and tend to be uninodal with a straight, cylindrical bole, but they do not grow as tall as those from Sumatra. The Sumatra trees may reach 200 feet in height and tend to be sinuous in growth (*40*). Some consider the two races as separate species: *P. merkusii* on Sumatra, and *P. merkusiana* on the Asian mainland (*41*).

Pinus monophylla—No varieties are recognized, but there are variants which have partly or mostly two needles in a fascicle, rather than just one (*137*).

Pinus monticola—Local variations associated with elevation and site are recognized. Progenies from high-elevation origins grow faster at high elevation than those from low-elevation origins (*217*). Seeds from northern Idaho are smaller than those from Washington and California (*235*).

Pinus mugo—A number of horticultural varieties have been described. They vary from a sprawling shrub, var. *pumilio*, to a small tree, var. *rostrata* (*180*). Varieties also differ in seed size and germination capacity (*187*). Seedlings of low-elevation origins are not hardy at high elevations (*256*).

Pinus muricata—Trees from origins north and south of Fort Ross, California, differ in growth form, foliage color, and cone shape. In California, trees from northern sources tend to grow larger with fuller and more compact crowns (*61*). In tests in Australia, the northern sources maintained better growth rate and form than the southern sources (*69*).

Pinus nigra—Several distinct varieties and numerous cultivars are recognized. The var. *caramanica* from the Crimea, Turkey, and Cyprus tends to have the largest seeds (17,500 to 20,800 per pound); the var. *corsicana* from Corsica has the smallest seeds (28,000 to 36,000 per pound) (*152, 187*). Wood in the Corsican variety is considerably better than that in typical Austrian pine, var. *austriaca*, from the Balkan peninsula and eastern Alps. Stands of var. *calabrica* planted in Belgium are considered one of the more cold hardy varieties. Other varieties are var. *cebennensis* from the Pyrenees in southern France, var. *hispanica* from Spain, and var. *mauritanica* from Morocco and Algeria.

Some general statements can be made for various geographic sources (*152*):

Western Groups: Sources in France and Spain are often proven to be drought resistant and are indifferent to soil type.

Central Groups: Sources in Corsica and Italy grow well and have good form. But they need a high humidity and grow poorly on limestone soils.

Eastern Groups: Sources in the Balkan and Crimea areas appear to do well on the poorer limestone soils.

Pinus palustris—Seedlings of different geographic origin differ in height, growth, cold resistance, and survival (*71, 260*). Southeastern and central Louisiana sources did poorly; southern Florida sources failed outside of their area of origin. Central Gulf Coast sources grow well throughout the Gulf Coast (*260*).

Pinus parviflora—Several horticultural forms are cultivated (*123*). *Pinus parviflora* is thought to consist of two geographical varieties which intergrade in central Honshu, Japan (*49*).

Pinus patula—Because of its rapid growth, this species has become one of the most important sources of wood in the summer rainfall areas of South Africa (*148*). It also grows well in East Africa, New Zealand, and Australia (*128, 152*). A variety, var. *longepedunculata,* from the States of Oaxaca and Chiapas, Mexico, has been reported. The cones of this variety open quickly at maturity, thus differing from var. *patula* which has closed cones. The seeds of var. *longepedunculata* are black with brown marks, while those of var. *patula* are pure black (*148*).

Pinus peuce—In Europe seeds from the Rila and Pirin Mountains in Bulgaria are considered to produce the best trees (*171*).

Pinus pinaster—This species is highly variable, and at least four main races are recognized (*152*). The French or Atlantic race, which is itself quite variable, is commonly found on the coastal sands. The Portuguese race is also found on coastal sands but is superior to the French race in growth, form, and drought resistance; it has done well in tests in South Africa and western Australia, and appears to have some seed dormancy (*105, 266*). The Corsican race is most commonly found in the mountains. The Moroccan race shows differences between mountain and near coastal origins, in that sources of mountain origin fail when planted on the coast. The mountain sources are thought to be frost resistant (*152*).

Pinus ponderosa—The three main varieties are var. *ponderosa,* var. *arizonica,* and var. *scopulorum.* These varieties differ in seed and cone size, needle length and number per fascicle, speed of germination, rate of growth, form, resistance to drought and low temperatures, and survival (*31, 71, 218, 257, 259*). Within the varieties there are also source differences in some of these characteristics. Speed of germination at different temperatures was found to vary for seeds from the Pacific Northwest, Rocky Mountains, and the Southwest. Southwest sources reached maximum germination at the lowest temperature (*31*). In tests in Oregon and Washington, growth rate generally increased with seed origins from east to west, and from south to north in the eastern part of the range; slowest growth was shown by sources from eastern and southeastern parts of the range (*218*). In tests in California, growth rate generally increased as seed source elevation decreased (*33*). In tests in northern Arizona, eastern and southeastern sources did well, but northern and western sources failed—as did the southernmost source (*125*). Northern sources of var. *scopulorum* are characterized by a relatively good growth rate and frost resistance (*257*). Southern sources of this variety are slower growing but frost resistant. In California, sources of var. *ponderosa* west of the Sierra Nevada are faster growing but less frost resistant than sources east of the crest (*122*).

Closely related to *P. ponderosa* in appearance is *P. washoensis.* This rare pine, which is often wrongly identified as *P. ponderosa* var. *ponderosa,* is known to be in only three areas: east slope of Mount Rose, Nevada; southern Warner Mountains, northeast California; and Bald Mountain Range in the eastern Sierra Nevada. Both its male and developing, second-year female cones are purple to purplish black, unlike ponderosa pine. Washoe pine flowers in July; its cones mature in August and September and open in September. Cones and seeds are handled in the same manner as var. *ponderosa,* and its seeds germinate promptly after a 60-day cold stratification (*47, 122*).

Pinus pungens—Seed weight, cone length and width appear to decrease as elevation increases and as latitude decreases. Cone serotiny is most common in the southern part of the range. No distinct varieties are recognized (*274*).

Pinus radiata—Monterey pine occurs naturally in four relatively small and well separated populations. The var. *binata* occurs on San Guadalupe Island and is slower growing than the three mainland populations (Monterey, Cambria, and Año Nuevo Point). The Cambria population has the largest cones and seeds, and the Monterey population has the smallest (*70*). In tests in Australia, trees of Cambria origin did not do as well as those from the Año Nuevo Point and Monterey populations (*69*).

Pinus resinosa—This species is considered one of the least variable of the pines, and no subspecies or varieties are recognized (*74, 266*). However, some height growth, form, and wood quality differences may exist among populations in the Lake States, New England States, and West Virginia. In northern sources, seeds are often smaller, lammas frequency is generally less, and frost resistance is higher than in southern sources (*74*).

Pinus rigida—No distinct geographic sources are known, but there are variations in form and development between populations. Throughout most of the range, trees consistently open cones and shed seeds soon after maturity; in southern New Jersey the vast majority bear cones that remain closed at maturity and only open at irregular intervals (*6, 71*). The latter trees are characteristic of areas with a history of wild fires (*71*).

Pinus sabiniana—Seeds from populations in mild climate areas germinated more quickly after stratification than those from the colder areas. Seedlings of southern origin grew longer than those of northern origin. Larger cones were more frequent in the northwest part of the range than in the Sierra Nevada (*82*).

Pinus serotina—Cone serotiny is greater in southern and coastal populations than in northern and Piedmont populations (*214*).

Pinus sibirica—Distinct differences in growth rate, branching habit and fat content of seeds exist between certain populations. No varieties are recognized, but several forms have been described. *Pinus sibirica* f. *humistrata* is a dwarf form that grows on mountain summits and ridges. *Pinus sibirica* f. *coronans* has a wide and dense crown, is reasonably drought resistant, and is found from sea level to 6,600 feet. *Pinus sibirica* f. *turfosa* grows on peat (*185*).

Pinus sylvestris—Scotch pine, the most widely planted introduced species in the United States, is probably the most intensively studied of all pines. The first comparative pine seed source trials involved this species. It is the pine with the greatest natural range, and it grows in many different ecological situations (*266, 268*). Numerous varieties, forms, and ecotypes have been described. A conservative estimate of the number of geographic varieties ranges from 21 to 52 (*268*). There is also considerable variation within named varieties. Sources differ in many characteristics including seed size, germination, dormancy, seed and cone color, tree form, growth rate, structure of root system, flowering characteristics, needle color, and susceptibility to heat, cold, or drought (*28, 186, 220, 266, 268*). Seed size decreases from the south (44,200 per pound in Spain) to the north (127,000 per pound in Lapland) (*101*). Growth rate tends to decrease from southern to northern sources. In tests in Sweden, southern sources grew faster and later in the autumn than did northern sources (*117*). Similar results were found in Michigan tests, where certain French sources grew three times as tall as northern Finnish and northern Siberian sources (*266, 268*). The more southern sources, however, were more susceptible to low temperatures than northern sources. Under Canadian prairie conditions, Russian and Finnish sources survived better than more southerly sources (*42*). In Michigan, needles of Spanish, southern France, Balkans, and Asia Minor origins remained green during the winter, while those of Siberian and Scandinavian origins turned yellow (*266, 268*). In tests conducted in Sweden, seed origin influenced germination rate at a given temperature. Sources from northern latitudes or high elevations germinated well over a wider range of temperatures than those of southern latitudes or low elevations (*117*). Sources in the extreme northern parts of the range and certain sources from Turkey and Greece show the greatest seed dormancy (*101*). Lack of a fully developed embryo accounts for part of the dormancy of northern sources (*116*). In some European localities, introduced sources have produced better trees than local sources.

Pinus strobus—Seeds from the western part of the range are lighter than seeds from the eastern part, and seeds of southern origin require a longer stratification period than those of northern origin (*72, 162, 264*). Field tests have demonstrated that southern sources, such as those from the southern Appalachians, tend to grow faster and to continue shoot elongation longer in the fall than do northern sources (*73, 265*). In artificial freezing studies and field observations in the northern Lake States, southern sources are more sensitive to low temperatures (*162, 196*). In fall, seedlings of eastern origin had blue-green foliage compared to the yellow-green foliage of northwestern sources (*267*).

Pinus taeda—Numerous field studies have demonstrated definite geographic variations in growth rate, drought and cold hardiness, disease resistance, and survival. Seedlings of Maryland origin tend to grow less than those of other origin when planted in different locations (*260, 261*). Southern sources outgrow northern sources in South Africa (*210*). In many of the tests, local seed sources were best. Sources west of the Mississippi River are more drought and disease resistant than most of the eastern sources. And southern sources tend to be more susceptible to low temperature damage than northern sources (*260*).

Pinus thunbergiana—The better formed trees are from inland sources (*145*).

Pinus torreyana—In a common planting on the California mainland, trees of mainland origin grew taller and had a single trunk, while trees from a Santa Rosa Island source were slower growing, bushy, and freely branched. The island source produced larger cones (*86*).

Numerous pine hybrids have been described. As a conservative estimate, at least 200 first-generation and second-generation hybrids as well as backcrosses, crosses between varieties of the same species, and crosses involving three or more different species either occur naturally or have been produced artificially (*122, 141, 169, 266*). No attempt is made here to provide yield statistics for the numerous hybrids, since such data are highly variable. The number of sound seeds produced depends on the species and individual trees involved, as well as on the environmental conditions under which the cross is made.

Some natural hybrids are relatively common; e.g., *P. palustris* × *taeda*, known as Sonderegger pine, which occurs in Louisiana and elsewhere in the South (*36*), and *P. contorta* × *banksiana* in central Alberta and southwestern Mackenzie (*272*). Most other hybrids occasionally occur where the two parent species are naturally associated. Examples of this in California are *P. ponderosa* × *jeffreyi*, *P. jeffreyi* × *coulteri*, *P. radiata* × *attenuata* (*48, 169*). In the South are *P. taeda* × *echinata* in east Texas, and *P. taeda* × *serotina* throughout their common range (*45, 214, 266*). The hybrid between *P. densiflora* and *P. thunbergiana* occurs naturally in Japan but has also been produced spontaneously in plantations of these species in Michigan (*264*). In Europe, *P. sylvestris* occasionally crosses naturally with both *P. nigra* and *P. mugo* where these species are planted near one another (*266*). These are but a few of the many hybrids which have been reported to occur naturally.

Several pine hybrids have been produced in relatively large numbers by controlled pollination methods. These include *P. rigida* × *taeda*, which is an important hybrid in the reforestation program in Korea, and *P. attenuata* × *radiata*, which is being planted in California and Oregon (*83, 106*). Many other hybrids are being produced in smaller numbers and tested for their suitability in various parts of the United States.

Flowering and fruiting.—In certain species, reproductive structures are first formed when the trees are only 5 to 10 years old—e.g., *P. attenuata*, *P. banksiana*, *P. clausa*, and *P. contorta;* in others they do not form until the trees are much older—e.g., *P. lambertiana* and *P. resinosa* (table 3). Pines are monoecious with male (microsporangiate) and female (megasporangiate) strobili borne separately on the same tree. Male strobili predominate on the basal part of new shoots, mostly on older lateral branches in the lower crown. Female strobili are found most often in the upper crown, primarily at the apical end of the main branches in the position of subterminal or lateral buds. But frequent exceptions will be found to this general scheme. For example, *P. banksiana*, *P. clausa*, *P. radiata*, or *P. attenuata* are multinodal in the bud, and female strobili are found occasionally at a secondary whorl position (*71, 122*). *Pinus attenuata*, *P. radiata*, and *P. virginiana* frequently produce female strobili in all parts of the crown (*71, 122*). In temperate climates, the earliest stages of male and female strobili can be detected in the developing buds during the summer or fall; the male develops 1 to several weeks before the female strobilus (*76, 122, 169*).

Male and female strobili of the southern and tropical pines emerge from buds in late winter; e.g. *P. elliottii* var. *densa*, *P. elliottii* var. *elliottii*, *P. glabra*, and *P. palustris*. Strobili of other pines emerge from the bud in early spring, or late spring and early summer (table 2). The male strobili are arranged in indistinct spirals

TABLE 2.—*Pinus: phenology of flowering and fruiting*

Species	Location	Flowering dates	Cone ripening dates	Seed dispersal dates	Data source
P. albicaulis	California	July	August–September	not shed [1]	*122, 240*
P. aristata	Arizona	July–August	September–October	September–October	*181, 206*
P. armandii	California	April–May	August	August–September	*122*
P. attenuata	do	April	January–February	closed cone [2]	*122*
P. balfouriana	do	July–August	September–October	September–October	*122, 225*
P. banksiana	Lake States	May–June	September	September [3]	*71*
P. brutia	California	March–May	January–March	closed cone [2]	*122*
P. canariensis	do	April–May	September	September–October	*122*
P. caribaea	Cuba	January–February.	July–August	September	*150*
P. cembra	Germany	May	August–October	not shed [1]	*194*
P. cembroides	California	May–June	November–December	November–December	*122*
P. clausa	Florida	September–December.	September	September [3]	*29, 235*
P. contorta					
var. *contorta*	California	May–June	September–October	Fall [3]	*122, 235*
var. *latifolia*	Rocky Mountains.	June–July	August–September	September–October [3]	*237*
var. *murrayana*	California	May–June	September–October	do	*122*
P. coulteri	do	do	August–September	October [5]	*122, 235*
P. densiflora	do	April	do	September–October	*122*
P. echinata	South Carolina	March–April	October–November	October–November	*71, 235*
P. edulis	Arizona	June	September	September–October	*132, 133, 134*
P. elliottii					
var. *densa*	Southern Florida.	January–April	August–September	September–November	*30*
var. *elliottii*	Florida	January–February.	September–October	October	*59*
P. engelmannii	Arizona	May	November–December	November–February	*62, 235*
P. flexilis	California, Montana.	June–July	August–September	September–October	*122*

TABLE 3.—*Pinus: height, seed-bearing age, seed crop frequency, and fruit ripeness criteria*

Species	Height at maturity	Year of first culti-vation	Seed-bearing age		Interval between large seed crops		Fruit ripeness criteria		
			Mini-mum	Data source	Time	Data source	Preripe color	Ripe color	Data source
	Feet		*Years*		*Years*				
P. albicaulis	20–107	1852	20–30	*53, 122, 190, 240*	3–5	*122, 240*	dark purple	dull purple to brown	*122, 190*
P. aristata	20–50	1861	20	*75, 190, 235*	102	*181*	green to brownish purple.	deep chocolate brown	*122, 225*
P. armandii	60–120	1895	20	*51, 184, 190*	....	....	green	yellowish brown	*51, 180*
P. attenuata	15–50	1847	5–8	*122, 190*	1	*122*	greenish brown	lustrous tawny yellow to light brown.	*122, 180*
P. balfouriana	35–60	1852	20	*190, 225*	5–6	*122*	deep purple	dark brown, red brown or russet brown.	*225*
P. banksiana	55–100	before 1783	3–15	*71, 190, 235*	3–4	*71*	green	lustrous tawny yellow to brown.	*71, 180*
P. brutia	65–100	....	7–10	*77*	1	*77*	do	yellow to reddish brown	*51, 122*
P. canariensis	100	....	15–20	*184*	3–4	*152*		nut brown	*51*
P. caribaea	60–100	....	....	*150*				yellow tan to light brown	*150*
P. cembra	33–75	1746	25–30	*180, 194*	6–10	*194, 256*	greenish violet	purplish brown	*51*
P. cembroides	15–25	1830		*51, 190*	5–8	*122*	green	yellowish to reddish brown, or lustrous brown.	*51, 180, 190*
P. clausa	15–80	1832	5	*71, 198, 235*	1–2	*71*		dark yellow brown	*199*
P. contorta									
var. *contorta*	20–40	1855	4–8	*122, 190, 225*	1	*122*	purple green	lustrous light yellowish brown to yellow brown.	*180, 199*
var. *latifolia*	25–150	1853	5–10	*19, 149, 180*	1	*149*	do	light brown	*149*
var. *murrayana*	50–100	....	4–8	*122, 225*	1	*122*	do	clay brown	*225*
P. coulteri	30–75	1832	8–20	*190, 235*	3–6	*225, 235*	green	shining brown to yellowish brown.	*122, 180, 225*
P. densiflora	70–120	1854	20–30	*51, 190*	2	*196*		dull tawny yellow to brown.	*180, 196*
P. echinata	8–100	1726	5–20	*71, 190, 198*	3–10	*71*	green	green to light or dull brown.	*180, 199*
P. edulis	10–40	1848	25–75	*71, 135, 190*	2–5	*135*	do	light yellow brown	*122, 134*
P. elliottii									
var. *densa*	25–85		8–12	*24, 139*	1–5	*24*	do	brown	*254*
var. *elliottii*	80–100	....	7–10	*89, 254*	3	*254*	do	brown yellow to brown	*254*
P. engelmannii	50–70		28–30	*136, 167*	3–4	*1*	brownish purple green.	light brown	*136*
P. flexilis	20–80	1861	20–40	*122, 190, 199*	2–4	*122*	green	lustrous yellowish to light brown.	*122, 180*
P. gerardiana	50–80	1839	....	*51*	....	....	do	brown	*122, 233*
P. glabra	80–90	....	10	*4, 88*			do	green	*17*
P. halepensis	50–80	1683	15–20	*51, 190*	1	*51*	do	lustrous yellowish brown or reddish brown.	*51*
P. heldreichii	60–100	1865	....	*51, 190*	....	....		yellowish or light to dull brown.	*51, 180*
P. insularis	100–150	....	5–10	*51, 111*	1	*251*	green	bright brown to dark brown.	*51, 111, 146*
P. jeffreyi	60–180	1853	8	*122, 190, 235*	2–4	*235*	dark purple to black.	dull purple to light brown	*122, 180, 225*

P. koraiensis	90–150	1861	15–40	*9, 190*	3–5	*9*		yellowish brown	*51*
P. lambertiana	100–225	1827	40–80	*190, 199, 235, 246*	3–5	*235*	green	lustrous greenish brown to light brown.	*122, 180*
P. leiophylla var. *chihuahuana*	30–80	...	28–30	*136, 167*	3–4	*1*	green	light brown	*191*
P. merkusii	60–100	...	10–20	*51, 40*	1–2	*40*	do	light brown	*40, 122*
P. monophylla	20–50	1848	20–25	*27, 190, 198*	1–2	*27, 198*	do	shining deep russet brown.	*27, 122*
P. monticola	90–200	1851	7–20	*4, 179, 190, 258*	3–7	*237*	green to purple black.	yellowish or beige brown thru reddish brown and dark brown.	*190, 241*
P. mugo	6–40	1779	10	*51, 190*	1	*51*	violet purple	lustrous tawny yellow to dark or cinnamon brown.	*190*
P. muricata	40–90	1846	5–6	*51, 190, 235*	2–3	*122*	green to purple	shiny light chestnut brown.	*122, 180, 199*
P. nigra	66–165	1759	15–40	*190, 256*	2–5	*174, 256*	yellowish green	shiny yellow brown to light brown.	*180, 190*
P. palustris	80–120	1727	20	*88, 190, 253*	5–7	*253*	green	green to dull brown	*190, 253*
P. patula	60–110	...	12–15	*148, 152*	...	...		yellow ochre to nut brown	*148*
P. parviflora	17–100	1861	...	*51, 190*	4–5	*9*		leathery-woody, brownish red to reddish brown.	*12, 180*
P. peuce	33–100	1863	12–30	*51, 180, 190*	3–4	*58*	green to yellow	tawny yellow to light brown.	*122, 180, 190*
P. pinaster	90–120	before 1660	10–15	*51, 60, 190*	3–5	*174*	purplish	lustrous light brown	*51, 180*
P. pinea	45–75	long cultivated		*180, 190*	...	...	green	shiny nut brown	*51, 122*
P. ponderosa var. *arizonica*	75–90	...	15–20	*191*	2–3	*235*	do	green brown to dull yellowish buff or brown.	*51, 191*
var. *ponderosa*	60–230	1826	16–20	*51, 180, 190, 235*	2–5	*235*	green to yellow green, rarely purple.	lustrous brownish green or yellow brown to to russet brown.	*122, 190*
var. *scopulorum*	50–115	...	6–20	*249*	2–5	*249*	green	purplish brown	*189, 249*
P. pumila	1–8	1807	...	*180*	...	...	green to violet purple.	dull reddish or yellowish brown.	*180*
P. pungens	30–60	1804	5	*12, 51, 155, 190*	...	...	deep green to brown.	lustrous light brown	*122, 155*
P. quadrifolia	15–30	1885	...	*225, 235*	1–5	*122, 225*	green	yellowish or reddish brown.	*51, 180*
P. radiata	5–150	1833	5–10	*130, 190, 235*	1	*130*	do	lustrous nut brown to light brown.	*130, 180, 190*
P. resinosa	70–150	1756	20–25	*71, 190*	3–7	*71*	do	purple with reddish brown scale tips to nut brown.	*71, 180, 190*
P. rigida	20–100	before 1759	3–4	*143, 190*	4–9	*143*	do	lustrous brown or light yellow brown.	*122, 180, 190*
P. roxburghii	150–180	1807	15–40	*51, 184, 233*	2–4	*233*	green to brown	light brown	*233*
P. sabiniana	40–80	1832	10–25	*51, 122, 190*	2–4	*122*	green to light brown.	reddish to red or chestnut brown.	*122, 225*
P. serotina	40–80	1713	4–10	*71, 199, 235*	1	*71*		lustrous light yellow to brown.	*190, 199*
P. sibirica	130	1837	25–35	*51, 109, 110, 185*	3–8	*110*	green	violet to light gray or brown.	*185, 190*
P. strobiformis	25–125	1840	15	*191, 235*	3–4	*191*	do	greenish brown to dark brown.	*191*

TABLE 3.—*Pinus: height, seed-bearing age, seed crop frequency, and fruit ripeness criteria*—Continued

Species	Height at maturity	Year of first cultivation	Seed-bearing age		Interval between large seed crops		Fruit ripeness criteria		
			Minimum	Data source	Time	Data source	Preripe color	Ripe color	Data source
	Feet		*Years*		*Years*				
P. strobus	80–220	1705	5–10	*88, 190, 199*	3–10	*80, 196*	green	yellow green to light brown.	*80*
P. sylvestris	80–130	long cultivated	5–15	*34, 190*	4–6	*34*	do	dull tawny yellow, greyish or dull brown, or cinnamon brown.	*35, 51, 122, 180*
P. taeda	90–110	1713	5–10	*51, 71, 190*	3–13	*71*	do	green, shiny light brown, or dull pale reddish brown.	*156, 180, 190*
P. thunbergiana	100–130	1855	6–40	*51, 145, 190*	----	----	deep lustrous purple.	nut or reddish brown	*145, 190*
P. torreyana	25–60	1853	12–18	*180, 225*	1	*235*	green to dark violet.	shiny deep chestnut brown to chocolate brown.	*180, 199, 225*
P. virginiana	50–100	1739	5	*71, 190*	1	*224*	green	lustrous dark purple to reddish brown and dark brown.	*71, 180, 224*
P. wallichiana	50–150	1827	15–20	*190, 233*	1–2	*233*	do	tawny yellow to light brown.	*122, 180*

in clusters 0.5 to 2 inches long (*51, 181, 209, 225*). Before ripening they can be green or yellow to reddish purple, but are light brown to brown at the time of pollen shed; in most species they fall soon after ripening. Female strobili emerge from the winter bud shortly after the male strobili and are green or red to purple (*51, 71, 181, 225*). At the time of pollination they are nearly erect, and 0.4 to 1.5 inches long and sometimes longer. After pollination, scales of the female strobili close, and the strobili begin a slow development. At the end of the first growing season they are about one-eighth to one-fifth the length of mature cones. Where temperatures are favorable, development continues through the winter as in *P. elliottii* var. *elliottii* in Florida, and in *P. attenuata* and *P. ponderosa* at low elevations in the Sierra Nevada (*122, 254*). Fertilization takes place in spring or early summer about 13 months after pollination, and the cones begin to grow rapidly. Growth of a new shoot leaves the developing cone in a lateral position. As the cones mature they gradually turn from green, purple, or violet purple to yellow, light brown, reddish brown, or dark brown (table 3).

Cones and seeds of most species mature rapidly during late summer and fall of the second year (table 2). Cones of a few species mature during late winter of the second year or early spring of the third year; e.g., *P. attenuata, P. brutia*, and *P. merkusii* (*25, 40, 122*). Seeds of *P. attenuata* and *P. brutia* are mature during the fall, about 16 to 18 months after pollination, but the cones are not fully developed until late winter (*25, 122*). *Pinus leiophylla, P. leiophylla* var. *chihuahuana*, and *P. pinea* require a full 3 years for their seeds and cones to ripen (*51, 136*). The requirements of *P. torreyana* are still unclear. This species has been described as needing 3 years to mature its seed, but there is evidence that the seeds mature in 2 years, with the cones requiring 3 years to open (*122*).

The interval between large cone crops is variable and depends on the species and environmental factors. Some species consistently produce a large crop every year, while others show a cyclic pattern of 2 to 10 years between large cone crops (table 3).

Mature cones (fig. 1) vary widely in size and weight. Those of *P. mugo* are 1 to 2 inches long and weigh about 0.06 ounce, while those of *P. lambertiana* may be 12 to 25 inches long and weigh about 1 to 2 pounds. Those of *P. sabiniana* and *P. coulteri* often weigh more than 2 pounds (*51, 180, 225*).

The mature cone consists of overlapping woody scales, each of which bears two seeds at the base on the upper surface. The cones of most species open on the tree shortly after ripening, and the seeds are rapidly dispersed (table 2). Drying causes the cone scales to separate owing to differential contraction of two tissue systems: woody strands of short, thick-walled, tracheid-like cells extending from the cone axis to the tip of the cone scales, and thick-walled scleronchyma cells in the abaxial zone of the scale (*2, 229*). In a few species with massive cones, the scales separate slowly, and seeds are shed over periods of several months; e.g., *P. coulteri, P. roxburghii, P. sabiniana*, and *P. torreyana* (*225, 233*).

In some species part or all of the mature cones remain closed from several to many years or open on the tree only at irregular intervals; e.g., *P. attenuata, P. banksiana, P. brutia, P. clausa, P. contorta* var. *latifolia, P. halepensis, P. muricata, P. pinaster, P. pungens, P. radiata*, and *P. rigida* (*51, 71, 225*). In addition to their closed-cone habit (serotinous cones), *P. banksiana, P. clausa, P. rigida*, and *P. contorta* have forms whose cones open promptly at maturity (*29, 71, 196, 197*). The closed-cone habit is the result of three factors: (a) extremely strong adhesion between adjacent, overlapping cone scales beyond the ends of the winged seeds (*138, 126*); (b) cone structure; and (c) the nature of the two tissue systems in the scales described above. The scales apparently are held together by a resinous substance. The melting point of the resin seal for *P. contorta* var. *latifolia* is between 113° and 122° F. (*44*). Heat, especially that from fire, melts the resin and permits the cones to open. Still other species shed partly opened or unopened cones, and the seeds are dispersed only when the cones have disintegrated on the ground; e.g., *P. albicaulis, P. cembra, P. pumila*, and *P. sibirica* (*51, 169, 185, 225*).

Commonly, cones that opened on the tree are shed within a few months to a year after the seeds are dispersed. In some species, however, opened cones may remain on the trees for up to 5 years or indefinitely; e.g., *P. attenuata, P. contorta* var. *latifolia*, and *P. rigida* (*71, 225*).

Mature seeds vary widely in size, shape, and color (*247a*) (fig. 2). They range in length from one-sixteenth to one-tenth inch (2 to 3 mm.) for *P. banksiana* to more than three-fourths inch (19 mm.) for *P. sabiniana*. They are ellipsoid (*P. radiata*), pear-shaped (*P. pumila*), cylindric (*P. gerardiana*), more or less triangular (*P. pungens*), ovoid (*P. peuce*), or convex on the inner and flattened on the outer side (*P. pinea*) (*51, 180*). The seedcoat, which may be reddish, purplish, greyish, brown, or black, and is often mottled, can be rather thin and papery to hard and even stony (*51, 209, 225*).

In most species a membranous wing is attached to the seed, but in some species the wings

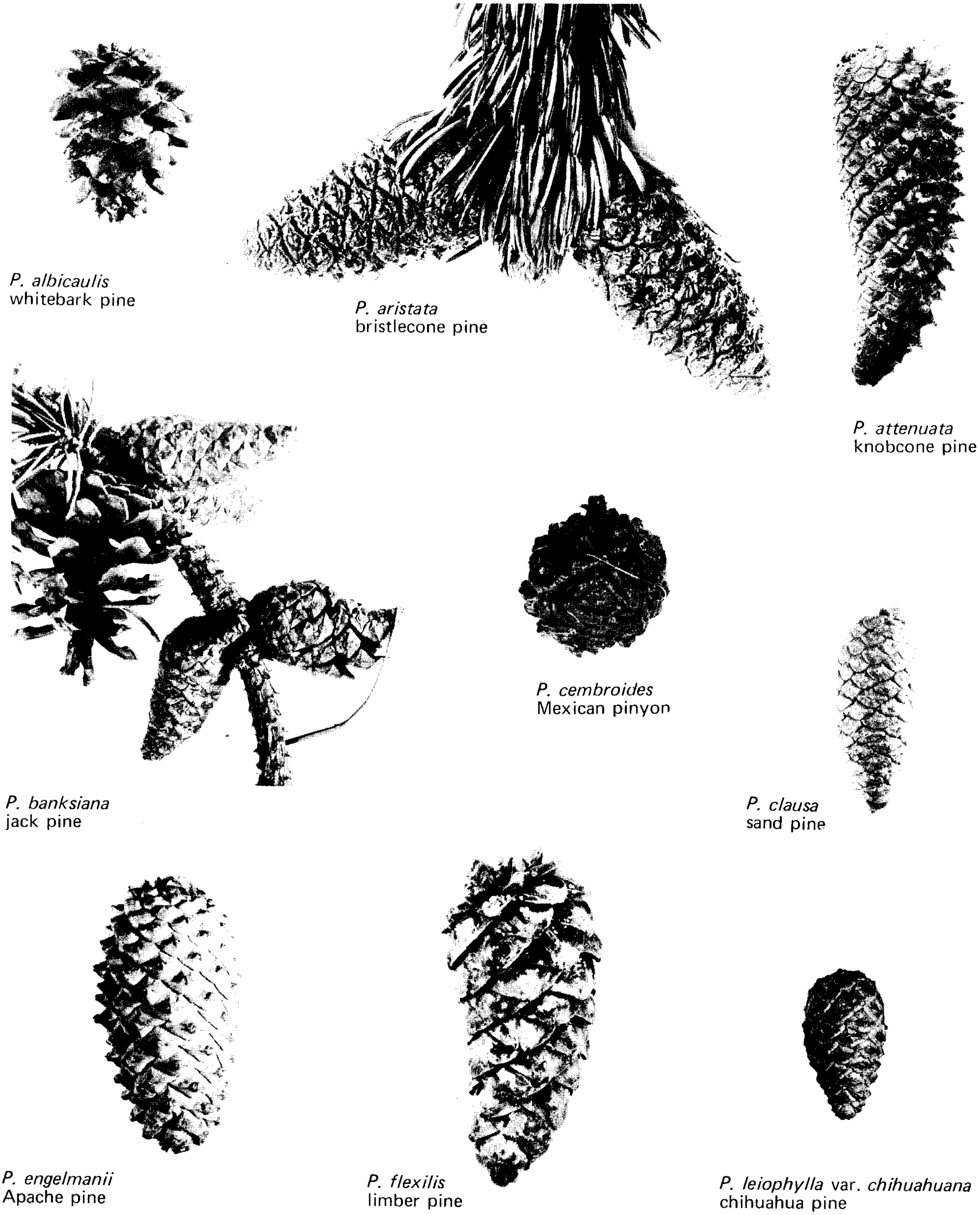
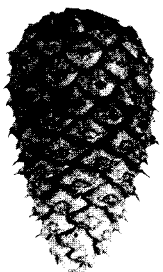


FIGURE 1.—*Pinus:* mature cones collected before seed dispersal, ½ ×.

P. monophylla
singleleaf pinyon

P. ponderosa var. *arizonica*
Arizona pine

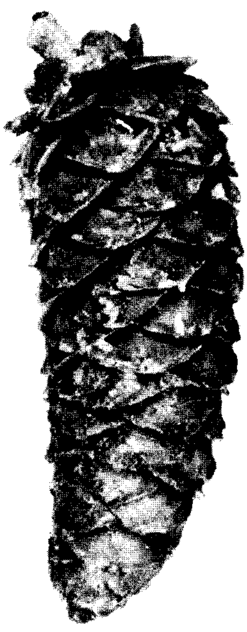
P. ponderosa var. *scopulorum*
Rocky Mountain ponderosa pine



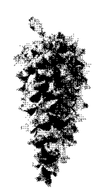
P. rigida
pitch pine

P. pungens
Table Mountain pine

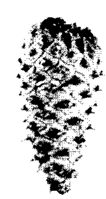
P. serotina
pond pine



P. strobiformis
southwestern white pine



P. sylvestris
Scotch pine



P. virginiana
Virginia pine

FIGURE 1.—*Pinus:* mature cones collected before seed dispersal, ½ ×—Continued.

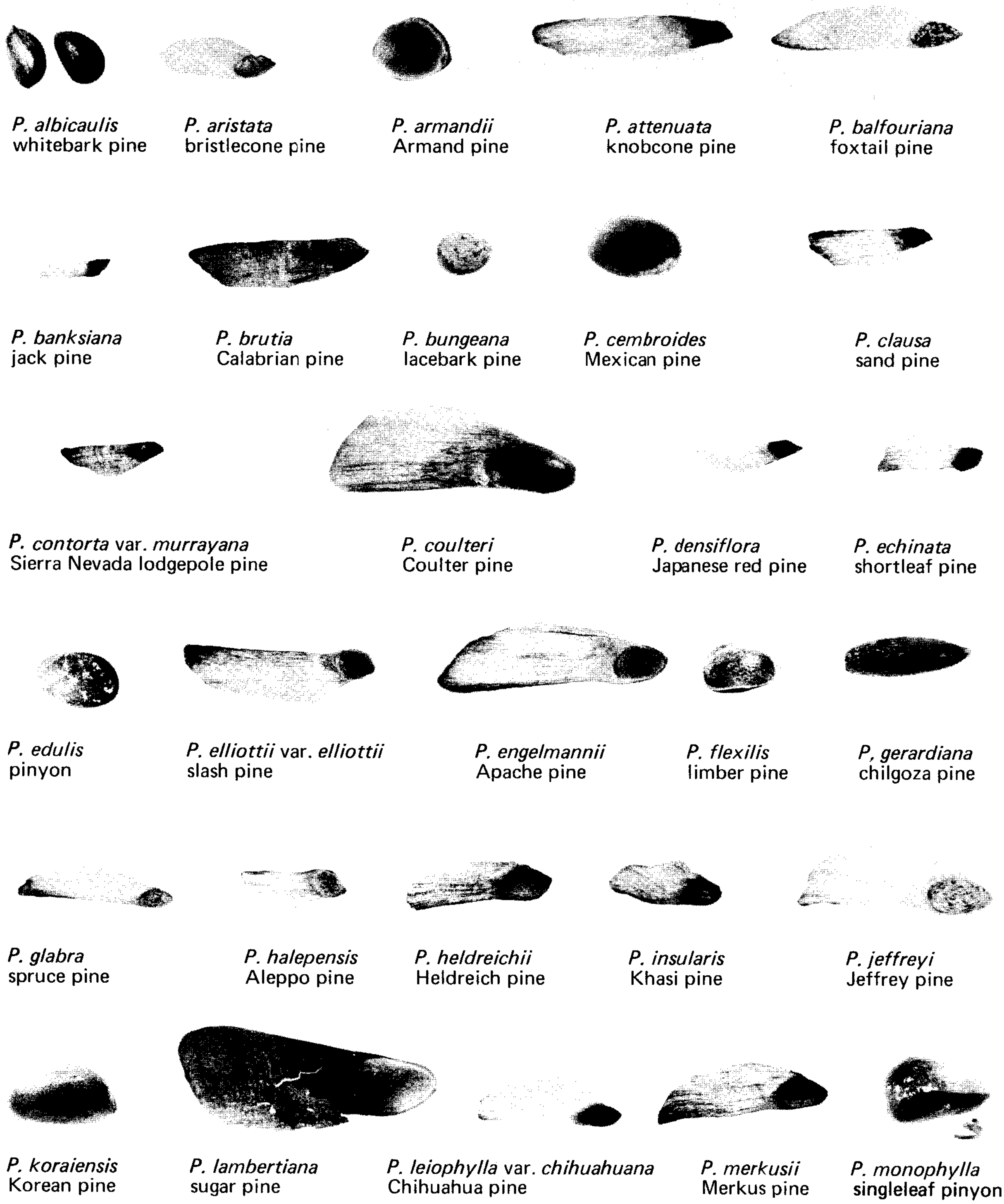


FIGURE 2.—*Pinus:* seeds as shed naturally from their cones, 1 ×; some are wingless when shed.

are absent or rudimentary; e.g., *P. albicaulis, P. armandii, P. cembra, P. flexilis, P. gerardiana, P. koraiensis, P. pumila, P. sibirica,* and *P. strobiformis* (*209, 225, 233, 247a*) (fig. 2). In others the wing or modified "wings" may remain attached to the cone scales when the seeds are shed; e.g., *P. cembroides, P. edulis, P. gerardiana, P. monophylla,* and *P. quadrifolia* (*225, 233*). The seed wings are easily detachable from the seed of most hard pines except *P. pinea, P. roxburghii,* and *P. canariensis;* those of the soft pines are firmly attached except for *P. aristata* and certain sources of *P. balfouriana* (*169, 209, 233*).

The mature seed consists of a seedcoat which encloses an embryo imbedded in a food-storage tissue, the endosperm (female gametophyte). Attached at the micropylar end of the whitish endosperm is a brown papery cap, the remnant of the nucellus. The endosperm and papery cap are covered by a thin, brown, membranous material—the remnant of the inner layer of the ovules integument (fig. 3).

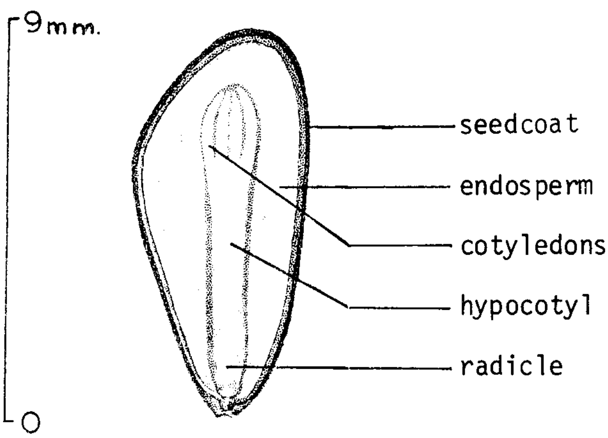


FIGURE 3.—*Pinus ponderosa,* ponderosa pine: longitudinal section through a seed, 6 ×.

Collection of cones.—Cones should be collected from trees superior in growth and form characteristics. Larger cones generally contain more seeds, but normally all cones are collected except those with obvious disease and insect damage. Widely spaced, dominant trees with full crowns produce the most seeds per cone, provided adequate pollen from other trees is available. When trees are isolated and pollen from other trees is limited, seed yield tends to be low. In dense, young stands most species usually produce little seed. Those species which form fire thickets are exceptions; e.g., *P. attenuata, P. banksiana, P. clausa, P. rigida,* and *P. serotina* (*71*).

Ripe cones can be collected from standing trees, from newly felled trees, and from animal caches. To avoid large yields of immature seed, collection from animal caches should not begin until late fall, when the seeds are definitely mature (*205*). For most species, cone collections from standing trees should start as soon as the cones are ripe and just cracking, since most seeds are shed promptly from opening cones. For closed-cone species, collections can be delayed without loss of seed, and frequently delay is even desirable. Although seeds may be mature in the fall, the closed cones are very difficult to open at that time; additional maturation on the tree facilitates both cone opening and seed extraction (*25, 122*).

To avoid extensive collections of immature or empty seeds, it is advisable to first check ripeness of seeds in small samples of cones from individual trees. A mature seed has a firm white to yellow, or cream-colored "endosperm" and a white to yellow embryo which nearly fills the endosperm cavity. With experience this visual check is very useful, and with some species it may be essential.

Ripeness for some species can be estimated by changes in cone color. Colors of green and ripe cones for most species are listed in table 3. For example, *P. ponderosa* var. *ponderosa* cones are mature when the color changes from green or yellow green to brownish green, yellow brown, or russet brown; *P. resinosa* cones turn from green to purplish with reddish brown on the scale tips; *P. strobus* cones turn from green to yellow green with brown on the scale tips or to light brown. For some species such color change comes too late to be a useful index; e.g., in *P. palustris* the ripe cones are still green in color and may have already started to open before turning brown (*254*).

For species in which changes in cone color may not be useful, flotation tests of cone specific gravity may be. These tests are based on the fresh weight of the cone. Species for which cone specific gravity has been related to seed maturity and their appropriate tests are shown in table 4. The easiest way to determine if cones have reached a desired specific gravity range is to see if samples of freshly picked cones will sink or float in liquids with known specific gravities. *Pinus ponderosa* seeds are ripe when the cones will float in kerosene, *P. strobus* is ripe when the cones just float in linseed oil, and *P. glabra* is ripe when the cones just float in SAE 20 motor oil. Cones from standing or felled trees should be tested only when fresh, since excessive drying will lead to erroneous conclusions as to maturity.

Collecting from felled trees should only take place after the seeds mature. Otherwise there

TABLE 4.—*Pinus: specific gravity of ripe cones and liquids used for testing ripeness by flotation*

Species	Specific gravity of ripe cones	Flotation test liquid [1]	Data source
P. aristata	0.59–0.80	kerosene	*206*
P. contorta var. *latifolia*	0.43–0.89		*149*
P. densiflora	1.10		*269*
P. echinata	0.88	SAE 20 motor oil, or 1 part kerosene to 4 parts linseed oil	*254*
P. edulis	0.80–0.86	kerosene	*204*
P. elliottii			
var. *densa*	<0.89	SAE 20 motor oil	*114*
var. *elliottii*	<0.90	SAE 20 motor oil	*254*
P. glabra	0.88	SAE 20 motor oil	*17*
P. jeffreyi	0.81–0.86		*203*
P. lambertiana	0.70–0.80		*203*
P. palustris	0.80–0.89	SAE 20 motor oil	*254*
P. ponderosa			
var. *arizonica*	0.88–0.97		*191*
var. *ponderosa*	0.80–0.86	kerosene	*71*
var. *scopulorum*	<0.85	kerosene	*223*
P. radiata	<1	water	*130*
P. resinosa	0.80–0.94	kerosene [2]	*71*
P. serotina	0.88		*114, 254*
P. strobiformis	0.85–0.95	95% ethanol	*191*
P. strobus	0.92–0.97	linseed oil	*235*
P. sylvestris	0.88–1.00		*66, 131*
P. taeda	0.88	SAE 20 motor oil, or 1 part kerosene to 4 parts linseed oil	
P. virginiana	<1.00		*68*

[1] Test should be made as soon after picking as possible to prevent excessive drying; the liquids have the following specific gravities: kerosene 0.80, 95 percent ethanol 0.82, SAE 20 motor oil 0.88, linseed oil 0.93. Five or more freshly picked cones should float before crop is considered ripe.
[2] Red pine cones which float in a 50–50 mixture of linseed oil and kerosene are within 10 days of being ripe.

is a risk of harvesting immature seeds. In some species, e.g., *P. taeda* and *P. echinata,* nearly mature cones can ripen in the crown on felled trees, but in other species they may not (*254*). With some species, slightly immature seeds can be successfully ripened in the cones after removal from the tree—(*P. elliottii* var. *elliottii*) (*23, 254*); in cold moist storage—(*P. lambertiana*) (*121*); or in prolonged cold dry storage in closed containers—(*P. virginiana*) (*37*). Such methods should only be attempted if completely mature seeds cannot be collected.

Cones most often are hand-picked, either from ladders or by climbing the trees. For some species, hand cutters or a cutting hook must be used to detach the cones, and hooks may be needed to bring the cone-laden branches to the picker. With certain species, mechanical tree shakers have been used for the rapid harvesting of cones; e.g., *P. elliottii* var. *elliottii, P. palustris,* and *P. taeda* (*119*). With a few others; e.g., *P. edulis, P. monophylla,* and *P. quadrifolia,* large amounts of seeds are collected by shaking the tree or beating the crown to extract the seeds, and then gathering them from the ground (*204, 235*).

Cone processing and seed extraction.—Cones should be dried immediately after collection to avoid mold development and excessive internal heating, which lead to rapid seed deterioration. Drying can be accomplished in 2 to 60 days by immediately spreading the fresh cones in thin layers on a dry surface in the sun, or on trays in a well-ventilated building, or by placing them in sacks hung from an overhead rack protected from rain (*205, 221, 223, 254*). The cones should dry slowly to prevent "case hardening." After initial drying, the cones can be stored temporarily in well-ventilated bags or trays. For many species, ripe cones open satisfactorily under the above conditions, but cones of some species may require additional heat in either a cone drying kiln or a heated shed. Properly air-dried cones of a few species may open satisfactorily after a few hours in a kiln, but those of other species may require several days. Cones of most species can be opened at kiln temperatures not exceeding 130° F. and a humidity of about 20 percent; but cones of a few species, e.g., *P. banksiana, P. clausa, P. ponderosa* var. *scopulorum,* require higher temperatures (*205, 221, 223, 235*) (table 5).

Cones stored long enough in containers to have dried without opening or cones dried under cool conditions may not open properly during kiln drying. In such cases, the cones must be soaked in water for 12 to 24 hours, and then kiln dried before they will open satisfactorily (*223*).

Serotinous cones have been opened by dipping them in boiling water for 10 to 120 seconds. Immersion times up to 10 minutes, however,

TABLE 5.—*Pinus: cone processing schedules and viable periods for seeds in cold storage*

Species	Cone processing schedule: Time in boiling water	Air-drying time[1]	Kiln drying: Time	Kiln drying: Mean temperature	Data source	Viable period for seeds in cold storage[2]: Time	Data source
	Seconds	*Days*	*Hours*	*°F.*		*Years*	
P. albicaulis[3]	0	15–30	0	----	*122*	8	*122, 166*
P. aristata	0	2–8	0	----	*206*	9	*166, 204*
P. armandii	0	15	0	----	*122*	----	----
P. attenuata	15–30	1–3	48	120	*122*	16	*122, 202*
P. balfouriana	0	2–8	0	----	*122*	16	*122, 202*
P. banksiana	0	----	2–4	150	*126*	10	*122, 213*
	10–30	3–10	0	----	*126*	----	----
P. brutia	0	3–20	0	----	*78, 122*	3	*122, 202*
	0	----	10	130	*78, 122*	----	----
P. canariensis	0	2–10	0	----	*122*	18	*122, 202*
P. caribaea	----	----	----	----	----	3	*150*
P. cembra[3]	----	----	----	----	----	1+	*172*
P. cembroides[4]	0	2–8	0	----	*122*	----	----
P. clausa	10–30	1	2–4	145	*114, 138*	5	*29*
P. contorta							
var. *contorta*	0	2–20	0	----	*63, 122*	17	*122, 202*
	0	----	96	120	*63, 122*	----	----
var. *latifolia*	[5] 30–60	2–30	0	----	*149*	7+	*202, 242*
	0	----	6–8	140	*235*	----	----
var. *murrayana*	0	2–20	0	----	*63, 122*	17	*122, 202*
P. coulteri	0–120	3–15	0	----	*122*	5	*122, 166*
	0	----	72	120	*122*	----	----
P. densiflora	0–30	3–4	0	----	*196, 264*	2–5	*98, 177,*
P. echinata	0	----	48	105	*159, 254*	35	*159, 255*
P. edulis[4]	0	2	0	----	*204*	----	----
P. elliottii							
var. *densa*	0	----	8–10	120	*22*	----	----
	0	4	0	----	*22*	----	----
var. *elliottii*	0	----	8–10	120	*254*	35	*113, 226*
	0	42	0	----	*254*		
P. engelmannii	0	----	60	110	*235*	----	----
P. flexilis	0	15–30	0	----	*122*	5	*122, 219*
P. gerardiana	0	15	0	----	*122*	----	----
P. glabra	0	----	48	100	*17*	1+	*15, 16*
P. halepensis	0	----	10	130	*122*	10	*78, 112*
	0	3–10	0	----	*118, 122*	----	----
P. heldreichii	0	5–20	0	----	*122*	----	----
P. insularis	0	5–20	0		*122, 146*	----	----
P. jeffreyi	0	----	24	120	*122*	18	*166, 122*
	0	5–7	0	----	*122*		
P. lambertiana	0	----	24	120	*122*	21	*202, 246*
	0	5–7	0	----	*122*	----	----
P. merkusii	0	5–7	0		*122*	2+	*78*
P. monophylla[4]	0	2–3	0		*122*	----	----
P. monticola	0	----	14	110	*122, 243*	20	*202, 246*
	0	5–7	0	----	----	----	----
P. mugo	0		48	120	*122, 174*	5	*112, 174*
P. muricata	0	----	48	120	*63*		
P. nigra	0	----	24	115	*174*	10+	*98*
	0	3–10	0	----	*122*	----	----
P. palustris	0	----	48	100	*254*	5–10	*14, 157*
P. parviflora	0	5–15	0	----	*122*	----	----
P. patula	15–30	1–2	48	115	*122*	21	*122, 202*
P. pinaster	0	----	----	115	*118, 174*	11	*112, 166*
	0	4–10	0	----	*118, 122*	----	----
P. pinea	----	----	----	----	----	18	*202*
P. ponderosa							
var. *arizonica*	0	----	60	110	*235*		
var. *ponderosa*	0	----	3	120	*26, 122, 235*	18	*26, 202*
	0	4–12	0	----	*26, 122, 235*	----	----
var. *scopulorum*	0	----	2	165	*67*	15+	*67*
	0	4–12	0	----	*122*		
P. pumila[3]	----	----	----	----	----		
P. pungens	0	----	72	120	*3*	9	*98*
	0	30	0	----	*3*		----

TABLE 5.—*Pinus: cone processing schedules and viable periods for seeds in cold storage*—Continued

Species	Cone processing schedule					Viable period for seeds in cold storage [2]	
	Time in boiling water	Air-drying time [1]	Kiln drying		Data source	Time	Data source
			Time	Mean temperature			
	Seconds	*Days*	*Hours*	*°F.*		*Years*	
P. quadrifolia [4]	0	2–8	0	----	*122*	----	----
P. radiata	60–120	0	48–72	120	*246*	21	*112, 202*
	60–120	3–7	0	----	*246*	----	----
P. resinosa	0	----	9	130	*221, 238*	30	*98, 213, 248*
P. rigida [6]	----	----	----	----	*52*	11	*52, 98*
P. roxburghii	0	----	----	----	*233*	4+	*56, 112*
P. sabiniana	0	----	48	120	*122*	5	*122*
P. serotina	0	----	48	105	*114*	----	----
P. sibirica [3]	----	----	----	----	----	2+	*238*
P. strobiformis	0	14	0	----	*191*	----	----
P. strobus	0	----	4–12	130	*221*	10	*80, 98*
P. sylvestris	0	----	10–16	120	*176, 212*	15	*98, 115*
	0	3–7	0	----	*122*	----	
P. taeda	0	----	48	105	*159, 254*	9+	*159, 235*
P. thunbergiana	0–30	5–20	0		*122, 177*	11	*202*
P. torreyana	0	5–20	0		*122*	6	*122, 166*
P. virginiana	0		2	170	*37*	5+	*112, 235*

[1] Air-drying times are for a temperature range of 60° to 90° F. When kiln-drying is used, it should be preceded by an air-drying period that was not reported for most species. A period of 3 to 7 days is recommended where no times are listed.

[2] Period after which at least 50 percent of the seeds germinated. Storage temperature ranges for most species were either 0° to 5° F. or 33° to 41° F. The lower range is preferred. Seed moisture contents between 5 and 10 percent were satisfactory.

[3] *P. albicaulis, P. cembra, P. pumila,* and *P. sibirica:* Cones must be broken up to release the seeds.

[4] *P. cembroides, P. edulis, P. monophylla,* and *P. quadrifolia:* An alternate procedure is to shake the tree to release the seeds and collect them on a cloth spread on the ground.

[5] *P. contorta* var. *latifolia:* Time required in boiling water is estimated. Reported treatment was 5 to 10 minutes in water at 148° F. or higher (*149*).

[6] *P. rigida:* Cones were soaked in water overnight and dried in a warm room (*52*).

have been needed to open some lots of serotinous cones (*122*). This procedure, by melting the resins between the cone scales and by wetting the woody cone, produces maximum scale reflexing (*138, 126*).

After the cones are opened they are shaken to remove the seeds. Seeds normally are extracted by placing the cones in a large mechanical tumbler or shaker, or in a small manual shaker for small lots. Seeds are then dewinged by machines of various types, by being flailed in a sack, or by rubbing. Dewinging of a few species can be simplified by first wetting the seeds, then letting them dry; wings are loosened by this method and can then be fanned out (*223, 254*). Care must be exercised in the use of mechanical dewingers, since they may injure the seed. Seeds of three species—*P. aristata* (*206*), *P. palustris* (*254*), and *P. sylvestris* (*115*)—are especially susceptible to mechanical damage and must be dewinged very carefully. The seeds are cleaned by using mechanical clipper cleaners, fanning mills, screens, or gravity separators to remove the mixture of broken seed wings, pieces of cone scale, and other impurities.

After completing the dewinging and cleaning processes, empty seeds of many species can be separated from the sound seeds by flotation in a liquid having a suitable specific gravity. This procedure has been used on the species listed below.

Species	*Flotation liquid for separating empty seeds*	*Data source*
P. brutia	water	*118*
P. coulteri	water	*122*
P. echinata	95% ethanol	*159*
P. echinata	water	*254*
P. elliottii var. *elliottii.*	water	*254*
P. glabra	95% ethanol	*15*
P. halepensis	95% ethanol	*118*
P. nigra	95% ethanol	*118, 174*
P. palustris	pentane	*158*
P. pinaster	95% ethanol	*118, 174*
P. pinea	water	*77, 118*
P. sabiniana	water	*122*
P. strobus	100% ethanol	*221*
P. sylvestris	petroleum ether	*127*
P. taeda	water	*159, 254*

Viability may be reduced after seeds have been immersed in an organic liquid such as ethanol, pentane, or petroleum ether. The reduction, however, can be minimized by using

TABLE 6.—*Pinus: cleaned seeds per pound and other yield data*

Species	Place of collection	Data for yield computations: Cones per bushel	Seeds per 100 pounds of cones	Seeds per bushel of cones	Data source	Cleaned seeds per pound: Range	Average	Samples	Data source
		Pounds	*Pounds*	*Pounds*		*Number*	*Number*	*Number*	
P. albicaulis	Idaho	----	----	----	----	2,200– 3,000	2,600	3	*240*
P. aristata	Arizona	26–28	4.0	1.1	*206*	17,500– 19,100	18,100	4	*206*
P. armandii	France	----	----	----	----	1,200– 1,870	1,600	2	*54*
P. attenuata	California, Oregon	----	----	0.1	*122*	15,200– 32,400	25,400	6	*122*
P. balfouriana	California	----	----	----	----	14,200– 22,000	16,900	3	*122*
P. banksiana	Lake States	40	1.0	0.2–0.7	*221, 235*	71,000–250,000	131,000	423	*235*
P. brutia	Europe	----	----	----	----	7,600– 11,600	9,100	5	*118*
P. canariensis	South Africa	----	----	----	----	4,000– 4,500	4,200	10	*184*
P. caribaea		----	----	----	----	23,700– 36,800	31,000	10+	*150*
P. cembra	Germany	----	----	----	----	1,600– 2,300	2,000	10+	*256*
P. cembroides		----	----	----	----	650– 2,100	1,100	5	*192*
P. clausa	Florida	----	3.5	0.6–0.9	*235*	65,000– 85,000	75,000	10+	*235*
P. contorta									
var. *contorta*	California	----	----	0.5–1.2	*63*	111,000–165,000	135,000	28	*235*
var. *latifolia*	Colorado to Montana.	35–50	0.8–1.0	0.2–0.8	*243, 245*	79,000–114,000	94,000	39	*245*
var. *murrayana*	California	40–50	0.55	0.2	*63*	116,000–119,000	117,000	4	*63*
P. coulteri	California	35–40	2.2	0.8	*63*	1,200– 1,600	1,400	8	*63*
P. densiflora	Japan	--	2.0	0.5–0.8	*235*	36,000– 64,000	52,000	26	*228*
P. echinata		35	2.0–3.0	0.4–1.1	*159, 235*	32,100– 72,900	46,300	144	*239*
P. edulis	Arizona	17	28	3.3	*204*	1,500– 2,500	1,900	9	*235*
P. elliottii									
var. *densa*	southern Florida	----	----	0.5–1.0	*24*	14,300– 16,700	15,400	30	*239*
var. *elliottii*		----	1.0–2.0	0.6–0.8	*170, 235*	9,610– 19,300	13,500	404	*239*
P. engelmannii	Arizona	37	1.1	0.4	*188*	----	10,000	1	*188*
P. flexilis		----	----	----	----	3,200– 6,800	4,900	44	*219*
P. gerardiana	India	----	----	----	----	1,100– 1,300	1,100	10	*207*
P. glabra	Louisiana	----	----	0.1–1.0	*17*	40,000– 52,000	46,000	8	*17*
P. halepensis	Italy	----	----	----	----	22,000– 40,000	28,000	10+	*152*
P. heldreichii		----	----	----	----	16,000– 32,000	21,000	18	*94, 238*
P. insularis	southeast Asia	----	----	----	----	20,000– 34,400	27,000	5+	*122*
P. jeffreyi	California	25–30	3.5	0.95–2.0	*235*	2,650– 5,300	3,700	26	*63*
P. koraiensis	Korea	----	----	----	----	740– 930	820	3	*238*
P. lambertiana	California	20–25	3.7	1.5–2.0	*63, 235*	1,500– 2,700	2,100	27	*63*
P. leiophylla var. *chihuahuana.*		----	----	0.75–0.88	*235*	----	40,000	1+	*235*
P. merkusii		----	----	----	----	12,800– 26,800	18,200	11	*40*

P. monophylla	Utah, Nevada	...	...	1.7–4.7	*63, 247*	1,030– 1,190	1,110	2	*226, 247*
P. monticola		25–30	1.0	0.3–0.8	*63, 235*	14,000– 32,000	27,000	99+	*235*
P. mugo	Germany	39	...	0.8	*172, 174*	57,000– 91,000	69,000	10	*256*
P. muricata	California	40–50	0.4	0.2	*63*	39,200– 50,800	46,800	3	*63*
P. nigra		32–40	2.0–4.0	0.4–1.2	*165, 174, 226, 256*	14,000– 39,000	26,000	159+	*235*
P. palustris	Louisiana	35	2.1	0.8	*159*	3,000– 7,000	4,900	220	*159*
P. parviflora		...	...	...	...	3,100– 4,600	3,900	3+	*54*
P. patula	Mexico, South Africa.	...	...	...	...	40,000– 60,000	52,600	3+	*129, 187*
P. peuce		...	...	...	...	10,000– 14,000	11,000	6	*187*
P. pinaster		...	3.5–5.5	...	*235*	6,750– 13,000	10,000	16	*55*
P. pinea	Europe	...	...	...	...	495– 720	600	4	*102, 187*
P. ponderosa									
var. *arizonica*	Arizona	36	0.9–2.3	0.7–1.0	*191, 235*	10,900– 11,800	11,400	10	*191*
var. *ponderosa*		21–60	2.0–7.0	0.6–2.0	*50, 164, 235, 245*	6,900– 23,000	12,000	185	*50, 235*
var. *scopulorum*	Black Hills	39	3.9	1.5	*249*	10,200– 15,300	13,100	74	*249*
P. pumila		...	...	...	...	...	10,800	1	*187*
P. pungens	West Virginia	...	3.0	0.4	*3, 235*	30,700– 38,000	34,200	3	*3*
P. quadrifolia	California	...	...	...	...	820– 1,200	960	3	*122, 238*
P. radiata	California	35–40	0.9	0.3	*63*	10,300– 15,700	13,300	7	*63*
P. resinosa	Lake States	35	1.0–2.0	0.5–0.8	*221, 235*	30,000– 71,000	52,000	529	*235, 238*
P. rigida	New York, Pennsylvania.	33–39	2.0–3.0	0.8	*65, 235*	42,500– 82,200	61,700	10	*182*
P. roxburghii	India	...	...	...	...	3,100– 11,300	5,600	36	*233*
P. sabiniana	California	...	...	...	...	530– 650	580	3	*122*
P. serotina	southeastern United States.	...	...	0.4	*235*	47,000– 63,000	54,000	4	*235*
P. sibirica	Siberia	...	...	...	...	1,600– 2,100	1,800	10+	*185*
P. strobiformis	Arizona	26	8.0	2.7	*191*	2,500– 2,900	2,700	10	*191*
P. strobus		15	2.0–3.0	0.3–1.7	*221, 235*	17,500– 53,000	26,500	300	*235, 238*
P. sylvestris	Europe and eastern United States.	27–56	2.0	0.4–0.6	*65, 235*	33,800–111,000	75,000	346+	*101, 235*
P. taeda		35	2.0–3.0	0.6–1.3	*159, 235*	12,300– 26,400	18,200	652	*239*
P. thunbergiana	Japan, Korea, and northeastern United States.	41	...	0.2–0.8	*145, 177*	26,000– 50,000	34,000	50	*235*
P. torreyana	California	...	...	...	...	400– 800	500	7	*235*
P. virginiana		...	3.0	0.5–0.9	*182, 235*	45,700– 91,100	55,400	30	*239*
P. wallichiana	India	...	...	...	...	7,200– 10,200	9,100	163	*207*

a short immersion time and by evaporating all traces of the liquid from the seeds before they are placed in storage (*15*).

When water is used for floating off the empty seeds, the remaining sound seeds should be dried to a moisture content between 5 and 10 percent before the seeds are placed in storage.

Numbers of cleaned seeds per pound and some data for computing yields of cones and seeds are given for 65 species and varieties in table 6.

Seed storage.—For most pines, high seed viability can be maintained for long periods of time with the proper storage methods. *Pinus resinosa* seed stored 30 years still produced vigorous seedlings in the nursery (*96*), as did those of *P. echinata* and *P. elliottii* var. *elliottii* stored for 35 years (*255*). Seeds of many species are now routinely stored for periods of 5 to 10 years. Storage temperature and seed moisture content are the two most important factors affecting the success of seed storage. As a general rule, seeds should be dried to a moisture content between 5 and 10 percent. Temperatures of 0° to 5° F. are preferred for most species for long-term storage (*122, 255*), but a range of 33° to 41° F. also has been used. The viable periods for seeds stored under these conditions are listed in table 5. Seeds of a few species such as *P. insularis* and *P. wallichiana* have remained viable for several years at ordinary room temperature (*38, 56*), but such storage is not recommended. Some seed lots deteriorate rapidly following removal from cold storage if they are held at room air temperature before sowing. Seeds should not be removed from storage more than a week before stratifying the seeds at low temperatures, sowing, or testing (*254*).

Pregermination treatments.—Most pines of temperate climates shed their seeds in the fall, and the seeds germinate promptly during the first spring. For some species, such as *P. cembra* or *P. peuce* germination may take place during the second or even third year after dispersal. Pine seeds display highly variable germination behavior when sown following extraction or storage. The type and degree of dormancy vary among species, geographic sources of the same species, and lots from the same source. Seed dormancy may result from prolonged extraction at too high temperatures, and dormancy may increase with prolonged storage (*97, 122*). Seeds of many species ordinarily germinate satisfactorily without pretreatment, but germination is greatly improved and hastened by first subjecting the seeds to cold stratification, especially if the seeds have been stored.

Stratification is accomplished by first soaking the seeds in water for 1 or 2 days and then placing them in a moist medium or in a plastic bag and holding them at a temperature between 33° and 41° F. for a specified period of time (Chapter 6). Recommended periods for both fresh and stored seeds of *Pinus* are listed in table 7 for 64 species and varieties.

TABLE 7.—*Pinus: recommended cold stratification periods (33°–41° F. in a moist medium) and other pregermination treatments*

Species	Recommended cold stratification period		Data sources
	Fresh seed	Stored seed	
	Days	*Days*	
P. albicaulis	90–120	90–120	*122*
P. aristata	0	0–30	*112, 204*
P. armandii	90	90	*97, 122*
P. attenuata	60	60	*122*
P. balfouriana	90	90	*122*
P. banksiana	0–7	0–7	*193, 248*
P. brutia	0	0–45	*78, 208*
P. canariensis	0	0–20	*152, 196*
P. caribaea	0	0	*150*
P. cembra [1, 2]	90–270	90–270	*99, 122, 194*
P. cembroides	0	0–30	*78, 108, 122*
P. clausa	21	21	*29*
P. contorta			
var. *contorta*	0	20–30	*122*
var. *latifolia*	0	30–56	*243, 244*
var. *murrayana*	0	28	*63, 122*
P. coulteri	0	21–90	*63, 108, 122, 246*
P. densiflora	0	0–20	*97, 99, 122*
P. echinata	0–15	15–60	*122, 159*
P. edulis [3]	0	0–60	*204*
P. elliottii			
var. *densa*	30	30	*239*
var. *elliottii*	0	15–60	*153, 227, 235*
P. engelmannii	0	0	*235*
P. flexilis	21–90	21–90	*99, 239*
P. gerardiana	0	0–30	*122*
P. glabra	28	28	*15, 160*
P. halepensis	0	0	*152*
P. heldreichii	30–42	30–42	*94, 99, 108*
P. insularis	0	0	*102, 152*
P. jeffreyi	0	0–60	*63, 108*
P. koraiensis [2]	90	90	*8, 9, 226*
P. lambertiana	60–90	60–90	*63, 97, 108, 122*
P. merkusii	0	0	*102, 152*
P. monophylla	28–90	28–90	*122, 247*
P. monticola	30–120	30–120	*97, 122, 235, 237, 246*
P. mugo	0	0	*122, 196*
P. muricata	0	20–30	*63, 122, 235*
P. nigra	0	0–60	*122, 196, 235*
P. palustris	0	0–30	*235, 254*
P. parviflora [2]	90	90	*9*
P. patula	60	60	*122*
P. peuce [4]	0–60	60–180	*99, 108, 122, 238*
P. pinaster [3]	0	60	*105, 152*
P. pinea [3]	0	0	*152*
P. ponderosa			
var. *arizonica*	0	0	*152*
var. *ponderosa*	0	30–60	*63, 122, 247*
var. *scopulorum*	0	20–60	*122, 249*

TABLE 7.—*Pinus: recommended cold stratification periods (33°–41° F. in a moist medium) and other pregermination treatments*—Continued

Species	Recommended cold stratification period		Data sources
	Fresh seed	Stored seed	
	Days	*Days*	
P. pumila	120–150	120–150	*8, 97, 122*
P. pungens	0	0	*3*
P. quadrifolia	0	0–30	*122*
P. radiata	0–7	7–20	*108, 122*
P. resinosa	0	60	*97, 122, 193*
P. rigida	0	0–30	*52, 235*
P. roxburghii	0	0	*122*
P. sabiniana [5]	60–120	60–120	*122, 165, 235*
P. serotina	0	0–30	*114*
P. sibirica [2]	60–90	60–90	*238*
P. strobiformis	60–120	60–120	*7, 191*
P. strobus	60	60	*122, 193, 235*
P. sylvestris	0	15–90	*91, 101, 235*
P. taeda	30–60	30–60	*161*
P. thunbergiana	0	30–60	*18, 99*
P. torreyana	30–90	30–90	*122, 235*
P. virginiana	0–30	30	*97, 239*
P. wallichiana	0–15	15–90	*56, 99*

[1] *P. cembra:* cold stratification period has been reduced to 90 days by first soaking the seeds in concentrated sulfuric acid for 3 to 5 hours, or by mechanically scarifying the seeds (*122, 194*), but acid treatment is not now recommended.

[2] *P. cembra, P. koraiensis, P. parviflora, P. sibirica:* In some lots embryos may be immature and require a warm moist stratification period (2 months at 70° to 80° F.) preceding the cold stratification period (*9, 99, 237*).

[3] *P. edulis* (*204*), *P. pinaster* (*152*) and *P. pinea* (*152*): Good germination has been obtained after soaking seeds in cold (40° F.) water for 24 hours with no subsequent stratification.

[4] *P. peuce:* a cold stratification period of 60 days was sufficient when seeds were first soaked in sulfuric acid for 30 minutes (*99, 122, 238*), but acid treatment is not now recommended.

[5] *P. sabiniana:* germination is speeded by cracking the thick seedcoats, before stratification (*122, 165, 235*).

Seeds of some species may exhibit extreme dormancy; e.g., those that require more than 60 days of stratification (table 7). The dormancy may be due to physiological or physical factors. A pretreatment may be needed to overcome a physiological block in the embryo; e.g., *P. lambertiana* (*121*), or effect a physical change in the seedcoat to make it permeable to water; e.g., *P. sabiniana* (*82, 121*). The dormancy can also be more complex; an anatomically immature embryo with a physiological block may be coupled with an impermeable seedcoat as in *P. cembra*. Acid scarification of seedcoats has been used with several species; e.g., *P. cembra, P. peuce*, and *P. sabiniana*, but prolonged cold stratification for 6 to 9 months is much more effective (*100, 121*). Acid scarification is not recommended for seeds of pines (*122*).

Seeds of *P. cembra, P. korainsis, P. parviflora*, and *P. sibirica* are suspected of having immature embryos at the time of collection. Germination has been increased by placing the seeds first in a warm moist environment for several months and then in cold stratification for several more months (table 7, footnote 2) (*8, 9, 173, 238*).

Germination tests.—For reliable tests of seed viability the seed is allowed to germinate under near-optimum conditions of aeration, moisture, temperature, and light. On the basis of extensive experience and experimentation, standardized seed tests for a number of pine species have been established by the Association of Official Seed Analysts (*10*), the International Seed Testing Association (*108*), and certain regional organizations such as the Western Forest Tree Seed Council (*263*). Recommendations and procedures given by these organizations and others who test seeds are summarized in table 8. In addition, the results of seed tests conducted under known conditions are given for 61 species and varieties.

The germination of pine seeds can be effectively tested in any medium or container that provides good aeration and holds adequate moisture. For a number of species, light, commonly supplied by a cool white fluorescent lamp, is required for reliable tests. When light is necessary, the usual exposure is 8 hours in each 24-hour period. Different temperatures are employed in seed testing; constant 68° F. and alternating 86°/68° F. regimes are most common. When alternating temperatures are used, the higher temperature ordinarily is for 8 hours and the lower is for 16. The duration of most tests is from 3 to 4 weeks. Usually 400 to 1,000 seeds per test are adequate. Germination is epigeal (fig. 4).

Cutting tests are commonly uesd for rough determinations of seed quality. Such tests can also provide information on soundness and can be used as an emergency guide in fall sowing of fresh seeds with embryo dormancy. X-ray methods too supply good information on soundness. Estimates of viability from the above tests are the most subject to error, since the seeds are not actually germinated (*221, 223, 254*) (Chapter 7).

Biochemical methods employing a rapid viability indicator such as one of the tetrazolium compounds can also be used, but are not generally recommended. The results are highly dependent on the analyst's experience, and the

TABLE 8.—*Pinus: germination test conditions and results*

Species	Pretreatment [1]	Germination test conditions: Daily light period	Medium [2]	Temperature [3]: Light	Temperature [3]: Dark	Duration	Germinative energy: Amount	Germinative energy: Period	Germinative capacity: Average	Germinative capacity: Samples	Data source
		Hours		*°F.*	*°F.*	*Days*	*Percent*	*Days*	*Percent*	*Number*	
P. albicaulis	+	8	TB, P	86	68	28					*10*
	+	0	s, pe		70/50	365			30	2	*240*
P. aristata	—	0	TB, P		86/68	14					*10*
	—	24	P	90/70		22	75	7	91	74	*206*
	—	0	s, pe		95/68	30			86	7+	*235*
P. attenuata	+	24	P, TB	72–78		30	79	5	92	1	*122*
	—	8	s		86/68	120	69	10	85	4	*238*
P. banksiana	—	8	TB, P	86	68	14	86	10	87	14	*10, 96*
	[4] +	8	s	86	68	8	54	5	69	29	*193*
	—	8	s	86	68	23	72	9	75	6	*21*
P. canariensis	—	0	TB		70	30	58	20	74	9	*96, 187*
	—	8	TB	68	68	21	63	7	76	4	*102*
P. caribaea	—	8+	P	72	72				72	3	*150*
P. cembra	+	0	s, P		86/68	28					*10*
	+	0	TB		86/68	90	21–42	17–37	37	8	*194*
	+	0	s		72/68	60	55	28	62	1	*172*
P. cembroides	—	0	B, P		68	28					*10*
P. clausa	—	8	K	72	72	30	86	14	90	19	*239*
	—	8	s + v	70	60–65	30	85	20	90	([6])	*29*
P. contorta											
var. *contorta*	+	8+	TB, P, v	86	68	28			60	3	*10, 63*
	—	0	s, pe		86/68	50			80	29	*235*
var. *latifolia*	+	8	TB, P	86	68	21	73	10	80	10	*10, 96*
	+	0	s		83/57	62			73	9	*238*
	[4] —	0	s		83/57	62			65	12	*238*
var. *murrayana*	—	10	s	78	78	30			75	3	*63, 122*
P. coulteri	+	0	s, P	77	59	28					*10*
	+	8	s, v	86	68	28			37	7	*63, 108*
P. densiflora	—	8	TB, P	86	68	21					*10*
	—	0	s		86/68	30	75	15	87	3	*103*
	+	0	s		86/68	24–60	54	15	83	4	*238*
	—	0	TB		75	30			74	20	*187*
P. echinata	—	8+	TB, P	86	68	28					*10*
	—	8	s + v	72	72	28	88	14	90	139	*239*
	+	8	s + pl	72	72	27	81	10	90	148	*159, 239*
P. edulis	+	0	TB	86	68	28					*108*
	+	0	P		90/70	16	80	7	96	4	*204*
P. elliottii											
var. *densa*	—	8+	s + v	72	72	32	30–79	7–11	32–82	30	*239*
	—	16	K	72	72	28	86	7	87	28	*22*
var. *elliottii*	—	8+	TB, P	86	68	28					*10*
	—	16	K	72	72	26	80	10	89	392	*87*
	+	16	K	72	72	26	75	9	84	83	*239*
P. engelmannii	—	0	P		90/70	16	70	4	88	4	*92*
P. flexilis	+	0	B, P	86	68	21					*10*
	+	8	TB	86	68	21					*108*
	—	8	s + v	72	72	27			42	1	*239*
	+	8	TB	86	68	30	69	14	82	1	*193*
P. gerardiana	—	0	TB		70	30–60			47	2	*187*

P. glabra	+	8	TB, P	86	68	16	----	----	----	----	*96*
	+	16	s + v	72	72	30	85	13	98	25	*13*
	—	16	s + v	72	72	30	46	30	98	30	*13*
P. halepensis	—	0	TB, P	----	68	28	----	----	----	----	*10*
	—	0	TB	----	68–71	30	50–66	20	79	5	*187*
	—	0	TB	----	64–66	30	65–80	16–20	89	12	*155, 156*
P. heldreichii	+	8	TB, P	86	68	28	----	----	----	----	*10*
	+	8	TB	86	68	40	----	----	72	14	*94*
	—	----	TB	----	70	40	----	----	69	1	*187*
P. insularis	—	8	TB	86 or 68	68	21	82	14	86	1	*10, 96, 102*
P. jeffreyi	+	8	TB, P, s	86	68	21	----	----	----	----	*10*
	+	24	P	72–78	----	30	95	5	99	1	*122*
	—	0	v	----	86/68	21	----	----	79	5	*63*
P. koraiensis	+	0	s	----	86/68	60	14	25	18	1	*238*
	+	8+	P	77	77	28	----	----	85–95	4	*8, 9*
	+	0	s, P	----	86/68	28	----	----	----	----	*10*
P. lambertiana	+	----	v	----	86/68	28	----	----	59	5	*63*
	+	24	s, P	72–78	----	30	49	21	55	1	*122*
P. leiophylla var. chihuahuana	—	0	pl	----	75	22	60	6	70	3	*92*
P. merkusii	—	8	TB	86	68	21	----	----	59	1	*96*
	—	8	TB	68	68	21	----	----	67	1	*102*
P. monophylla	—	24	pl	75	----	21–35	39–50	7	86–90	2	*247*
P. monticola	+	0	P, s	----	86/68	28	----	----	----	----	*10*
	+	8	s + pl	72	72	71	39	11	44	11	*239*
P. mugo	—	8	P, TB	86	68	14	----	----	----	----	*10*
	—	0	TB	----	86/68	30	25	10	45	30	*93*
	—	8	TB	86	68	20	76	10	80	30	*93*
P. muricata	—	0	TB	----	68	35	----	----	----	----	*108*
	+	0	v	86	68	28	----	----	38	5	*63*
	+	24	P	72–78	----	30	70	7	85	1	*122*
P. nigra	—	8	TB, P	86	68	14	91	10	92	49	*10, 93*
	—	0	TB	----	86/68	30	54	10	86	49	----
P. palustris	—	16	P	68	68	21	----	----	----	----	*10*
	—	16	s + v	72	72	30	90	10	95	100	*236*
P. parviflora	—	0	P	72/64	----	10–14	----	----	----	----	*10*
	+	8	s	86	68	28	71	35	----	----	*8, 108*
	+	8+	TB	77	77	28	----	----	80	1	*9*
P. peuce	+	0	s	----	68–86	28	----	----	----	----	*108*
	—	0	TB	----	68–71	30	----	----	69	4	*187*
P. pinaster	—	8	TB	68	68	35	----	----	----	----	*108*
	+	8	P, TB	68	68	28	41	7	79	8	*96, 102*
	+	0	TB	----	68	30	70	20	83	5	*195*
P. pinea	+	0	s	----	68	28	----	----	----	----	*108*
	+	8	TB	68	68	21	30	7	81	4	*96, 102*
	—	0	TB	----	64	22	88	14	98	3	*151*
P. ponderosa var. arizonica	—	0	pl	----	75	20	52	10	75	8	*191*
var. ponderosa	+	8	TB	86	68	21	----	----	----	----	*108*
	+	8+	TB	86	68	21	----	----	67	100	*63*
	—	0	s, pe	----	85/65	30–60	14–87	7–29	59	186	*235*
var. scopulorum	—	16	K	72	72	30	84	11	86	4	*21*
	—	0	s	----	68–86	30–60	50	19	64	40	*238*
P. pumila	+	8+	TB	77	77	30	----	----	77	9	*8*
P. pungens	—	0	s + pe	----	70–85/70–75	45–60	----	----	55	3	*3*
	—	0	s, pe	----	75	40	----	----	65	9	*235*
P. quadrifolia	+	24	TB	72–78	----	30	46	9	69	1	*122*

TABLE 8.—*Pinus: germination test conditions and results*—Continued

Species	Pretreatment[1]	Germination test conditions: Daily light period	Medium[2]	Temperature[3]: Light	Temperature[3]: Dark	Duration	Germinative energy: Amount	Germinative energy: Period	Germinative capacity: Average	Germinative capacity: Samples	Data source
		Hours		*°F.*	*°F.*	*Days*	*Percent*	*Days*	*Percent*	*Number*	
P. radiata	+	8	TB	86	68	28	...	...	...	...	*108*
	—	8+	P	68	68	25	16	7	81	9	*96, 102*
	—	8+	v	86	68	28	...	...	67	15	*63*
P. resinosa	—	0	TB, P	...	86/68	14	69	10	83	23	*10, 93*
	—	0	s	...	86/68	30	25–75	7–25	75	551	*238*
P. rigida	—	8	TB, P	86	68	14	77	10	86	6	*10, 93*
	+	0	TB	...	86/68	30	24	10	47	6	*93*
	—	8	TB	86	68	45	60	18	70	19	*238*
P. roxburghii	—	0	TB	...	68–71	30	...	...	83	5	*187*
	—	0	s	...	...	30	79	10	81	135	*207*
P. sabiniana	+	0	s	...	72	30	...	...	76	3	*122*
	+	24	TB	72–78	...	30	...	...	13	1	*122*
P. serotina	—	8	s + pl	72	72	30	90	10	73	1	*239*
P. sibirica	+	0	s	...	68–86	60	...	...	7	1	*238*
	—	0	TB	...	68–71	60+	...	...	40	4	*187*
P. strobiformis	—	0	TB	...	86/68	35	...	...	94	8	*7*
	—	0	pl	...	75	46	...	...	39	31	*191*
P. strobus	+	8+	TB, P	86	68	21	...	...	...	...	*10*
	+	8+	K	86	68	40	33	8	100	20	*79*
	+	8+	K	72	72	40	...	...	93	28	*80*
P. sylvestris	—	8	TB, P	86	68	14	78	10	81	99	*10, 93*
	—	8	TB	...	86/68	30	46	10	59	99	*93*
	—	24	s	72–77	...	50	...	...	89–100	36	*212*
	—	8	TB	68	68	30	18–99	14	21–99	18	*116*
P. taeda	—	8+	TB, P	86	68	28	...	...	...	...	*10*
	—	16	s + pl	72	72	30	90	17	90	481	*239*
P. thunbergiana	—	8+	TB, P	86	68	21	50	10	75	4	*10, 93*
	—	8+	TB	75	75	30	69	10	76	19	*103*
	+	0	TB	...	77/70	28	...	...	85	100	*177*
P. torreyana	+	0	s, pe	...	80/65	60	...		81	21	*235*
P. virginiana	—	8+	TB	86	68	21	...	...	...	...	*10*
	—	8+	K	72	72	28	87	10	90	29	*239*
	—	0	s, pe	86	68	30	...	...	65	5	*235*
P. wallichiana	—	8+	TB, P	86	68	18	...	...	...	...	*10*
	—	0	TB	...	76/70	60	44	20	64	12	*187*

[1] +: pretreatment was used; usually cold stratification.
—: no pretreatment.

[2] The symbols for the various media are a follows:
TB: seeds are germinated on top of one or more layers of an absorbent paper (blotters).
B: seeds are germinated between blotters.
P: covered petri dish with an absorbent medium.
v: vermiculite.
s: sand or soil.
pl: perlite.
pe: peat.
K: Kimpak.

[3] When alternating temperatures are used, the higher is for 8 hours and the lower is for 16 hours. The daily light period usually coincides with the period of higher temperature.

[4] Seeds from old cones.

age of the seed. The viability estimates often are much higher than the germination capacities obtained from germination tests (*223*) (Chapter 7).

Nursery and field practice.—Pines are successfully nursery grown in most parts of the United States and in virtually all soil types. The soil should be fertile, and of good drainage and aeration. In most large nurseries the soil is fumigated in the fall or spring before sowing to control soil-borne diseases, insects, nematodes, and weed seeds. Nursery practices are summarized for 35 species and varieties in table 9.

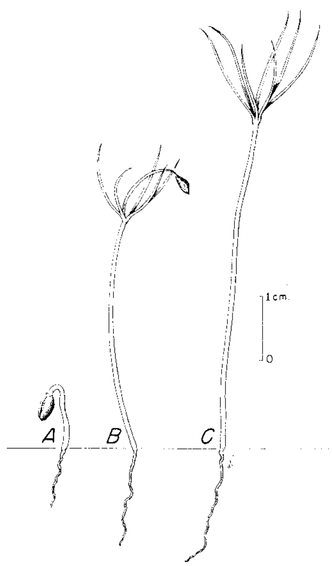


FIGURE 4.—*Pinus resinosa*, red pine: seedling development at 1, 7, and 30 days after germination.

In temperate regions, pine seeds can be sown in the fall or spring. It is now common practice to spring-sow nondormant seeds. Dormant seeds too may be spring-sown, but they must be pretreated. Some nurseries pretreat dormant seeds of all species in the same manner; however, this is not to be recommended. The pregermination treatment used on each species seed lot should be that which achieves best germination for that lot. Seeds with embryo dormancy can be sown in fall without a pretreatment. Compared to seedlings produced by spring-sown seeds, those from fall-sown seeds are commonly larger and better developed after one season. With fall-sown seeds, however, sowing must be late enough to avoid fall germination, so that seedlings are not subject to winter freeze damage and mortality. Fall-sown beds also are more subject to losses from rodent damage.

The seeds can be either drill-sown or broadcast by hand or machine, but most large nurseries drill-sow in beds because it is more economical. The amount of seed sown per unit area and the sowing density vary with the species, seed size and germination capacity, and the desired density. The stock density influences the vigor and size of the seedlings and transplants produced. The stock density will depend on the species, the length of time seedlings will remain in the nursery bed, and whether they will be transplanted.

Seeds are sown at densities selected to produce from 15 to 75 seedlings per square foot. Higher tree survival factors are obtained when medium-to-low sowing densities are used. Most nurseries sow seeds at a slightly higher density if the seedlings are to be placed in transplant beds for one or more years. A lesser density is desired for 2–0 than 1–0 seedlings. Depending on the species, seed lot, and nursery, sowing densities range from 2 to 20 ounces of seed per 100 square feet of bed. One northwestern nursery drill-sows *P. monticola* at 35 seeds per lineal foot in rows spaced 3.5 inches apart to obtain a density of 120 seedling per square foot for 2–0 seedlings (*243*). A second western nursery drill-sows *P. monticola* at 18 seeds per lineal foot with 6 inches between rows to obtain a density of 35 seedlings per square foot for its 2–0 seedlings (*246*). Ultimately, then, experience determines the correct sowing density for a given species and nursery for a particular planting situation. Average nursery germination has ranged from 20 to 85 percent of the germination capacities found in laboratory tests. Of the seeds that germinate, as little as 19 and as much as 90 percent produce useable seedlings; the average has been about 55 percent.

At the time of sowing, seeds are drilled or pressed firmly into the soil, then uniformly covered with 1/8 to 3/4 inch soil, sand, or mulch. Fall-sown seeds should be placed slightly deeper than spring-sown seeds to protect them from wind erosion and frost action. Large-seeded species, as *P. albicaulis*, *P. lambertiana*, and *P. monophylla*, are covered to a depth of 1/2 inch. Smaller seeds require the least covering. The southern pines, *P. echinata*, *P. elliottii*, *P. palustris*, *P. taeda*, and *P. virginiana*, are pressed into the soil surface and covered with burlap or chopped pine straw. Such materials protect the seeds from birds or displacement by rain and help maintain soil moisture. *Pinus contorta* (var. *contorta* and var. *latifolia*), *P. densiflora*, and *P. thunbergiana* are sown 1/8 inch deep; *P. banksiana*, *P. canariensis*, *P. edulis*, and *P.*

TABLE 9.—*Pinus: nursery practice*

Species	Presowing stratification period[1]	Season for sowing	Seedlings per square foot	Sowing depth	Mulch: Type	Mulch: Depth	Tree percent	Out-planting age	Data source
	Days		*Number*	*Inch*		*Inch*		*Years*	
P. attenuata	60	spring	25	⅜	none		80	1–0	*246*
P. banksiana	0	fall or spring	30	¼	do		50–60	½–1½, 1–0, 2–0, 1–1, 1–2	*213, 221*
P. canariensis	0	spring		¼	sponge rok	¼–½	35–50	1–0, 2–0, ½–1½	*77, 122, 152*
P. clausa	0	do		¼–½	none		70	1–0	*29*
P. contorta									
var. *contorta*	28	do	30	⅛	do		48	1–0	*63*
var. *latifolia*	28–35	do	48	⅛	sawdust	½	60	2–0	*245*
var. *murrayana*	30–60	do	25–60	⅜	peat moss[3]	¼–½	70–75	1–0, 2–0	*246*
P. coulteri	60	do	25	½	none		80	1–0	*246*
P. densiflora	0	do	50	⅛–¼	sand, sawdust			2–0, 3–0, 1–1	*264, 222*
P. echinata	15–60	do	40	pressed[2]	pine straw		60	1–0	*159*
P. edulis	60	do	30	¼	sawdust	½	80	2–0	*20*
P. elliottii									
var. *densa*	0	do	35	pressed[2]	pine straw	½	80	1–0	*24*
var. *elliottii*	0	do	30–35	pressed[2]	sawdust or pine straw.		58–74	1–0	*87*
P. insularis	0	do	30	⅜	none		50	1–0	*38, 250, 251*
P. jeffreyi	28–60	do	25–30	¼–⅜	do		58–80	1–0, 2–0	*63, 246*
P. lambertiana	90	do	30–35	⅜–½	do		21–80	1–0, 2–0	*63, 246*
P. monophylla	90	do	25–30	½	sawdust	¼–½	33	2–0	*247*
P. monticola	42–90	do	35–120	¼–⅜	do[3]	¼–½	32–90	2–0, 3–0	*243, 246*
P. mugo	40–50	do	50	⅜	peat moss	¼–½	55	3–0	*43*
P. muricata	28–40	do	30–75	⅛–¾	do[3]	¼–½	37–60	1–0	*43, 63*
P. nigra	0	fall	50–60	½–¾	do	¼–½	60–65	2–0, 2–1, 2–2	*43, 221*
	35–45	spring							*43, 221*
P. palustris	0	spring	15	pressed[2]	pine straw		75	1–0	*57, 159*
P. pinaster	0	do	30	¼–½				1–0	*174*
P. ponderosa									
var. *ponderosa*	28	do	25–46	¼–⅜	none		48–80	1–0, 2–0, 1–2, 3–0	*11, 245, 246*
var. *scopulorum*	20–30	do	35–40	⅛–¼	do		70	2–0	*245*
	0	fall or spring	50–65	½	do		70	1–2, 2–1, 2–2	*223*
P. pungens	0	do	20–33	¼–½	straw		19–28	1–0, 2–0	*3*
P. radiata	35–45	spring	25–75	⅛–¾	peat moss[3]	¼–½	34–70	1–0	*43, 63*
P. resinosa	0	fall or spring	30–50	¼–⅜	none		65–80	2–0, 3–0, 2–1, 2–2	*213, 221*
P. rigida	0	spring	30–35	pressed[2]	sand	⅛		2–0	*52*
P. roxburghii	0	do		⅛–½			30–35	1–1, 2–1	*129, 233*
P. strobus	0	fall	20–50	pressed[2] or ⅝	sawdust or wood fiber.	⅛–¼	55–85	2–0, 3–0, 2–1, 2–2	*80, 221*
	30	spring							
P. sylvestris	0	fall	30–60	⅛–½	peat moss[3]	¼–½	25–70	1–0, 2–0, 2–1, 2–2	*63, 221*
	2–60	spring							
P. taeda	30–60	spring	40	pressed[2]	pine straw		60	1–0	*211, 234*
P. thunbergiana	0	fall or spring	50–100	⅛	straw and burlap (winter).		31	2–0, 1–1	*99, 145*
P. virginiana	0	fall	30–35	pressed[2] or ¼	pine needles, sand or sawdust.	½–½	63–90	1–0, 2–0	*224, 271*
	14	spring							
P. wallichiana	0	fall	broadcast	½	none		46	1–1, 1–1–1	*99, 233*
	15–20	spring							

[1] Stratification in a moist medium at 33° to 41° F.
[2] Seeds were pressed into the soil surface making the sowing depth approximately equal to the diameter of the seed.
[3] Mulch not always used.

monticola are commonly sown ¼ inch deep. Care should be taken not to sow the seed too deep.

Germination is complete for most species from 10 to 50 days after spring sowing. But some lots of dormant seed species, even after pregermination treatment, may continue to germinate several months to a year after sowing; e.g., *P. albicaulis, P. cembra, P. peuce,* and *P. strobiformis* (*122*).

In most nurseries, fungicides are used to control damping-off, and sprays are used during the season to control insects and other diseases. In southern nurseries the fusiform rusts on *P. taeda* and *P. elliottii* and brown spot on *P. palustris,* and in Lake States nurseries the sweetfern blister rust on *P. banksiana, P. sylvestris,* and *P. ponderosa* are controlled by repeated applications of fungicides.

Generally, transplants or older age classes are recommended for difficult sites. In the Lake States and Prairie Plains, for example, *P. banksiana* is grown as 1–0 or 1½–0 stock for easy to average sites, 1–1 or 2–0 for difficult sites, and 2–1, 1–2, or 2–2 for windbreaks. Most of the white pines are grown as 2–0 and 3–0 or as transplants 2–1 and 2–2. In specialized nurseries, pines are routinely grown as container plants. Either young seedlings or seeds are planted directly in containers with a soil mix. Depending on the nursery, partial shade is provided during the germination and seedling establishment phases. Normally, container-grown pines are cultured 1 to 5 years before outplanting. Care must be taken not to grow pines in too small a container for too long a time since they will become container-bound or rootbound.

Methods of mulching, watering, shading, pest control, lifting, and other nursery operations have been described in several regional handbooks (*95, 107, 221, 223, 254*). Each one contains much useful information on nursery production of pine seedlings.

All pine species can be vegetatively propagated either by rooting or grafting (*122, 178, 231*). However, rooting success for most species decreases rapidly when scions are taken from trees older than 5 years. *Pinus radiata, P. attenuata, P. densiflora,* and *P. thunbergiana* are relatively easy to root. But only *P. radiata* is extensively propagated by rooting cuttings under nursery and greenhouse conditions (*230*). Selected trees of many other species are cloned by rooting of cuttings. Grafting also is routinely used to propagate rare material or to clone individual plants, as in seed orchard programs designed to produce genetically improved forest tree seed (*122*).

Literature and Other Data Sources Cited

(1) Albert, R.
Data filed 1970. USDA Forest Serv., Region 3, Coronado Natl. Forest.

(2) Allen, R., and Wardrop, A. B.
1964. The opening and shedding mechanism of the female cones of *Pinus radiata*. Aust. J. Bot. 12: 125–134.

(3) Allison, A. C.
Correspondence, 1969. Virginia Dep. Nat. Resour.

(4) Altman, P. L., and Dittmer, D. S.
1962. Biological handbook of growth. 608 p. Fed. Am. Soc. Exp. Biol., Wash., D. C.

(5) Andreev, V. N.
1925. *Pinus peuce* Griseb., *In* [Dendrology, vol. I, Gymnosperms p. 96.] Ukraine State Printing Office. (In Russian.)

(6) Andresen, J. W.
1963. Germination characteristics of *Pinus rigida* seed borne in serotinous cones. Broteria 32(3–4): 151–178.

(7) ———
1965. Stratification of seed of *Pinus strobiformis*. Tree Plant. Notes no. 72, p. 5–7.

(8) Asakawa, S.
1957. [Studies on hastening the germination of the seeds of the five-leaved pines.] Gov. Forest Exp. Stn., Meguro (Tokyo) Bull. 100: 41–54. (In Japanese.)

(9) ———
Correspondence, June 17, 1969. Minist. Agric. For., Meguro, (Tokyo) Japan.

(10) Association of Official Seed Analysts.
1965. Rules for testing seeds. Proc. Assoc. Off. Seed Anal. 54(2): 1–112, illus.

(11) Baker, L. A.
Correspondence, 1969. Oreg. State Forest. Dep., Dwight L. Phipps Forest Nursery, Elkton, Oreg.

(12) Bailey, L. H.
1939. The standard cyclopedia of horticulture. 3 vol., 3,639 p. The Macmillan Co., New York.

(13) Barnett, J. P.
Data filed 1968. USDA Forest Serv., South. Forest Exp. Stn., New Orleans, La.

(14) ———
1969. Long-term storage of longleaf pine seeds. Tree Plant. Notes 20(2): 22–25.

(15) ———
1970. Flotation in ethanol affects storability of spruce pine seeds. Tree Plant. Notes 21(4): 18–19.

(16) ——— and McLemore, B. F.
1967. Improving storage of spruce pine seed. Tree Plant. Notes 18(2): 16.

(17) ——— and McLemore, B. F.
1967. Study of spruce pine cone maturity and seed yield. Tree Plant. Notes 18(2): 18.

(18) Barton, L. V.
1930. Hastening the germination of some coniferous seeds. Am. J. Bot. 17: 88–115.

(19) Bates, C. G.
1930. The production, extraction, and germination of lodgepole pine seed. U.S. Dep. Agric. Tech. Bull. 191, 92 p.

(20) Bennett, M.
Communication, 1969. Arizona Cypress Gardens, Sedona, Ariz.

(21) Benson, D. A.
Data filed 1969. USDA Forest Serv., Eastern Tree Seed Lab., Macon, Ga.

(22) ———
Data filed 1970. USDA Forest Serv., Eastern Tree Seed Lab., Macon, Ga.

(23) Bevege, D. I.
1965. An investigation of cone and seed maturity of slash pine in southern Queensland. Aust. For. 29(3): 135–148.

(24) Bonninghausen, R. A.
Communication, 1968. Florida Forest Serv., Tallahassee.

(25) Boskok, T. E.
1970. [Seed maturation period in *Pinus brutia, Picea orientalis* and *Abies bornmuelleriana.*] Orm. Arast. Enst. Tek. Butll. 42: 64 p. (In Turkish.)

(26) Boyd, R. J., Jr.
Data filed 1970. USDA Forest Serv., Intermt. Forest and Range Exp. Stn., Moscow, Idaho.

(27) Britton, N. L., and Shafer, J. A.
1908. North American trees. 849 p. Henry Holt and Co., New York.

(28) Brown, J. H.
1969. Variation in roots of greenhouse grown seedlings of different Scotch pine provenances. Silvae Genet. 4(4): 111–117.

(29) Burns, R. M.
Data filed 1968. USDA Forest Serv., Southeast. Forest Exp. Sta., Marianna, Fla.

(30) Byrd, R. E.
Communication, 1968. Labelle, Florida.

(31) Callaham, R. Z.
1962. Geographic variability in growth of forest trees. *In* Tree growth. T. T. Kozlowski (ed.), p. 311–325. Ronald Press Co., New York.

(32) ———
1963. Provenance research: investigation of genetic diversity associated with geography. Unasylva 18(2–3): 73–74.

(33) ——— and Liddicoet, A. R.
1961. Altitudinal variation at 20 years in ponderosa and Jeffrey pines. J. For. 59(11): 814–820.

(34) Carlisle, H., and Brown, A. H. F.
1968. Biological flora of the British Isles. *Pinus sylvestris* L. J. Ecol. 56(1): 269–307.

(35) Cerepnin, V. L.
1964. [The importance of *Pinus sylvestris* seed origin, weight, and colour in selection.] Sel. Drev. Porod *v* Vost. Sibiri. p. 58–68. (In Russian.)

(36) Chapman, H. H.
1922. A new hybrid pine (*Pinus palustris* × *Pinus taeda*). J. For. 20: 729–734.

(37) Church, T. W., Jr., and Sucoff, E. I.
1960. Virginia pine seed viable two months before natural cone opening. USDA Forest Serv., Northeast. Forest Exp. Stn. Res. Note 102, 4 p.

(38) Claveria, J. R.
1953. Growing Benguet pine (*Pinus insularis*) in Cebu Province. Philippine J. For. 9: 57–76.

(39) Cocozza, M. A.
1961. Osservazioni sul circlo riproduttivo di *Pinus heldreichii* Christ. var. *leucodermis* Ant. del monte pollino. Accad. Ital. Sci. For. 10: 97–110. (In Italian.)

(40) Cooling, E. N. G.
1968. Fast growing timber trees of the lowland tropics. *Pinus merkusii.* No. 4. 169 p. Commonw. For. Inst., Dep. For., Oxford Univ.

(41) ——— and Gaussen, H.
1970. In Indo China: *Pinus merkusiana* sp. nov. et non *P. merkusii* Jungh. et de Vriese. Trav. Lab. For. Toulouse Tome 1 Vol. 8, Art. 7, 8 p.

(42) Cram, W. H., and Brack, C. G. E.
1953. Performance of Scotch pine races under prairie conditions. For. Chron. 29(4): 334–342.

(43) Critchfield, H. M.
Correspondence, October 9, 1969. Glass Mountain Tree Farm and Nursery, St. Helena, Calif.

(44) Critchfield, W. B.
1957. Geographic variation in *Pinus contorta.* Maria Moors Cabot Found. Publ. 3, 118 p.

(45) ———
1963. Hybridization of the southern pines in California. South. Forest Tree Improv. Comm. Publ. 22: 40–48.

(46) ———
1966. Phenological notes on Latin American *Pinus* and *Abies.* J. Arnold Arbor. 47(4): 313–318.

(47) ——— and Allenbaugh, G. L.
1965. Washoe pine on the Bald Mountain Range, California. Madroño 18(2): 63–64.

(48) ——— and Krugman, S. L.
1967. Crossing the western pines at Placerville, California. Univ. Wash. Arbor. Bull. 30(4): 78–81, 92.

(49) ——— and Little, E. L., Jr.
1966. Geographic distribution of the pines of the world. U.S. Dep. Agric. Misc. Publ. 991, 97 p.

(50) Curtis, J. D.
1955. Effects of origin and storage method on the germinative capacity of ponderosa pine seed. USDA Forest Serv., Intermt. Forest and Range Exp. Stn. Res. Note 26, 5 p.

(51) Dallimore, W., and Jackson, A. B.
1967. A handbook of Coniferae and Ginkgoaceae. Ed. 4, rev. by S. G. Harrison, 729 p. St. Martin's Press, New York.

(52) Dansbury, C.
Correspondence, 1968. Washington Crossing State Forest Nursery, Titusville, New Jersey.

(53) Day, R. J.
1967. Whitebark pine in the Rocky Mountains of Alberta. For. Chron. 43(3): 278–282.

(54) Debazac, E. F.
1964. Manuel des conifères. 172 p. École Nat. Eaux Forêts, Nancy.

(55) Delevoy, G.
1935. Note preliminaire sur l'influence de l'origine des graines chez le pin maritime. Bull. Soc. Cent. For. Belg. 42(3): 97–105.

(56) Dent, T. V.
1947. Seed storage with particular reference to the storage of seed of Indian forest plants. Indian Forest Rec. (N.S.) Silvic. 7(1): 1–134.

(57) Derr, H. J.
1955. Seedbed density affects longleaf pine survival and growth. Tree Plant. Notes no. 20, p. 28–29.

(58) Dimitroff, I.
1926. [Study of the seed material of *Pinus peuce*.] Ann. Univ. Sofia. Fac. Agric. 4: 259–306. (In Bulgarian.)

(59) Dorman, K. W., and Barber, J. C.
1956. Time of flowering and seed ripening in southern pines. USDA Forest Serv., Southeast. Forest Exp. Stn. Pap. 72, 15 p.

(60) Duff, C. E.
1928. The varieties and geographical forms of *Pinus pinaster* Soland., in Europe and South Africa, with notes on the silviculture of the species. S. Afr. Dep. For. Bull. 22-a, 55 p.

(61) Duffield, J. W.
1951. Interrelationships of the California closed-cone pines with reference to *Pinus muricata* D. Don. Ph.D. Thesis Univ. Calif. Berkeley. 114 p.

(62) ———
1953. Pine pollen collections dates—annual and geographic variation. USDA Forest Serv., Calif. Forest and Range Exp. Stn. Res. Note 85, 9 p.

(63) Eden, J.
Correspondence, 1969. Calif. Div. Forest., Davis State Forest Nursery, Davis, Calif.

(64) Edwards, M. U.
1954–55. A summary of information on *Pinus contorta*. For. Abstr. 15: 389–396; 16: 3–13.

(65) Eliason, E. J.
1942. Data from cone collections of various species in New York. New York Conserv. Dep. Notes Forest Invest. 39, 1 p.

(66) ——— and Hill, J.
1954. Specific gravity as a test for cone ripeness with red pine. Tree Plant. Notes no. 17, p. 1–4.

(67) Ellis, R. W.
1969. Correspondence, August 20, 1969. USDA Forest Serv., Mt. Sopris Nursery, Carbondale, Colorado.

(68) Fenton, R. H., and Sucoff, E. I.
1965. Effects of storage treatments on the ripening and viability of Virginia pine seed. USDA Forest Serv. Res. Note NE-31, 6 p.

(69) Fielding, J. M.
1961. Provenances of Monterey and Bishop pines. Commonw. For. Bur. Bull. 38, 30 p. Canberra.

(70) Forde, M. B.
1964. Variation in natural population of *Pinus radiata* in California. Part 3. Cone characters. Part 4. Discussion. N. Z. J. Bot. 2(4): 459–485.

(71) Fowells, H. A.
1965. Silvics of forest trees of the United States. U. S. Dep. Agric., Agric. Handb. 271, 762 p.

(72) Fowler, D. P., and Dwight, T. W.
1964. Provenance differences in the stratification requirements of white pine. Can. J. Bot. 42: 669–673.

(73) ——— and Heimburger, C.
1969. Geographic variation in eastern white pine 7-year results in Ontario. Silvae Genet. 18(4): 123–129.

(74) ——— and Lester, D. T.
1970. Genetics of red pine. USDA Forest Serv. Res. Pap. WO–8, 13 p.

(75) Fritts, H. C.
1969. Bristlecone pine in the White Mountains of California. Growth and ring-width characteristics. Tree-Ring Pap. 4, 44 p. Univ. Ariz. Press, Tucson.

(76) Gifford, E. M., and Mirov, N. T.
1960. Initiation and ontogeny of the ovulate strobilus in ponderosa pine. Forest Sci. 6(1): 19–25.

(77) Goor, A. Y.
1955. Tree planting practices for arid areas. FAO Forest. Dev. Pap. No. 6, 126 p.

(78) ——— and Barney, C. W.
1968. Forest tree planting in arid zones. 409 p. Ronald Press Co., New York.

(79) Graber, R. E.
1965. Germination of eastern white pine seed as influenced by stratification. USDA Forest Serv. Res. Pap. NE–36, 9 p.

(80) Graber, R. E.
Data filed 1967. USDA Forest Serv., Northeast. Forest Exp. Stn., Upper Darby, Penn.

(81) ———
Data filed 1970. USDA Forest Serv., Northeast. Forest Exp. Sta., Upper Darby, Penn.

(82) Griffin, J. R.
1962. Intraspecific variation in *Pinus sabiniana* Dougl. PhD thesis, 274 p. Univ. Calif., Berkeley.

(83) ——— and Conkle, M. T.
1967. Early performance of knobcone and Monterey pine hybrids on marginal timber sites. USDA Forest Serv. Res. Note PSW–156, 10 p.

(84) Haasis, F. W., and Thrupp, A. C.
1931. Temperature relations of lodgepole pine seed germination. Ecol. 12: 728–744.

(85) Haller, J. R.
1957. Taxonomy, hybridization and evolution in *Pinus ponderosa* and *Pinus jeffreyi*. PhD thesis 169 p. Univ. Calif., Los Angeles.

(86) ———
1967. A comparison of the mainland and island populations of Torrey pine. *In* Biology of the California Islands. Symp. Proc., R. N. Philbrick (ed.). Santa Barbara Botanic Garden, Santa Barbara.

(87) Hamner, J. G.
Data filed 1968. Bellville Nursery, Union-Camp Corp., Savannah, Ga.

(88) Harlow, W. M., and Harrar, E. S.
1950. Textbook of dendrology. Third ed., 555 p. McGraw-Hill Book Co., Inc., New York.

(89) Harrar, E. S., and Harrar, J. G.
1946. Guide to southern trees. 712 p. Whittlesey House, McGraw-Hill, Book Co., Inc., New York.

(90) Harris, R. W., Leiser, A. T., and Chan, F. J.
1970. Vegetation management on reservoir recreation sites. Univ. Calif., Davis, Dep. Environ. Hortic. Annu. Rep., 17 p.

(91) Hartmann, H. T., and Kester, D. E.
1968. Plant propagation: principles and practices. Ed. 2, 702 p. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

(92) Heidmann, L. J.
Data filed 1969. USDA Forest Serv., Rocky Mountain Forest and Range Exp. Stn., Flagstaff, Ariz.

(93) Heit, C. E.
1958. The effect of light and temperature on germination of certain hard pines and suggested methods for laboratory testing. Proc. Assoc. Off. Seed Anal. 48: 111–117.

(94) ———
1963. Balkan pine—promising new exotic conifer. Am. Nurseryman 118(12): 10, 11, 32, 34, 36.

(95) ———
1964. Tips on growing healthy, vigorous conifer seedlings and transplants. N. Y. Christmas Tree Grow. Bull. 2(1): 5 p. [also Am. Christmas Tree J., Feb. 1966].

(96) ———
1967. Laboratory germination studies and suggested testing methods for 10 less common and exotic *Pinus* species. (Unpublished.)

(97) ———
1967. Propagation from seed. Part 9. Fall sowing of conifer seeds. Am. Nurseryman 126(6): 10–11. 60–69.

(98) ———
1967. Propagation from seed. Part 10. Storage method for conifer seeds. Am. Nurseryman 126(8): 14–54 (not inclusive).

(99) ———
1968. Propagation from seed. Part 12. Growing choice, less common pines. Am. Nurseryman 127(2): 14–15, 112–120.

(100) ———
1968. Thirty-five year's testing of tree and shrub seeds. J. For. 66(8): 632–634.

(101) ———
1969. Propagation from seed. Part 19. Testing and growing Scotch pine seeds from different sources. Am. Nurseryman 129(7): 10–15, 110–118.

(102) ———
Correspondence, 1969. New York Agric. Exp. Stn., Geneva, N. Y.

(103) ——— and Eliason, E. J.
1940. Coniferous tree seed testing and factors affecting germination and seed quality. N. Y. State Agric. Exp. Stn. Tech. Bull. 255, 45 p.

(104) Holst, M.
1962. Seed selection and tree breeding in Canada. Can. Dep. For., Forest Res. Br. Tech. Note 115, 20 p.

(105) Hopkins, E. R.
1960. Germination stimulation in *Pinus pinaster*. West. Aust. For. Dep. Bull. 66, 10 p.

(106) Hyun, S. K.
1962. Improvement of pines through hybridization. IUFRO Proc. 13, Vol. 1 (2), 2 p.

(107) International Crop Improvement Association.
1963. Minimum seed certification standards. Int. Crop Improv, Assoc. Publ. 20, 128 p.

(108) International Seed Testing Association.
1966. International rules for seed testing. Proc. Int. Seed Test. Assoc. 1966: 1–152.

(109) Iroshnikov, A. I.
1963. [Fruit bearing of stone pine forests in the northwestern part of the eastern Sayan.] *In* Fruiting of the Siberian stone pine in east Siberia. A. P. Shimanyuk (ed.), p. 98–109. Akad. Nauk SSSR Sibirskoe Otdel, Vol. 62 [Engl. Transl. TT65–50123, CFSTI, U. S. Dep. Commerce].

(110) ——— Lebkov, V. F., and Cherednikova, Yu. S.
1963. Fruit bearing of stone pine forests of the Lena-Ilim interfluvial area. *In* Fruiting of the Siberian stone pine in east Siberia. A. P. Shimanyuk (ed.), p. 35–79. Akad. Nauk SSSR Sibirskoe Otdel, Vol. 62. [Engl. Transl. TT65–50123, CFSTI, U. S. Dep. Commerce].

(111) Jacaline, D. V., and Lizardo, L.
1958. Silvical characteristics of Benguet pine (*Pinus insularis* Endl.). Philippines Bur. For. Silvical Leafl. 2, 32 p.

(112) Jones, L.
1962. Recommendation for successful storage of tree seed. Tree Plant. Notes no. 55, p. 9–20.

(113) ———
1966. Storing pine seed: What are best moisture and temperature conditions? Georgia Forest Res. Counc., Res. Pap. 42, 8 p.

(114) ——— and Benson, D.
Data filed 1969. USDA Forest Serv., Southeast. Forest Exp. Stn., Macon, Ga.

(115) Kamra, S. K.
1967. Studies on storage of mechanically damaged seed of Scots pine (*Pinus sylvestris* L.). Stud. For. Suecica 42, 19 p.

(116) ———
1969. Investigations on the suitable germination duration for *Pinus sylvestris* and *Picea abies* seed. Stud. For. Suecica 73, 16 p.

(117) ——— and Simak, M.
1968. Germination studies on Scots pine (*Pinus sylvestris* L.) seed of different provenances under alternating and constant temperatures. Stud. For. Suecica 62, 14 p.

(118) Karschon, R.
1961. Studies in nursery practice for pines. La-Yaaran 11(1): 1–12.

(119) Kmecza, N. S.
1970. Using tree shakers for pine cone collections in Region 8. Tree Plant. Notes 21(1): 9–11.

(120) Kraus, J. F.
1963. The Olustee arboretum. USDA Forest Serv., Res. Pap. SE–4, 47 p.

(121) Krugman, S. L.
1966. Artificial ripening of sugar pine seeds. USDA Forest Serv. Res. Pap. PSW–32, 7 p.

(122) ———
Data filed 1969. USDA Forest Serv., Pac. Southwest Forest and Range Exp. Sta., Institute of Forest Genetics, Placerville, Calif.

(123) Krüssmann, G.
1960. Die Nadelgehölze. Ed. 2, 335 p. Paul Parey, Berlin and Hamburg.

(124) Lamb, G. N.
1915. A calendar of the leafing, flowering and seeding of the common trees of the eastern United States. U. S. Mon. Weather Rev., Suppl. 2, p. 3–19.

(125) Larson, M. M.
1966. Racial variation in ponderosa pine at Fort Valley, Arizona. USDA Forest Serv. Res. Note RM–73, 7 p.

(126) LeBarron, R. K., and Roe, E. I.
1945. Hastening the extraction of jack pine seeds. J. For. 43: 820–821.
(127) Lebrun, C.
1967. [Separation of (full and empty) seeds by specific gravity measurement through immersion in liquids.] Rev. For. Franc. 19(11): 786–789. (In French.)
(128) Leloup, M.
1956. Tree planting practices in tropical Africa. FAO Forest. Develop. Pap. 8, 306 p.
(129) Letourneux, C.
1957. Tree planting practices in tropical Asia. FAO Forest. Develop. Pap. 11, 172 p.
(130) Libby, W. J.
Correspondence, February 26, 1968. Sch. For. and Conserv., Univ. Calif., Berkeley.
(131) Lindquist, C. H.
1962. Maturity of Scots pine seed. Can. Dep. Agric., Res. Br., Summary report for the Forest Nursery Station, Indian Head, Saskatchewan, p. 20–21.
(132) Little, E. L., Jr.
1938. The earliest stages of piñyon cones. USDA Forest Serv., Southwest. Forest and Range Exp. Stn. Res. Note 46, 4 p.
(133) ———
1938. Stages of growth of piñyons in 1938. USDA Forest Serv., Southwest. Forest and Range Exp. Stn. Res. Note 50, 4 p.
(134) ———
1940. Suggestions for selection cutting of piñyon trees. USDA Forest Serv., Southwest. Forest and Range Exp. Stn. Res. Note 90, 3 p.
(135) ———
1941. Managing woodlands for piñyon nuts. Chron. Bot. 16: 348–349.
(136) ———
1950. Southwestern trees—a guide to the native species of New Mexico and Arizona. U.S. Dep. Agric., Agric. Handb. 9, 109 p.
(137) ———
1968. Two new pinyon varieties from Arizona. Phytologia 17(4): 329–342.
(138) ——— and Dorman, K. W.
1952. Geographic differences in cone opening in sand pine. J. For. 50(3): 204–205.
(139) ——— and Dorman, K. W.
1952. Slash pine (*Pinus elliottii*), its nomenclature and varieties. J. For. 50: 918–923.
(140) ——— and Dorman, K. W.
1954. Slash pine (*Pinus elliottii*) including South Florida slash pine. USDA Forest Serv., Southeast. Forest Exp. Stn. Pap. 36, 82 p.
(141) ——— and Righter, F. I.
1965. Botanical descriptions of forty artificial pine hybrids. U.S. Dep. Agric. Tech. Bull. 1345, 47 p.
(142) Little, S.
1941. Calendar of seasonal aspects for New Jersey forest trees. Forest Leaves 31(4): 1–2, 13–14.
(143) ———
1959. Silvical characteristics of pitch pine (*Pinus rigida*). USDA Forest Serv., Northeast. Forest Exp. Stn. Pap. 119, 22 p.
(144) ———
1969. Local seed sources recommended for loblolly pine in Maryland and shortleaf pine in New Jersey and Pennsylvania. USDA Forest Serv. Res. Pap. NE–134, 16 p.
(145) Littlefield, E. W.
Data filed 1932. New York State Dep. Conserv.
(146) Lizardo, L.
1950. Benguet pine (*Pinus insularis* Endl.) as a reforestation crop. Philippine J. For. 7(1–4): 43–60.
(147) Loiseau, J.
1945. Les arbres et la forêt. Vol. 1, 204 p. Vigot freres, Paris.
(148) Loock, E. E. M.
1950. The pines of Mexico and British Honduras. Union S. Afr. Dep. For. Bull. 35, 244 p.
(149) Lotan, J. E.
Data filed 1969. USDA Forest Serv., Intermt. Forest and Range Exp. Stn., Bozeman, Mont.
(150) Luckhoff, H. A.
1964. Natural distribution, growth, and botanical variation of *Pinus caribaea* and its cultivation in South Africa. Ann. Univ. Stellinbosch vol. 39, ser. A, no. 1, 160 p.
(151) Magini, E.
1955. [Conditions of germination of Aleppo and Italian stone pines.] Ital. For. Mont. 10(3): 106-124. (In Italian.)
(152) ——— and Tulstrup, N. P.
1955. Tree seed notes. FAO For. Develop. Pap. 5, 354 p.
(153) Malac, B. F.
1960. More on stratification of pine seed in polyethylene bags. Tree Plant. Notes no. 42, p. 7–9.
(154) Mastrogiuseppe, R. J.
1968. Geographic variation in foxtail pine. USDA Forest Serv., Pac. Southwest Forest and Range Exp. Stn., Progress Rep., 15 p. Inst. Forest Genet., Placerville, Calif.
(155) McIntyre, A. C.
1929. A cone and seed study of the mountain pine (*Pinus pungens* Lambert). Am. J. Bot. 16: 402–406.
(156) McLemore, B. F.
1961. Hila of full and empty longleaf pine seeds are distinguishable. Forest Sci. 7: 246.
(157) ———
1961. Storage of longleaf pine seed. Tree Plant. Notes no. 47, p. 15–19.
(158) ———
1965. Pentane flotation for separating full and empty longleaf pine seeds. Forest Sci. 11: 242–243.
(159) ———
Data filed 1968. USDA Forest Serv., South. Forest Exp. Stn., New Orleans, La.
(160) ——— and Barnett, J. P.
1967. Effective stratification of spruce pine seed. Tree Plant. Notes 18(2): 17–18.
(161) ——— and Czabator, F. J.
1961. Length of stratification and germination of loblolly pine seed. J. For. 58: 267–269.
(162) Mergen, F.
1963. Ecotypic variation in *Pinus strobus* L. Ecol. 44: 716–727.
(163) Mikhalevskaya, O. B.
1960. [The biology of *Pinus pumila* Rgl. in Kamchatka.] Nauch. Dokl. Vyssh. Shkoly, Biolog. Nauk. 3: 136–141. (In Russian.)

(164) Miller, H., and Lemmon, P. E.
1943. Processing cones of ponderosa pine to extract, dewing, and clean seed. J. For. 41(12): 889–894.
(165) Mirov, N. T.
1936. A note on germination methods for coniferous species. J. For. 34(7): 719–723.
(166) ———
1946. Viability of pine seed after prolonged cold storage. J. For. 44(3): 193–195.
(167) ———
1956. Photoperiod and flowering of pine. Forest Sci. 2: 328–332.
(168) ———
1962. Phenology of tropical pines. J. Arnold Arbor. 43(2): 218–219.
(169) ———
1967. The genus *Pinus*. 602 p. Ronald Press Co., New York.
(170) Muller, C. A.
Data filed 1968. Ala. Div. For., Edward A. Hauss Nursery, Atmore, Ala.
(171) Müller, K. M.
1932. *Pinus peuce*, the Macedonian white pine as a substitute for *Pinus strobus*. Blister Rust News 16(3) Suppl.: 62–70.
(172) Nather, H.
1958. [Germination of Swiss stone pine seed.] Cent. Ges. Forstwesen 75(1): 161–170. (In German.)
(173) ———
Correspondence, January 9, 1969. Institut für Waldbau, Austria.
(174) Nederlandsche Boschbouw Vereeniging.
1946. Boomzaden: Handleiding inzake het oogsten, behandelen, bewaren en uitzaaien van boomzaden. 171 p. Wageningen. (In Dutch.)
(175) Newcomb, G. B.
1962. Geographic variation in *Pinus attenuata* Lem. PhD thesis, 190 p. Univ. Calif., Berkeley.
(176) Nyman, B.
1963. Studies on the germination in seeds of Scots pine. Stud. For. Suecica 2, 164 p.
(177) Ohmasa, M.
1956. Tree planting practices in temperate Asia: Japan. FAO For. Develop. Pap. 10, 156 p.
(178) O'Rourke, F. L. S.
1961. The propagation of pines. Proc. Int. Plant Propag. Soc. 11: 16–22.
(179) Otter, F. L.
1933. Idaho's record trees. Idaho For. 15: 37–39.
(180) Ouden, P. den, and Boom, B. K.
1965. Manual of cultivated conifers. 526 p. Martinus Nijhoff, The Hague.
(181) Pearson, G. A.
1931. Forest types in the southwest as determined by climate and soil. U.S. Dep. Agric. Tech. Bull. 247, 144 p.
(182) Pennsylvania Department of Forest and Water.
Data filed (n. d.). Mont Alto, Penn.
(183) Posey, C. E., and McCullough, R. B.
1969. Tenth year results of a shortleaf pine seed source study in Oklahoma. Okla. Agric. Exp. Stn. Bull. B–668, 14 p.
(184) Poynton, R. J.
1961. A guide to the characteristics and uses of trees and shrubs quoted in the price list of the Forest Department. Repub. S. Afr. Bull. 39, 50 p.
(185) Pravdin, L. F.
1963. Selection and seed production of the Siberian stone pine. *In* Fruiting of the Siberian stone pine in east Siberia. A. P. Shimanyuk (ed.). Akad. Nauk SSSR Sibirskoe Otdel Vol. 62, p. 1–20. [Engl. Transl. TT65–50123, CFSTI, U. S. Dep. Commerce.]
(186) ———
1964. Scots pine variation, intraspecific taxonomy and selection. 208 p. Acad. Nauk SSSR [Engl. Transl. TT69–55066, CFSTI, U.S. Dep. Commerce.]
(187) Rafn, J.
1915. The testing of forest seeds during 25 years, 1887–1912. 91 p. Langkjaers Bogtrykkeri, Copenhagen. (Printed for private circulation.)
(188) Read, A. D.
1932. Notes on Arizona pine and Apache pine. J. For. 30: 1013–14.
(189) Read, R.
Personal communication, 1969. USDA Forest Serv., Rocky Mountain Forest and Range Exp. Stn., Lincoln, Nebr.
(190) Rehder, A.
1940. Manual of cultivated trees and shrubs hardy in North America. Second ed., 996 p. The Macmillan Co., New York.
(191) Rietveld, W. J.
Data filed 1969. USDA Forest Serv., Rocky Mountain Forest and Range Exp. Sta., Flagstaff, Ariz.
(192) Robbins, G. T.
Data filed 1945. USDA Forest Serv., Southwest Forest and Range Exp. Stn., Inst., Forest Genet., Placerville, Calif.
(193) Roe, E. I.
Data filed 1939-1941. USDA Forest Serv., North Cent. Forest Exp. Stn., St. Paul, Minn.
(194) Rohmeder, E., and Loebel, M.
1940. Keimversuche mit Zirbelkiefer. Forstwiss. Centralbl. 62: 25–36. (In German.)
(195) Rossi, E.
1929. Sulla germinabilita de seme di *Pinus maritima* in rapporto alla temperatura. Ist. Bot. R. Univ. Pavia Atti., Ser. IV, 1: 107–115. (In Italian.)
(196) Rudolf, P. O.
Data filed 1970. USDA Forest Serv., North Cent. Forest Exp. Stn., St. Paul, Minn.
(197) Rudolph, T. D., Schoenike, R. E., and Schantz-Hansen, T.
1959. Results of one-parent progeny tests relating to the inheritance of open and closed cones in jack pine. Univ. Minnesota For. Note 78, 2 p.
(198) Sargent, C. S.
1905. Manual of the trees of North America. 826 p. Houghton, Mifflin and Co., Boston and New York.
(199) ———
1965. Manual of trees of North America (exclusive of Mexico). Ed. 2, 934 p. Dover Pub., Inc., New York.
(200) Savory, B. M.
1962. The taxonomy of *Pinus khasya* (Royle) and *Pinus insularis* (Endlicher). Empire Forest. Rev. 41 (1): 67–80.
(201) Schmitt, D., and Namkoong, G.
1965. Pine species in the Harrison Experimental Forest Arboretum. USDA Forest Serv. Res. Pap. SO–18, 18 p.

(202) Schubert, G. H.
1952. Germination of various coniferous seeds after cold storage. USDA Forest Serv., Calif. Forest and Range Exp. Stn. Res. Note 83, 7 p.

(203) ———
1955. Effect of ripeness on the viability of sugar, Jeffrey, and ponderosa pine seed. Soc. Am. For. Proc. 55: 67–69.

(204) ———
Data filed 1969. USDA Forest Serv., Rocky Mountain Forest and Range Exp. Stn., Flagstaff, Ariz.

(205) ——— Heidmann, L. J., and Larson, M. M.
1970. Artificial reforestation practices for the southwest. U.S. Dep Agric., Agric. Handb. 370, 25 p.

(206) ——— and Rietveld, W. J.
Data filed 1970. USDA Forest Serv., Rocky Mountain Forest and Range Exp. Stn., Flagstaff, Ariz.

(207) Sen Gupta, J. N.
1936. Seed weights, plant percents, etc., for forest plants in India. Indian Forest Rec. (n. s.) Silvic. 2(5): 175–221.

(208) Shafiq, Y., and Omer, M.
1969. The effect of stratification on germination of *Pinus brutia* seed. Mesopot. Agric. 4: 96–99.

(209) Shaw, G. R.
1914. The genus *Pinus*. Arnold Arbor. Publ. 5, 96 p.

(210) Sherry, S. P.
1947. The potentialities of genetic research in South African forestry. Pretoria, Dep. For., 11 p.

(211) Shoulders, E.
1961. Effect of nurserybed density on loblolly and slash pine seedlings. J. For. 59: 576–579.

(212) Simak, M., Ohba, K., and Suszka, B.
1961. Effect of X-irradiation on seeds of different weight from individual trees of Scots pine (*Pinus sylvestris* L.). Bot. Notiser 114(3): 300–312.

(213) Slayton, S.
Data filed 1969. USDA Forest Serv., J. W. Toumey Nursery, Watersmeet, Mich.

(214) Smouse, P. E.
1970. Population studies in the genus *Pinus* L. PhD thesis, 126 p. N. C. State Univ., Raleigh.

(215) Snow, A. G., Jr.
1960. Silvical characteristics of Virginia pine. USDA Forest Serv., Northeast. Forest Exp. Stn., Stn. Pap. 131, 22 p.

(216) Squillace, A. E.
1966. Geographic variation in slash pine. Forest Sci. Monogr. 10, 56 p.

(217) ——— and Bingham, R. T.
1958. Localized ecotypic variation in western white pine. Forest Sci. 4(1): 20–33.

(218) ——— and Silen, R. R.
1962. Racial variation in ponderosa pine. Forest Sci. Monogr. 2, 27 p.

(219) Steinhoff, R. J.
1964. Taxonomy, nomenclature, and variation within the *Pinus flexilis* complex. PhD thesis. 81 p. Mich. State Univ.

(220) Steven, H. M., and Carlisle, A.
1959. The native pinewoods of Scotland. 368 p. Oliver and Boyd, Edinburgh and London.

(221) Stoeckeler, J. H., and Jones, G. W.
1957. Forest nursery practice in the Lake States. U.S. Dep. Agric., Agric. Handb. 110, 124 p.

(222) ——— and Rudolf, P. O.
1956. Winter coloration and growth of jack pine in the nursery as affected by seed source. Z. Forstgenet. Forstpflanzenzuecht. 5: 161–165.

(223) ——— and Slabaugh, P. E.
1965. Conifer nursery practice in the prairie-plains. U.S. Dep. Agric., Agric. Handb. 279, 93 p.

(224) Straun, W. H.
Correspondence, 1969. N. C. State Forest Serv., Morganton, N. C.

(225) Sudworth, G. B.
1908. Forest trees of the Pacific slope. 441 p. USDA Forest Serv., Wash., D.C.

(226) Swingle, C. F. (compiler).
1939. Seed propagation of trees, shrubs, and forbs for conservation planting. SCS–TP–27, USDA Soil Conserv. Serv., 198 p. Wash., D.C.

(227) Swofford, T. F.
1958. Stratification harmful to some loblolly and slash pine seed. Tree Plant. Notes No. 32, p. 5–6.

(228) Takayama, Y.
1966. [Studies on the seed orchard of Japanese red pine (*Pinus densiflora* Sieb. & Zucc.). I. On the 1000-seed weight of the crops from the grafted clones of Japanese red pine.] J. Jap. For. Soc. 48(5): 199–208. (In Japanese.)

(229) Thompson, N. S.
1968. The response of pine cone scales to changes in moisture content. Holzforschung 22(4): 124–125.

(230) Thulin, I. J., and Faulds, T.
1968. The use of cuttings in the breeding and afforestation of *Pinus radiata*. N. Z. For. 13(1): 66–77.

(231) Ticknor, R. L.
1969. Review of the rooting of pines. Proc. Int. Plant Propag. Soc. 19: 132–137.

(232) Tkachenko, M. E.
1939. [General forestry.] 745 p. Goslestekhizdat, Leningrad. (In Russian.)

(233) Troup, R. S.
1921. The silviculture of Indian trees. Vol. 3, p. 1013–1095. Clarendon Press, Oxford.

(234) Turner, E. E.
Correspondence, 1968. Louisiana State For. Comm., Woodworth, La.

(235) USDA Forest Service.
1948. Woody-plant seed manual. U.S. Dep. Agric. Misc. Publ. 654, 416 p.

(236) ———
Data filed (n.d.). South. Forest Exp. Stn., New Orleans, La.

(237) ———
Data filed 1928–1937. Intermt. Forest and Range Exp. Stn., Moscow, Idaho.

(238) ———
Data filed 1952. North Cent. Forest Exp. Stn., St. Paul, Minn.

(239) ———
Data filed 1957, 1959, 1966–68. Eastern Tree Seed Lab., Macon, Ga.

(240) ———
Data filed 1966–1970. Intermt. Forest and Range Exp. Stn., Moscow, Idaho.

(241) ———
Data filed 1967. Project 2302 for development of blister rust resistant western white pine. Intermt. Forest and Range Exp. Stn., Moscow, Idaho.

(242) ———
Data filed 1969. Bend Nursery, Bend, Oreg.

(243) ———
Data filed 1969. Coeur d'Alene Nursery, Coeur d'Alene, Idaho.

(244) ———
Data filed 1969. Lucky Peak Nursery, Boise, Idaho.

(245) ———
Data filed 1969. Mt. Sopris Tree Nursery, Carbondale, Col.

(246) ———
Data filed 1969. Placerville Nursery, Placerville, Calif.

(247) ———
Data filed 1969. Div. Timber Manage., Region 4, Ogden, Utah.

(247a) Uyeki, Homiki.
1927. The seeds of the genus *Pinus* as an aid to the identification of species. Suigen Agric. For. Coll., Bull. 2, 129 p. (Korea.)

(248) Vandemillen, E.
Data filed 1969. USDA Forest Serv., Eveleth Nursery, Eveleth, Minn.

(249) VanDeusen, J. H.
Data filed 1969. USDA Forest Serv., Rocky Mountain Forest and Range Exp. Stn., Rapid City, S. Dak.

(250) Veracion, V. P.
1964. Correlation of cone size and weight with the numbers, size and weight of seeds of Benguet pine (*Pinus insularis*, Endl.). Philippines Bur. For. Occas. Pap. 16, 11 p.

(251) ———
1966. Correlation of the size of seeds to the germination and early growth of Benguet pine (*Pinus insularis*, Endl.). Philippines Bur. For. Occas. Pap. 26, 7 p.

(252) Vines, R. A.
1960. Trees, shrubs, and woody vines of the Southwest. 1,104 p. Univ. Texas Press, Austin.

(253 Wahlenberg, W. G.
1946. Longleaf pine. 429 p. Charles Lathrop Park For. Found., Wash., D.C.

(254) Wakeley, P. C.
1954. Planting the southern pines. U.S. Dep. Agric., Agric. Monogr. 18, 233 p.

(255) ——— and Barnett, J. P.
1968. Viability of slash and shortleaf pine seed stored for 35 years. J. For. 66: 840–841.

(256) Wappes, L.
1932. Wald und Holz ein Nachschlagebuch für die Praxis der Forstwirte, Holzhändler und Holzindustriellen. Vol. 1, 872 p. J. Neumann, Berlin.

(257) Weidman, R. H.
1939. Evidence of racial influences in a 25-year test of ponderosa pine. J. Agric. Res. 59: 855–888.

(258) Wellner, C. A.
1962. Silvics of western white pine. USDA Forest Serv., Intermt. Forest and Range Exp. Stn. Misc. Publ. 26, 24 p.

(259) Wells, O. O.
1964. Geographic variation in ponderosa pine. 1. The ecotypes and their distribution. Silvae Genet. 13(4): 89–103.

(260) ———
1969. Results of the southwide pine seed source study through 1968–69. Tenth South. Conf. Forest Tree Improv. Proc.: 117–129.

(261) ——— and Wakeley, P. C.
1966. Geographic variation in survival, growth and fusiform-rust infection of planted loblolly pine. Forest Sci. Monogr. 11, 40 p.

(262) ——— and Wakeley, P. C.
1970. Variation in shortleaf pine from several geographic sources. Forest Sci. 16(4): 415–423.

(263) Western Forest Tree Seed Council.
1966. Sampling and service testing western conifer seeds. 36 p.

(264) Wright, J. W.
Correspondence, 1969–1970. Sch. For., Mich. State Univ., East Lansing.

(265) ———
1970. Genetics of eastern white pine. USDA Forest Serv. Res. Pap. WO-9, 16 p.

(266) ———
1962. Genetics of forest tree improvement. FAO For. and Forest Prod. Stud. 16, 399 p.

(267) ——— Lemmien, W. L., and Bright, J.
1963. Geographic variation in eastern white pine—6 year results. Mich. Agric. Exp. Stn. Q. Bull. 45(4): 691–697.

(268) ——— Pauley, S. S., Polk, R. B., Jokela, J. J. and Read, R. A.
1966. Performance of Scotch pine varieties in the North Central Region. Silvae Genet. 15(4): 101–110.

(269) Yanagisawa, T.
1965. Effect of cone maturity on the viability and longevity of coniferous seed. Gov. Forest Exp. Stn., Meguro (Japan) Bull. 172: 45–94.

(270) York, H. H., and Littlefield, E. W.
1942. The naturalization of Scotch pine, northeastern Oneida County. J. For. 40(7): 552–559.

(271) Zarger, T. G.
Correspondence, October 25, 1968. Tenn. Valley Auth., Norris, Tenn.

(272) Zavarin, E., Critchfield, W. B., and Snajberk, K.
1969. Turpentine composition of *Pinus contorta* × *Pinus banksiana* hybrids and hybrid derivatives. Can. J. Bot. 47(9): 1443–1453.

(273) Zobel, B.
1953. Geographic range and intraspecific variation of Coulter pine. Madroño 12: 1–7.

(274) Zobel, D. B.
1969. Factors affecting the distribution of *Pinus pungens*, an Appalachian endemic. Ecol. Monogr. 39(3): 303–333.