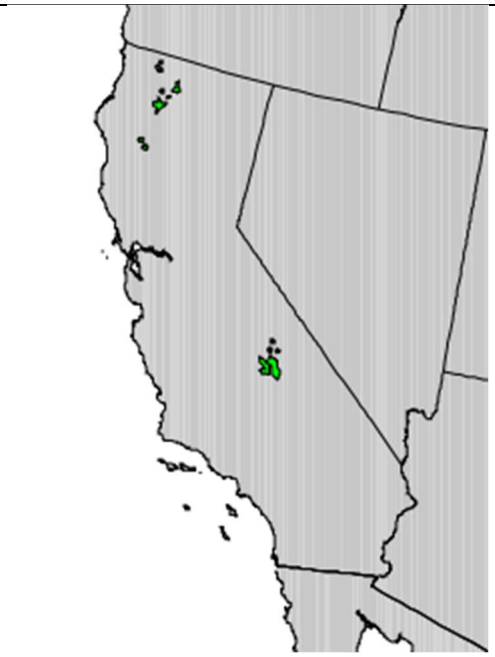
Plant Propagation Protocol for *Pinus balfouriana*
ESRM 412 – Native Plant Production
URL: https://courses.washington.edu/esrm412/protocols/2021/PIBA.pdf

Closed 1st- year and open 2nd-year female cones of southern foxtail pine. USFS photo by Janet Fryer.

A stand of southern Foxtail pine. USFS photo by Janet Fryer.

TAXONOMY	
Plant Family	
Scientific Name	*Pinaceae*
Common Name	Pine Family
Species Scientific Name	
Scientific Name	*Pinus balfouriana* Grev. & Balf.
Varieties	
Sub-species	*Pinus balfouriana* subsp. *balfouriana* (northern foxtail pine) *Pinus balfouriana* subsp. *austrina* R.J. & J.D. Mastrogiuseppe (southern foxtail pine)
Cultivar	
Common Synonym(s)	
Common Name(s)	Foxtail pine
Species Code (as per USDA Plants database)	PIBA

GENERAL INFORMATION	
Geographical range	 Map from Fryer (2018) Foxtail Pine has a restricted range. The northern variety is found in the Klamath Mountains of northern California. The southern variety occurs in parts of the southern Sierra Nevada. The distributions of the two subspecies are separated by about 300 mi (Eckert & Sawyer, 2002). The Oregon State University Herbarium houses a sample of foxtail pine collected in 2006 from two small individuals (6-7 feet tall) found growing in the Klamath Mountains approximately 1 mile north of the California/Oregon border (Callahan). This may be foxtail pine's only documented, natural presence outside of California.
Ecological distribution	High elevation conifer stands (Eckert & Sawyer, 2002).
Climate and elevation range	The northern variety mostly occurs at elevations of 6900-8200 ft. The southern variety occurs between 8,900 and 12,000 ft. (Fryer, 2004) Both subspecies experience similar climate conditions, with wet winters and relatively dry summers punctuated by afternoon thunderstorms (Eckert & Sawyer, 2002).
Local habitat and abundance	Foxtail pine often occurs as the dominant tree species in exposed, high elevation sites with soil types that do not support other conifers. In less harsh sites, it can commonly be found growing among whitebark pine at higher elevations, or red firs and/or western white pine at lower elevations (Eckert & Sawyer, 2002).
Plant strategy type / successional stage	Foxtail pine dominates in soils other trees cannot tolerate. Foxtail pine has traits characteristic of fire adaptation, and its seedlings often colonize burned sites. It also pioneers on serpentine and subalpine sites, but due to its shade intolerance, it is ultimately replaced by other conifers where competition occurs (Fryer, 2004).
Plant characteristics	Pine tree with five needles per fascicle. It usually grows to 20-50 ft, but occasionally more than 72 ft. It is unusual among North American conifers in that it very rarely assumes a Krummholz form (shape distorted by high winds). It has thick bark and short branches. Female cones are 2.4-7.5 inches long, with small prickles and ~0.3 inch seeds with wings approximately three times the length of the seed. Southern and Northern foxtail pine closely resemble each other and Great Basin bristlecone pine, but these can be easily distinguished because their distributions do not overlap (Fryer, 2004). Trees of the southern subspecies can live to around 2000 years. In the northern population, the maximum age is around 800-1000 years because trees succumb to heart rot and fire. (Eckert & Sawyer, 2002)

PROPAGATION DETAILS

Note: Little information is available for foxtail pine propagation. This protocol has been supplemented as indicated with information related to *Pinus longaeva*, the Great Basin bristlecone pine. This species is very closely related to foxtail pine, shows very similar growth and reproductive habits, and readily hybridizes with foxtail pine (Critchfield, 1977).

Ecotype	
Propagation Goal	Plants
Propagation Method	Seed
Product Type	Container (plug)
Stock Type	Depends on how long seedlings are grown before outplanting. See discussion in "Guidelines for Outplanting"
Time to Grow	1-3+ years
Target Specifications	Unknown
Propagule Collection Instructions	Mature cones are collected from trees. Cones do not mature until very shortly before opening, which occurs over an approximately two-week period starting around late September. Cones collected earlier will not yield viable seeds (Critchfield, 1977). Cones are deep purple before ripening and dark or reddish brown when ripe (Bonner & Karrfalt, 2008).
Propagule Processing/Propagule Characteristics	Cones are immediately air-dried in a well-ventilated area for 2-8 days. Unlike some other pine species, opening of cones in a kiln is not recommended or required. (Bonner & Karrfalt, 2008). Seeds are cleaned and de-winged using tumblers, screens, or other typical methods. There are 14,000-22,000 cleaned seeds per pound (Bonner & Karrfalt, 2008). Germination % (after stratification) for seeds stored in air-tight containers at 5-32 F was found to decrease from 86% to 72% after 10 years. (Schubert, 1952)
Pre-Planting Propagule Treatments	90 days cold stratification is recommended. (Krugman & Jenkinson, 1974)
Growing Area Preparation / Annual Practices for Perennial Crops	A well-drained growing medium should be used, mimicking the plants' natural growing conditions (Fryer, 2004). Highest germination % has been observed at 20 C (Mastrogiuseppe & Mastrogiuseppe, 1980). Sowing around May is likely appropriate, as this is the approximate time of snowmelt in foxtail pine's natural habitat.
Establishment Phase Details	In a study of *Pinus longaeva,* seeds planted in a natural habitat the previous fall had peak germination around July, when soil moisture % was still elevated from snowmelt (Smithers & North, 2020). Misting to keep the growing medium moist throughout germination may mimic these natural conditions.
Length of Establishment Phase	In a controlled growing setting, germination of stratified seed appeared to be complete within 10 weeks. (Schubert, 1952)
Active Growth Phase	In a study of *Pinus longaeva* seeds directly sown in a natural habitat, the growing season was defined as May to September. This study monitored three sites over three years. The site and year with the highest percentage of seedlings surviving their first growing season also had the highest soil moisture content. In this site and year, soil moisture content remained between 4 to 8% from July to September, corresponding to the active growth phase. (Smithers & North, 2020). Although moisture also seems to be a primary limiting factor on foxtail pine seedling

	establishment in natural habitats (Lloyd, 1997), this species is adapted to relatively dry summers (Eckert and Sawyer, 2002), suggesting relatively infrequent watering is appropriate.
Length of Active Growth Phase	3 months
Hardening Phase	In natural conditions, *Pinus longaeva* experiences a period of winter dormancy from approximately October to May (Smithers & North, 2020). Foxtail pine trees cultivated outdoors in the mild climate of Placerville, CA did not survive to reproductive age (Critchfield 1977), suggesting the species may require a cold dormancy period. Exposing the seedlings to increasingly cold temperatures in the fall may help induce this state.
Length of Hardening Phase	1-2 months
Harvesting, Storage and Shipping	In their natural environment, the seedlings would be covered by snow for several months during the winter. Winter storage at approximately 0 C may mimic natural conditions. In the *Pinus longaeva* study, seedlings growing in their natural habitat very rarely died during the winter, suggesting cultivated foxtail pine would also be highly resilient during this period.
Length of Storage	Approximately 6 months
Guidelines for Outplanting / Performance on Typical Sites	In a study of *Pinus longaeva* seeds directly sown in a natural habitat in the fall 2014, seedlings surviving until October 2015 appeared to have high survival over the next two years of observation, even though consecutive years had drier and therefore less favorable conditions. This suggests outplanting 1-year-old foxtail pine seedlings in spring could produce acceptable survival percentages. However, in the study, competing vegetation had been thoroughly removed and a mesh was installed to protect from predators (Smithers & North, 2020), which may have enhanced survival. Despite the promising results seen in the *P. longaeva* study, it is important to consider that both *P. longaeva* and foxtail pine are very slow growing, not usually producing secondary leaves (leaves in fascicles) until their 3rd growing seasons, even in controlled growing conditions (Critchfield, 1977). Wild foxtail pine seedlings have been found to grow only 0.2-0.9 inches per year (Fryer, 2004). Very small transplanted seedlings may be very vulnerable to desiccation or other damage, so it may be preferable to grow in a controlled environment for multiple years if possible. In the *P. longaeva* study, approximately 18% of seeds sown in 2014 had germinated and were alive at the end of 2017 in the site with the highest soil moisture content. Drier sites had much lower survival. During the study, no naturally germinating foxtail pine was observed within the study plots even though mature adults were in the vicinity. The experimenters found that seeds buried 5 cm deep in the soil had very high germination rates compared to seeds left on the surface, where they naturally fall. Animals were excluded from the study plots (Smithers & North, 2020), but foxtail pine's usual single-stem habit suggests it does not typically grow from animal caches. (Fryer, 2004) Together, this suggests that simply burying seeds

	at the outplanting site will result in much higher regeneration than would naturally occur within a wild population. A study analyzing naturally occurring foxtail pine populations found that seedling establishment was associated with higher winter snow and lower summer temperature, which the author attributed to decreased water stress in seedlings (Lloyd 1997). These two studies suggest it could be effective and more economical to directly seed foxtail pine at the outplanting site if steps can be taken to protect seedlings from desiccation while maintaining high sun exposure.
Other Comments	
INFORMATION SOURCES	
References	Bonner, Franklin T.; Karrfalt, Robert P., eds. 2008. The Woody Plant Seed Manual. Agric. Handbook No. 727. Washington, DC. U.S. Department of Agriculture, Forest Service. Callahan, F. s.n. (OSC 217775). Specimen at Oregon State University, Corvallis, Oregon. https://oregonflora.org/dbimages/OFPimages/OFPImages_big/1523/OSC217775.jpg Critchfield, William B. 1977. Hybridization of foxtail and bristlecone pines. Madrono. 24(4): 193-244. [713] Eckert, Andrew J.; Sawyer, John O. 2002. Foxtail pine importance and conifer diversity in the Klamath Mountains and southern Sierra Nevada, California. Madrono. 49(1) Fryer, Janet L., comp. 2018. Tree species distribution maps from Little's "Atlas of United States trees" series. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: https://www.fs.fed.us/database/feis/pdfs/Little/aa_SupportingFiles/LittleMaps.html [92602]. Fryer, Janet L. 2004. Pinus balfouriana. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: www.fs.fed.us/database/feis/plants/tree/pinbal/all.html [2021, May 25]. Krugman, Stanley L., and James L. Jenkinson. 1974. Pinus L. pine. In Seeds of woody plants in the United States. C. S. Schopmeyer, tech. coord. p. 598-638. U.S. Department of Agriculture, Agriculture Handbook 450. Washington, DC

	Lloyd, Andrea H. 1997. Response of tree-line populations of foxtail pine (Pinus balfouriana) to climate variation over the last 1000 years. Canadian Journal of Forest Research. 27(6): 936-942. [47903] Mastrogiuseppe, R. J., and J. D. Mastrogiuseppe. "A Study of Pinus Balfouriana Grev. & Balf. (Pinaceae)." Systematic Botany, vol. 5, no. 1, 1980, pp. 86–104. JSTOR, www.jstor.org/stable/2418738. Accessed 25 May 2021. Schubert, G. H., United States., & California Forest and Range Experiment Station. (1952). Germination of various coniferous seeds after cold storage. Berkeley, Calif: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station. Smithers, B.V., North, M.P. Mechanisms of species range shift: germination and early survival of Great Basin bristlecone pine and limber pine. *Plant Soil* **457,** 167–183 (2020). https://doi.org/10.1007/s11104-020-04732-9
Other Sources Consulted	Barbour, Michael G.; Major, Jack, eds. 1977. Terrestrial vegetation of California. New York: John Wiley & Sons. Baskin, Jerry M.; Baskin, Carol C.. 2002. Propagation protocol for production of Container (plug) *Pinus aristata* Engelmann plants University of Kentucky Lexington, Kentucky. In: Native Plant Network. URL: http://NativePlantNetwork.org (accessed 2021/05/25). US Department of Agriculture, Forest Service, National Center for Reforestation, Nurseries, and Genetic Resources.
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