Ponderosa Pine Seed Collection on the Colorado Front Range

A Field Guide

As the Colorado Front Range ramps up efforts to reforest burn scars, there is an increasing demand for native conifer seedlings. To meet this demand, nurseries purchase seeds from private seed collection companies when available, but supply is limited, and land managers increasingly rely on direct collection to ensure the use of climatically-appropriate seed stock.

This field guide summarizes the ponderosa pine reproductive cycle and is an illustrated field guide to cone crop forecasting, collection planning, collection methods, and cone handling. A separate document (Schloegel and Chambers, 2023) summarizes frequently asked questions about the ecology of ponderosa pine seed production on the Colorado Front Range. For those engaged in seed collection, we include references to in-depth resources at the end of this document (Portlock, 1996; Bonner et al., 2008; Kolotelo, 1997). Additionally, a Supplemental Information document can be found with all figures, tables, and cone identification tags for simple use in the field.

The reproductive cycle

An understanding of the chain of events, from flowering to cone ripening and eventual seed dispersal, is critical to successful seed collection. Ponderosa pine (*Pinus ponderosa*

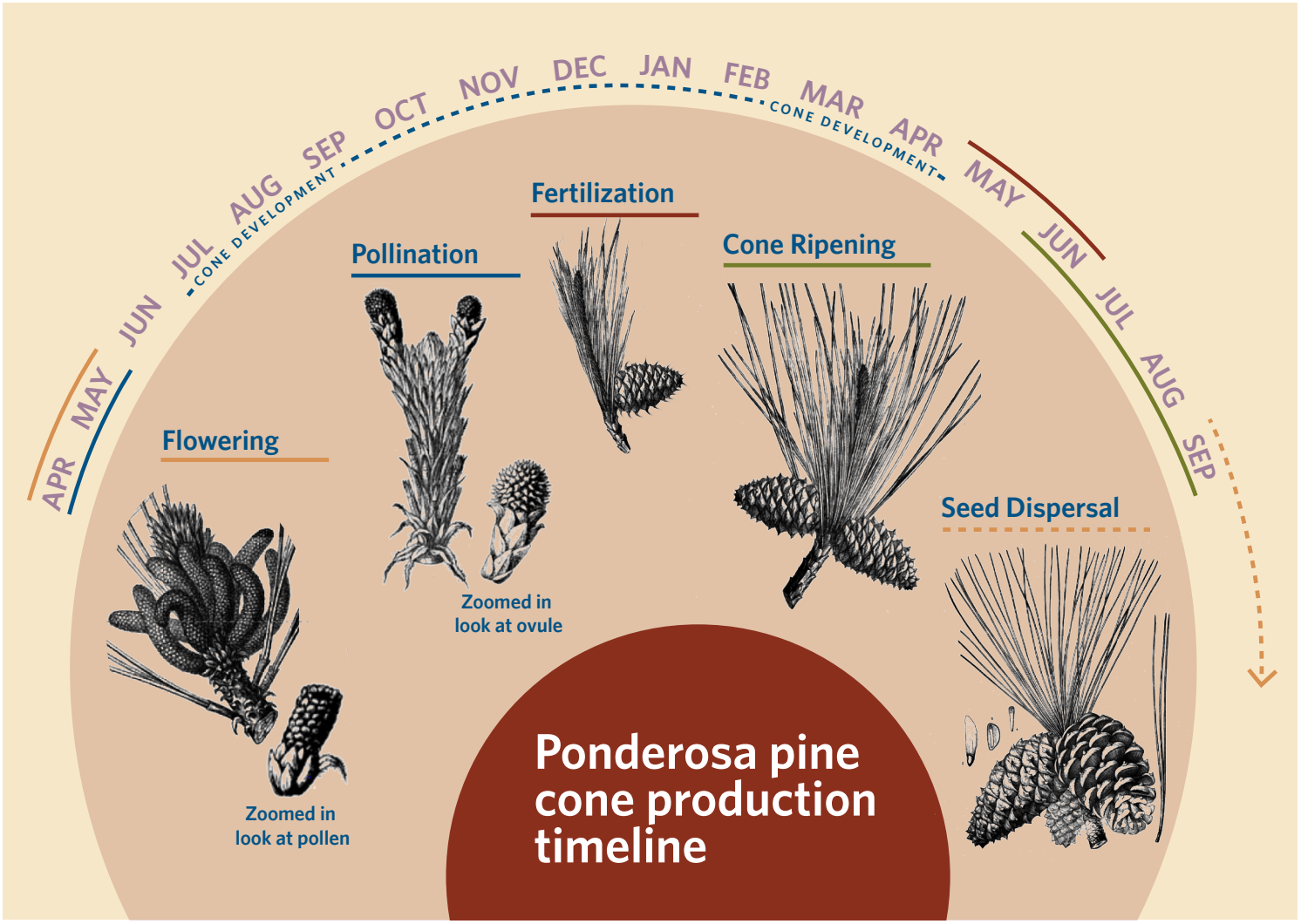

Figure 1. A timeline of ponderosa pine cone development from pollination to seed maturity. Portions of this figure are adapted from Sargent (1898). Source: A. Martinovich/The Nature Conservancy.

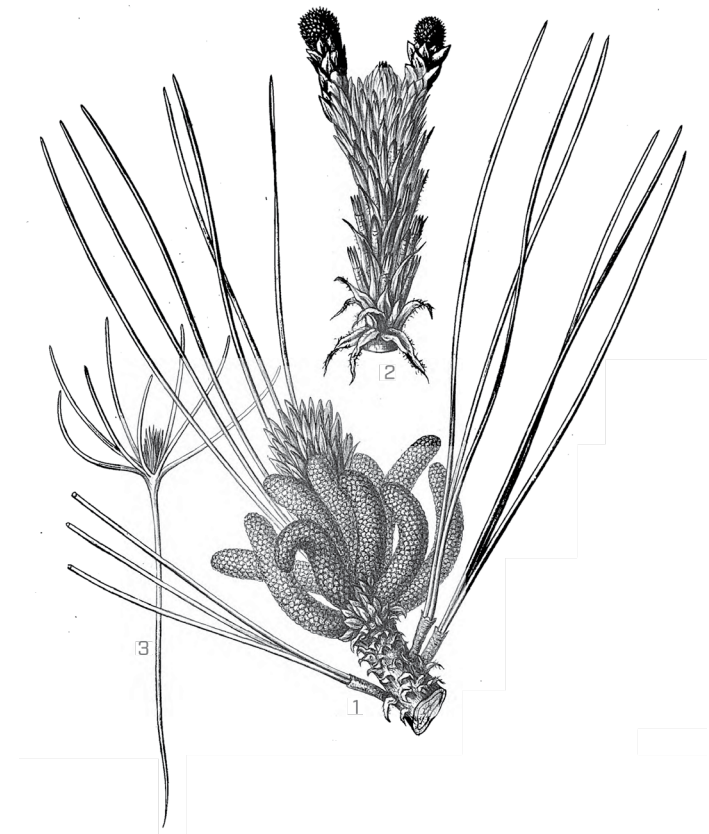

Figure 2. A drawing to scale of a male pollen sacs and a female ovule cone: 1) branch tip with male pollen sacs, 2) branch tip with female cones, and 3) a seedling plant (Sargent, 1898).

var. scopulorum) requires 16-17 months for seeds to become fully mature within a cone (Fig. 1). If cones are collected too early, seed development is interrupted and the resulting seedlots will have poor germination rates.

A ponderosa pine tree can begin flowering at 20 years of age or younger, but most trees do not produce significant seed crops until 60 years of age (Bonner et al., 2008). Because both pollen and seed cones occur on the same trees, younger trees may direct greater resources to producing less-energy intensive pollen cones, while older trees produce proportionally more seed cones.

Pollination and Fertilization

Pollination is the successful union of male pollen grains with female ovules (Fig. 2 & 3). Pine pollen is wind dispersed from May through June of the first year. Open stand structures and weather conditions, especially dry winds, can be advantageous for dispersal, while wet or humid conditions often impede it.

Fertilization occurs when pollen fertilizes the ovule. Fertilization of the female cones is not immediate but occurs in year two when a pollen tube grows and enters the ovule. Ovule cones ("conelets") remain small in the interval between pollination and fertilization.

Cone ripening

Once fertilization occurs between April and May of the second year, seed development occurs quickly, and the cone rapidly enlarges.

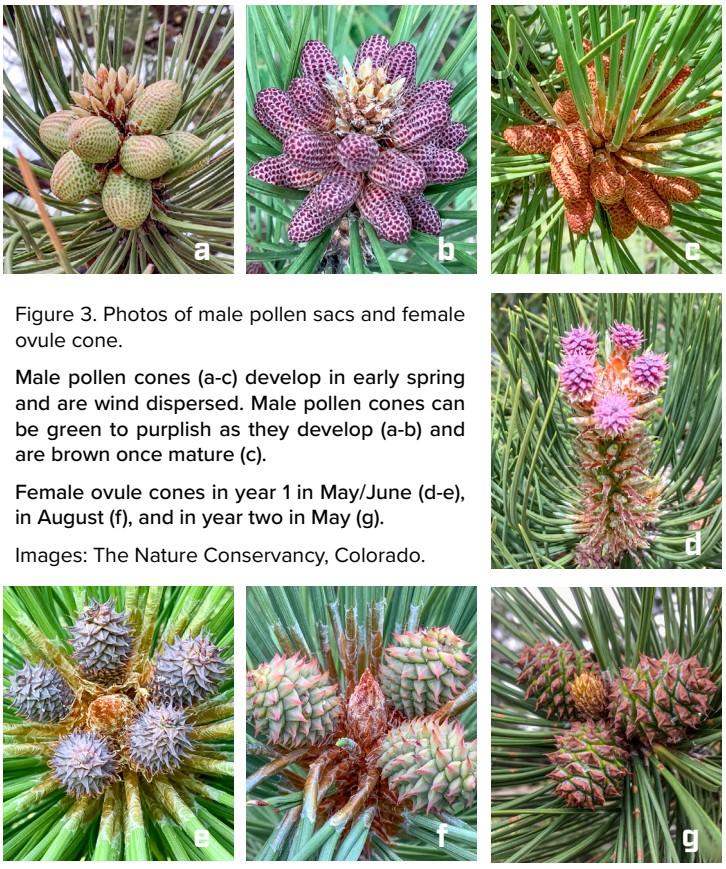

Figure 3. Photos of male pollen sacs and female ovule cone.

Male pollen cones (a-c) develop in early spring and are wind dispersed. Male pollen cones can be green to purplish as they develop (a-b) and are brown once mature (c).

Female ovule cones in year 1 in May/June (d-e), in August (f), and in year two in May (g).

Images: The Nature Conservancy, Colorado.

Cone collection

Cones should be collected when seeds reach full maturity, but before cones open (Fig. 1). Timing for collection is critical, as the seeds of ponderosa pine are quickly dispersed once mature.

Seeds can be collected from the wild, called a "woods run collection," or from established seed orchards. In Colorado, most cones are collected from the wild because there are very few maintained seed orchards, and none for ponderosa pine to our knowledge.

When stored properly, seeds can remain viable for 20 years or longer (Bonner et al., 2008).

Cone collection strategy

Land management agencies or other interested parties might create a seed needs assessment to inform collection efforts. A needs assessment aligns seed supply needs with on-the-ground cone crop production and collection operations. It includes information such as the quantity of seed needed by species, per geography and by elevational gradient, to meet current and projected reforestation needs. Long-term projections of seed needs may influence annual decision-making, potentially driving collections even during light years when scarce seeds of certain sources might still be of high priority, or minimally during a heavy production year from sites with abundant stock when those seed sources are low priorities or are already well-represented in one's seed inventory.

Crop Forecasting: evaluating cones and seeds to predict crop location, quality, and quantity

The goal of crop forecasting is to identify sites with a good developing cone crop that may be suitable for collection. The initial scouting trip aids in the establishment of a collection plan that would include notes on budget and contracting needs.

Cone Scouting

The initial scouting trip(s) serve to identify potential collection sites by evaluating the extent and size of the developing cone crop. Either during this initial visit, or on a second trip, scouts will also evaluate the degree of fertilization and phase of seed development. Scouting is best timed for late June and July when developing cones are rapidly enlarging and easy to spot but while there is also still plenty of time for making collection plans and logistical arrangements before cones ripen.

A collection site should contain 100-150 cone-bearing trees, although collection will likely occur at a minimum of 20 trees. An adequate number of trees for collection ensures maximum genetic diversity within the collection. Cones should be collected from parent trees with desirable characteristics likely to impart survival advantages to seedlings, such as the absence of disease and insect infestations, absence of mistletoe, evidence of drought tolerance, or climate adaptability. If land management objectives include the possibility of active timber management, secondary criteria such as parent tree form, branch angle, and other characteristics traditionally considered desirable for commercial forestry could be considered, but such criteria should be secondary to the characteristics mentioned above which would translate more directly to seedling survival and performance on harsh reforestation sites subject to changing climates. We recommend collecting from a minimum of 20 parent trees with a minimum 200-foot distance between them.

Figure 4. In a mast year (heavy), ponderosa pines will have 5-7 cones on each lateral bud (a and b), while in a non-mast year it will have 1-3 cones (c). Images: The Nature Conservancy, Colorado.

The size of a cone crop varies annually, and with practice it can be characterized as light, average, or heavy. Heavy crops occur during mast years (Fig. 4).

In a mast year (heavy), a ponderosa pine may have as many as 5-7 cones per whorl. Cone cuts have 7-10 seeds per face, all seeds are fertilized (or "full"), and cones show little or no insect infestation.

During non-mast years (light or average), trees typically have 1-3 cones per whorl. Cone cuts may have many empty or unfertilized seeds and high levels of insect infestation.

Macrosite characteristics of areas with cone crops

Open-grown trees may experience better pollen mixing, suggesting that trees occurring in low density ponderosa pine savannas or management units that have been thinned within the last ~5 year (or slightly more) are more likely to have cones than those growing in dense stands. Similarly, higher levels of cone production are typically observed on stand edges relative to stand interiors.

Time needed

Cone production is highly localized and can occur in a single sub watershed. Generally, the first scouting trip may occur over 3-5 field days depending on the size of your agency's land holdings. With appropriate training and planning, scouting may also be combined with other routine field operations where feasible to minimize additional travel and personnel costs.

Tools to evaluate cones

To scout cones, bring binoculars, a camera, written or digital surveys to record field data, and tools for harvesting and cutting cones. Digital apps, such as ESRI's Survey 123 (survey and geomarker) or Avenza (geomarker only) can aid in the collection of location and crop data. Tools for cone harvesting should include climbing equipment and/or a pole pruner (with an extendable pole), hand pruners, cone cutter, and thick gloves. It is essential to bring a 10x hand lens (loupe) to evaluate the development of the seed embryo. Finally, a degreaser such as olive oil or citrus oil cleaner will be helpful to remove sap from hands and tools.

Cone scouting tools checklist

- ✔ Binoculars
- ✔ Camera
- ✔ Written or digital surveys materials
- ✔ Pole pruner (with extendable pole) or climbing equipment
- ✔ Hand pruners
- ✔ Cone cutter
- ✔ Thick gloves
- ✔ 10x hand lens (loupe)

Harvest cones for a cut test

Harvest ~5 cones from 5-10 trees to evaluate fertilization and seed development. Aim to harvest cones from the mid- to upper-canopy if possible, using an extendable pole or climbing to reach higher branches. There are often significant differences in fertilization and insect predation between cones in the top of the tree, versus the bottom.

Data collection for cone scouting

- Location and Date
- Species
- Size of cone crop (light, average, heavy)
- Close-up photo
- Site features that influence collection (access, slope, property ownership)
- Property ownership or name
- Number of trees with cones

A cone cutter

Use a cut test to safely cut open the cone to visually discern viable and/or degraded seed, as well as any potential insect damage.

A DIY cone cutter allows one to safely cut cones. The Canadian Forest Services has several models (Portlock, 1996), but any butcher block and clean cutting knife can be used to cut the cone by attaching a hinge at the tip of the blade. (Fig. 5)

The cut test

A field cut test allows collectors to characterize the crop by estimating the proportion of viable seed in each cone and the degree of maturity and insect damage.

On the cone face, make sure that the seed is cut lengthwise to assess the degree of maturity by looking at the internal structures of the seed. All fertilized seeds have an embryo that is surrounded by a food reserve, the megagametophyte, and encased in a protective seed coat (Fig. 6). Collectors can use a 10x hand lens to look at these structures. As seeds mature, the embryo expands and occupies a greater

Figure 5. An example cone cutter. Image: The Nature Conservancy, Colorado.

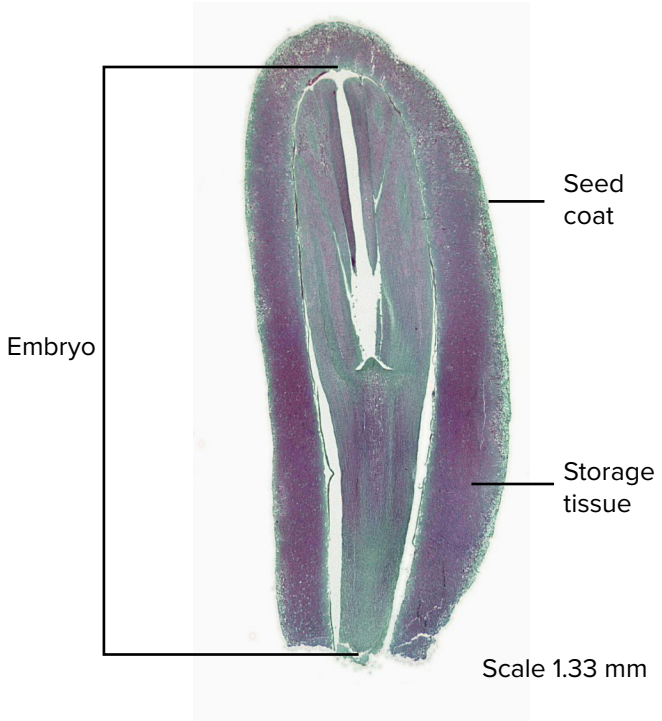

Figure 6. The seed has an embryo surrounded by tissue, the megagametophyte, which are encased inside a protective seed coat. Above, a mature pine seed with the embryo filling 90% of the cavity. Image: Jon Houseman and Matthew Ford via Wikimedia Commons (CC BY-SA https://creativecommons.org/licenses/by-sa/4.0/deed.en)

percentage of the cavity. A mature seed has a fully developed embryo, which fills at least 90% of the cavity.

Not all seeds are viable. Collectors can visually discern viable versus degraded seeds, using the proportion between the two to create an estimate of the viability of the seedlot. Degraded seeds are either "empty" because there was no fertilization or "dead-filled" which indicates that the seeds have deteriorated. Empty seeds are common and reflect insufficient pollination. Dead-filled seeds are usually dark in color, rotten looking, and can be more easily discerned visually.

$$\textbf{Estimated viability of seed crop (\%)} = \frac{[(\text{Total seeds per cut face}) - (\text{Dead or degraded seeds per cut face})]}{(\text{Total seeds per cut face}) \times 100}$$

Some collectors evaluate seed maturity using a specific gravity test. As cones mature, they lose water, and their specific gravity decreases. It is possible to conduct a ripeness test using a portable balance, graduated cylinder, and water to directly determine the density of cones in the field and compare those densities to the specific gravity thresholds specified by Bonner et al. (2008). Kerosene is frequently used to evaluate cone maturity; however, because this test uses a potential pollutant, this method is not described here.

Things to avoid: non-native or ornamental "look-alike" pines

Be wary of non-native pines and avoid collecting from locations where they could be present or where you are

unable to make a positive identification. Ornamental pines, including Norway pines, are planted in homeowner associations (HOAs), alongside access roads to ditches, dams, or other water infrastructure, near to cabins and homes, or anywhere that site remediation is required.

Cone and seed quality

For those interested in large-scale collection, we recommend collecting when a minimum of 7-10 seeds per cut face are filled, or the cone is 75% fertilized. Each seed collector's criteria for what constitutes a collectible crop might differ due to how much seed is needed, collection resources available, cost of collection resources, and other factors.

Collection Planning

Obtain permission

If you collect on third-party land, first secure the appropriate collection permission. Each land management agency has a unique permitting system, which may include a fee.

Develop a collection plan

A collection plan will define the specific area for collection including access, suggested collection methods (there may be more than one), number of pickers required and where to find them, volume of cones needed from this site, interim cone storage site, plans for processing the cones (e.g., drying, extraction, cleaning, testing, preparation for storage and packaging, etc.), seed storage location(s), and expected budget to collect, process and store seeds.

For most widespread conifers, managers have historically negotiated collection contracts as a price per bushel of cones harvested. Reports from the southwestern USA suggest that this model may underestimate costs and be prone to market failures, especially in years with low cone yields. For this reason, many collectors in the southwestern USA prefer to operate on day rate contracts, where the collector is guaranteed a fixed fee per day of collection along with coverage of incidental costs.

For ponderosa pine, a bushel is the equivalent of just under 2 buckets (5-gallon size) or approximately 40-50 cones, which typically yield ~1 lb. of seed or ~10,000/seeds. Please note that the number of cones in a bushel can vary by area and year, with seed yields depending on rate of fertilization.

Developing a collection plan

- ✔ Define collection area
- ✔ Obtain access permission
- ✔ Determine collection methods
- ✔ Number of cone collectors needed
- ✔ Volume of cones needed
- ✔ Interim storage sites
- ✔ Plan to process cones
- ✔ Seed storage location
- ✔ Expected budget for collection, processing, and storage of seeds

Monitor seed development

The goal is to collect closed cones with fully mature seeds and making field observations of seed development throughout the second year of cone development is critical to planning collection dates (Table 1). On the Colorado Front Range, collection timing is typically late August through September, but timing varies by year and by elevation. Generally, cones ripen first at lower elevations and southern and western aspects, and later at higher elevations and northern and eastern aspects.

Physical characteristics of a ripening ponderosa pine cone with mature seed	
Cone	Green to brownish-yellow, russet brown to purplish brown
Scales/bracts	Slight flexing at scale
Seed wing	Detaches from scale, light brown
Seedcoat	Tan
Embryo	White to yellow, nearly fills 90% of cavity endosperm

Table 1. Common physical attributes of ponderosa pine cones and parts indicating that cone is ready to be harvested.

By August (at the latest), initiate monitoring of seed development in selected stands beginning every two weeks but increasing the frequency as the collection period approaches. Hot days, dry winds, or cold periods can speed up maturation. As one gains experience with field identification of mature seed (Fig. 7 & 8), efforts to minimize the number of monitoring visits can save money. As the period for cone maturity approaches, we recommend monitoring once weekly. If you observe cones starting to open on the top of a tree, it is time to collect.

Avoid cones with insect damage

Avoid collecting cones with visible insect damage (Fig. 9), including curved cones which indicate damage. During non-mast years, seed predation from insects can vary between 50-90% of the crop. Insect damage can often be seen in early August, when a good crop suddenly changes color (cones stop growing and desiccate) or shows visible external signs

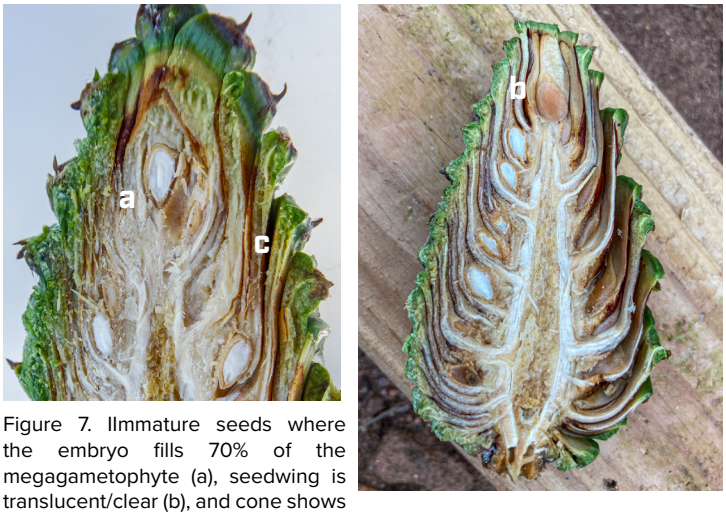

Figure 7. Immature seeds where the embryo fills 70% of the megagametophyte (a), seedwing is translucent/clear (b), and cone shows slight flexing at scale margins (c). Images: The Nature Conservancy, Colorado.

Figure 8. Cone cut showing mature seed with embryo filling 90% of cavity (a) and dark seedwing and seed coat (b). Image: The Nature Conservancy, Colorado.

of cone damage such as exit holes, frass, excess sap on the cone exterior, a change in color, or mold or spores.

Collection methods

There are several methods to collect cones with varying costs. It is likely that you may use one or more techniques at a given site.

Bucket trucks: Bucket trucks are commonly used for collection in seed orchards and along roadways and rights-of-way with flat, hard ground.

Climbing: Climbing is often the best choice for tall pines and for collections in old growth or mature stands. Climbing requires specialized skills, experience, and equipment that are beyond the scope of this publication. Additionally, policies, standards, and practices for safe tree climbing vary by employer, sector, and jurisdiction, although the most widely accepted standards are contained within the USDA Forest Service's National Tree Climbing Guide (USDA 2015) and ANSI Z133 published by the American National Standards Institute (ANSI 2006). Any personnel who may need to climb during seed collection duties should receive appropriate instruction from a qualified instructor before working in accordance with the standards and policies applicable to their employer and/or in force in the jurisdiction within which they operate. These standards may also be referenced in seed collection contracts for tree climbing collection services to clearly reference and communicate expectations regarding safe climbing practices.

Figure 9. Examples of insect damage to cones and seeds. Images: The Nature Conservancy, Colorado.

Felling: Trees in cutting units may be felled, especially if by felling they accomplish a dual goal to reduce or mitigate wildfire risk. Felling should only be used in select circumstances since it removes the mother tree from the pool of future cone production and reduces the genetic diversity of the stand. Coordinating cone collection with wildfire mitigation activities is one of the most commonly used methods to obtain seeds.

Rifle or shotgun harvesting: Highly trained individuals operating in sufficiently rural areas may use high-powered rifles or shotguns to shoot cones out of trees. In the Southwest, we found that a 28-inch barrel shotgun with a turkey choke firing #4 shot was safer and more cost-effective than a rifle. Given the skill and equipment needed, this is mostly used for tree improvement collections or to harvest small numbers of cones for monitoring purposes.

Squirrel caches: In the past, collectors raided squirrel caches as a source of cones, but today this is less common because cones can become infected with fungi in the cache and the parent trees of cones collected from a cache are unknown, thereby making the genetics of the seedlot unknown. In addition, concerns exist around the removal of the squirrels' food supply.

Safety is a pre-requisite for cone collection. Collection should be done by trained collectors with appropriate experience, safety equipment, insurance, and in accordance with applicable laws, policies, and standards for the area in which the collection is occurring.

To locate cone collectors in your area, the directory of the Reforestation, Nurseries and Genetic Resources (RNGR) may be useful: https://rngr.net/marketplace/directory. During years with widespread masting, it is unlikely that contract collectors will be available due to demand, so we recommend developing a list of local forestry contractors and climbers for cone picking, as well as volunteers including service clubs, students, and interested non-profits for cone sorting and storage.

Cone collection equipment

For collection, we include a general list of equipment you will need. In addition, you will need to assure that contractors or staff have specialized equipment for the selected collection method. For more information about specific equipment for each collection technique, see Portlock (1996).

Cone handling

- Remove all needles, branches, and other debris from cones before placing them in a burlap sack.
- Fill clean burlap sack ½ to 2/3 full, leaving ample headspace in the bag so that cones can expand as they dry. Clean burlap or other sacks, approximately 25 x 40 inches in size, should allow for proper air flow.
- Create two paper labels per sack (Fig. 10). Place one label inside the sack. Adhere the second label to the string or zip tie used to tie shut the sack. Use string, a wire-tie tag, or zip ties to firmly close the sack.
- Tie sacks near the mouth and leave extra space in the sack for cone movement and expansion as cones dry.

Cone Identification Tag

Species: _____

Seed zone: _____

Elevation: _____

Location: _____

Date Collected: _____

Cone Collector and organization:

_____

_____

Figure 10. A sample tag to tie to bags of collected cones might include the following information. A printable sheet of this tag is available in the Supplemental Information document.

- At the end of the day, record the date and location of the collection site (site name and coordinates), species, collection techniques, collectors, and number of bushels collected on a collection record (Fig. 11). Consider using an app, such as ESRI's Survey123 to record these data and georeference the collection point. Otherwise, use a paper survey.

Cone handling labels

Close tracking of the seed source is important for future outplanting efforts. The seed source affects plant performance, including growth rate, cold, heat and drought tolerance, and ultimately survival. Seed origin is important because trees are locally adapted to the characteristics of the environment in which they are growing. However, a long-term underlying warming trend will require updated transfer guidelines and decisions to match seedlings grown from particular seed sources to the climatic conditions that the trees will face over coming decades.

Cone collection equipment

- ✔ Binoculars
- ✔ Buckets (5-gallon size)
- ✔ Camera
- ✔ Cone collection forms (tags)
- ✔ Collection sacks, tags, ties
- ✔ Cone cutter
- ✔ Degreaser such as olive oil or Gojo/citrus cleaner
- ✔ Gloves (used or old as they will get sappy)
- ✔ GPS unit
- ✔ Hand clippers
- ✔ Pens, pencils
- ✔ Safety equipment: hard hat, high vis vest, first aid, sunscreen
- ✔ Tarp

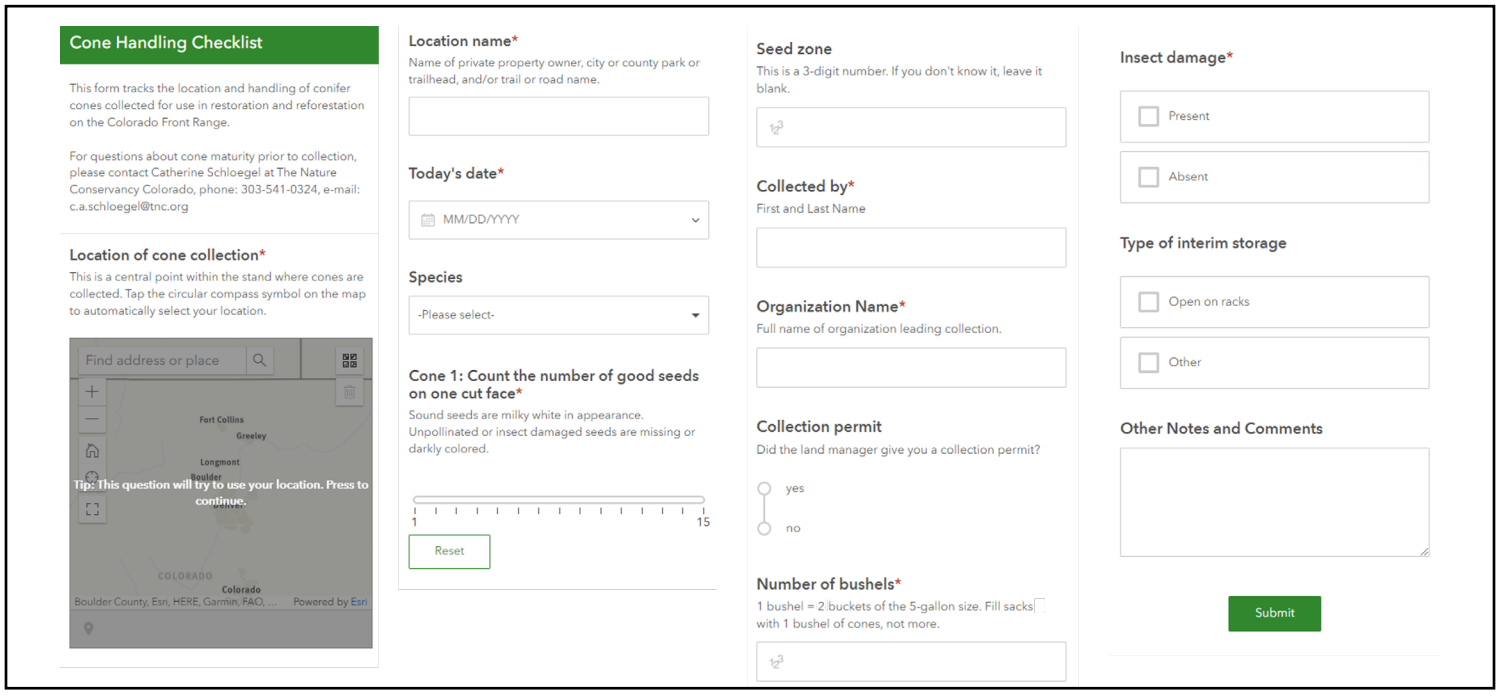

Figure 11. An example Survey 123 checklist to record the collection location, species, and other site-specific factors. A paper survey or other digital may also be used. Image: The Nature Conservancy, Colorado.

Interim storage at the field site and offsite prior to transport

Freshly harvested cones are moist, and cones will dry and open once picked. During the day of collection, sacks can be stored onsite and out of direct sunlight.

At the end of day of collection, cones should be moved to an offsite interim storage location, where they may be stored for up to a month until all collections are completed. The interim storage set-up should be off the ground, on racks, and in a shady area with good air circulation. Interim storage could utilize a carport, barn, open shed, shaded sort yard, or a warehouse with a fan. Temporary storage racks can be as simple as pallets or as complex as professional scaffolding. While in interim storage, turn cone bags every 1-2 days for the first two weeks, and then at least once weekly. Cold storage, such as in refrigerated trucks, is not necessary on the Colorado Front Range. Animal damage and seed predation by squirrels and rodents can be a problem during interim storage and cone drying, so efforts should be made to exclude small mammals from storage and drying areas. See Portlock (1996) for additional ideas.

Cone transport and seed extraction, processing, and storage

Transport to extraction plant

Avoid heat exposure during transport to the seed extractory. Cones can be transported in a trailer truck or other enclosed truck, using pallets to separate the cones and maintain air flow. For cones that have been in interim storage for several weeks and are mostly dry, it is unlikely to need a refrigerated truck for transport, especially given the cost.

Seed extraction, processing, and storage

Seed extraction is the removal of seeds from the cone, followed by the removal of the wings from the seed. The Reforestation, Nurseries, and Genetic Resources (RNGR) Marketplace and Directory can be used to identify seed cleaners, also known as extractors.

Seed storage is best done by professionals who have equipment to keep the seed at the proper temperature and moisture concentration for long-term storage. This may include nurseries or seed banks.

As seeds are placed in storage, a sample of seeds per lot should be sent for germination testing. The National Seed Laboratory (https://www.fs.usda.gov/science-technology/nsl/seed-testing) offers germination, purity, seed weight, moisture content, and x-ray analysis of internal seed structures and has extensive experience with conifers.

Key resources for further information

American National Standards Institute (ANSI), 2006. American national standard for arboricultural operations — Safety requirements (Z133.1 — 2006) International Society of Arboriculture, Champaign, IL. https://hiepro.ehawaii.gov/resources/101379/Attach%20III%20Safety%20Reqmnts%20CSD22005HCC.pdf

Bonner F.T., Karrfalt R.P., editors. 2008. The woody plant seed manual, Agriculture Handbook 727. Washington, DC, USA: U.S. Department of Agriculture, Forest Service. Retrieved from: https://www.fs.usda.gov/rm/pubs_series/wo/wo_ah727.pdf

Kolotelo, D. 1997. Anatomy and Morphology of Conifer Tree Seed. British Columbia Ministry of Forests, Nursery and Seed Operations Branch, British Columbia. Retrieved from: https://rngr.net/publications/anatomy-and-morphology-of-conifer-tree-seed

Portlock, F.T. 1996. A Field Guide to Collecting Cones of British Columbia conifers. British Columbia Tree Seed Dealers' Association and British Columbia Ministry of Forests. Retrieved from: http://www.yellowpointpropagation.com/uploads/4/4/1/8/4418310/cones.pdf

Reforestation, Nurseries and Genetic Resources website is a leading source of technical information for nurseries and land managers regarding production and planting of trees and other native plants for reforestation, restoration, and conservation. Rngr.net is a collaborative effort between the USDA Forest Service and Southern Regional Extension Forestry. https://rngr.net/

Sargent, C.S. 1898. The Silva of North America: A Description of the Trees which grow naturally in North America exclusive of Mexico. Houghton, Mifflin and Company and the Riverside Press, Boston and New York.

United States Department of Agriculture (USDA). 2015. National Tree Climbing Guide. Retrieved from: https://www.fs.usda.gov/treeclimbing/media/NationalTreeClimbingGuide2015April.pdf

Front Range specific resources

Bodenham, J., and R.E. Stevens. 1981. Insects Associated with Second-Year Ponderosa Pine Cones, Larimer and Boulder Counties, Colorado. The Southwestern Naturalist 26:375–378. Retrieved from: https://www.jstor.org/stable/3671079

Schloegel, C.A. and M.E. Chambers. 2023. Ponderosa Pine Cone and Seed Collection: Frequently Asked Questions and Answers for the Colorado Front Range. Colorado Forest Restoration Institute. CFRI-2308. Retrieved from: https://cfri.colostate.edu/wp-content/uploads/sites/22/2023/07/PonderosaPineConeSeedCollectionQA_Schloegel_Chambers_CFRI2308.pdf

Authors: Schloegel, Catherine A.[1], Chambers, Marin E.[2], Sloan, Joshua L.[3]

1. The Nature Conservancy, Colorado. 2. Colorado Forest Restoration Institute, Colorado State University, 3. New Mexico Highlands University, New Mexicao Reforestation Center

This work was supported by the Center for Disaster Philanthropy and the Southwest Forest Health and Wildfire Prevention Act.

Citation: Schloegel, C.A., Chambers, M.E., Sloan, J.L. Ponderosa Pine Seed Collection on the Colorado Front Range - A Field Guide. CFRI-2409.

July 2024 • CFRI-2409