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MANUAL TRANSMITTAL SHEET

Release	5-171
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Subject: MS-5712 Tree Seed Manual

FOIA Designation Letter: P

1. Updates, supersedes, or rescinds:

MS-5712 Rel. 5-20

2. Explanation of Materials Transmitted:

This manual update includes new science in the field of seed source selection and climate adaptation. The manual also expands on numerous processes in the tree seed supply chain designed to provide BLM field users guidance on acquiring a tree seed inventory. New policy for maintaining and reviewing annually a tree seed inventory at each state office will ensure that field offices have adequate seed that is genetically appropriate to restore forests and woodlands after severe disturbances.

3. Reports Required:

None

4. Delegations of Authority Updated:

New responsibility is delegated to the state directors to maintain a tree seed inventory and review a record of the inventory annually.

5. Filing Instructions: File as directed below.

REMOVE	INSERT
All of MS-5712 (Rel. 5-20) (Total: 9 Pages)	All of MS-5712 (Rel. 5-171) (Total: 39 Pages)

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1. Overview

1.1. Purpose

The purpose of this manual is to provide policy and guidance for the sourcing of tree seed and the maintenance of a tree seed inventory that is adequate to meet the Bureau of Land Management (BLM) reforestation needs and respond to disturbances that impact forest ecosystems.

1.2. Objectives

A. Ensure that an adequate, reliable, and continuous supply of seed is available to meet current and future reforestation needs created by natural and anthropogenic disturbances.

B. Ensure that seed sourcing and seed inventory contain the genetic diversity represented in BLM managed forests.

C. Improve program efficiency and effectiveness in tree seed sourcing, collection, handling, and storage needed to conduct successful reforestation across the spectrum of climatic and site conditions.

D. Establish a seed inventory database and policies to maintain the inventory.

1.3. Authority

A. Federal Land Policy and Management Act of 1976 (43 U.S.C. 1701 et seq.).

B. Omnibus Public Land Management Act of 2004 (Public Law 108-447) Sec 118. (43 USC 1474e) Notwithstanding 31 U.S.C. 3302(b), states that "sums received by the Bureau of Land Management for the sale of seeds or seedlings, may hereafter be credited to the appropriation from which funds were expended to acquire or grow the seeds or seedlings and are available without fiscal year limitation".

1.4. Responsibility

A. The Director sets national policy for forest management.

B. Assistant Director, Resources and Planning develops policy and procedures for maintaining adequate seed for BLM reforestation.

C. State Directors maintain seed inventory adequate to respond to reforestation needs and acquiring the scientific expertise needed to implement a tree seed program as described in this manual.

1.5. References

A. BLM Manuals

1. MS-5000, Forest Management (Rel. 5-139)

2. MS-5710, Reforestation (Rel. 5-20)

B. Technical publications contributing to program implementation:

1. Alfaro, R. I., B. Fady, G. G. Vendramin, I. K. Dawson, R. A. Fleming, C. Saenz-Romero, R. A. Lindig-Cisneros, T. Murdock, B. Vinceti, C. M. Navarro, T. Skroppa, G. Baldinelli, Y. A. El-Kassaby, and J. Loo. 2014. The role of forest genetic resources in responding to biotic and abiotic factors in the context of anthropogenic climate change. Forest Ecology and Management, Vol. 333. pp. 76-87.

2. Banerjee, S. M., K. Creasey, and D. D. Gertzen. 2001. Native woody plant seed collection guide for British Columbia. British Columbia Ministry of Forests. Victoria, B.C. Canada.

3. Berdeen, J., B. Chamberlain, T. Grubb, A. Henderson, B. Mayo, M. Mielke, K. Purcell, D. Ringner, M. Roberts, D. Stubbs, and M. Thorning. 2015. National Tree Climbing Guide. Tech. Rep. 0567-2819-MTDC. U. S. Department of Agriculture, Forest Service. Missoula Technology and Development Center. 88 p.

4. Bonner, F. T. and R. P. Karrfalt. 2008. The Woody Plant Seed Manual. Agricultural Handbook 727. United States Department of Agriculture, Forest Service. Washington, DC. 1223 p.

5. Burns, R. M. and B. H. Honkala. 1990. Silvics of North America: 1. Conifers. Agricultural Handbook 654. United States Department of Agriculture, Forest Service. Washington, DC.

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8. Eis, S. and D. Craigdaille, G.R. Powell. 1982. Reproduction of conifers: A handbook for cone crop assessment. Forestry Technical Report 31. Canadian Forestry Service, Victoria, B.C. Canada. 46 p.

9. Eremko, R. D., D. G. W. Edwards and D. Wallinger. 1989. A guide to collecting cones of British Columbia. FRDA Report 055. British Columbia Ministry of Forests. Victoria, B.C. Canada.

10. Hedlin, A. F., H. O. Yates, D. C. Tovar, B. H. Ebel, T. W. Koerber, and E. P. Merkel. 1980. Cone and seed insects of North American conifers. Environment Canada, Forestry Service, Pacific Forestry Centre, Victoria, BC, co-published by the United States Forest Service and Secretaría de Agricultura y Recursos Hidráulicos, México. 122 p.

11. Kolotelo, D., E. Van Steenis, M. Peterson, R. Bennett, D. Trotter, and J. Dennis. 2001. Seed handling guidebook. British Columbia Ministry of Forests. Victoria, B.C. Canada.

12. Kolotelo, D. 1997. Anatomy and morphology of conifer tree seed. Forest Nursery Technical Series 1.1. British Columbia Ministry of Forests. Victoria, B.C. Canada.

13. Portlock, F. T. 1996. A field guide to collecting cones of British Columbia conifers. British Columbia Ministry of Forests. Victoria, B.C. Canada.

14. Society for Ecological Restoration. 2023. Seed information database. https://sert-sid.org/

15. Stewart, W. 2020. Reforestation practices for conifers in California. University of California. Berkeley, CA.

16. Ward, K., R. Shoal, and C. Aubry. 2006. Whitebark pine cone collection manual. United States Department of Agriculture, Forest Service. Pacific Northwest Region.

17. Willan, R. L. 1985. A guide to forest seed handling. FAO Forestry Paper 20/2. Food and Agriculture Organization of the United Nations, DANIDA Forest Seed Centre.

18. Williams, B. K., R.C. Szaro, and C. D. Shapiro. 2009. Adaptive Management: The U.S. Department of the Interior Technical Guide. Adaptive Management Working Group. U.S. Department of the Interior, Washington, DC.

1.6. Policy

The BLM's policy is to maintain a tree seed inventory that meets the reforestation treatments needs. This includes an overall objective of managing for resilient, resistant, and where appropriate, transitional forests and woodlands on BLM managed lands given the diverse habitats, site conditions, climate trends, and genetic diversity present on BLM lands.

1.7. File and Records Maintenance

All tree seed records are managed in accordance with established records retention and disposal policies. Refer to BLM Manual 1220, Records and Information Management, for policies and procedures. See the General Record Schedule for information on the disposition of records.

2. Planning Seedlot Collections

Seedlot planning assesses the current and future need for tree seed for reforestation treatments following large-scale disturbances (e.g., wildfires, drought, insect and disease outbreaks, and blowdown events), for riparian and wildlife habitat improvement, T&E species recovery, habitat connectivity, post-harvest reforestation, reclamation, or road rehabilitation. Utilization of species distribution models and seed transfer systems in concert with planning collections that are genetically appropriate to the current and future planting site environment will ensure long-term success. Seed collection planning considers factors such as cone crop periodicity, locations and types of seed collection sources, genetic diversity, seed yields, germination rates, nursery propagation factors, and storage conditions as well as capacity to determine adequate and reliable quantities of seed to maintain.

2.1. Seed Transfer Systems and Seed Zone Mapping

Successful reforestation requires tree seeds adapted to a planting site's current and predicted future conditions. When identifying an appropriate seed transfer system to utilize, it is important to understand the limitations and levels of uncertainty of the system and what factors or conditions have been integrated into the system. Factors such as physiography, soil, aspect, slope, photoperiod, and vegetation community considered in association with the seed-transfer system allows for selecting the optimal seedlot for a planting site. Maintaining collection location information for each seedlot will allow for implementation of a seed-transfer system most suitable for the region and the species as genecological information and climate science advances.

When facing increased uncertainty, multiple seedlots suitable for a given planting site may be considered to increase the probability that some portion is well adapted for the potential future climate conditions. In areas in which plant assemblages have been identified to change through predictive modeling, assisted migration of a portion of the seed mix may be considered to transition sites as a climate adaptation strategy.

Seed transfer systems can be categorized into three primary groups characterized by either discrete boundary of each zone or each seedlot having a unique deployment zone.

A. Fixed Zone Systems. These systems have a discrete boundary where all seed remain in the zone in which it originated. Boundaries are usually delineated along geographic, climatic, genetic, or ecological contour. Planting or collection locations can be dynamic within the seed zone. Examples of developed tools include Seed Zones of Washington, Seed Zones of Oregon, California Tree Seed Zones, Western Wildland Environmental Threat Assessment Center Seed Zone Map, Eastern Seed Zones Data Viewer

B. Focal Point Systems. These systems determine how far seeds can be transferred from their point of origin (distance and elevation). Every seed source has a unique deployment zone in which it may be planted, or alternatively, every reforestation site has a unique seed sourcing zone from which seed sources may be obtained. The area within the critical seed transfer distance of the focal point delineates the focal point seed transfer zone. Focal point systems offer greater flexibility than fixed zone systems, however, are more difficult to implement because they require the development of a unique deployment zone for every seed source (or a unique sourcing zone for every planting location). Examples of developed tools include the Seedlot Selection Tool and SeedWhere.

C. Focal Zone Systems. These systems generally have many small, fixed zones. Seed transfer is permitted into zones with similar biotic and abiotic factors to that of the zone that the seed was sourced from. Examples of developed tools include Zone Matcher (Climate-based Seed Deployment Zones for the Pacific Northwest).

Seed transfer zones can range from generalized for all species (provisional) to species specific (empirical), and from climate based to geographically based. Tree improvement programs also reference breeding zones, which is the geographic area where the progeny of developed genotypes is well adapted and may include more than one seed transfer zone. Selecting a system that has seed transfer zones developed with the most specificity towards species and geographical location can reduce the potential of experiencing deleterious effects such as outbreeding depression, where subsequent progeny are less adapted to their existing location as well as the original environment of either seed source parent.

Assisted migration can be incorporated into all seed transfer systems. Provenance studies have shown that moving seed should be gradual, such as smaller changes in elevation and/or latitude. To mitigate the risk of a seed movement being unsuccessful, consider conducting a planting with multiple seedlots from both local seed and translocated seed as identified through the seed transfer system, using climate trajectories at shorter timescales to mitigate the risk of maladaptation during the seedling and sapling stages. The long-term success of a reforested site is contingent on understanding the climatic tolerances of planted seed sources.

2.2. Seed Collection Sources

Collection of a broad genetic base from distinct sources may be necessary to represent the entire planning area and ensure genetic diversity to be resilient to potential future climate conditions.

A. Natural Stands. Standards for collections made from natural stands have been established to ensure that seedlots are genetically representative of the stand, that appropriate seedlots can be identified to be bulked prior to nursery production, and that seedlings are able to be deployed within the appropriate seed transfer zone. Optimal parameters for wild collected seedlots consist of equal amounts of seed collected from 20 trees per stand. Collection stands should be separated by more than 600 feet or further, when possible, to optimize genetic diversity. Evaluation of natural stands that have been impacted by disturbance should be made prior to collection to ensure that remaining trees provide appropriate genetic diversity and genetic quality. Collections from natural stands with high conservation value may be considered for gene conservation banking.

B. Seed Production Areas. Seed production areas typically are natural stands exhibiting desirable phenotypic characteristics that are managed for the purpose of seed production. Plantations may be used for seed production areas if the identity of the source material is known and the seedlot was collected using methods to maintain appropriate genetic representation. Collections standards are the same as from natural stands, with no fewer than 20 trees represented in a collection. In an even spaced stand, a guideline for the minimum viable area of a seed production area is 12 acres. Stands reserved for seed production areas should be at least 1,000 feet from a high proportion of phenotypically undesirable trees of the same species. Natural stand seed production areas can be considered for in situ gene conservation management.

C. Seed Orchards. Seed orchards allow for the efficient production of seed in a managed environment. Seed orchards provide for a reliable seed source as certain abiotic factors affecting cone production can be controlled, such as supplemental watering, and certain biotic factors can be controlled such as pests and competition. In addition, orchards reduce the logistical challenges of wild collections. Parent trees of orchard stock should be individually tested and selected for desirable and heritable characteristics, such as white pine blister rust resistance or insect resistance. Seed orchard units are typically delineated by breeding zone and maintained to produce seed of broad adaptability across a breeding zone. Seed orchards may or may not be part of tree improvement programs.

D. Tree Improvement Programs. Tree improvement programs are breeding programs, often developed collaboratively and cooperatively with research geneticists, to meet various objectives such as building a species' resistance to diseases or increasing yield for economically important species.

3. Estimating Seed Crops

Monitoring cone crop development and estimating yield size is important to determining if seed yield will economically meet collection needs and to maximize the quality and quantity of seed collected. Knowledge of species-specific and regionally influenced patterns such as cone crop periodicity, timing of flowering, timing to cone maturity, and timing to seed dispersal is necessary to forecast seed crops and plan for collection. Knowledge of species-specific reproduction and seed biology is also necessary for forecasting seed crops including the minimum age to reproductive maturity. Additionally, it is important to know if the species is monoecious or dioecious, to differentiate between perfect or imperfect flowers (in angiosperms) or between male or female strobili (in gymnosperms), and the reproductive cycle. Species specific information can be found in published literature as well as technical guides such as *The Woody Plant Seed Manual* (Bonner, 2008), *Silvics of North America* (Burns, 1990), *A Guide to Collecting Cones of British Columbia Conifers* (Eremko, 1989) and *Native Woody Plant Seed Collection Guide for British Columbia* (Banerjee, 2001). Monitoring biotic and abiotic site conditions that could affect seed yield in addition to conducting field checks to evaluate cone and seed maturity is necessary to plan collection. Multiple assessments and evaluations can be made during cone crop development that provide information to support timely decisions related to planning collections. Estimating seed crops enables an assessment of the cost per bushel for collection and processing and if a reasonable price per pound of seed can be achieved e.g., collection efficiency.

3.1. Forecasting Seed Crops

Seed forecasting or monitoring a tree at early stages in the reproductive cycle to determine the potential for seed production enables identification of stands with potential collection suitability. Reproductive monitoring of buds, pollination intensity, and early signs of cone development to determine rates of pollination success will indicate potential for a low, moderate, or high cone production year. Planning collections in mast seed years will result in improved collection cost efficiency, less seed loss due to insect damage, and increased genetic diversity collected per seed lot.

Seed forecasting may begin once reproductive buds can be distinctively identified from vegetative buds providing a preliminary estimate on the following year's flowering potential. Evaluating the proportion of female reproductive buds to vegetative buds occurs from the seed-cone producing area of the crown. In the spruces and true firs, evaluations are made in the upper one-third of the crown. For all other species, evaluations are made in the upper two-thirds of the crown. Evaluations for reproductive buds occur in the late fall or early winter. Evaluations are made from at least ten trees distributed throughout a potential collection area, with three branches from each tree being collected. Identification between female, male, and vegetative buds can be accomplished through cross-sectioning each bud or by placing sampled branch tips in water in a warm and well-let room to force bud break. Additional guidance can be obtained from technical guides such as *Reproduction of Conifers, a handbook for cone crop assessment* (Eis, 1983).

Monitoring weather conditions during staminate flower or staminate strobili (pollen-producing cone) development and pollination will also provide preliminary determinations on seed scouting efforts and seed collection planning. Dry and warm weather during pollination will generally enhance wind pollination, while rain or high humidity will hinder wind pollination. Late spring freezes can also impact pollination potential.

Knowledge of species-specific seed cone development following pollination and fertilization will assist in seed forecasting. In true firs, spruce, and hemlock fertilization occurs two to four weeks following pollination and the fertilized seed cones rapidly enlarge into a mature woody cone the same season. In pines, fertilization of cones occurs about 12 to 13 months following pollination and then enlargement of the cone and seed development follows. In junipers, the scales of cones will fuse after fertilization and form a berrylike structure. Some juniper species may pause seed development and overwinter before seeds fully mature the year after fertilization occurred.

Post-fertilization cone or fruit growth monitoring as well as monitoring for premature shedding events will also provide preliminary determinations towards seed collection planning. In both angiosperms and gymnosperms, premature shedding may occur shortly after pollination if the pistillate flower or strobilus has not been fertilized. Additional premature shedding occurs as a result of abiotic and biotic factors such as frost, hail, drought, extended periods of above normal temperatures, and insects or other pathogens. Premature shedding also occurs of immature but sometimes full-sized cones or fruits in the absence of known stressors.

Monitoring for pests and pathogens that impact cone development and seed production can also be used to forecast seed crops and identify stands that are unsuitable for collection. Pest damage can be identified externally by looking for deformed cones or cones with exit holes, pitch exudations, or discolored areas. Internally examining a cone for insect damage can be conducted by a cut face test. Technical guides, such as *Cone and Seed Insects of North American Conifers* (Hedlin, 1980), are useful in identifying pest symptoms and signs. Stands impacted by fungal pathogens causing cone rusts, sirococcus blight (*Sirococcus strobilinus*) and pitch canker (*Fusarium moniliforme* var. *subglutinans*) may also be deemed unsuitable for collection due to reduced yield.

3.2. Cone Crop Monitoring

Cone crop monitoring provides more formal information than seed forecasting and are conducted as the seed cone develops, beginning as early as mid-June and continuing until cone harvest. Species and regional specific reproductive cycles will dictate timing of cone crop surveys. Information gathered from cone crop surveys and monitoring will provide the information necessary for planning collection and cone processing logistics. Cone crop monitoring consists of rating the stand, conducting a cone crop survey, sampling cones, estimating seed yield, and monitoring for pests and pathogens. Stand location information (GPS coordinates) and site description (aspect, slope, species composition, stand age, stand health, soil properties) will assist in returning to stands for further evaluation.

A. Cone-Crop Rating. Specific guidance has been developed for some species and specific localities. In the spruces and true firs, rating evaluations should be made in the upper one-third of the crown of all reproductive aged plants. For all other species, rating evaluations may be made in the upper two-thirds of the crown of all reproductive aged plants. Rating of cone crops should occur once ovulate strobili (seed cones) are visible and distinguishable, usually early summer (early- to mid-June) of the year the cones are collectable. Standard operating procedures to conduct cone-crop ratings include that observers use binoculars with no less than a 7X magnification while standing 1-2 tree heights away from the tree with the sun behind the surveyor in early morning or late afternoon with low cloud cover and light wind. Several rating systems have been developed, anywhere from a 4-level to a 10-level rating. Ratings are subjective and local knowledge as well as species specific guidance should be obtained to determine the crop potential of the species being observed. Trees located along edges, such as roadsides, should be avoided for cone crop rating as they will frequently have heavier cone crops and are not representative of the entire stand.

Table 1: General Cone Crop Rating Guidance

Crop rating	Definition
No Crop	No cones are observed on any trees
Very Light	Fruits or cones on less than 25% of trees
Light	Some cones seen on more than 25% of trees OR Many cones seen on less than 25% of trees
Medium	Many cones seen on 25-50% of trees
Heavy	Many cones seen on more than 50% of trees
Very Heavy	Many cones observed on almost all trees

B. Cone Crop Surveys. Cone crop surveys are necessary to estimate seed crop yield. Surveys should be completed with the same standard operating procedures as identified in the Cone-Crop Rating guidance. Maturing cones can be distinguished from older cones with the following general criteria: maturing cones are yellowish green to green compared with dark brown for older cones; maturing cones will be closed while older cones will be open and dry; maturing cones will be among the needles while older cones will be father back from the tip. A sample of 20 - 30 trees per stand should be surveyed to determine average yield per tree. For all trees except western redcedar and western hemlock, count the number of cones visible on the tree within the appropriate canopy section. For western redcedar and western hemlock, count the cones on one-twentieth of the visible crown. Use defined conversion factors to convert the count obtained to the estimated number of cones to expect within the collectible area of the tree.

Table 2: Conversion factors for Cone Crop Surveys

Species	Common Name	Conversion Factor
Abies amabilis	Pacific silver fir	1.7
Abies grandis	Grand fir	1.7
Abies lasiocarpa	Subalpine fir	1.7
Abies procera	Noble fir	1.5
Callitropsis nootkatensis	Alaska yellow cedar	40.0
Larix occidentalis	Western larch	2.0

Picea sp.	Spruce	2.0
Pinus contorta	Lodgepole pine	4
Pinus ponderosa	Ponderosa pine	1.5
Pinus monticola	Western white pine	1.5
Pseudotsuga menziesii	Douglas Fir	2.0
Thuja plicata	Western redcedar	40.0
Tsuga heterophylla	Western hemlock	40.0
Tsuga mertensiana	Mountain hemlock	2

C. Cone Sampling. Standards for sampling cones and evaluating seed crops are established in order to determine seed yield and seed development as well as to identify problems such as insect damage. Cone sampling usually begins in mid-July and may continue on two-week intervals to monitor for cone ripeness, seed maturation, and insect damage. General guidelines for sampling trees include that 5-10 cones per tree are collected from no less than 10 trees from within the stand. Sampled trees should be no less than 200 feet apart. Sample cones from all aspects of the tree. True firs and spruces should be sampled from the upper 1/3 of the crown and all other species should be sampled from the upper 2/3 of the crown. Multiple evaluations can be completed from each sampled cone or a subset of sampled cones, including the cut face test, seed count, and seed cut test.

a. Cut Face Test. Cut face test guidelines are available for many species including orientation of cutting and seed count guidelines to determine economically viable collections. For most species, cones should be cut lengthwise on the axis to expose a cross section of the cone (cut face) with the axis of the cone bisected for accurate evaluation. Exceptions to the orientation of cone cutting including yellow cedar, western redcedar, and true firs. From one cut face, count the number of filled seeds (filled, sound seeds usually exhibited with megagametophyte that is white and of a nut-like consistency), observe for cone damage caused by insects, and identify the stage of ripeness of the seed. Only count seeds that were cut, if the seedcoat remained intact then do not include in seed count. For cones with evidence of insect damage, one seed count should be deducted from each cut face count. Minimum number of seed per cut face thresholds have been established to determine if seed collection is economically viable based on seed yield, however, if a species is critically needed, minimum thresholds may be considered too restrictive.

Table 3: Minimum average number of good seeds on cut face for economically viable collection.

Species	Common Name	Seed Count
Abies amabilis	Pacific silver fir (cut ½" off axis)	50% or 8-12
Abies concolor		50% or 10
Abies grandis	Grand Fir (cut ½" off axis)	50% or 12-14
Abies procera	Noble fir (cut ½" off axis)	50%

Abies lasiocarpa	Subalpine fir (cut ½” off axis)	50% or 4-10
Abies magnifica		50% or 10
Callitropsis nootkatensis	Alaska yellow cedar (cut perpendicular)	2
Larix occidentalis	Western larch	2-3
Picea engelmannii	Engelmann Spruce	5-7
Picea pungens	Blue spruce	7
Picea sitchensis	Sitka spruce	7-14
Pinus albicaulis	Whitebark pine	10
Pinus contorta	Lodgepole pine (coastal)*	5-7
Pinus contorta	Lodgepole pine (interior)*	3-5
Pinus flexilis	Limber pine	10
Pinus jeffreyii	Jeffrey pine	7
Pinus labertiana	Sugar pine	10
Pinus monticola	Western white pine	10
Pinus ponderosa	Ponderosa pine	6-10
Pseudotsuga menziesii	Douglas fir	5-6
Thuja plicata	Western red cedar (cut perpendicular)	2
Tsuga heterophylla	Western hemlock	3-8
Tsuga mertensiana	Mountain hemlock	3-10

*Conducting cut face test on cones of Lodgepole pine may be difficult. An alternative method to count seeds is by extracting seeds from the cone by submerging cones in boiling water for 10 seconds and then placing in a 65 degree C (150 degree F) oven for 3-4 hours.

Species specific guidance and illustrations can be found in published literature as well as technical guides, such as *The Woody Plant Seed Manual* (Bonner, 2008), *A Guide to Collecting Cones of British Columbia Conifers* (Eremko, 1989) and *A Field Guide to Collecting Cones of British Columbia Conifers* (Portlock, 1996).

b. Seed count. A complete count of seeds per cone may be conducted if equations for using cut face seed counts to estimate seeds per cone are not available for the species or not applicable to local collection stands. Conducting seed counts from the sample of cones when cone crop surveys and cut face tests identify that a viable seed crop is present allows for calculation of seed yield estimates.

c. Seed cut test. The seed cut test provides an assessment of seed development, seed development abnormalities, and seed maturity. Seed cut tests are included in sampling once embryo development and megagametophyte maturity are expected to be measurable, usually beginning late-July to mid-August depending upon species and local environmental factors. Standard guidelines are to evaluate 10-20 seeds per cone with a seed cut test. A razor blade or scalpel is used to bisect the seed longitudinally. A 10X hand lens is used to examine the megagametophyte and embryo. Generally, embryonic maturity is indicated when the embryo fills at least 90% of the cavity within the megagametophyte. The maturity of the megagametophyte is indicated as being near the consistency of coconut meat and does not shrink away from the seed coat even when exposed to air for several hours. Each seed tested should be evaluated as potentially viable or non-viable, as determined by embryo development, megagametophyte maturity, and developmental abnormalities. Evaluation of seed development will allow for estimating the time until collection can begin. Illustrations and species-specific guidelines can be found in technical guides such as the *Seed Handling Guidebook* (Kolotelo, 2001), *A Field Guide to Collecting Cones of British Columbia Conifers* (Portlock, 1996) and *Anatomy and Morphology of Conifer Tree Seed* (Kolotelo, 1997).

3.3. Estimating Seed Crop Yield

Estimating crop yield for a collection area includes evaluation of the number of collectable trees per acre and the number of accessible acres in the collection stand for the purpose of determining collection quantities. Trees identified as a collectable tree will vary based on collection method, but regardless of collection method, avoid collection from trees that are diseased, have mistletoe, cankers, or other obvious infections or genetic deformities. The age of a collectable tree will depend on the species of tree, but generally ranges from 35-120 years old. For stands that will be collected through climbing, additional criteria for climbable trees include that the bole is straight, the crown is tight, the limbs within the collectable portion of the crown are short or longer limbs appear limber enough to allow climbers to use a cone hook to pull the outer limb tip towards the bole without breaking the branch, the tree is less than 48 inches in diameter, and the tree does not have epicormic growth. Collectable trees within natural stands and seed production areas are no less than 200 feet apart.

Calculations used to determine the quantity of seed available from within a stand and the number of trees necessary for collection require several variables including the average number of cones per bushel and the seed weight. Refer to Appendix 1 for seed yield equations. Variables obtained from the most local source possible averaged over several years of sampling generally lend to the most accurate seed yield calculations. Utilizing seed weight test results taken from prior collections within the stand and measuring cones per bushel during sampling or obtaining seed weights and cones per bushel estimates from production nurseries will provide useful, locally derived variables. In the absence of locally derived variables, sources are available that provide data on seed weights and cones per bushel, including the *Seed Information Database*, (Society for Ecological Restoration, 2023), *The Woody Plant Seed Manual* (Bonner, 2008), *Anatomy and Morphology of Conifer Tree Seed* (Kotelo, 1997), *Silvics of North America* (Burns, 1990).

3.4. Assessing Cone and Seed Ripeness

Monitoring stands as cones continue to mature will allow for the identification of proper collection timing. Cones collected at physiological maturity increase potential for seeds to have the highest initial vigor and maintain vigor and viability under optimal storage conditions for longer periods of time, dependent upon species-specific seed storage characteristics. Collection prior to physiological maturity decreases seed yield due to underdevelopment of embryo and megagametophyte, decreases levels of seed extraction from cones, and increases loss from high moisture levels (i.e. increased risk of mold and heating). Collections conducted too late in the season results in reduced seed yield due to natural cone flaring and seed dispersal or increased seed predation. General indicators of maturation include cone color, bract color, seed wing color, scale color, and firmness of megagametophyte. Physical indicators of maturation include cone moisture content, cone specific gravity, and embryo development assessed through seed cut test (refer to sampling methods outlined in section 3.2.C.). Protocols for conducing specific gravity measurements are provided in *The Woody Plant Seed Manual* (Bonner, 2008). Monitoring general indicators of maturity will determine when physical indicators of maturity should be measured. The time between physiological maturity and the time of natural seed fall varies by species and location but is generally a short window. Serotinous cones, however, can be collected several months after physiological maturity as the seeds will be contained within the cones.

Table 4: Cone maturity guidelines

Species	Common Name	Cone and Seed Appearance	Specific Gravity	Seed Maturity	Natural Dispersal
Abies amabilis	Pacific silver fir	cones – green with yellow tinge, turning gray or purple embryo - yellow to yellow-green, 90% extended		late August	mid-September
Abies concolor	white fir	cones – yellow-green, green-purple, to bright yellow-brown embryo – pale yellow-green, almost filling embryo cavity (90-100%) megagametophyte – whitish, fleshy, firm, may have oily appearance	0.85 – 0.96	September	3 weeks after cone ripening
Abies grandis	grand fir	cones – light brown, yellow-green, greenish-purple embryo – yellow to yellow-green, 90% extended	<0.90	August – September	3 weeks after cone ripening
Abies lasiocarpa	subalpine fir	cone – green with yellow tinge, turning gray or purple		mid-August to	mid-September

		embryo – yellow to yellow-green, 90% extended		mid-October	to late-October
Abies magnifica	red fir	cone – greenish-brown to russet brown with reddish or gray tinge embryo – pale yellow-green, fills 90-100% of the cavity megagametophyte – fleshy and firm, may appear oily	<0.75	mid-August	
Abies procera	noble fir	cone – light brown embryo – 90% extended	<0.90	mid-August	late-September to early-October
Callitropsis nootkatensis	Alaska yellow cedar			mid-September	early winter
Larix occidentalis	western larch	green-brown-purple		mid- to late-August	early-September
Picea engelmannii	Engelmann spruce	cones-green tinged with red to shiny brown embryo – yellow green, 90% of cavity length	0.90	August to early-September	September
Picea pungens	blue spruce	cones – green tinged with red to pale shiny brown embryo – yellow-green, 90% of cavity length	0.95	August	early- to late-September
Picea sitchensis	Sitka spruce	cones – yellow-green to brown		late-August to early-September	October
Pinus albicaulis	whitebark pine	cone – dark purple to dull purple to brown		September	
Pinus contorta	lodgepole pine (coastal)	cone – light yellowish brown to yellow-brown	0.43-0.89	September to October	
Pinus contorta var. *latifolia*	lodgepole pine (interior)	light brown, yellow brown		August to September	
Pinus edulis	pinyon			early-September	mid-September
Pinus flexilis	limber pine	cone – yellowish brown to light brown		August to September	September to October

Pinus jeffreyii	Jeffrey pine	cone – dull purple to light brown embryo – fills 90% cavity length, cream to white in color megagametophyte – whitish to opaque, firm to nutlike	0.81-0.86		
Pinus lambertiana	sugar pine	cones – light brown	0.62		August (progressing from low to high elevations)
Pinus monophyla	singleleaf pinyon	cones – brown		September	September
Pinus monticola	western white pine	cone – yellowish beige-brown to reddish, dark brown		August to September	late-August to mid-September
Pinus ponderosa var. *scopulorum*	ponderosa pine	cones –brownish-yellow, russet brown to purplish-brown embryo – white to yellow, nearly fills cavity	locality specific (ranges from 0.80 in Arizona to 1.00 in Black Hills)	September to October	
Pinus sabiniana	gray pine		0.59 – 0.96		
Pseudotsuga menziesii	Douglas-fir	cones – green with brownish or purplish tinge embryo – yellow-green, almost filling cavity megagametophyte – whitish, opaque, firm		late-July to mid-August	mid-August to mid-September
Thuja plicata	western red cedar	cones – light brown	0.62		October
Tsuga heterophylla	western hemlock	cone – brown with red-brown tips		mid- to late-September	late-October
Tsuga mertensiana	mountain hemlock	brown		late-September	

Additional guidance can be found in *Anatomy and Morphology of Conifer Tree Seed* (Kotelo, 1997), *Silvics of North America* (Burns, 1990), and *A Guide to Collecting Cones of British Columbia Conifers* (Eremko, 1989).

4. Cone Collection and Handling

Cone handling during collection, post-harvest storage, and transport is critical in maintaining viable seed. Cone processing and seed cleaning prepare seed for long-term storage, and testing provides essential information to calculate propagation potential from a seedlot that informs nursery operations on sowing rates.

4.1. Planning the Collection

Cone collection planning provides for adequate quantities to be collected to fulfill needs identified as outlined in Chapter 2 "Seedlot Collection Planning". Collection planning considers factors such as collection method suitable for species and site, labor force, supplies, capacity of interim storage location, capacity of processing and seed extraction facilities, identification of seed testing facility, and identification of long-term storage location. Collection planning data (outlined in Chapter 3 "Estimating Seed Crops") can be used to develop statements of work for procurement actions, identify resources necessary for collection, identify an extractory that has experience with techniques suitable for processing the species collected, and identify a long-term seed storage location that has conditions optimum for maximizing longevity of stored seed viability.

Collections from natural stands and seed productions areas should consist of collecting similar amounts of seed per unrelated tree within the stand to ensure genetic representation. General guidelines are to collect no more than two bushels per tree from trees that are no less than 200 feet apart, collecting from no fewer than 20 trees per stand. Species-specific literature may provide more restrictive or less restrictive guidelines. Refer to Appendix 1 for an equation to determining the number of bushels per collectable tree necessary to meet collection targets.

4.2. Collection Methods

Selecting a collection method factors in multiple variables such as the height and structure of the collection tree(s), access to and within the stand, availability of equipment and equipment operators, qualifications of labor force, size and quality of collection, and available funding. Various methods have the potential to reduce cone production in near future years, such as clipping or the use of helicopter cone rakes which remove branch tips that have reproductive buds or female strobili that are the crop of the next year to few years. Refer to BLM H-1112-1, Safety and Health Management Handbook, and State/District/Field Office safety protocols for any applicable safety procedures. A specific risk assessment is required for specialized collection methods and may require specialized safety equipment or training. Other federal agency guidelines can be a good reference for completing a risk assessment.

A. Climbing. Cone collection by climbing requires individuals proficient in climbing and skilled in identifying cone ripeness for the species of collection. Trees suitable for climbing branches should be well spaced and large enough to support a climber. Additional criteria are listed in section 3.3. "Estimating Seed Crop Yield". Climbers should not use climbing spurs when collecting from species with stems that can be easily damaged such as white pines, five-needle pines, and white fir. Collections are bagged in the tree and lowered to the ground with ropes to minimize risk of damage to the cones and seeds. Additional guidance on tree climbing can be found in the *National Tree Climbing Guide* (USDA Forest Service, 2015).

B. Collecting from felled trees. Collection from felled trees can include natural and planned felling of trees. Best practices for collecting from felled trees is for cones to be collected within days of felling and for collected cones to have not encountered the soil as contact with the ground will increase the risk of fungal contamination. Felling operations that are conducted before cones have reached physiological maturity will cause ripening to cease and seeds to not reach maturity, resulting in low to no viability. Felling operations that are conducted when cones have reached the natural dispersal stage may result in cones shattering and seeds being lost due to impact.

   a. Collecting from harvest and silvicultural activities: When possible, coordinate the timing of felling operations with physiological cone maturity. Cones should be collected as quickly as possible after trees have been felled.

   b. Storm damage: Opportunistically collecting from storm damaged trees may yield the least favorable collection conditions as the cones may have not reached physiological maturity. Cut seed tests will enable determination of megagametophyte and embryo development to determine if a viable collection can be made.

C. Clipping. Clipping branches is practical during both ground-based operations and during climbing operations. Collections made from the ground are suitable for short-statured trees with care taken to ensure that trees are within the collectable age range and the collection is made from the proper crown height for the species. When clipping branch tips during climbing operations avoid contact with soil by using tarps for branch tips to be dropped onto.

D. Helicopter. Collection with helicopter cone rakes can be an efficient method when a large quantity of high-quality cones is available and concentrated in the top of narrow, conical crowns. Collection with helicopter cone ranks poses the risk of damage to the trees. Placement of large, well secured tarps will prevent soil contact that could result in the transmission of pathogens. Spreading of cone piles as quickly as possible will prevent heat buildup that can damage cones and seed.

E. Lifts. Suitable sites for the use of truck mounted ladders, hydraulic lifts, and bucket trucks are sites that are accessible by vehicle, have a level ground surface, and trees are spaced to allow equipment access. These sites are usually restricted to seed orchards; however, natural stands and seed production area sites may have suitable access. This method may further limit the collectible portion of the tree crown.

F. Purchase. Seed purchased as a commercial product should be collected from similar types of Seed Collection Sources identified in Section 2.2 and should be handled, processed, and tested with the same considerations as outlined throughout Chapter 4. Class certifications provide reasonable assurance that the correct species, genetic source, and quality are being acquired. Additional information on seed classes and certifications can be found in *The Woody Plant Seed Manual* (Bonner, 2008, Chapter 6). Seed label requirements of commercially sold seed are determined through state seed laws, and the inclusion of tree seed under state seed laws varies by state. In states in which seed laws do not include tree seed under labeling requirements, Section 5.4 outlines seed tests that should be conducted prior to purchasing commercially available tree seed. Tree Improvement Cooperatives, cooperative agreements, interagency agreements, and memorandums of agreement may also be considered as suitable strategies to obtain seed, ensuring that considerations are made as outlined in Chapter 4. Seed tests conducted near the time of purchase reflects the current condition of the seedlot, with general guidelines in place that seed tests should be conducted no more than 9 months prior to time of purchase. Suboptimal storage conditions following testing may negate test results prior to purchase or possession.

4.3. Minimum Data Required for Collected Cones.

Collection records compiled at time of cone harvest ensure the integrity of seed source identification. At a minimum, the data collected should include:

- Species – The USDA NRCS PLANTS database should be used for all species nomenclature and species codes.
- Location information –
    - Natural stands and seed production areas - Location information must include the geographic coordinates (e.g., lat/long) of the mid-point of the collection stand and the elevation/elevation band. The geographic coordinate system and datum that coordinates were collected in should be recorded.
    - Tree Improvement Programs and Orchards – Location information must include seed orchard location and Breeding Unit name.
- Dates of collection.
- Number of bushels collected.
- Number of trees collected.

Additional data may be recorded on collection records as identified by needs of the program such as collection method, seed transfer zone or breeding zone, elevation range, cut face seed count, or other information obtained from sampling.

4.4. Collection and Proper Handling

Monitoring cone conditions and weather conditions leading up to collection and during collection will determine the feasibility of conducting collections. Weather conditions during collection, such as wind or rain, may delay collections due to climber safety or site access with other equipment. Rainy conditions may also cause cones that had begun to naturally flare and release seed to close back up, resulting in cones with low seed counts to be collected. Low humidity and dry winds can cause cone flaring and natural seed dispersal to progress more quickly. Conducting cut face samples, seed counts, and seed cut tests (outlined in section 3.2.C. “Cone Sampling”) and assessing cone ripeness and seed maturity (outlined in section 3.4 “Assessing Cone and Seed Ripeness”) at time of collection will inform if site conditions have changed such that alternative sites would be more suitable for collection, if quantity of cones collected will need increased or decreased to meet collection needs, or cone collectors are collecting current year cones that meet contract specifications. A general guideline for sampling includes inspecting a minimum of three cones per bushel.

General guidelines and best management practices during collection include:

- Collection supplies should be cleaned and sanitized prior to collection, including the use of new bags or bags that have been sanitized with hot water or steam treatments. Quick drying is important to minimize mold.
- Collection bags should be made of a strong mesh fabric or burlap. Weave of material must be open enough to allow free air flow but tight enough to prevent loss of seed. Bag should be turned inside out so that the rough seams are on the outside of the bag.
- Inspect and relocate bags to interim storage daily.
- Field-clean collections prior to bagging, including removal of branches, needles or leaves, and other debris and to sort out immature and insect damaged cones or cones infected with other pathogens.
- Cones should be measured and then placed into bags at pre-determined volume per bag. Bags should not be filled more than half full and then tied securely near the top of the bag (4-5 inches from the top) to allow for cone expansion and air flow.
- Each bag should be labeled with two tags, one tag attached externally and one tag inside the bag. Information included on the tag should include, at minimum, species, location, and date of collection written in waterproof ink. Location must be able to be cross referenced to elevation, seed zone, and collection method. If not, provide these on the tag also.
- Bagged cones should be placed on their side and lie free from each other in the shade, allowing for free air movement around bags. Bags should not be placed directly on soil surface or exposed to direct sunlight or excessive moisture. If bags do become wet, cones should be removed from the bag then spread out to surface dry and re-bagged into dry sacks. Cone bags should generally not be covered with plastic.
- If bags cannot be adequately protected at the collection site, consider moving bags daily to interim storage (as outlined in Section 4.5), inspecting tags to ensure accuracy, and keeping an inventory of the number of bags received and inspected.
- Serotinous cone collections should be made from the current year's crop as signified by weathering. Age of cones can be assessed by color with cones from the current year's crop being brown, bronze, or gold colored on all faces and tightly closed. Cones that are 2-7 years old can be identified as being weathered, or gray on up to 66% of surface. Cones that are over 5 years old can be identified on being weathered or gray on over 67% of the surface of the cone.

Proper and gentle cone handling during collection, field processing, and transport is critical in maintaining viable seed. In addition to sampling for cone ripeness and seed maturity and monitoring for the use of best management practices, on-site monitoring and inspection during collection includes ensuring that bags are lowered from tree crowns with ropes and that cone bags are handled gently.

4.5. Interim Storage

Interim storage, or field storage, is storage between the time in which collections are made until the time that cones are transported for processing. Species specific guidance will enable decisions to be made regarding length of time seed can be in interim storage. The use of general guidelines requires knowledge of the type of storage characteristics are best for the species, either recalcitrant, orthodox, or sub-orthodox. Recalcitrant seeds lose viability when dried and require immediate cool storage above freezing temperatures in a container that is moisture proof to retain moisture but allows for gas exchange. Guidelines for interim storage of orthodox seeds differ based on whether the seed is contained within a fleshy fruit or within a non-fleshy fruit or a cone. Orthodox seeds within fleshy fruits should be stored temporarily similar as recalcitrant seeds until the pulp is removed as to allow for ease of processing. Non-fleshy fruits and cones are allowed to dry at a gradual rate during interim storage.

Planning for interim storage prior to collection ensures that adequate interim storage capacity will be available, considering factors such as number of bushels to be stored, access restrictions, and length of time bags will remain in interim storage. General guidelines and best management practices for interim storage for conifer species classified as orthodox include:

- Cones of most species should be maintained in interim storage for approximately two to four weeks prior to shipping to an extractory to allow for the gradual reduction in moisture. Exceptions include western hemlock and western redcedar which should be shipped to processing facilities immediately.
- Control measures should be in place to prevent rodent or other animal damage to cones and bags.
- Storage facilities should have adequate air circulation and be protected from moisture, direct sunlight, and temperature extremes.
- Storage facilities should have adequate rack capacity to hold all bags until transport is made to processing facilities. Pallets can be used to increase storage capacity. Bags should never be placed directly on the floor.
- Bags should be handled with care and placed on racks in interim storage daily. Bags should not be left in transport vehicles or other confined spaces overnight.
- Transport from collection site to interim storage should be in open-sided trucks or trailers or refrigerated vans. Care should be taken to prevent contact with external heat sources, such as placing cone bags on top of a pallet within a truck bed to protect from heat transfer from exhaust.
- Storage racks should allow for unrestricted air movement, with sacks lying on their side and free from each other, and cones spread within the bag as evenly as possible, allowing for cones to expand.
- Bags should be monitored and turned at regular intervals, generally daily.

Species specific guidelines may indicate that seed may remain in the cones for longer periods of time without affecting seed viability, such as cone collections from species that have a high degree of cone serotiny. Collections of serotinous cones from stands that have varying degrees of serotiny should be processed before cones exhibiting less serotiny begin to open. Cones of species suitable for delayed seed extraction should be protected from subfreezing temperatures as to minimize loss of viability.

4.6. Cone Transport

Planning for cone transport from interim storage to a seed extractory or processing facility includes arrangement for transport that is suitable for maintaining seed viability. General guidelines and best management practices for suitable transport include:

- Inform processing facility of anticipated shipment arrival and quantities.
- Arrange for shipment to arrive during working hours of processing facility with adequate time for shipment to be unloaded.
- Arrange a transport vehicle that can maintain cool temperatures, such as a commercial refrigerated trailer, van, or other trailer maintained between 5 -15° C (40 – 60° F).
- Ensure air circulation between cone sacks, using pallets or racks to stack cone sacks no more than two deep. Layering of cone sacks and pallets can increase use of space inside of transport vehicle while ensuring air flow.
- If cone moisture is high during transport, vents should be opened to allow for moisture to escape.
- Non-refrigerated vehicles and trailers are suitable for transporting serotinous cones or cones that have been well conditioned during interim storage.
- Transport time should be minimized to 24 hours or less.
- Shipment should immediately be placed onto drying racks at the processing facility.
- A list of collections with inventory of cone sacks should be included with the shipment.
- Upon arrival at the processing facility, a verification of inventory and inspection of cone sacks for damage should be completed, and if needed a sample of cones inspected from no less than 10% of the sacks to assess cone maturity, insect and pathogen damage, and status of cone curing.

5. Cone and Seed Processing

Cone processing entails the drying and separation of seeds from cones. Seed processing entails the removal of debris and non-viable seeds, the reduction of seed moisture content, and the purification of seed. Propper processing ensures seedlot condition is suitable for storage and facilitates more uniform germination in bareroot and container operations. Cleanliness and sanitation during seed processing is necessary to reduce the spread of pathogens. Cleaning all cone and seed processing equipment between each seedlot to remove debris and disinfecting with detergents or sterilants reduces the potential for pathogens to spread between seedlots.

Seed characteristics will determine the seed processing procedures such as thickness of seed coat, presence of resin vesicles, and storage characteristics of seed (recalcitrant, orthodox, sub-orthodox). Fruits collected from angiosperms may require different processing guidelines than provided. For information on processing fruits and seeds of angiosperms or specific guidance for conifer species, species-specific guidelines should be consulted. General protocols can be found in the *Seed Handling Guidebook* (Kolotelo, 2001) and species-specific protocols can be found in *The Woody Plant Seed Manual* (Bonner, 2008).

5.1. Cone Curing

Cone curing allows for gradual and uniform moisture loss, effectively reducing the risk of overheating and fungal growth. The length of time for cone curing varies by initial cone moisture content as well as by species characteristics. Typically cone curing will occur for two to four weeks prior to cone processing. Monitoring during cone curing includes assessing for presence and extent of fungal infections, and presence and damage caused by insects. Cone curing reduces occurrence of case hardening and less complete extraction of seeds.

5.2. Cone Processing

Cone processing includes separating debris from cones, drying cones either by ambient conditions or by kiln in order to open cone scales, and extraction. Complete curing prior to kilning reduces the risk of case-hardening, a condition caused by the outer layers of the cone drying more quickly than the interior and trapping seeds inside the cone resulting in reduced seed yields. Kilning is typically conducted with either a rotary kiln or a batch kiln, also known as a progressive kiln. True firs and incense cedar, which are sensitive to heat damage, can usually be extracted without kilning. Serotinous cones may require a hot water or steam treatment prior to kilning.

A. Rotary kilns. Rotary kilns typically consist of a wire drum with an adjustable rotation speed designed to allow released seeds to fall through the drum as seeds are released from cones. Rotary kilns can process one seedlot at a time.

B. Batch kilns. Batch kilns, also known as progressive kilns, typically allow for multiple seedlots to be treated simultaneously. Trays of cones are progressively exposed to warmer temperatures through the drying process. Cones dried with batch kilns require additional processing to complete extraction, such as tumbling or screening.

Kiln temperatures are progressively increased during the process in order to avoid case hardening, typically operating from 30° to 60 ° C (90° to 140° F), depending on species and seed characteristics. Low dormancy species, such as western redcedar and western hemlock should not be exposed to kiln temperatures above 30° C (86° F). Serotinous lodgepole pine that has not been hot water treated or steamed can be exposed up to 60° C (140° F). Most other species can be kilned in temperatures up to 40.5° C (105° F). Kiln temperatures must never exceed lethal temperatures for seeds, typically around 66° C (150° F). Kilning typically reduces seed moisture content to 7-8%. Sampling and inspecting cones for unreleased, viable seed during kilning will indicate if additional kilning is necessary.

Additional cone processing may include tumbling or screening. Tumbling extracts and separates seeds from cones. Sampling and inspecting cones for viable seeds remaining in cones will ensure that the duration of tumbling is kept at a minimum, allowing for seed yield to be maximized while reducing the risk of seed damage caused by excessive tumbling. Screening, either mechanically operated or manually operated (hand-screening), separates debris and inert material from seeds by passing over mesh screens sized for the species and type of debris present within the lot. Hand-screening species that are highly sensitive to mechanical damage, such as incense cedar, will reduce the potential for seed damage.

5.3. Seed Processing

Seed processing and upgrading removes debris, inert material, and empty, immature, or otherwise unviable seed from the seedlot. Seed processing improves seed storage life as well as provides for more economical seedling production. Seed processing activities include screening, de-winging, final cleaning or upgrading, and seed drying. Monitoring the progress of the seedlot through each stage of processing will ensure that equipment is calibrated appropriately such that viable seed is not discarded, and that over-processing is not causing damage to seeds. Seeds that do not have a hard seedcoat are more susceptible to damage. Seeds that have resin vesicles, such as *Abies*, *Thuja*, and *Tsuga* species, are most susceptible to damage during processing.

A. Screening. A multi-screened vibrational seed cleaner is typically used for screening to remove cone scales, foliage, and other debris. The screen aperture and vibrational speed is determined by the seed size and the type of debris in the lot. Hand screening is suitable for species highly susceptible to mechanical damage.

B. De-winging. De-winging, or removing the seed wing from the seed coat, utilizes physical abrasion from seeds passing over each other to break off the seed wing. De-winging reduces storage volume, facilitates final cleaning, and improves sowing efficiencies. Various types of equipment are used for de-winging including rotary drums with variable rotation speed, macerators, and brush-type or auger-type de-wingers. De-winging can be completed with the addition of moisture (wet processing) or be conducted with dry seed. Species specific guidelines should be followed as some species are more susceptible to damage from dry processing whereas other species are more thoroughly de-winged at seed moisture contents below 15%. Monitoring de-winging will ensure that the process is kept as brief as practicable. Seed wings can be separated from the seedlot by gently blowing air across the lot or separating with an aspirator or pneumatic separator.

C. Final cleaning. Final cleaning, or upgrading, is conducted to increase uniformity of germination rates by removing damaged or otherwise unviable seeds from the seedlot. Most methods separate seeds by weight, with methods commonly conducted with an aspirator or pneumatic separator or a gravity table. Each seedlot requires calibration of equipment settings as determined through examination of seeds by cut tests or x-ray tests. Other methods include Incubation-Drying-Separation (IDS) which involves imbibition of the seedlot followed by gradual drying and separation by specific gravity. General guidelines for final cleaning is to maximize purity of the seedlot.

Examination under x-ray during seed processing is a non-destructive method for calibration of settings on seed processing equipment and to determine progress through final cleaning. Small seedlots or seedlots of highly valuable seed can be cleaned using x-ray visualization to prevent damage caused by standard seed cleaning methods.

5.4. Seed Testing

Seed testing, or formal seed analysis, quantifies seedlot quality and allows the estimation of the number of potential seedlings from a quantity of seed. Extractories and seed processing facilities may be equipped to conduct seed testing or seed samples may be shipped to a separate lab. Seed testing rules have been established through the International Seed Testing Association (ISTA) as the International Seed Testing Rules and through the Association of Official Seed Analysts (AOSA) as the Rules for Testing Seeds. Additionally, propagation nurseries may have specific tests that are required or recommended prior to propagation. Common tests include moisture content, seed purity, seed weight, and germination.

A. Sampling. Sampling procedures for formal seed analysis ensure that the sample is representative of the entire seedlot. Guidelines are provided by the ISTA and AOSA on accepted procedures to draw a representative sample from a seedlot, with consideration to weight and number of containers of a seedlot. Species that do not have detailed sampling rules identified by the ISTA or AOSA should follow general guidelines, such as a working sample for purity analysis should be 2,500 seeds (based on weight of 100 counted seeds) or a working sample for conducting a germination test only is to be 400 seeds. Seed labs may provide additional guidance for sampling methodology and sample size. When testing includes analysis of moisture content, samples should be taken quickly and placed into a moisture-proof container.

B. Purity Analysis. The seed purity analysis identifies the composition of the seed lot as a function of the weight of pure seed and the weight of the seedlot with inert material and other seed contained within. ISTA has established a 3-part purity analysis (pure seed, other seed, inert material) whereas AOSA has established a 4-part purity analysis (pure seed, weed seed, other crop seed, inert material). Damaged seed is counted as pure seed during analysis if the damaged seed is more than one-half the size of the undamaged seed. Seedlots containing a high percentage of damaged seed may indicate high purity but low germination test results. Purity analysis that is lower than 98% can be considered for additional cleaning while also considering the scarcity of the seed. State seed laws may have additional testing requirements when seed is purchased commercially, such as noxious weed tests.

C. Seed weight. Seed weight is commonly expressed in grams per 1,000 pure seeds. ISTA standards are for eight replicate samples of 100 seeds each to be tested.

D. Moisture content. Seed moisture content is the percentage of moisture as measured by weight. Results of seed moisture tests should ensure that seed is in correct range for storage, typically 5-9% for orthodox species. Two methods, direct or indirect, can be used. The direct method, or oven drying method, is considered most accurate, however, oven drying is a destructive testing method that removes moisture from the seed. Indirect method, or using an electronic moisture meter, requires that calibration curves have been determined for the species. When calibration curves for a species have been determined, moisture meters are typically accurate within 1% of oven drying.

E. Germination tests. Germination tests determine germination capacity, or the quantity of seedlings that can be produced under optimal and controlled conditions. Analysis should include speed of germination and a count of germinants that are considered normal under AOSA guidelines. Germination tests typically consist of 4 replicates of 100 seed, however paired trials require a larger sample size. Germination protocols should be based on published methods for a particular species and be replicable, including pretreatments such as stratification or scarification and conditions such as light and temperature. Germination test results will be used by nurseries to determine sowing rates. Nurseries may have minimum germination percentages that they will accept for a seedlot or may not accept old test results. Typically, germination tests should be conducted no more than six to nine months prior to propagation.

Additional tests may be beneficial to interpret or supplement germination tests, especially in species that are known to have high dormancy or germination tests that were unusually low for upgraded seed lots. Embryo excision is useful in assessing viability in several species of pine trees that have high levels of dormancy or variable germination test results. Vigor tests, such as tetrazolium testing, indicate active respiration of the embryo. Tetrazolium test results can be used to indicate a reduction in seed vigor preceding a loss in germination capacity of a seedlot or be used instead of germination tests as a faster testing method. X-radiography (x-ray) tests are valuable in interpreting germination test results. X-ray tests are non-destructive and can be used to identify percent of filled seed, presence of insect larvae, or other abnormalities. Fungal assays may be required by some propagation nurseries, or testing for fungal pathogens may be beneficial if a select seedlot has had a history of fungal related issues in the nursery.

5.5. Retesting

Retesting of seedlots at regular intervals and prior to nursery propagation allows for identifying when loss of viability will impact the ability to meet reforestation objectives and allow for maximizing seedling production within the nursery. Annual testing of moisture levels with a moisture meter and retesting viability every three to five years is optimal. Some nurseries will require a germination test that is no more than 6 to 9 months old at time of propagation.

Section 6.4 “Removal of Seed from Storage” provides guidance on including retesting samples within the seedlot in long-term storage.

6. Long-term Seed Storage and Inventory Requirements

Managing and maintaining long-term seed storage enables access to a viable seed supply to meet reforestation need both for planned needs and for response to major disturbances. Seed storage can be categorized as short-term (temporary storage between the time of seed processing and nursey propagation the following season), long-term (seed storage necessary to maintain reliable supply of seed, accounting for cone crop periodicity), and ex situ germplasm conservation banking (cryogenic seed banking through The National Plant Germplasm System). Seed storage should be controlled to minimize deterioration of seed viability, with controls dependent on duration of storage and seed storage characteristics.

Seed quality at the time of storage initiation impacts storage longevity. Improper handling during any part of the process, overheating, or damage to the seed coat due to over-processing causes seeds to deteriorate more quickly and reduces longevity of seed viability in storage.

6.1. Seed Storage Considerations

Maintaining and managing seed viability in storage requires knowledge of the species' seed characteristics, seed quality before storage, seed moisture content, optimum storage temperature, and proper selection of storage container. Seed characteristics are available for most forestry tree species. Many species' information can be found in *The Woody Plant Seed Manual* (Bonner, 2008) and the *Seed Information Database* (Society for Ecological Restoration, 2023).

A. Seed Characteristics. Seed characteristics are classified as orthodox, recalcitrant, or intermediate. Similar to interim storage guidelines provided in Section 2.4, the knowledge of seed storage characteristics will guide the use of general guidelines for long-term seed storage.

   a. Orthodox seeds can be dried to moisture contents between 5-9% and stored at subfreezing temperatures. Seeds should be stored in airtight containers to prevent seeds from reabsorbing moisture from ambient conditions. Species specific standards for moisture content should be referenced in literature. Orthodox seeds can generally be stored for long periods of time without significant loss of viability, however immature seed, damage caused during handling and processing, and storage conditions can accelerate loss of viability. Orthodox seeds are further classified as true orthodox and sub-orthodox. True orthodox seeds are characterized by thicker seed coats and can exhibit very long viability under optimal conditions. Sub-orthodox seeds typically have thinner seed coats, higher fat content, and include species that have resin vesicles. Viability under optimal conditions for sub-orthodox species is generally around 15 years or less. Orthodox species stored in long-term storage should be stored at -18° to -20° C (0° to -4° F). Seeds stored for 3 years or less can be stored between 0° to 5° C (32° to 41° F)
   b. Recalcitrant seeds cannot be dried below 25-45% moisture content. Recalcitrant seeds are further identified as temperate or tropical recalcitrant. Temperate

recalcitrant can be stored near freezing temperatures (not below -3°C/26° F) whereas tropical recalcitrant are sensitive to low temperatures and longevity is usually in the order of months. Seeds should be stored in containers that reduce moisture loss while allowing for gas exchange. Moisture content levels must be maintained throughout storage and may require rewetting of seeds.

c. Intermediate seeds display storage characteristics and tolerances that range between the thresholds of orthodox and recalcitrant behaviors. Intermediate seeds can generally be dried to between 10-20% moisture content and should be stored at temperatures warmer than orthodox seeds. Intermediate storage behaviors may range in tolerance between sub-freezing temperatures to above freezing temperatures. Viability is generally 5 years or less.

B. Storage containers. Proper selection of a storage container considers the seed storage characteristics, seed quantity, and seed morphology.

a. Recalcitrant seeds must have gas exchange without loss of moisture and seed desiccation. Polyethylene bags with micro perforations are generally suitable for storage of recalcitrant seeds. Bag thickness should be greater than 3 mil but not exceed 10 mils. Storage of recalcitrant seeds should not be in containers made of high-density polyethylene (HDPE).

b. Orthodox seeds should be sealed in airtight, moisture-proof containers. Polyethylene bags, plastic containers, or fiberboard drums are all adequate storage vessels. Polyethylene bags should be heavy weight (no less than 6 mil). Polyethylene bags, if used alone, should be sealed and double bagged. Polyethylene bags can also be placed inside a fiberboard drum, cardboard box, or plastic bin.

C. Storage units and cooling equipment. Storage units and cooling equipment should have capacity sufficient for the volume of seed. Units should have a reliable power source as well as a back-up generator. Temperature alarms should indicate if temperature is outside of an acceptable range.

6.2. Seed Inventory Management

Seed longevity in storage is a product of seed maturity at time of collection, seed quality, seed morphology, genetics, pre-processing conditions, handling during processing, and long-term storage conditions. Seed deterioration will occur even under optimal storage conditions with seedlot exhibiting loss of vigor and subsequent loss of viability. Management of a seed inventory recognizes inevitable loss, monitors storage conditions, retests germination capacity on seedlot, and plans the use of seedlots prone to accelerated deterioration. General guidelines for retesting were provided in Section 5.5 “Retesting”. Inventory management also considers the minimum germination rates that a seedling nursery may accept. Managing inventories that have low germination capacity (i.e., 50% or less) could include planning for the use of pre-germination or germinant transplanting methods for propagation in order to maximize seedling quantities produced. Managing inventory also includes maintaining seedlot identity and proper labeling of seedlots to ensure proper seed source selection for appropriate planting locations. Bulking of seedlots from within on seed transfer zone to meet seed needs for nursery propagation is allowable, however, storage of non-bulked, individual seedlots allow for more flexibility in site selection.

6.3. Estimating Ten Year Seed Need

Offices with regular or episodic reforestation needs should estimate 10-year seed need which would be updated annually in the state office seed inventory record. The estimate should identify the appropriate seedlot for the planting site or identify the species, seed or breeding zone, and elevation band. The need may be informed by a resource management plan as well as consideration for needs arising from severe disturbances such as wildfire.

6.4. Seed Inventory Records

The maintenance and annual review of seed inventory records should be conducted by each BLM state office. The review should ensure an adequate seed inventory that represents species and genetic diversity and is adequate to respond to reforestation needs, including the potential for large-scale disturbances (refer to Chapter 2, "Seedlot Collection Planning"). Inventory records should be maintained from time of collection through planting.

Minimum data requirements of the seed inventory include source identification and seed test results. Specific data fields should include:

- Species – Scientific nomenclature should be used when identifying the species. The United States Department of Agriculture's NRCS PLANTS database should be used for all scientific names and species symbols (species code).
- State/District/Field Office code – Originating office of the collection should be identified.
- Date of collection.
- Source identification.
    a. GPS coordinates (Lat/Long) for natural stand collections or seed production areas.
    b. Seed Orchard location and Breeding Unit names for tree improvement program seed within seed orchards.
- Elevation/Elevation band.
- Balance of seed weight within storage.
- Seed weight (grams per 1,000 seeds or seeds per pound).
- Purity analysis.
- Moisture content.
- Germination rate.
- Germination test date.
- Germination test type.
- Storage location.

Additional data may be maintained within the inventory based on the needs of the state or program. Additional data considered for inclusion may include collection data such as collection method, bushels collected, cut face seed count, seed lot number used for identification within a storage facility, or seed transfer zone or breeding zone identification. Delineation of seed zone boundaries may change during the storage life of the seed; metadata should be kept when using seed transfer zones and breeding zones to identify the convention used.

6.5. Selling Excess Seed or Seedlings

The BLM may sell seed and seedlings determined to be in excess of the BLM's reforestation needs. Revenue from sales is retained by the BLM in subactivity L71220000, WBS LVTFHX292990 and available until expended. Funds can be expended by the office that generated the funds on seed and seedling production, as the priority, as well as other activities consistent with the subactivity that was used to produce the seed or seedlings that were sold consistent with 43 USC 1474e. Seed or seedling pricing should take into account market prices and consider production costs. An invoice with the seedlot or seedling information, quantity, unit price, and total cost should be provided to the buyer with instructions to submit payment to the BLM. Coordinate with the Central Billing System (CBS) collections officer for where the payment should be sent.

6.6. Removal of Seed from Storage

Proper handling of seed when removing from long-term storage conditions and introducing to ambient conditions is critical in maintaining viability of seedlot. Removing seed from storage may be temporary or permanent, such as removal of seed from storage for relocation to different storage facility, retesting seed, or sending whole or partial seedlots to production. Inventory records should be updated upon each incidence of removal, change of storage location, or balance deduction.

Planning for seed retesting at the time of packaging seed for long-term storage will minimize the risk associated to exposing the entire seedlot to ambient conditions when the retesting sample is collected. Subdividing testing samples and accessibly placing them inside of the airtight container at the commencement of long-term storage allows for only the testing sample to be brought to equilibrium with ambient temperatures at retesting intervals.

Removal of seeds for shipment to a new storage location or to propagation should consider controls against damage to seeds as a result of temperature fluctuations, moisture fluctuations, or physical damage. Shipment times should be as short as practicable. General guidelines for shipment of a seedlot of orthodox seed are to keep the seed dry and to pack the seed container in insulating material that will protect the seed from high or fluctuating temperatures. If shipping the entire seedlot, the airtight container should remain sealed prior to and during shipment. If the seedlot must be subdivided prior to shipment or opened during shipment, the container should remain closed until it has reached ambient temperature. If the potential for absorption of moisture is expected to have an effect on seed quality, silica gel packets or other desiccants can be placed inside container. The shipment container should be rigid and strong to protect from physical damage due to compression. Additional guidelines to protect against physical damage during shipment include double wrapping packages such as placing a sealed polyethylene bag inside a burlap bag and placing into a sturdy container. Shipment containers should be as full as possible to minimize free movement of seeds within container. General guidelines for the shipment of recalcitrant seeds include shipping in an unsealed container to reduce the potential for seed damage caused by overheating from cellular respiration. Recalcitrant seeds should be packaged with slightly moistened sphagnum moss, sawdust, or vermiculite to maintain moisture content. All seed shipped should be clearly labeled with seedlot identity information on each container within the package.

Glossary of Terms

-A-

Angiosperm. The phylum of vascular flowering plants that produce seeds enclosed in an ovary. This botanical group includes hardwoods.[1]

Assisted migration. Human movement of tree seed and seedlings from current locations to sites modeled to experience analogous environmental conditions in the future. Such moves may be latitudinal, longitudinal, or altitudinal, and are designed to reduce extinction risks for those species not able to naturally migrate, and to maintain forest productivity (Alfaro, R. I., et al. 2014).

-D-

Dioecious. A species having male and female flowers (or strobi) produced on separate plants.[1]

-E-

Epicormic. A shoot arising spontaneously from an adventitious or dormant bud on the stem or branch of a woody plant often following exposure to increased light levels or fire.[1]

Ex situ. Off the site; away from the natural habitat.[1]

Extractory. A facility for tree cone and seed processing.

-F-

Fertilization. The union of the nucleus and other cellular constituents of a male gamete (pollen) with those of a female gamete (ovum) to form a zygote from which may develop a new plant.[1]

Fruit. The seed-bearing organ of a flowering plant; a ripened ovary.[1]

-G-

Gametophyte. Gamete-producing phase or generation in trees that alternate haploid and diploid phases or generations.[1]

Genecological. The synthesis of genetics, ecology, taxonomy, and plant physiology for population differentiation and adaptation in plants.[1]

Genotype. An individual's hereditary (genetic) constitution.[1]

Germplasm. Within an individual or group, the collective hereditary materials that are the physical basis for inheritance; the hereditary stream.[1]

Gymnosperm. The group of vascular flowering plants that produce seeds not enclosed in an ovary (naked seeds). An important division is Coniferophyta, which contains most conifers. The pollen- and ovule-bearing structures are strobi but are often called flowers for convenience.[1]

-I-

Imperfect flower. Flower bearing only one sexual reproductive organ – either male or female.

In situ. On site; within the natural habitat.

-M-

Mast year. A year in which there is abundant production of seed.[1]

Megagametophyte. The female gametophyte.[1]

Monoecious. A population or species having functional male and female flowers (or strobi) in separate places on the same plant.[1]

-O-

Orthodox seed. Seeds which will survive drying and/or freezing during ex-situ processing and storage.

-P-

Perfect flower. Flower with both male and female reproductive structures.

Photoperiod. The period of time each day during which an organism receives illumination, day length.

Physiographic. Landform including surface geometry and underlying geologic material.[1]

Physiological. Pertaining to life processes and functions of organisms, their cells, tissues, and organs.[1]

Pitch exudation. Causes a viscous resin to form on a cone.

Pollination. Disposition of pollen on the receptive part of the female flower or strobilus.[1]

-R-

Recalcitrant seed. Seeds that do not survive drying and freezing during ex-situ processing and storage.

-S-

Seedlot. A collection of seeds usually of known origin.[1]

Seed-transfer system. Guidelines for the movement of seed source to manage risk of maladaptation for restoration and reforestation.[1]

Serotiny. Fruit or cones that remain on a tree without opening for one or more years; in some species cones open and seeds are shed when heat is provided by fire or hot and dry conditions.[1]

Strobili. A cone of a conifer. Pines are monoecious with male cones usually borne in the lower crown and female cones in the upper crown of the same tree.[1]

Sub-orthodox seed. Seed that can be stored under the same conditions as orthodox seeds, but for much shorter periods.

-V-

Viability. Capacity of a seed to germinate and develop under given conditions.

Vigor. Attribute that includes aging tolerance, seed dormancy, viability, rapid germination, and seedling establishment.

[1] Definitions are from or are adapted from the Dictionary of Forestry 2nd Edition. 2018. Ed. R. Deal. The Society of American Foresters. Bethesda, MD.

Appendix 1 – Seed Yield and Cone Collection Equations

1. Determining seed yield from average seed count per sampled cone:

$$Seed\ yield\ per\ bushel = \boldsymbol{average\ filled\ seed\ per\ cone} * \boldsymbol{average\ cones\ per\ bushel}$$

$$Seed\ yield\ per\ bushel\ (pounds) = \frac{\boldsymbol{average\ filled\ seed\ per\ cone} * \boldsymbol{average\ cones\ per\ bushel}}{\boldsymbol{average\ seeds/pound}}$$

When a factor is available to derive seeds per cone from cut face test, the following equations can be used to determine seed yield:

$$Seed\ yield\ per\ bushel = \boldsymbol{average\ filled\ seed\ per\ cut\ face} * \boldsymbol{species\ factor} * \boldsymbol{average\ cones\ per\ bushel}$$

$$Seed\ yield\ per\ bushel\ (pounds) = \frac{\boldsymbol{average\ filled\ seed\ per\ cone} * \boldsymbol{species\ factor} * \boldsymbol{average\ cones\ per\ bushel}}{\boldsymbol{average\ seeds/pound}}$$

When grams per 1,000 seed is available for local stand or collection, convert to seeds/pound:

$$Seeds\ per\ pound = \frac{\boldsymbol{1,000}}{\boldsymbol{grams\ per\ 1,000\ seed}} * \boldsymbol{453.592\ grams\ per\ pound}$$

2. Determining seed yield from within stand, using cone crop survey:

$$Yield\ per\ stand\ (bushels) = \frac{\boldsymbol{average\ cones\ per\ tree} * \boldsymbol{numberof\ collectable\ trees\ per\ acre} * \boldsymbol{number\ of\ acres\ in\ stand}}{\boldsymbol{average\ cones\ per\ bushel}}$$

3. Determining number of bushels per collectable tree necessary to meet collection targets:

$$Minimum\ bushels\ per\ tree\ to\ be\ collected = \frac{\boldsymbol{target\ pounds/seed\ yield\ per\ bushel\ (pounds)}}{\boldsymbol{number\ of\ collectable\ trees\ in\ stand}}$$