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Users Guide for Seeds of Western Trees and Shrubs

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Cover photo: Winged seeds of noble fir *(Abies procera* Rehd.) as they appear shortly before the mature cone shatters.

Abstract

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Because the role of tree and shrub seed is indispensable in the renewal of forests and ranges, their identity and quality are critically important. This guide briefly covers recommended practices for maintaining the identity of seeds, for sampling them, and for testing them for quality. Practices associated with the testing and use of tree seed have developed over many years, whereas those for shrub seed are just developing. Selected references, excerpts from official seed testing rules, addresses of seed testing laboratories, and sources of information for shrub seed are included.

Keywords: Seed (tree), seed (shrub), seed testing, seed quality.

Preface

This report is the second revision of a booklet describing sampling and testing procedures for seeds of native western species. It supersedes "Sampling and Service Testing Western Conifer Seeds" published by the Western Forest Tree Seed Council (1966). Previous material has been updated, and selected information has been added on shrub seed, on labeling, and on seed certification. Geographic coverage has been broadened. The authors served as the Seed Testing Subcommittee of the Western Forest and Range Seed Council responsible for this revision.

The Western Forest and Range Seed Council, affiliated with the Western Forestry and Conservation Association, is a voluntary organization whose members share a common interest in tree and shrub seed. Its geographic areas of concern are the 11 westernmost States and British Columbia. The Council's interests were redefined in 1982 to encompass seeds of all forest and range species. Before then, its emphasis was on forest tree seed under the title Western Forest Tree Seed Council.

Pertinent sections of the "Rules for Testing Seeds," published by the Association of Official Seed Analysts in 1981 (with revisions through 1984), are reproduced with permission in appendix 3.

Contents

Introduction

Large quantities of tree and shrub seed are collected, stored, and sown in the West or are exported. Because their role is vital in the renewal of forests and ranges, the identity and quality of tree and shrub seed are critically important. Procedures have been developed for maintaining the identity of seeds, and workable methods have been prescribed for testing the quality of most species.

The state of the art is described in this booklet for anyone who buys, sells, or uses seeds of western trees or shrubs. Recommended practices for maintaining the identity of seeds, for sampling them, and for testing their quality are covered briefly. Actual collection techniques or detailed procedures related to certification of seed are not covered. An overview is intended; greater detail can be obtained from seed specialists, from sources cited in the text or included in the selected references, and from organizations listed in the appendixes.

Practices associated with the collection, processing, testing, and use of western tree seed, especially conifers, have developed over many years, whereas those for shrub seed are just developing. Consequently, the level of information available differs substantially. Information is presented jointly for tree and shrub seed when possible, but when necessary, applicability to shrub seed is described separately.

Seed Identity

Large amounts of tree and shrub seed are collected from native wild stands; smaller amounts are collected from genetically improved or tested stands. Correct and adequate identification of seed must start at the collection site and is critically important for seeds collected from any source. It has been demonstrated repeatedly that production of healthy new stands requires use of seed or stock adapted to the site. Maintaining the identity of its source is an essential step in correctly matching seed or stock to site.

Adequate identification of seed requires: (1) correct botanical identification by species and variety, (2) location and elevation of collection area, (3) native origin of the plants that produced the seed, and (4) information available on verified genetic traits. Identification and labeling of a, seed lot must begin with a knowledgeable collector recording pertinent information. Because seed origin and genetic traits are so critically important, formal procedures are often used to certify that the information on the label is accurate.

Labeling Seed

Each container of fruits, cones, or seeds collected in the field should be adequately labeled (fig. 1). As a minimum, the label should indicate the species (and variety, if known), the precise geographic location of the collection, the elevation, the date of collection, and the signature of the collector. Additional information on the label or accompanying the collection may include the State, county, seed zone, soil type, number and description-of seed parents, and any special features. Notes on cone maturity, insect damage, or possible poor pollination can also contribute to better understanding and to better processing of a particular seed lot. A durable, legible label should be firmly attached to the outside of each container to insure continuous identity of its contents. An identical label may be placed inside the container if damage to or loss of the outside label seems likely.

Integrity of each collection must be maintained in the field, throughout transport and processing, and during storage and use. This requires physically keeping track of the collection, step by step; preventing its contamination during processing by seeds of other lots; and keeping accurate records of lot description, size, and disposition.

Figure 1.—Identification of seed must start at the collection site and is critically important for seed from any source.

Seed Collection Zones

Collection zones have proved useful for describing origin of seeds from native stands. Labeling a seed collection by its exact origin is most precise, but such information does not indicate which collections are from similar origins. Delineation of forested areas into zones judged to contain environmentally similar conditions serves this need until supplanted by information from actual studies.

Collection zones for tree seed have been recognized for a decade or more in Arizona, British Columbia, California, New Mexico, Oregon, and Washington (Rudolf 1974), and more recently in Colorado and Wyoming. The zones have been delineated on different bases and have been used to varying extents. If used consistently, they will become more valuable as experience accumulates on performance of seeds from different zones. Seed zone maps for Oregon and Washington are on a common basis; they have been used extensively and will serve as an example (fig. 2). Zone boundaries in Oregon and Washington delineate areas that were considered physiographically and climatically different. Single digits of a three-digit number code designate first the broad geographic zone, then the smaller geographic zone within the broad zone, and third, a local zone. Two digits are added to identify elevation within a zone in 500-foot (150-m) increments. Seed zone maps are improved and revised periodically. Contact the certifying agency in your State or Province for current information on tree seed zone maps.

Origin of genetically improved tree seed is commonly described by its exact parentage, or more broadly, by breeding zones. A breeding zone is the geographic area represented by the parents of progeny in a seed orchard. Seed produced by fertilization that occurs within the orchard represents the geographic area or breeding zone. As information on genetic variation accumulates, both seed zones and breeding zones may eventually be replaced with more precise delineations based on genetic variation or on guidelines for seed movement.

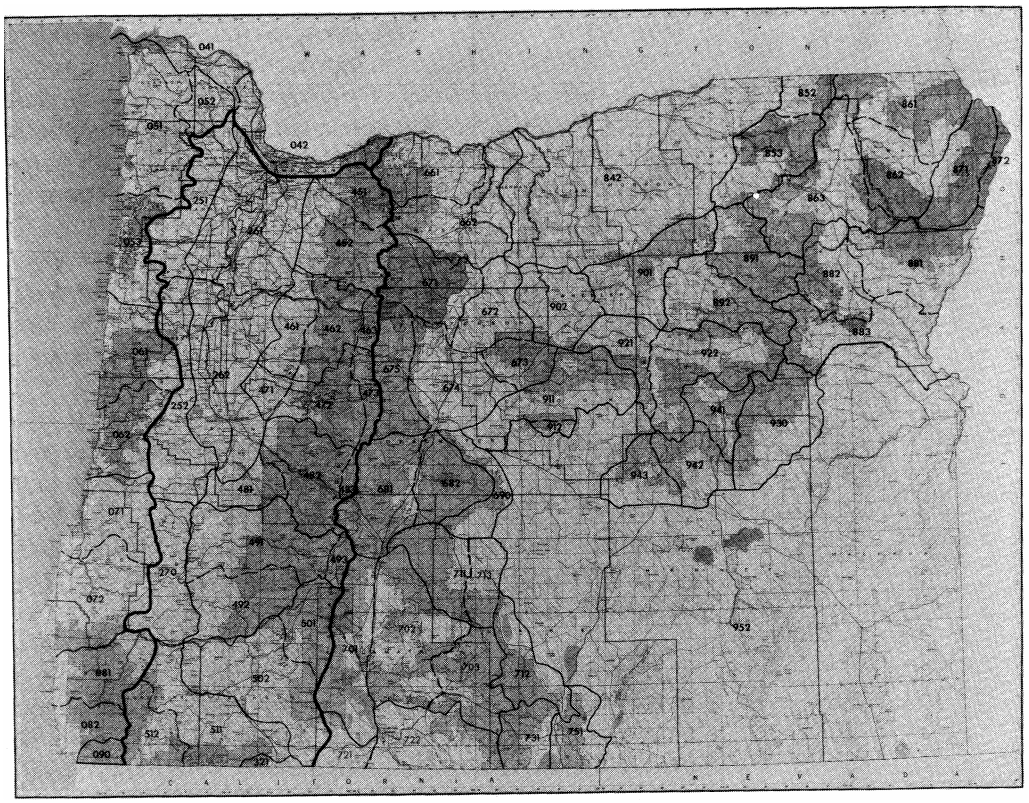

Figure 2. —Seed collection zones for Oregon.

Collection zones have not yet been delineated for shrub seed, but the need to delineate limits for the transfer of shrub seed has been recognized. Preliminary guidelines on adaptability and transfer have been developed for selected shrub populations in the intermountain region from results of field planting trials. Up-to-date information on adaptability and other traits of shrub species is obtainable from many USDA Forest Service and Soil Conservation Service offices, from other Federal and State agencies, and from universities (see appendix 1, p. 24).

Certification

Formal certification of tree or shrub seed involves independent verification of the information appearing on a seed label. The verified information may include the species and variety, the geographic origin and elevation, the male and female parentage, and sometimes the test results from progeny or clones. Before such information can be certified, actual inspection of seed collection, of processing methods and of record keeping are necessary, as well as audits of the seed lot at various steps in processing and storage.

Certification of tree seed was formalized in Oregon and Washington in 1966 when the Northwest Forest Tree Seed Certifiers Association was formed with the assistance of the Western Forest Tree Seed Council (Hopkins 1968, Stein 1975). In subsequent organizational steps, actual verification work became the responsibility of each State's agricultural seed certification agency. Tree seed certification is now relied on heavily in Oregon and Washington-more than 1 million pounds (453 592 kg) of seed representing 17,743 lots of 26 tree species were certified in the various designated classes by 1983.

Tree seed in Oregon and Washington may be certified as meeting the standards for one of six classes. The classes represent increasing degrees of certainty about the origin and genetic composition of the seed, varying from an audit class (a verification of records showing that the seeds were collected from the stated origin), to procedural or field verification of origin, to selection of one or both parents, or to selected parents whose progeny have been tested and evaluated for genetic improvement (DeYoe 1984).

Certification of tree seed is gaining attention in other Western States and in British Columbia. California and New Mexico have adopted standards very similar to those in the Pacific Northwest. Organizational activity is under way in several other States. Requests for certification of other reproductive materials such as "plus" trees, scions, nursery stock, and plantations are also increasing.

Arrangements have been made for certifying origin of shrub seed in New Mexico and both origin and quality in Colorado. Efforts to develop uniform shrub certification services in the Western States are under way. It has been proposed that four types of shrub populations eventually be recognized: (1) nonselected populations, (2) selected populations, (3) managed populations, and (4) shrub seed orchards from selected parents or named varieties.

Extensive programs for the genetic improvement of tree populations have been underway for years; programs for the improvement of shrub populations are much smaller, but they are expanding. Shrub populations are being tested for desirable characteristics and range of adaptation. A few shrub cultivars have been identified and released for commercial seed production (U.S. Department of Agriculture, Soil Conservation Service 1984). Information on the status of tree or shrub improvement programs is primarily available from such organizations as the Industrial Forestry Association, Inland Empire Tree Improvement Cooperative, State Agricultural Experiment Stations and Extension Services, USDA Forest Service Experiment Stations, and USDA Soil Conservation Service Offices.

State certification agencies certify tree and shrub seed for export under regulations of the Organization for Economic Cooperation and Development (OECD Scheme) to the European Economic Community (EEC) and to other participating countries. In Canada, tree seed is certified under the OECD Scheme by designated units of the Canadian Forestry Service (Piesch and Stevenson 1976).

Sampling Seed

An objective assessment of quality is needed to guide the storage, selling, buying, and use of seed. Quality of seed is determined for a limited sample drawn from the entire lot. There are recommended practices for defining the seed lot, for drawing a representative sample, and for testing the sample of seeds for germination and other quality attributes.

The Seed Lot

A seed lot is generally defined as a quantity of seed from a particular location and elevation (fig. 3). It usually constitutes the total yield from a particular cone or fruit collection transported from the field in bags or containers. Yearly collections of seed from the same location and elevation are usually handled as separate lots. Any lot or portion thereof destined for a specific transaction or use may become a specific entity to be tested for quality.

Figure 3. —A seed lot usually consists of the yearly collection of seed from a particular location and elevation or stand.

Yield of seed from one collection may be stored in a single container, or it may consist of hundreds or thousands of pounds stored in a number of bags or containers. There are no prescribed limits for size of a seed collection; however, the larger the amount, the more difficult it may be to obtain a representative sample. Thus, some practical. upper limits have been specified in international and domestic testing conventions (Bonner 1974). In the Pacific Northwest, collections of tree seed that exceed 500 pounds (227 kg) have generally been divided into approximately equal smaller lots. For example, 700 pounds (318 kg) would be sampled as two lots of approximately 350 pounds (159 kg) each. Limits based on similar practical considerations could be used for shrub seed.

The Sample

A small portion of a seed lot, a sample, is obtained and forwarded to a testing laboratory for specified quality determinations. It is critically important that the sample taken be representative of the entire seed lot because laboratory test results indicate only the quality of the submitted sample. If the sample is representative, the quality determined for the sample accurately reflects the quality of the entire lot.

Drawing a representative sample from a seed lot would be a simple matter if the lot were fully homogenous; any portion of the lot would then constitute a representative sample. Rarely, however, is it certain that a lot is completely homogenous. Consequently, the sampling method must produce a representative sample from a unit of seed assumed to be heterogenous.

A representative sample is obtained by combining portions taken from throughout the seed lot (Association of Official Seed Analysts 1981). It is recommended practice to take equal portions (subsamples) from each bag or container sampled. If bags or containers are of unequal size or fullness, the amount taken from each should be in proportion to its content. If the seed lot is in one to six bags or containers, everyone is to be sampled. When there are more than six bags or containers, five should be sampled plus at least 10 percent of the number in the lot, but not more than 30, all designated at random. A bulk seed lot should be sampled to the same intensity as a lot in bags or containers. If a seed lot is packaged in many small packets, entire packets may be used as subsamples.

Subsamples drawn from the seed lot are combined into one composite sample unless a subsample differs distinctly in appearance from other subsamples. If such a nonuniform subsample is found, its source is tagged and the subsample is kept separate but is submitted to the seed laboratory with the rest of the sample.

If the composite sample contains substantially more seeds than are needed, it may be divided. Use of a proven mechanical halving device is recommended because it is critically important to achieve an unbiased subdivision of the sample. No impurities—rocks, stems, damaged seeds, weed seeds, and so forth—are to be removed! It is mandatory that the composite sample, or any subdivided portion, continue to be truly representative of the seed lot sampled.

Sampling Mechanics

Bags or containers of free-flowing seed are generally sampled with a partitioned probe or trier (fig. 4). The tool should be long enough that seeds can be drawn from all depths within the container. The probe or trier should be inserted closed, then opened so its slots admit seeds simultaneously from different positions in the container. If a container is sampled by one probe thrust only, a diagonal path is recommended. If probed more than once, successive thrusts should be along different paths.

Seeds that are not free flowing, such as cedars, true firs, and various shrub species are usually sampled by hand. The hand, open and with the fingers held closely together, is inserted into the seeds, closed, and withdrawn holding a representative subsample. Handfuls of seeds are drawn from well-separated points within each container sampled, giving due attention to proportional sampling.

Seed lots too small for sampling with a trier or by hand can be sampled by systematically dividing the lot itself. Several kinds of mechanical dividers are available; the most widely used ones in the United States are the Gamet Precision and Boermer dividers (fig. 5).[1/] Other sampling techniques for small lots include "random cups," "spoon," and "modified halving" (International Seed Testing Association 1976b).

Sample Size

The size of the sample to be submitted for testing depends on the number and type of tests desired. A germination test requires a minimum of 600 seeds; about 2,500 are required for a complete analysis for purity, germination, and weight per thousand seeds (Association of Official Seed Analysts 1981). When additional or special tests are requested, the sample submitted must be suitably larger. Also, if purity or viability is low, or any other condition that might necessitate retesting is suspected, the submitted sample should be at least double the minimum size. A generous sample permits the seed laboratory to use mechanical dividers to obtain the working sample.

One to two ounces (28 to 56 g) of seed are required for moisture determination. The size of sample needed increases for species with larger seeds. This sample must be submitted separately in a moisture-proof container.

[1/] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

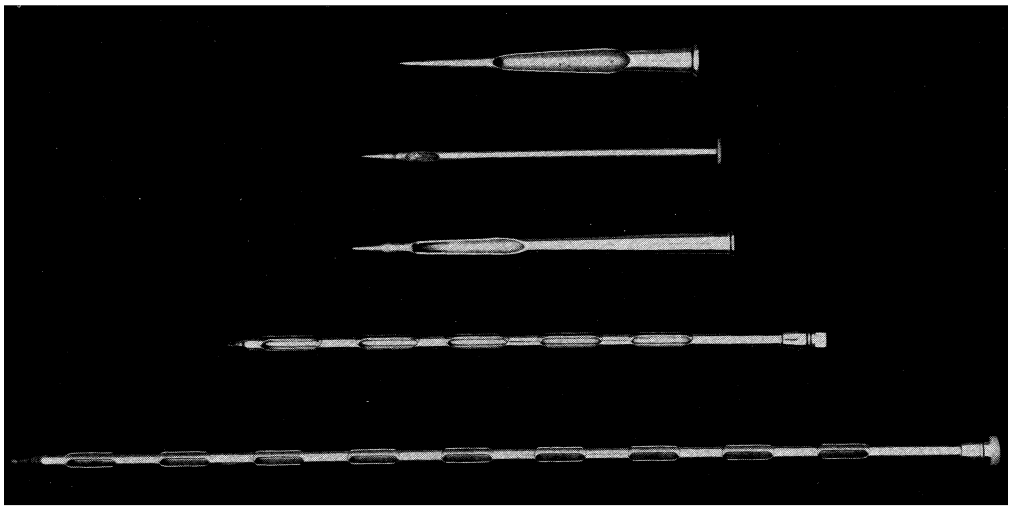

Figure 4.—Probes or triers of appropriate length are used to sample free-flowing seeds in bags or containers.

Figure 5. —Mechanical dividers can be used to sample a small lot or to split an oversize sample.

Directions provided by the seed testing laboratory usually include the number of seeds required for any special test. Estimated weight of seeds for the number required can be determined from table 1 in appendix 3 (p. 28); can be calculated from data in. Agriculture Handbook 450 (Schopmeyer 1974); or can be determined from a sample of the seed itself. Number of seeds per unit weight varies by purity, moisture content, source, collection year, and other factors.

Care of Seed

Tree and shrub seed are perishable biological materials. From the time of collection, seeds must be handled, processed, stored, and used under reasonable environmental and physical conditions, or they may quickly lose viability. Seeds of individual species vary greatly in physical structure, strength of outer coat, and the environmental extremes they can withstand. Information on characteristics of many species and specifics for handling each can be found in Agriculture Handbook 450 (Schopmeyer 1974) or in other sources (Eddleman 1977, 1980; Heit 1970, 1971; Plummer and others 1968; Stevens and others 1981; Swingle 1939; Vories 1981; Wasser 1982).

Viability of most western tree and shrub seed can be maintained while they are shipped and prepared for testing if the sample is handled gently, if favorable moisture conditions are maintained, and if exposure to extreme temperatures is avoided. A good estimate of quality can be obtained only if both the seed lot and the sample drawn from it are given suitable care during the testing period. Thus, ongoing handling and storage practices should be maintained for the entire seed lot while the sample from it is being tested.

It is best but not always possible to draw and package a sample of seed under storage conditions. If seed is in cold storage and is not in moisture-proof containers, samples for moisture determination must be drawn, packaged, and sealed under the storage conditions. Otherwise, moisture will condense on the cold seeds when they are exposed to warmer air, increasing their weight and their apparent moisture content. Seed in moisture-proof containers may be removed from storage and allowed to equilibrate to room temperature before the containers are opened and a sample is taken for moisture determination.

Submitting Samples

Seed samples should be carefully labeled, adequately packaged, and immediately forwarded to the testing laboratory. A plastic bag or a closely woven cloth bag makes a suitable inside container which should be enclosed in a strong rigid container for shipment. The bag of seeds should be snugly packed in the shipping container to prevent free movement of individual seeds. Samples for moisture determination or any samples of seed requiring high moisture content should be sent in full or nearly full moisture-proof containers. Metal cans with grooved friction lids or sealable plastic bags 5 mil or more in thickness make satisfactory moisture-proof containers.

Each sample shipped should be carefully labeled with the sender's name and seed lot identification. One copy of this information should be included in the shipping container. It is good practice to send another copy, including test instructions, independent of the seed shipment. Some laboratories furnish forms on which the customer designates tests desired and records pertinent information about the seed lot.

If the sample contains treated seeds, appropriate precautionary information should be prominently displayed on a separate label. The information should include name of the chemical, harmfulness of the residue and date of treatment. A strong plastic bag should enclose whatever bag or packet holds the sample of treated seeds.

Seed samples will be checked for quantity, condition, and instructions when they are received by the testing laboratory. If containers were broken or torn in shipment, resulting in damaged seeds or intermixed samples, replacement samples will be requested. If the submitted sample does not contain sufficient seeds for the tests requested, it will be held in storage long enough to permit the sender to supply additional seeds or new instructions. Unused portions *of* submitted samples are usually held in nonrefrigerated storage for 6 to 36 months. If such storage is suitable for the species, the samples could be retested, if necessary; otherwise, the seed lot would have to be resampled.

Seed Testing

The primary purpose for testing seeds is to determine their quality. The elements of seed quality measured most often are purity, germination or viability, moisture content, weight per thousand, and attributes revealed by X-ray.

Rules for Testing Seeds

Procedures for testing various kinds of seed, including tree and shrub seed, are described in two publications. "Rules for Testing Seeds," published in 1981 by the Association of Official Seed Analysts (AOSA), is the primary reference used by seed analysts throughout the United States and Canada. These rules are revised periodically to include new species and procedures. The rules promote uniformity in testing so that seed quality as determined by different laboratories will be comparable. "International Rules for Seed Testing," published in 1976 by the International Seed Testing Association (ISTA), is used by seed analysts in many foreign countries. AOSA and ISTA rules are similar, but there are certain differences. A shipper may choose to request an ISTA test so that a foreign buyer will more readily accept the test. Most laboratories can perform either AOSA or ISTA tests.

Sections of the AOSA rules pertaining to tree and shrub seed are in appendix 3. These excerpts are for the readers' information and convenient reference. Persons specializing in seed testing should obtain the complete AOSA rules. Contact your nearest State seed testing laboratory (appendix 2) for up-to-date information on AOSA and ISTA rules. Some, but not all, State laboratories test tree and shrub seed.

Purity

Purity expresses the composition of a seed lot and its degree of contamination by unwanted components. A purity test involves the mechanical separation of a working sample into (1) pure seed, (2) other crop seed, (3) weed seed, and (4) inert matter (fig. 6). The four components are then weighed and percentages are calculated on the basis of the original weight if the working sample weighed 25 grams or more, or on the sum of the weights of component parts if the working sample weighed less than 25 grams (appendix 3, section 2.5).

The size of the sample to be analyzed for purity varies with species; as a general rule, approximately 2,500 seeds (or their equivalent weight) should be examined (appendix 3, sections 2.3 to 2.4).

The component "other crop seed" includes seeds of species normally grown for crops that occur in amounts of 5 percent or less. When another crop seed occurs in amounts greater than 5 percent, the sample is referred to as a mixture and that other crop seed becomes part of the mixture. Inert matter includes soil, plant parts, and certain types of damaged seeds. Refer to appendix 3, sections 2.7 to 2.10, for detailed definitions of the four purity components.

Figure 6. —In a purity analysis, the working sample is divided into component parts-pure seed, other crop seed, weed seed, and inert matter.

Before the purity test is made, the submitted sample must be repeatedly mixed and then properly divided to obtain a representative subsample (working sample) of appropriate size. Such efforts insure that the purity test will reflect the true composition of the submitted sample.

Germination

A germination test determines the capability of a seed lot to produce normal seedlings under favorable, controlled conditions. It involves a minimum of 400 seeds selected at random from the pure seed fraction after seeds of other crops, weed seeds, and inert matter have been removed. The 400 seeds are usually tested in units of 50 or 100 seeds each (fig. 7). Often, a paired test is made so that the user can evaluate seed performance with and without prechilling. When paired tests are run, it is common to germinate either 200 or 400 seeds without prechilling and 200 or 400 after prechilling.

Not every seed that germinates is included in the germination count; only those defined as normal by seed testing rules comprise the germination percent (fig. 8). Albino seedlings and various other abnormal germinants are not counted (appendix 3, section 4.5, and appendix I of the testing rules). Percent germination is calculated for each replicate by this formula:

$$\text{Percent germination} = \frac{\text{number of normal seedlings}}{\text{number of seeds sown}} \times 100.$$

The average for the replicates tested is reported as the germination percent for the sample.

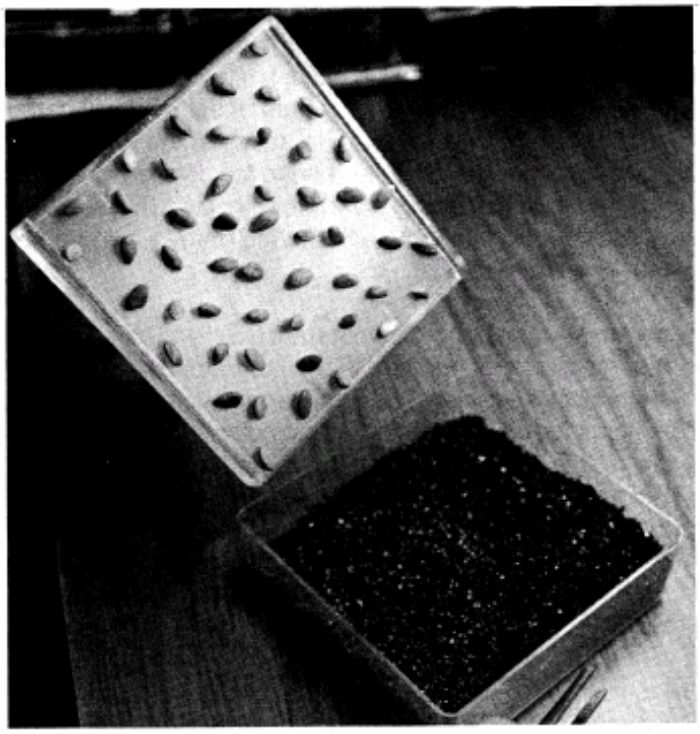

Figure 7. —A vacuum plate is used to place seeds in a germination dish.

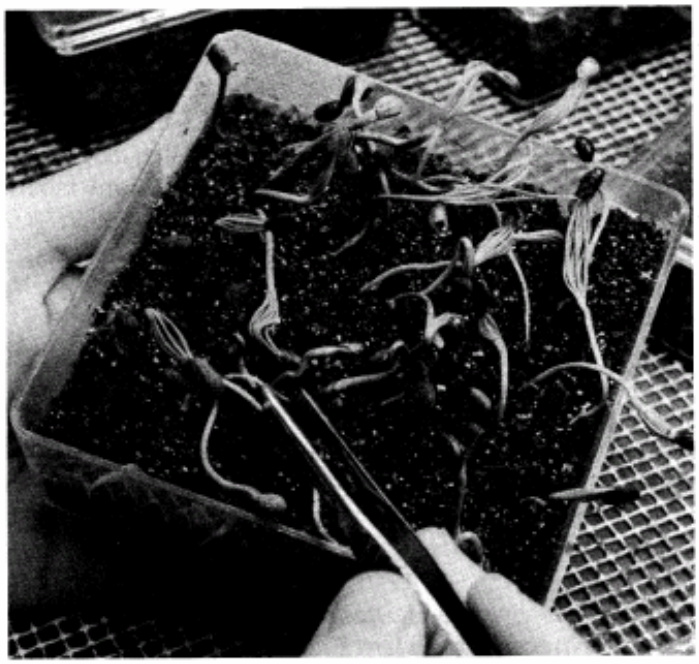

Figure 8. —A germination test determines capability of a seed lot to produce normal seedlings under favorable, controlled conditions.

If firm ungerminated seeds remain at the end of the prescribed test period, their presence is reported. Seeds remaining intact are cut with a razor blade or otherwise tested for viability; those with solid, white kernels and normal structure are considered firm. Firm seeds are usually dormant; if so, they will germinate when their dormancy is overcome. Large numbers of firm seeds at the end of the germination test indicate to the user that a longer prechilling period, a different pretreatment, or different germination conditions may be necessary for the seed lot Persons evaluating germination results may consider adding firm seeds to the germination percent in assessing the total potential viability of a lot

Speed of germination is an important quality to consider when seedlings are to be raised in a nursery or greenhouse. Many laboratories report weekly counts so that their customers can evaluate speed of germination. If you wish to find the recommended test conditions for germination of a particular species, refer to appendix 3, sections 4.9 and 4.12. Locate the kind of seed, then read from left to right to determine substrata, germination temperature, length of germination test, and additional directions such as length of chill, light requirements, and so forth. For species not yet included in AOSA rules, helpful information may be found in Agriculture Handbook 450 (Schopmeyer 1974); in publications by Eddleman (1980), Tiedemann and others (1984), Vories (1981), Wasser (1982); or by contacting local seed laboratories.

Quick Viability Tests

Seed viability or germination potential can be quickly estimated by several methods. Such methods, used when there is not enough time for a germination test, are often referred to as "quick" tests. Quick tests can be classed as chemical, growth, and appearance tests. The concepts, procedures, and utility of the main ones have been summarized by Danielson (1972).

Tetrazolium or TZ test. —The most popular chemical viability test is the tetrazolium or TZ test, in which live tissues stain red (fig. 9). It is one of the most rapid quick tests, requiring 24 to 48 hours to complete. The TZ test is particularly useful for determining viability of very dormant seeds that would otherwise require months of chilling or other lengthy pretreatment to overcome dormancy. Many laboratories routinely conduct TZ tests "in-house" on samples showing low germination to verify germination test results. The TZ test enables them to evaluate the causes for low germination such as dormancy, dead or dying tissues, empty seeds, presprouting, mechanical injury, and inadequate germination test procedures.

There is evidence that the TZ test provides an equal or even a better estimate of viability for some species than the standard germination test does. Hardin (1981) compared TZ and germination test results for seeds of several trees and bitterbrush and reported excellent correlations except for *Abies.* Viability of *Abies* species as indicated by TZ test is often higher than indicated by germination test In some instances, emergence in the nursery has been closer to TZ than to germination test results.

Tetrazolium-testing procedures for tree and shrub seed have not yet been standardized on a national or regional level. Experience has shown that small variations in technique may have a significant impact on results. For example, when the Oregon State University Seed Laboratory changed from making a slice across the cotyledon end of conifer seeds to a vertical slice that exposed more megagametophyte tissue, TZ penetrated more uniformly and results were more reliable and reproducible. Procedures for TZ testing of agricultural seed are given by Grabe (1970); techniques for conifers and shrubs are obtainable from some seed testing laboratories and at workshops.

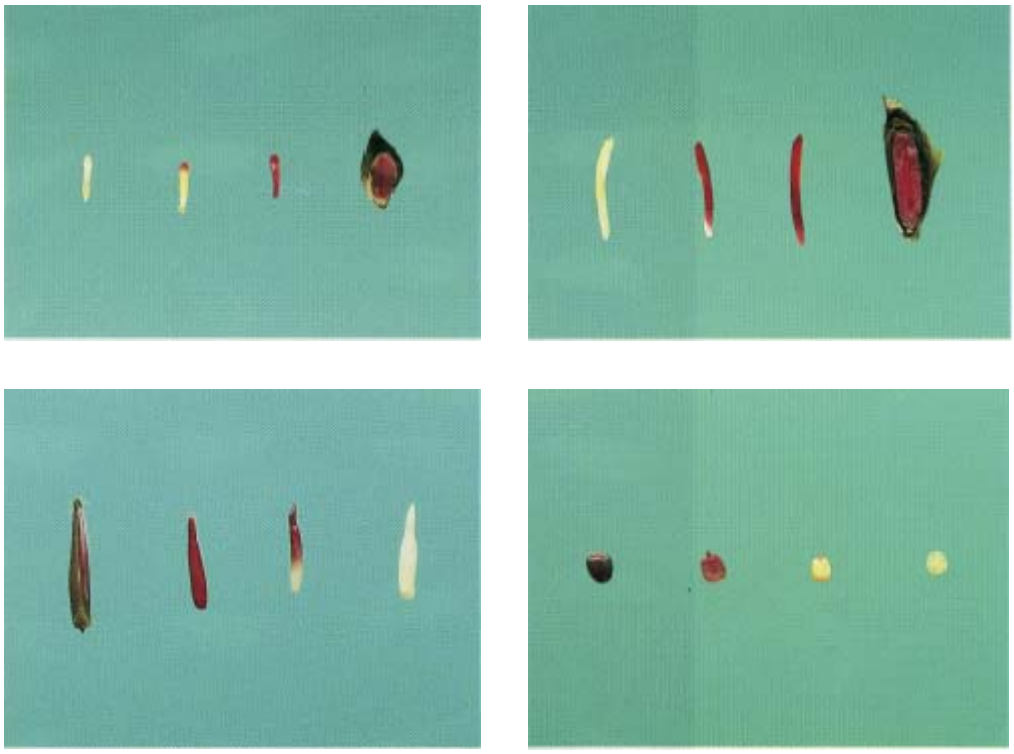

Figure 9.—Through metabolic processes, living tissue exposed to a colorless tetrazolium solution stains red, permitting identification of fully healthy endosperms and embryos, and those that are not alive or have various amounts of dead tissue. Views of Douglas-fir (A), noble fir (B), cliffrose (C), and ceanothus (D) treated with TZ show, right to left, a seed sliced open, a healthy embryo, a partly living embryo, and a dead embryo.

X-ray test.—Many aspects of quality can be evaluated from X-ray pictures of seed (fig. 10). Information obtainable simply from appearance includes (1) structure and development of individual seeds, (2) full and empty seeds, (3) insect-infested seeds, and (4) seed coat and internal mechanical injuries. When used to determine filled and empty seeds, X-ray is much more accurate than the older "cut" test.

European analysts determine seed viability with X-ray by use of such contrast agents as barium chloride and sodium iodide. Use of contrast agents is also gaining popularity in the United States. The technique is based on differential absorption. Nonviable seed tissue soaked in a contrast agent is more absorbant than viable tissue, making possible differentiation between the two on X-ray film. Damage arising from bruises, insects, and other reasons can also be detected. An excellent reference on radiographic analysis of agricultural and tree seed has been published by the Association of Official Seed Analysts (Belcher and Vozzo 1979).

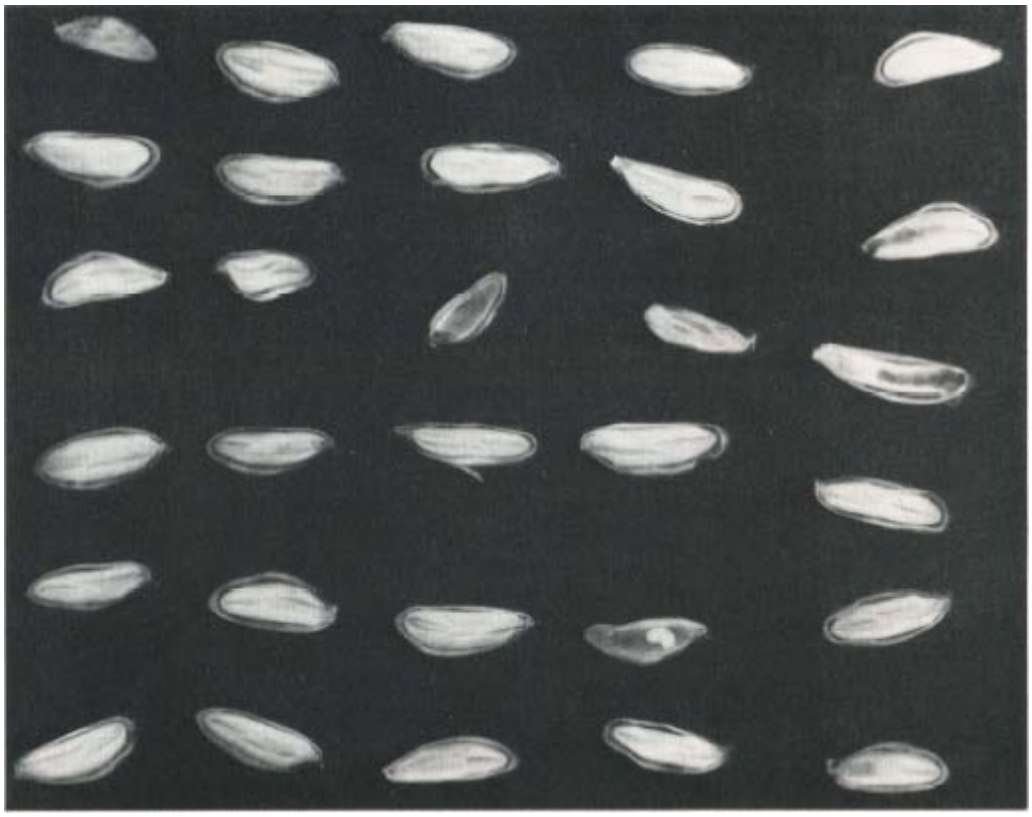

Figure 10. —characteristics of individual seeds can be determined nondestructively by X-ray, as is illustrated by these Shasta red fir seeds: column 5 (on the right), top to bottom-embryos of the second, third, fourth, and sixth seeds are partly consumed by insect larvae; column 4, fifth seed-kernel entirely consumed by insect larva; column 1 (first seed), column 3 (third seed), and column 4 (third seed)-hollow seeds; column 2, third seed-seed misshapen, contents appear shriveled.

Hydrogen peroxide test.—The hydrogen peroxide test (H_2O_2) is classed as a growth test because there is root growth during the test period. For this reason, it is preferred by some over the TZ test. It is also less expensive than the TZ test because it requires less work. Seeds are placed in dilute hydrogen peroxide after removing enough of the radicle end of the seed to expose the tip of the root. During the ensuing 5- to 8-day soak period, viable seeds react by elongation of their roots. Ching and Parker (1958) described the basic procedures.

Excised embryo test.—The excised embryo test is also a growth test and is preferred by some because it involves no chemicals and relies strictly on a critical evaluation of the embryo. Basically, embryos are removed from seeds and are incubated under favorable temperature and light conditions. Greening and growth indicate embryo viability. Testing the viability by means of excised embryos requires substantial skill and closely controlled growth conditions. Heit's (1955) paper is a good basic reference.

Cut test. —In some circumstances, a cut test is useful for very roughly estimating seed quality. A number of seeds are cut in half lengthwise with a sharp knife or razor blade and the percentage that have full, firm, whitish endosperm is determined. The relative size of the embryo can also be observed. The cut test is often used as an immediate check of seed quality in the field or during various steps in processing. It indicates what percentage of the seeds are filled or have normal embryos, but actual viability remains unknown.

Other Quality Tests

Seed moisture content. —Moisture content is one of the most important factors influencing seed viability. For many species, high moisture during storage results in rapid loss of seed viability. Moisture content of most conifer seeds should be 9 percent or less prior to storage; 5 to 7 percent appears best (Danielson and Grabe 1973, Wang 1974).

Seed moisture content can be measured by several methods. The ovendry method is one of the most accurate; seeds are dried in an oven after their wet weight has been determined. In 24 to,48 hours at temperatures near 85 °C, water within the seeds is driven off. The seeds are then cooled in a desiccator and reweighed. The difference between the two weights is the weight of water lost. Moisture content is calculated by substituting weight values in the formula:

$$\text{Percent seed moisture} = \frac{\text{weight of water lost, grams}}{\text{original wet weight, grams}} \times 100.$$

Note that seed moisture content is calculated on the basis of the original wet weight of the seeds rather than on their dry weight, as is used in determining moisture content of soils.

A variety of meters are available for determining seed moisture content. They provide rapid estimates, but many are not calibrated for tree or shrub seed. It is advisable to compare meter readings with ovendry results to check the meter and, if necessary, to calibrate it.

For accurate determination of seed moisture content, loss of moisture must be avoided prior to the initial weighing. Care in handling and packaging has already been emphasized; prompt weighing of seed after the sealed package has been opened is also mandatory. Seeds of certain species contain volatile oils and resins. ISTA rules prescribe special procedures for determining moisture content of such species. Consult a seed testing laboratory for the specifics of special moisture tests.

Seed weight. —Information on weight of seed is most useful for calculating sowing densities. Weight is often expressed per 1,000 pure seeds. From weight per thousand, the number of seeds per pound or per kilogram can readily be calculated. For example, if the weight of 1,000 pure seeds is 12.50 grams, the number of pure seeds per pound can be calculated by the ratio:

$$\frac{\text{Number of seeds per lb}}{453.59 \text{ grams}} = \frac{1{,}000 \text{ seeds}}{12.50 \text{ grams}};$$

$$\text{number of seeds per lb} = \frac{1{,}000 \times 453.59}{12.50};$$

$$\text{number of seeds per lb} = 36{,}287.$$

Seed Commerce

The market value of seed is directly affected by results of purity and germination or viability tests. Other factors, such as scarcity, certification class, quantity, and special processing may also influence the value of a seed lot. Because germination or viability test results are only estimates of the seedling potential for a lot, some interpretation of test results is usually necessary. Practices commonly accepted in seed transactions are described briefly below.

Interpreting Test Results

Because dormancy varies among lots, seeds of some species are often tested for germination both with and without prechilling. Generally, the highest value obtained in such dual tests is accepted as indicative of the germination potential for the seed lot. Test results that reflect full viability of the lot, such as tetrazolium staining and excised embryo, may indicate higher potential than is indicated by germination test because the latter excludes dormant seeds and abnormal seedlings. Results of cut tests also tend to be higher than germination tests because they determine if healthy appearing endosperm and embryo are present, but not actual viability or germination potential. Neither viability nor germination test results indicate precisely how a seed lot will perform under various field conditions, but results of laboratory germination tests have generally been c9nsidered the best indicator. Rapid viability and X-ray tests are becoming more reliable, and when they are properly performed and evaluated, results may deserve equal consideration with those of germination tests (Hardin 1981).

Firm ungerminated seeds often remain after completion of a standard germination test. Testing laboratories report separately the percent germination and the percent firm ungerminated seeds. It is possible that firm ungerminated seeds would have germinated if given more time, longer prechilling, or more suitable germination conditions. In seed transactions, the accepted potential of a seed lot may be the percent germination or the sum of the percent germination and the percent firm ungerminated seeds.

In addition to providing the basis for pricing or sowing a seed lot, germination test results provide other useful information. Rate, vigor, and uniformity of germination and duration of the germination period are helpful indicators of seed quality and response. The amount of firm ungerminated seed or deteriorated seed may signal the need for a longer or shorter chilling period. Seed analysts and seedsmen are good sources of assistance for interpretation of test results.

Pure Live Seed

When a seed lot is nearly pure, which is attainable for many tree and shrub seed, it is often priced and bought or sold directly on the basis of the germination or viability percent. For practical purposes, minor impurities can be ignored. But if substantial amounts of impurities (other crop seed, weed seed, and inert matter) are present, a common basis is needed for comparing and pricing seed lots that differ in purity and viability. Equable comparisons can be made by expressing quality and value of each lot on a pure live seed (PLS) basis, as follows:

$$\text{Percent PLS} = \frac{\text{percent germination or viability} \times \text{percent purity}}{100};$$

$$\text{price per lb PLS} = \frac{\text{price per lb for impure seed}}{\text{percent pure live seed} \div 100}.$$

The number of pure live seed per pound is calculated as:

$$\text{Number PLS per lb} = \text{number of pure seed per lb} \times \frac{\text{percent germination or viability}}{100}.$$

Many shrub seeds are marketed on a pure live seed basis. Sometimes the minimum acceptable quality for tree seed, or incentives for high quality, has also been set on a pure live seed basis.

Processing Standards

Production of clean seed of high viability is a universal goal of the seed industry. Generally attainable minimums for purity and viability of many tree and shrub species are listed in table 1 . For storage, seeds of most conifers should have a moisture content of 5 to 9 percent, wet-weight basis. Moisture content requirements for storage of western shrub and hardwood seed are not as well defined. Seeds of many shrub species store satisfactorily in warehouses at ambient temperatures (Plummer and others 1968, Stevens and others 1981); for these, initial moisture content in the same range as for conifers appears satisfactory (fig. 11). Some shrub and hardwood seed require cold storage, and others require conditions that preserve high moisture content.

Initial moisture content required for satisfactory dry storage of seed depends somewhat on intended length and method of storage, as well as on species requirements (Stein 1974). Slightly higher moisture levels are tolerable for storage near or below freezing, but the upper limits on suitable moisture content have not been defined. Generally, the higher the storage temperature, the more detrimental high moisture content is likely to be.

When a lot contains many unfilled seeds, there is concern that the moisture content determined for the lot may not adequately reflect the moisture content of the live, filled seeds. Since unfilled seeds are likely to hold less moisture in their seed coats than is held in the seed coats plus endosperms and embryos of filled seeds, moisture content for filled seeds may be higher than the average determined for the lot. Actual differences for lots with different percentages of filled seed have not been determined. This concern applies particularly to *Abies* species and to several shrubs where the percentage of filled seed may often be unavoidably low.

Table 1—Recommended minimum standards for purity and viability of tree and shrub seed.[1/]

Species			
Scientific name	Common name	Purity	Viability
		- -Percent- -	
	TREES		
Abies amabilis	Pacific silver fir	95	35
Abies concolor	White fir	95	40
Abies grandis	Grand fir	95	40
Abies lasiocarpa	Subalpine fir	95	35
Abies magnifica var. *shastensis*	Shasta red fir	95	40
Abies procera	Noble fir	95	40
Alnus rubra	Red alder	95	60
Amelanchier alnifolia	Western serviceberry	95	85
Cercocarpus ledifolius	Curlleaf cercocarpus	90	80
Cercocarpus montanus	Alderleaf cercocarpus	90	80
Chamaecyparis lawsoniana	Port-Orford-cedar	95	50
Chamaecyparis nootkatensis	Alaska-cedar	95	35
Cornus stolonifera	Red-osier dogwood	95	85
Cowania mexicana	Cliffrose	95	85
Crataegus douglasii	Black hawthorn	95	70
Elaeagnus angustifolia	Russian-olive	98	90
Gleditsia triacanthos	Honeylocust	98	80
Juniperus osteosperma	Utah juniper	98	60
Juniperus scopulorum	Rocky Mountain juniper	98	60
Larix occidentalis	Western larch	90	60
Libocedrus decurrens	Incense-cedar	90	50
Picea brewerana	Brewer spruce	95	80
Picea engelmannii	Engelmann spruce	95	80
Picea sitchensis	Sitka spruce	95	80
Pinus attenuata	Knobcone pine	98	80
Pinus contorta	Lodgepole pine	98	80
Pinus jeffreyi	Jeffrey pine	98	80
Pinus lambertiana	Sugar pine	98	80
Pinus monticola	Western white pine	98	80
Pinus ponderosa	Ponderosa pine	98	80
Prunus americana	American plum	98	70
Prunus virginiana	Chokecherry	98	70
Pseudotsuga menziesii	Douglas-fir	98	80
Rhus glabra	Smooth sumac	90	40
Sambucus cerulea	Blue elder	95	50
Sequoia sempervirens	Redwood	90	25

See footnotes at end of table.

Table 1—Recommended minimum standards for purity and viability of tree and shrub seed[1/] (continued)

Species			
Scientific name	Common name	Purity	Viability
		- - Percent - -	
Sequoiadendron giganteum	Giant sequoia	90	40
Shepherdia argentea	Silver buffaloberry	98	80
Thuja plicata	Western redcedar	95	60
Tsuga heterophylla	Western hemlock	98	70
Tsuga mertensiana	Mountain hemlock	98	70
	SHRUBS		
Amorpha canescens	Leadplant amorpha	95	90
Artemisia nova	Black sagebrush	[2/] 10	80
Artemisia tridentata	Big sagebrush	[2/] 10	80
Atriplex canescens	Fourwing saltbush	95	50
Atriplex confertifolia	Shadscale saltbush	95	35
Atriplex gardneri	Gardner saltbush	95	45
Atriplex lentiformis	Big saltbush	90	70
Atriplex polycarpa	Cattle saltbush	90	40
Caragana arborescens	Siberian peashrub	95	90
Ceanothus sanguineus	Redstem ceanothus	98	85
Ceanothus velutinus	Snowbrush ceanothus	98	85
Chrysothamnus nauseosus	Rubber rabbitbrush	[2/] 12	75
Colutea arborescens	Common bladdersenna	98	65
Cotoneaster acutifolia	Peking cotoneaster	98	80
Ephedra viridis	Green ephedra	95	85
Eriogonum heracleoides	Wyeth eriogonum	95	75
Eurotia lanata	Common winterfat	50	85
Fallugia paradoxa	Apacheplume	80	75
Grayia spinosa	Spiny hopsage	90	80
Kochia prostrata	Prostrate summercypress	90	90
Lonicera tatarica	Tatarian honeysuckle	90	85
Potentilla fruticosa	Bush cinquefoil	70	70
Prunus besseyi	Bessey cherry	98	70
Purshia tridentata	Antelope bitterbrush	95	90
Rhus trilobata	Skunkbush sumac	95	40
Ribes aureum	Golden currant	95	65
Rosa woodsi	Woods rose	95	70
Sarcobatus vermiculatus	Black greasewood	85	40

See footnotes at end of table.

Table 1—Recommended minimum standards for purity and viability of tree and shrub seed[1/] (continued)

Species			
Scientific name	Common name	Purity	Viability
		- - Percent - -	
Spiraea douglasi	Douglas spirea	80	80
Symphoricarpos albus	Common snowberry	95	80
Symphoricarpos oreophilus	Mountain snowberry	95	80
Syringa vulgaris	Common lilac	90	70

[1/] Recommended standards for conifers developed by consensus among members *of* the Western Forest and Range Seed Council. Minimums for shrubs and hardwood trees are based on data published by Plummer and others (1968), Wasser (1982), and on a compilation by Kent R. Jorgensen that is part of an Agriculture Handbook in preparation for publication.

[2/] Suitable levels for range seedings. Minimum purity of 50 percent is recommended for nursery seedings of *Artemisia* species and 40 percent for *Chrysothamnus* species.

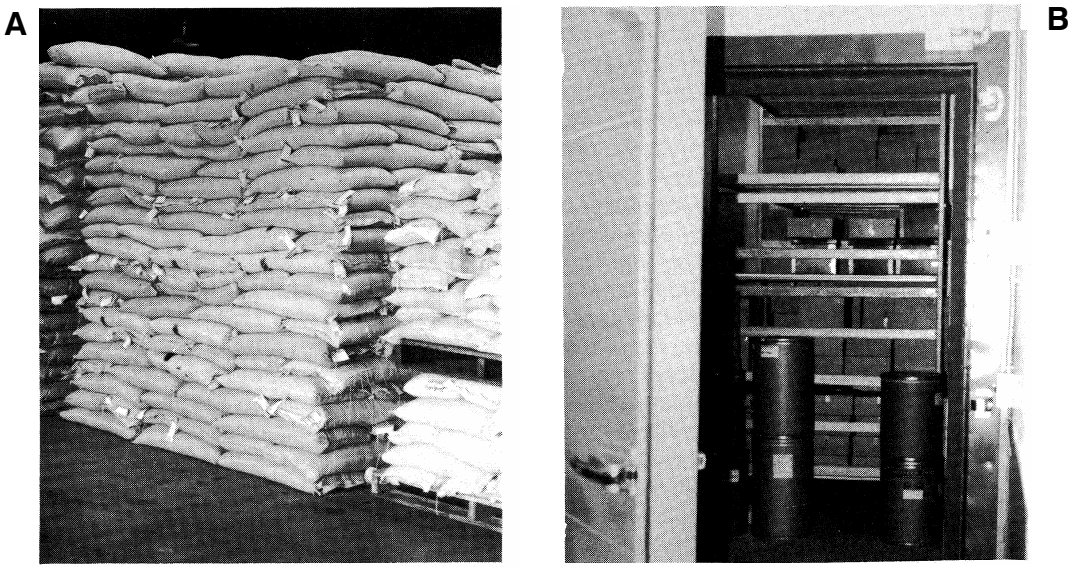

Figure 11. —Many shrub seed store well in warehouses at ambient temperatures (A); conifer seed are generally stored at temperatures below freezing (B).

Phytosanitary Certificate

Seed destined for export must usually be certified as being free of harmful insects and diseases. Such certificates are import requirements of the country receiving the seed. The appropriate forms are usually provided by the importer, and the actual inspection of the seed is conducted by federally licensed inspectors. Contact your State department of agriculture for the location of the nearest office where phytosanitary inspections are made and for the quarantine requirements of individual countries.

References

Association of Official Seed Analysts. Rules for testing seeds. Journal of Seed Technology. 6(2): 1-116; **1981** (with 1982,1983, and 1984 revisions).

Belcher, Earl; Vozzo, J.A. Radiographic analysis of agricultural and forest tree seeds. Contrib. 31. In: Handbook on seed testing. [Place of publication unknown]: Association of Official Seed Analysts; **1979**. 117 p.

Bonner, F.T. Seed testing. In: Schopmeyer, C.S., tech. coord. Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture; **1974**: 136-152.

Ching, Te May; Parker, M.C. Hydrogen peroxide for rapid viability tests of some coniferous tree seeds. Forest Science. 4(2): 128-134; **1958.**

Danielson, H. Rodger. Quick-tests for determining viability of Douglas fir seed. In: Anderson, Harry W.; Bryan, James A.; Eide, Rex P., eds. Proceedings of joint meeting, Western Forest Nursery Council and Intermountain Forest Nurserymen's Association; 1972 August 8-10; Olympia, WA. Olympia, WA: Washington State Department of Natural Resources; **1972**: 104-110.

Danielson, H. Rodger; Grabe, Don F. Storage of noble fir seeds. In: Grabe, Don F., ed. Proceedings of the Association of Official Seed Analysts; 1973 June 9-15; Ottawa, Canada. Corvallis, OR: Cascade Printing Company; **1973**; 63: 161-165.

DeYoe, David R. Certification of tree seed. Ext. Circ. 1101. Corvallis, OR: Oregon State University Extension Service; **1984**.4 p.

Eddleman, Lee E. Indigenous plants of southeastern Montana. I. Viability and suitability for reclamation in the Fort Union basin. Spec. Publ. 4. Missoula, MT: University of Montana, Montana Forest and Conservation Experiment Station; **1977**. 122 p.

Eddleman, Lee E. Survey of viability of indigenous grasses, forbs, and shrubs: techniques of initial acquisition and treatment for propagation in preparation for future land reclamation in the Fort Union basin. Annu. Prog. Rep. Missoula, MT: University of Montana; **1980**. 87 p.

Grabe, Don F., ed. Tetrazolium testing handbook for agricultural seeds. Contrib. 29. In: Handbook on seed testing. [Place of publication unknown]: Association of Official Seed Analysts; **1970**. 62 p.

Hardin, Ed. Quick test vs. standard germination test. In: Proceedings of Intermountain Nurseryman's Association and Western Forest Nursery Association combined meeting; 1980 August 12-14; Boise, ID. Gen. Tech. Rep. INT-109. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; **1981**: 71-73.

Heit, C.E. The excised embryo method for testing germination quality of dormant seed. In: Clark, B.E., ed. Proceedings of the Association of Official Seed Analysts; 1955 June 26-30; Stillwater, OK. Washington, DC: Sauls Lithograph Co.; **1955**; 45: 108-117.

Heit, C.E. Germinative characteristics and optimum testing methods for twelve western shrub species. In: Crosier, Willard F., ed. Proceedings of the Association of Official Seed Analysts; 1970 June 21-26; Jefferson City, MO. [Place of publication unknown]: Association of Official Seed Analysts; **1970**; 60: 197-205.

Heit, C.E. Propagation from seed, part 22: testing and growing western desert and mountain shrub species. American Nurseryman. 133(10): 10-12,76-89; **1971.**

Hopkins, Howard G. Forest tree seed certification in the Pacific Northwest. Journal of Forestry. 66(5): 400-401 ; **1968**.

International Seed Testing Association. International rules for seed testing, rules 1976. Seed Science and Technology. 4(1): 3-49; **1976a**.

International Seed Testing Association. International rules for seed testing, annexes 1976. Seed Science and Technology. 4(1): 51-177; **1976b.**

Leadem, C.L. Quick tests for tree seed viability. Land Manage. Rep. 18. Victoria, BC: Province of British Columbia, Ministry of Forests; **1984**. 45 p.

McDonough, W.T. Seed physiology. In: Sosebee, Ronald E., ed. Rangeland plant physiology. Range Sci. Ser. 4. Denver, CO: Society for Range Management; **1977:** 155-184.

Piesch, R.F.; Stevenson, R.E. Certification of source-identified Canadian tree seed under the O.E.C.D. scheme. For. Tech. Rep. 19. Ottawa, ON: Canadian Forestry Service; **1976**. 18 p.

Plummer, A. Perry; Christensen, Donald R.; Monsen, Stephen B. Restoring big-game range in Utah. Publ. 68-3. Salt Lake City, UT: Utah Division of Fish and Game; **1968.** 183 p.

Pollard, D.F.W. Forest tree seed certification under the OECD scheme in Canada: 1976-1980 summary report. BC-X-229. Victoria, BC: Canadian Forestry Service, Pacific Forest Research Centre; **1982**. 10 p.

Rudolf, Paul O. Tree-seed marketing controls. In: Schopmeyer, C.S., tech. coord. Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture, Forest Service; **1974**: 153-166.

Schopmeyer, C.S., tech. coord. Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture, Forest Service; **1974**. 883 p.

Stein, William I. Harvesting, processing, and storage of fruits and seeds. In: Schopmeyer, C.S., tech. coord. Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture, Forest Service; **1974**: 98-125.

Stein, William I. Activities of the Western Forest Tree Seed Council. In: Proceedings of Western Forest Nursery Council Meeting; 1974 August 5-7; Portland, OR. Portland, OR: U.S. Department of Agriculture, Forest Service; **1975**: 3-7.

Stevens, Richard; Jorgensen, Kent R.; Davis, James N. Viability of seed from thirty-two shrub and forb species through fifteen years of warehouse storage. Great Basin Naturalist. 41 (3): 274-277; **1981**.

Swingle, Charles F., comp. Seed propagation of trees, shrubs, and forbs for conservation planting. SCS-TP-27. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; **1939**. 198 p.

Tiedemann, Arthur R.; McArthur, E. Durant; Stutz, Howard C.; Stevens, Richard; Johnson, Kendall L., comps. Proceedings, symposium on the biology of *Atriplex* and related chenopods; 1983 May 2-6; Provo, UT. Gen. Tech. Rep. INT-172. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; **1984**. 309 p.

U.S. Department of Agriculture, Soil Conservation Service. Improved plant materials cooperatively released by SCS. Plant Mater. Tech. Note 42 (rev.). Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; **1984**. 19 p. Updated annually. Available on request from SCS Plant Materials Centers and SCS State and District offices.

Vories, Kimery C. Growing Colorado plants from seed: a state of the art. Vol. 1. Shrubs. Gen. Tech. Rep. INT-103. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; **1981**. 80 p.

Wang, B.S.P. Tree-seed storage. Pub l. 1335. Ottawa, ON: Canadian Forestry Service; **1974**.32 p.

Wasser, Clinton H. Ecology and culture of selected species useful in revegetating disturbed lands in the West. FWS/OBS-82/56. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service; **1982**.347 p.

Western Forest Tree Seed Council. Sampling and service testing western conifer seeds. Portland, OR: Western Forestry and Conservation Association; **1966**. 36 p.

Young, James A.; Evans, Raymond A.; Kay, Burgess L.; Owen, Richard E.; Budy, Jerry. Collecting, processing, and germinating seeds of western wildland plants. ARM-W-3. Oakland, CA: U.S. Department of Agriculture, Science and Education Administration; **1981**. 44 p.

Appendix 1
Public Sources of Information on Native Shrubs

Arizona

Plant Materials Center
USDA Soil Conservation Service
3241 Romero Road
Tucson, AZ 85705

Forestry Sciences Laboratory
Rocky Mountain Forest and
Range Experiment Station
USDA Forest Service
Northern Arizona University
Tucson, AZ 86001

British Columbia

Agriculture Canada Research
Station
3015 Ord Road
Kamloops, BC
Canada V2B 8A9

Botanical Gardens
University of British Columbia
6501 N.W.Marine Drive
Vancouver, BC
Canada V6T 1W5

California

Plant Materials Center
USDA Soil Conservation Service
P.O. Box 68
Lockeford, CA 95237

College of Agriculture and
Environmental Science
Department of Agronomy and
Range Science
Department of Environmental Horticulture
University of California, Davis
Davis, CA 95616

Colorado

College of Forestry and Natural Resources
Department of Range Science
College of Natural Sciences
Department of Botany and Plant Pathology
Colorado State University
Fort Collins, CO 80523

Upper Colorado Environmental
Plant Center P.O. Box 448
Meeker, CO 81641

Western Energy and Land Use Team
U.S. Fish and Wildlife Service
Drake Creekside Building One
2627 Redwing Road
Fort Collins, CO 80526

Idaho

Plant Materials Center
USDA Soil Conservation Service
Box AA
Aberdeen, ID 83210

Forestry Sciences Laboratory
Intermountain Research Station
USDA Forest Service
316 East Myrtle Street
Boise, ID 83702

Montana

Plant Materials Center
USDA Soil Conservation Service
Route 1, Box 1189
Bridger, MT 59041

College of Agriculture
Department of Animal and Range Sciences
Department of Plant and Soil Science
Montana State University
Bozeman, MT 59717

Nevada

Intermountain Research Station
USDA Forest Service
920 Valley Road
Reno, NV 89512

Nevada Division of Forestry
201 S. Fall Street
Carson City, NV 89710

Renewable Resource Center
USDA Agricultural Research Service
920 Valley Road
Reno, NV 89512

New Mexico

Plant Materials Center
USDA Soil Conservation Service
1036 Miller Street, S.W.
Los Lunas, NM 87031

Forestry Sciences Laboratory
Rocky Mountain Forest and
Range Experiment Station
USDA Forest Service
2205 Columbia, S.E.
Albuquerque, NM 87106

College of Agriculture and Home Economics
Department of Animal and Range Sciences
Department of Crops and Soils
Department of Horticulture
New Mexico State University
Las Cruces, NM 88003

Oregon

Eastern Oregon Agricultural
Research Center
Star Route 1-4.51 Highway 205
Burns, OR 97720

Plant Materials Center
USDA Soil Conservation Service
3420 N.E. Granger Avenue
Corvallis, OR 97330

Forestry and Range Sciences Laboratory
Pacific Northwest Research Station
USDA Forest Service
Route 2, Box 2315
La Grande, OR 97850

School of Agriculture
Department of Rangeland Resources
Oregon State University
Corvallis, OR 97331

Utah

Great Basin Research Area
Utah Division of Wildlife Resources
P.O. Box 704
Ephraim, UT 84627

Shrub Sciences Laboratory
Intermountain Research Station
USDA Forest Service
735 North 500 East
Provo, UT 84601

Washington

Forestry Sciences Laboratory
Pacific Northwest Research Station
USDA Forest Service
1133 N. Western Avenue
Wenatchee, WA 98801

Plant Materials Center
USDA Soil Conservation Service
257 Johnson Hall
Washington State University
Pullman, WA 99163

Wyoming

High Plains Grasslands Research Station
USDA Agricultural Research Service
8408 Hildreth Road
Cheyenne, WY 82009

College of Arts and Sciences
Department of Botany
College of Agriculture
Plant Science Division
Range Science Division
University of Wyoming
Laramie, WY.82071

Appendix 2
Addresses of Official State Seed Testing Laboratories

Arizona State Seed Inspector
1688 W. Adams, Room 414
Phoenix, AZ 85007

California State Seed Laboratory
1220 N. Street
Sacramento, CA 95814

Colorado State Seed Laboratory
E -10 Plant Science Bldg.
Colorado State University
Fort Collins, CO 80523

Idaho State Seed Laboratory
2240 Kellogg Lane
Boise, ID 83702

Montana State Seed Laboratory
Montana State University
Bozeman, MT 59717

Nevada State Seed Laboratory
P.O. Box 11100
Reno, NV 89510

New Mexico State Seed Laboratory
Box 3190
Las Cruces, NM 88003

Oregon State Seed Laboratory
Oregon State University
Corvallis, OR 97331

Utah Department of Agriculture Seed Laboratory
350 N. Redwood Road
Salt Lake City, UT 84116

Washington State Seed Laboratory
2015 South 1st St.
Yakima, WA 98903

Wyoming State Seed Laboratory
University Station Box 3333
Laramie, WY 82071

Appendix 3
Sections of Official Testing Rules Most Pertinent to Tree and Shrub Seed

Sections of the Association of Official Seed Analysts (1981) rules for testing seeds are reproduced for the reader's information and for convenient reference. Most excerpts include full sentences; nonpertinent parts of paragraphs and entire subsections have been omitted (shown by ellipses). The numbering system used in the AOSA rules has been retained to facilitate quick referencing to the full rules. Persons who need more information and those specializing in seed testing should obtain a set of current rules. Information on where to obtain the official rules can be provided by your nearest State seed testing laboratory (appendix 2).

The following sections are reproduced from pages 1 to 116 of "Rules for Testing Seeds" (Association of Official Seed Analysts 1981, with revisions through 1984); titles of "continued" tables may not appear where they do in the original "rules":

1. SAMPLING

* * * * * * *

1.4 Size of submitted sample

a. *For composite sample to test for quality.* — The following are minimum weights for samples of seed to be submitted for purity, germination and noxious weed seed examination:

* * * * * * *

(6) Tree and shrub seed samples shall consist of at least 600 seeds per sample for germination purposes. If a purity analysis or a noxious-weed seed examination is required, the submitted sample shall provide at least the minimum weights of working samples set forth in section 2.4.

* * * * * * *

2. ANALYSIS OF THE SEED

The analysis for purity and the test for germination for law enforcement, labeling, and general information as to seed quality, should determine for the sample analyzed: (1) the purity composition, including an identification to determine the kind of seed, and if possible from appearance, the varietal composition; (2) the rate of occurrence of noxious-weed seeds per unit weight; and (3) the percentage germination of the pure seed under consideration.

* * * * * * *

2.2 Obtaining the working sample

The working sample on which the actual analysis is made shall be taken from the submitted sample in such a manner that it will be representative. The sample shall be repeatedly divided to the weight to be used for the working sample. Some form of efficient mechanical divider should be used. In case the proper mechanical divider is not available, the sample shall be thoroughly mixed and placed in a pile and the pile shall be repeatedly divided into halves until a sample of the desired weight remains. To avoid damage to large seed, caution should be observed to prevent them from falling great distances on hard surfaces.

2.3 Weight of working samples

a. *Kinds of seed listed in Table* 1. — The weight of the working samples for the purity analysis and noxious-weed seed examination shall not be less than that prescribed in Table 1, except as noted in c below.

b. *Kinds of seed not listed in Table* 1. — The weight of the purity working sample and its corresponding noxious-weed seed working sample may be determined from Table 1 by a kind of seed that is similar in size and weight, and which would provide approximately 2,500 seeds in the purity working sample.

c. *In samples that are believed to be unusually small-seeded or large-seeded for the kind being tested.* — The size of the purity working sample may be based on a sample containing no less than 2,000 seeds without regard to the weight specified in Table 1, provided that in no case shall less than one-fourth gram be analyzed.

* * * * * * *

2.4, Table 1.***

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Table 1. Weights for working samples, TREE and SHRUB SEEDS

Kind of seed	Minimum weight for purity analysis[a]	Approximate number of seeds per gram[b]	Approximate number of seeds per ounce[c]
	Grams	Number	Number
Abies amabilis (Loudon) Forbes Pacific silver fir	100	25	705
Abies balsamea (L.) Miller balsam fir	20	130	3,740
Abies concolor (Gordon) Hildebrand white fir	75	35	995
Abies fraseri (Pursh) Poiret fraser fir	20	125	3,500
Abies grandis (D. Don) Lindley grand fir	50	50	1,450
Abies homolepis Siebold & Zuccarini nikko fir	40	65	1,780
Abies lasiocarpa (Hooker) Nuttall subalpine fir	30	85	2,340
Abies magnifica A. Murray California red fir and Shasta red fir (var *shastensis)*	200	13	355
Abies procera Rehder noble fir	80	30	915
Abies veitchii Lindley veitch fir	20	130	3,680
Acer ginnala Maximowicz amur maple	75	35	950
Acer macrophyllum Pursh bigleaf maple	350	7	195
Acer negundo L. boxelder or negundo maple	100	25	710
Acer pensylvanicum L. striped maple	100	25	710
Acer platanoides L. Norway maple	400	6	165
Acer pseudo-platanus L. sycamore maple	200	13	370
Acer rubrum L. red maple	50	50	1,420

Table 1. Weights for working samples, TREE and SHRUB SEEDS (continued)

Kind of seed	Minimum weight for purity analysis[a]	Approximate number of seeds per gram[b]	Approximate number of seeds per ounce[c]
	Grams	Number	Number
Acer saccharinum L. silver maple	500	3	90
Acer saccharum Marshall sugar maple	175	14	380
Acer spicatum Lamarck mountain maple	50	50	1,420
Ailanthus altissima (Miller) Swingle tree of heaven or ailanthus	80	30	915
Berberis thunbergii DC. Japanese barberry	40	60	1,690
Berberis vulgaris L. European barberry	30	85	2,340
Betula alleghaniensis Britton yellow birch	3	985	27,900
Betula lenta L. sweet birch	2	1,420	40,400
Betula nigra L. river birch	3	825	23,400
Betula papyrifera Marshall paper birch	1	3,040	86,300
Betula pendula Roth European white birch	½	5,290	150,000
Betula populifolia Marshall gray birch	½	9,380	266,000
Catalpa bignonioides Walters southern catalpa	50	45	1,280
Catalpa speciosa (Barney) Engelman northern catalpa	50	45	1,280
Cedrus atlantica (Endlicher) Carriere Atlas cedar	200	12	350
Cedrus deodara (D. Don) G. Don deodar cedar	300	8	225
Cedrus libani A. Richard cedar of Lebanon	200	11	305
Celastrus scandens L. American bittersweet	40	55	1,630
Celastrus orbiculata Thunberg oriental bittersweet	20	120	3,360
Chamaecyparis lawsoniana (A. Murray) Parlatore Port Orford cedar	5	465	13,100
Chamaecyparis nootkatensis (D. Don) Spach Alaska cedar	10	240	6,750
Cupressus arizonica Greene Arizona cypress	30	90	2,500
Fraxinus americana L. white ash	100	22	625
Fraxinus excelsior L. European ash	200	13	370

Table 1. Weights for working samples, TREE and SHRUB SEEDS (continued)

Kind of seed	Minimum weight for purity analysis[a]	Approximate number of seeds per gram[b]	Approximate number of seeds per ounce[c]
	Grams	Number	Number
Fraxinus latifolia Bentham Oregon ash	150	18	505
Fraxinus nigra Marshall black ash	100	25	710
Fraxinus pennsylvanica Marshall var. *subintgerrima* (Vahl) Fernald green ash	100	25	710
Fraxinus pennsylvanica var *lanceolata* (Borkh.) Sargent green ash	60	40	1,080
Gleditsia triacanthos L. honey locust	400	6	175
Larix decidua P. Miller European larch	15	170	4,810
Larix eurolepis A. Henry Dunkeld larch	10	240	6,750
Larix kaempferi (Lamarck) Carriere Japanese larch	10	260	7,380
Larix occidentalis Nuttall western larch	8	315	8,940
Larix sibirica (Muenchausen) Ledebour Siberian larch	25	95	2,690
Liquidambar styraciflua L. sweetgum	15	180	5,130
Malus spp. apple	50	45	1,250
Malus spp. crabapple	20	145	4,130
Picea abies (L.) Karsten Norway spruce	20	140	4,000
Picea engelmannii Engelmann engelmann spruce	8	300	8,440
Picea glauca (Moench) Voss white spruce	6	405	11,500
Picea glauca var. *albertiana* (S. Brown) Sargent western white spruce, Alberta white spruce	6	415	11,800
Picea glauca (Moench) Voss var. *glauca* Black Hills spruce	5	510	14,400
Picea glehnii (F. Schmidt) Masters Sakhalin spruce	8	300	8,520
Picea jezoensis (Sieb. & Zucc.) Carriere yeddo spruce	6	405	11,500
Picea koyamai Shirasawa Koyama spruce	8	310	8,770
Picea mariana (P. Miller) B.S.P. black spruce	3	890	25,300
Picea omorika (Pancic) Purkyne Serbian spruce	8	320	9,080

Table 1. Weights for working samples, TREE and SHRUB SEEDS (continued)

Kind of seed	Minimum weight for purity analysis[a]	Approximate number of seeds per gram[b]	Approximate number of seeds per ounce[c]
	Grams	Number	Number
Picea orientalis (L.) Link oriental spruce	15	175	4,780
Picea polita (Sieb. & Zucc.) Carriere tigertail spruce	40	65	1,810
Picea pungens Engelmann and var. *glauca* Beissner blue spruce and Colorado blue spruce	10	235	6,630
Picea rubens Sargent red spruce	8	310	8,750
Picea sitchensis (Bongard) Carriere sitka spruce	5	465	13,100
Pinus albicaulis Engelmann whitebark pine	300	8	225
Pinus aristata Engelmann bristlecone pine	50	50	1,440
Pinus banksiana Lambert jack pine	10	290	8,190
Pinus cembra L. Swiss stone pine	500	4	115
Pinus cembroides Zuccarini Mexican pinyon pine	500	4	115
Pinus contorta Loudon lodgepole pine (including var. *latifolia*)	10	225-300	6,400-8,440
Pinus coulteri D. Don coulter pine, bigcone pine	500	3	85
Pinus densiflora Siebold & Zuccarini Japanese red pine	25	100	2,810
Pinus echinata P. Miller shortleaf pine	25	105	3,000
Pinus elliottii Engelmann slash pine	70	30	905
Pinus flexilis James limber pine	250	10	275
Pinus halepnesis P. Miller Aleppo pine	50	55	1,560
Pinus heldreichii Christ var. *leucodermis* (Antoine) Fitschen Bosnian pine	50	45	1,220
Pinus jeffreyi Greville & Balfour Jeffrey pine	300	7	200
Pinus lambertiana Douglas sugar pine	500	5	130
Pinus monticola D. Don western white pine	40	60	1,690
Pinus mugo Turra var. *mugo* Swiss mountain pine	20	135	3,880
Pinus mugo var. *mughus* (Scop.) Zenari mugo swiss mountain pine	15	180	5,150

Continued

Table 1. Weights for working samples, TREE and SHRUB SEEDS (continued)

Kind of seed	Minimum weight for purity analysis[a]	Approximate number of seeds per gram[b]	Approximate number of seeds per ounce[c]
	Grams	Number	Number
Pinus nigra Arnold Austrian pine	50	55	1,630
Pinus nigra Arnold var. *poiretiana Schneider* *Corsican pine*	30	70	2,010
Pinus palustris Miller longleaf pine	250	9	265
Pinus parviflora Siebbold & Zuccarini Japanese white pine	250	9	265
Pinus ponderosa P. & C. Lawson ponderosa pine, western yellow pine	90	25	750
Pinus resinosa Aiton red pine, Norway pine	20	115	3,260
Pinus rigida Miller pitch pine	20	135	3,880
Pinus strobus L. eastern white pine	40	60	1,690
Pinus sylvestris L. scotch pine	15	155	4,420
Pinus taeda L. loblolly pine	60	40	1,150
Pinus thunbergii Parlatore Japanese black pine	30	75	2,130
Pinus virginiana Miller Virginia pine, scrub pine	20	115	3,260
Pinus wallichiana A. B. Jackson Himalayan pine	125	20	570
Prunus armeniaca L. apricot	500	1	19
Prunus avium (L.) L. cherry	400	6	165
Prunus domestica L. plum (prune)	500	2	50
Prunus persica (L.) Batsch peach	1,500		7
Pseudotsuga menziesii (Mirbel) Franco grey douglas fir, var. *caesia* (Mirbel) Franco and blue douglas fir, var. *glauca* (Beissner) Franco	30	85	2,380
Pseudotsuga menziesii (Mirbel) Franco var. *menziesii* green douglas fir	25	95	2,630
Pyrus communis L. pear	70	35	940
Robinia pseudoacacia L. black locust	50	55	1,500
Rosa multiflora J. A. Murray multiflora rose	25	100	2,810
Sequoia sempervirens (D. Don) Endlicher redwood	12	210	5,950

Table 1. Weights for working samples, TREE and SHRUB SEEDS (continued)

Kind of seed	Minimum weight for purity analysis[a]	Approximate number of seeds per gram[b]	Approximate number of seeds per ounce[c]
	Grams	Number	Number
Sequoiadendron giganteum (Lindley) Buchholz giant sequoia	12	200	5,670
Syringa vulgaris L. common lilac	12	200	5,670
Thuja occidentalis L. northern white cedar, eastern arborvitae	3	765	21,600
Thuja orientalis L. Oriental arborvitae (Chinese arborvitae)	50	50	1,450
Thuja plicata D. Don western red cedar, giant arborvitae	3	915	25,900
Tsuga canadensis (L.) Carriere eastern hemlock, Canada hemlock	6	410	11,700
Tsuga heterophylla (Rafinesque) Sargent western hemlock, Pacific hemlock	4	655	18,600
Ulmus americana L. American elm	15	150	4,250
Ulmus parvifolia Jacquin Chinese elm	7	355	10,000
Ulmus pumila L. Siberian elm	15	145	4,060

[a]If it is necessary to conduct a noxious-weed seed determination, see section 2.3 for size of working sample. For peach, the 1,500 gram purity analysis may be considered the portion examined for noxious-weed seeds. In no other case does the amount examined for noxious-weed seeds need to exceed 500 grams.

[b]Figures in parentheses are the average number of seeds per gram to be used in computations of special tolerances. See Section 5.2c.

[c]The number of seeds per pound or the weight of 1,000 seeds can be calculated in the laboratory for individual lots from the sample submitted.

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2.5 The purity analysis

a. *Separation of component parts.* —The working sample shall be weighed in grams to four significant figures and shall then be separated into four parts: (1) kind or cultivar to be considered pure seed; (2) other crop seed; (3) inert matter; and (4) weed seed. The four component parts shall be weighed in grams to the same number of decimal places as the working sample. The percentage of each part shall be determined to two decimal places.

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b. *Calculation of percent of component parts in the sample.*

(1) Minimum working sample less than 25 grams: Percentages shall be based on the sum of the weights of the component parts and not on the original weight. However, the sum of the weights of the component parts shall be compared with the original weight of the working sample as a check against loss of material or other error.

(2) Minimum working sample of 25 grams or more: The other crop seed, inert matter, and weed seed shall be weighed and their percentages calculated on the basis of the original weight. The pure seed need not be weighed; its percentage may be determined by subtracting the sum of the percentages of the other three components from 100.

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2.6 **Seed unit**. — The seed unit is the structure usually regarded as a seed in planting practices and in commercial channels. ***

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2.7 **Kind or cultivar considered pure seed**. —The pure seed shall include all seeds of each kind and/or cultivar under consideration which are present in excess of 5% of the whole. Under certain circumstances kinds and/or cultivars present to the extent of 5% or less of the whole may be considered pure seed; for example, kinds or cultivars shown on a label as components of a mixture in amounts of 50/0 or less. The following shall be included with the pure seed:

a. Immature or shriveled seeds and seeds that are cracked or otherwise damaged. This does not include seeds of legumes, crucifers, and conifers with the seed coats entirely removed. See section 2.10a(1).

b. Pieces of broken and otherwise damaged seeds which are larger than one-half of the original size. * * *

c. Insect-damaged seeds, provided that the damage is entirely internal, or that the opening in the seed coat is not sufficiently large to allow the size of the remaining mass of tissue to be readily determined. * * *

d. Seeds that have started to germinate.

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h. Seed units with nematode galls, fungus bodies (i.e., ergot, smut, etc.) and spongy or corky caryopses which are entirely enclosed within the seed unit. * * *

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2.8 **Other crop seed**. —Seeds of plants grown as crops (other than the kind or cultivar included in the pure seed) shall be considered other crop seeds, unless recognized as weed seeds by laws, regulations, or by general usage. All interpretations and definitions for *pure seed* in section 2.7 shall also apply in determining whether seeds are *other crop or inert matter.* ***

2.9 **Weed seed**.-Seeds, florets, bulblets, tubers, or sporocarps of plants recognized as weeds by laws, official regulations, or by general usage shall be considered weed seeds. * * *

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2.10 **Inert matter**.-Inert matter shall include seeds and seedlike structures from both crop and weed plants and other materials not seed as follows:

a. Seeds and seedlike structures from crop plants.

(1) Seeds of legumes, crucifers, and conifers with the seed coats entirely removed. Refer to section 2.7a.

(2) Pieces of broken and damaged seed units, including those that are insect damaged, which are half the original size or less; see section 2.7b and c. * * *

(5) Broken and unattached wings of tree and shrub seeds.

(6) Attached wings of tree and shrub seeds as follows:

(a) for *Cedrus, Picea, Tsuga,* and *Pinus* (except as noted below) the entire wing shall be detached and classed as inert matter;

(b) for *Abies, Larix, Libocedrus, Pseudotsuga, Pinus echinata, Pinus elliottii Pinus palustris, Pinus rigida,* and *Pinus taeda* the wing shall be detached and removed as inert matter, except for that part which encloses the seed and is ordinarily not removed in seed conditioning;

(c) the seed wing shall not be removed as inert matter for *Acer, Betula, Catalpa, Chamaecyparis, Cupressus, Fraxinus, Liquidambar, Liriodendron, Platanus, Thuja,* and *Ulmus.*

(7) Seedlike structures from trees and shrubs consisting of wings with a thickened spot instead of a seed.

(8) Seed units with nematode galls or fungus bodies (smut, ergot, and other sclerotia) which are not entirely enclosed within the seed unit. ***

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b. Seeds and seedlike structures from weed plants ***

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c. Other non-seed matter.

(1) Free nematode galls or fungus bodies such as smut, ergot and other sclerotia.

(2) Soil particles, sand, stones, chaff, stems, leaves, flowers, cone scales, pieces of bark, pieces of resin, etc.

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4. GERMINATION TESTS

4.1 Source of seeds for germination

a. *When both purity and germination tests are required. —Seeds* for germination shall be taken from the separation of the kind or cultivar considered pure seed and shall be counted without discrimination as to size or appearance.

b. *When only* a *germination test is required.* —If only a germination test is required and the pure seed is determined or estimated to be at least 98 percent, the pure seed for the germination test may be taken indiscriminately from a representative portion of the bulk.

If the pure seed is found to be less than 98 percent the seed for the test shall be obtained by separating the sample into two components as follows: (a) pure seed and (b) other crop seed, weed seed, and inert matter. In making this separation at least 1/4 of the quantity required for a regular purity analysis shall be used. If the reduced amount is used the sample must be well mixed and divided so that the subsample obtained will be representative of the sample.

4.2 Definitions

a. *Seed germination.* —In seed laboratory practice, germination is defined as the emergence and development from the seed embryo of those essential structures which, for the kind of seed in question, are indicative of the ability to produce a normal plant under favorable conditions. Refer to 4.2d and e.

b. *Normal seedlings.* —Seedlings possessing the essential structures that are indicative of their ability to produce plants under favorable conditions.

c. *Abnormal seedlings*. —All seedlings that can not be classified as normal seedlings.

d. *Hard seeds.* —Seeds which remain hard at the end of the prescribed test period because they have not absorbed water due to an impermeable seed coat. Seeds known and recognized to contain hard seed are indicated by footnotes in Table * * 5. The percentage hard seed is to be reported in addition to the percentage germination.

e. *Dormant seed.* —Viable seeds, other than hard seeds, which fail to germinate when provided the specified germination conditions for the kind of seed in question. Viability of ungerminated seeds may be determined by any appropriate method or combination of methods, such as a cutting test, tetrazolium test, scarification, and application of germination promoting chemicals. ***

f. *Prechill.* —Place the seed on or in moist substrata at the indicated low temperature for the specified period of time. Tree and shrub seeds may be prechilled whenever it is deemed necessary.

Procedures for tree and shrub seed prechill:

(1) Place seed in closed dish on moist substratum.

(2) Place seed in a loosely woven bag or screen and insert in a moisture holding medium such as peat, sand, or vermiculite.

(3) Soak seed for 24 hours in tap water at room temperature (18-22^0 C), drain excess water and place in a suitable capped glass or plastic vial, or polyethylene bag.

g. *Predry.* —Place the seed in a shallow layer at a temperature of 35^0 C to 40^0 C for a period of 5 to 7 days, with provision for circulation of the air.

4.3 Moisture and aeration. — The substratum must be moist enough to supply the needed moisture to the seeds at all times. Avoid supplying excessive moisture which will restrict aeration of the seeds. Except as provided for those kinds of seeds requiring high moisture level's in the germination media, the substrata should never be so wet that a film of water is formed around the seeds. For most kinds of seeds, blotters or other paper substrata should not be so wet that by pressing, a film of water forms around the finger. See section 4.9-b.

The addition of water subsequent to placing the seeds in test will depend on the evaporation from the substrata in the germination chambers. Since the rate of evaporation will depend upon the relative humidity of the air, it is desirable to keep water in the germination chambers or to provide other means of supplying a relative humidity of approximately 95 percent. Germination tests should be inspected at frequent intervals to insure that an adequate moisture supply is available at all times.

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4.4 Number of seeds for germination. —At least 400 seeds shall be tested for germination except that in mixtures 200 seeds of those kinds present to the extent of 15 percent or less may be used. In this case an additional 2 percent is to be added to the regular germination tolerances. These seeds shall be tested in replicate tests of 100 seeds or less to avoid crowding on the substratum.

4.5 Evaluation of seedlings

a. *Seedlings infected with fungi or bacteria.* —Such seedlings shall be regarded as normal if they are otherwise normal. A seedling that has been seriously damaged by bacteria or fungi from any source other than the specific seed shall be regarded as normal if it is determined that all essential structures are present.

Germination counts should be made on samples where contamination and decay are present at approximately 2-day intervals between the usual first count and the final count. During the progress of the germination test, seeds which are obviously dead and moldy and which may be a source of contamination of healthy seeds should be

removed at each count and the number of such dead seeds should be recorded. When symptoms of certain diseases develop which can be readily recognized and identified, their presence should be reported.

If a chemical preparation is used to reduce the spread of micro-organisms, the results, should be regarded as supplemental information and reported as such.

b. *Guides for evaluation of seedling.*

(1) Sand and/or soil tests. Such tests shall be considered the guide in determining the classification of questionable seedlings grown on approved artificial media when there is doubt as to the proper evaluation of the seedlings.

* * * * * * *

4.7 Calculation of percentage germination

a. *When* a *single test is made* in accordance with these rules and retesting is not required, the average of the four, three, or two 100-seed replicates shall be reported as the percentage germination or germination and hard seeds.

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4.9 Explanation of Tables 3, 4, and 5

Tables 3, 4, and 5 contain specific germination requirements for the kinds of seeds listed in column 1. Some explanations of these tables and additional germinaton requirements and conditions are as follows:

a. *Substrata.*-Symbols for substrata in column 2, Tables 3 and 4 are: B = between blotters; TB = top of blotters; T = paper toweling, used either as folded towel tests or as roll towel tests in horizontal or vertical position; S = sand or soil; TS = top of and or soil; P = covered petri dishes with (a) two layers of blotters, or (b) three thicknesses of filter paper, or (c) top of sand or soil; C = creped cellulose paper wadding (0.3-inch thick Kimpak or equivalent) covered with a single thickness of blotter through which holes are punched for the seed which are pressed for about one-half their thickness into the paper wadding; RB = blotters with raised covers, prepared by folding up the edges of the blotter to form a good support for the upper fold which serves as a cover, preventing the top from making direct contact with the seeds; TC = on top of creped cellulose paper without a blotter.

Symbols for substrata in column 2, Table 5, are the same as for Tables 3 and 4 except that "P" includes (in addition to the above indicated materials) sponge rok, vermiculite, terralite, or a mixture of 50% sand and vermiculite, sand and perlite, etc. If there is question as to whether a paper substratum is toxic to developing seedlings, check tests should be made on Whatman's No.2 filter paper or its equivalent. Seeds of celery, celeriac, chicory, dandelion, timothy, and Bermudagrass are particularly sensitive to toxic substrata. If root injury is evident on substratum moistened with potassium nitrate, retests should be made on substratum moistened with water.

b. *Moisture.*- The directions and suggestions given under the heading "*Moisture and Aeration"* section 4.3 should be observed. ***

c. Temperature.-Single numerals in the Tables indicate constant temperatures. Two numerals separated by a dash indicate an alternation of temperature, the test to be held at the first temperature for approximately 16 hours and at the second temperature for approximately 8 hours per day. If the tests are not subjected to alternating temperatures over weekends and on holidays, they are to be held at the lower temperature during this time. In the case of species of *Trifolium, Medicago* and *Vicia faba,* the temperature should not exceed 20° C and a temperature of 17° to 18° C is more desirable. A sharp alternation of temperature, such as obtained by hand transfer, may be beneficial in breaking dormancy.

d. *Duration of test.* —The duration of test for each of the various kinds of seeds is given in Tables 3, 4, and 5. The following deviations from the prescribed test are permitted:

(1) The prechilling period is not included in the germination periods given in Tables 3, 4, and 5 unless otherwise specified.

(2) The number of days stated for the first count is approximate and a deviation of one to three days is permitted.

(3) Any test may be terminated prior to the number of days listed under "Final Count" if the analyst is positive the maximum germination of the sample has been attained.

(4) If at the end of the prescribed test period, the seedlings are not sufficiently developed for positive evaluation, the test may be extended two more days.

(5) If any test indicates low vitality, this fact should be reported.

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In tests of tree and shrub seed, seed remaining at the end of the test should be cut and examined for any fresh, firm, possibly viable seed which may have potential planting value. A retest of prechilled seed may be advisable when an extremely high percent of firm, fresh seed is found.

e. *Light.* —Where light is prescribed in Tables 3, 4, and 5, it should be provided by a cool white fluorescent source. The illuminance for dormant seed should be 75-125 ft-c (750-1250 lux). The seeds should be illuminated for at least 8 hours in every 24. Where the seeds are germinated at alternating temperatures they should be illuminated during the high temperature period. *** seeds for which light is prescribed should be germinated on top of the substratum. ***

For tree and shrub seed, an intensity of at least 50 ft-c, and preferably 75-100 ft-c, should be provided. Up to 16 hours of light may be beneficial to some kinds and certain lots of other kinds, as noted in Table 5.

f. *Potassium nitrate.* —A two-tenths (0.2) percent solution of potassium nitrate (KNO_3) is used in moistening the substratum and is prepared by dissolving 2 grams of KNO_3 in 1000 ml of distilled water. The grade of the potassium nitrate shall meet A.C.S. specifications.

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4.12, Table 5. Methods of testing for laboratory germination, TREE and SHRUB SEEDS

Kind of seed	Substrata	Temperature °C	Test duration days	Additional Directions
Abies amabilis Pacific silver fir	P	15-25	28	Light; prechill 0-5° C 14 days. Light; some sources may need prechill 21 days at 3-5° C.
Abies balsamea balsam fir	TB, P	20-30	21	Light; prechill 28 days at 3-5° C.
Abies concolor white fir	TB, P	20-30	28	Light; many lots complete in 14-21 days. A few sources from the Pacific coast region may need prechill for 3 weeks at 3-5° C.
Abies fraseri fraser fir	TB, P	20-30	21	Light; prechill 28 days at 3-5° C.
Abies grandis grand fir	TB, P	20-30	28	Light; prechill 14 days at 3-5° C. Vermiculite (P) is satisfactory. Dark; prechill 21 days at 3-5° C.
Abies homolepis nikko fir	TB, P	20-30	21	Light; prechill 21 days at 3-5° C.
Abies lasiocarpa subalpine fir	TB, P	20-30	28	Light.
Abies magnifica California red fir and shasta red fir	TB, P	20-30	21	Prechill 28 days at 3-5° C.
Abies procera noble fir	TB, P	20-30	28	Light; prechill 14 days at 3-5° C. Vermiculite is recommended if TB is not used. Dark; prechill 21 days at 3-5° C.
Abies veitchii veitch fir	TB, P	20-30	28	Light.
Acer spp. (See Purity Table 1). maples, boxelder	P	18 to 22	14	Use embryo excision method[a]. Prechill 2 months 3-5° C. It is an advantage to remove the pericarp before testing.
Aesculus pavia L. red buckeye	TC	20-30	28	
Ailanthus altissima tree of heaven, ailanthus	TB	20-30	21	
Berberis thunbergii Japanese barberry	P	18-22	10-14	Use embryo excision method[a].
Berberis vulgaris European barberry	P	18-22	10-14	Use embryo excision method[a].
Betula spp. (See Purity Table 1). birches	P	20-30	21	Light.
Carya illinoensis (Wangenheim) K. Koch pecan	TC	20-30	28	Prechill 60 days at 3-5° C.
Carya ovata (Miller) K. Koch shagbark hickory	TC	20-30	28	Prechill 60 days at 3-5° C.
Casuarina spp. beefwood	C, TB	20-30	14	Light.
Catalpa bignonioides southern catalpa	TB	20-30	21	
Catalpa speciosa northern catalpa	TB	20-30	21	
Cedrus spp. (See Purity Table 1). cedars	TB	20	21	Prechill 14 days at 3-5° C.

Table 5. Methods of testing for laboratory germination, TREE and SHRUB SEEDS (continued)

Kind of seed	Substrata	Temperature °C	Test duration days	Additional Directions
Celastrus spp. (See Purity Table 1). bittersweet	P	18-22	10-14	Use embryo excision method[a].
Chamaecyparis spp. (See Purity Table 1). cedars, falsecypress	TB, P	20	28	Use KNO_3 if dormant.
Cornus florida L. flowering dogwood	C, TB P	20-30 18-22	28 10	Prechill 90 to 120 days at 3-5° C. Embryo excision.
Cornus stolonifera Michaux red-osier dogwood	P	18-22	10	Prechill 90 days at 3-5° C. Embryo excision.
Crataegus mollis Scheele downy hawthorn	C, TB	20-30	14	2 hrs. H_2SO_4, followed by 90 days prechill at 20° C then 120 days at 3-5° C. TZ[b] may also be used.
Cupressus arizonica Arizona cypress	TB	20-30	28	Light; some lots need 20 days prechill.
Eucalyptus deglupta Blume	C, TB	20-30	14	
Eucaluptus grandis Sieber ex Bentham	C, TB	25	14	Light.
Fraxinus spp. (See Purity Table 1). ash	P	18-22	10-14	Use embryo excision method[a]. TZ[b] may also be used. Prechill 3-5° C in moist substratum 3 months.
Gleditsia triacanthos L. honey locust	B	20	21	See footnote[c].
Grevillea robusta silk-oak	C, TB	20-30	21	Light.
Larix decidua European larch	TB, P	20-30	21	Light.
Larix eurolepis Dunkeld larch	TB, P	20-30	21	Light.
Larix kaempferi Japanese larch	TB, P	20-30	16	Light; prechill 21 days at 3-5° C.
Larix occidentalis western larch	TB, P	20-30	21	Light; if dormant, prechill or use KNO_3.
Larix sibirica Siberian larch	TB, P	20-30	21	Light.
Libocedrus decurrens incense-cedar	C, TB	20-30	28	Prechill 30 days at 3-5° C.
Liquidambar styraciflua sweetgum, red gum	TB	20-30	28	Light; sensitive to drying in test.
Liriodendron tulipifera L. yellow-poplar	C, TB	20-30	28	Prechill 60 days at 3-5° C; or use TZ or embryo excision.
Magnolia grandiflora L. southern magnolia	C, TB	20-30	42	Prechill 45 days at 3-5° C; or use TZ.
Malus spp. apple, crabapple	P	18-22	7-10	Use embryo excision method[a]. TZ[b] may also be used.
Nyssa aquatica L. water tupelo	TC	20-30	21	Prechill 30 days at 3-5° C.
Nyssa sylvatica Marshall black tupelo	C, TB	20-30	28	Prechill 21 days; very few lots dormant.
Picea abies Norway spruce	TB	20-30	16	20° C and 25° C temperatures are also satisfactory.
Picea engelmannii engelmann spruce	TB, P	20-30	16	Light; sensitive to excessive moisture; use KNO_3 if dormant.
Picea glauca white spruce	TB	20-30	21	Light; some Canadian seed sources require prechill for 14-21 days at 3-5° C.
Picea glauca var. *albertiana* western white spruce, Alberta white spruce	TB	20-30	21	Light.

Table 5. Methods of testing for laboratory germination, TREE and SHRUB SEEDS (continued)

Kind of seed	Substrata	Temperature °C	Test duration days	Additional Directions
Picea glauca var. *glauca* Black Hills spruce	TB	20-30	21	Light.
Picea glehnii sakhalin spruce	TB, P	20-30	14	Prechill 21 days at 3-5° C.
Picea jezoensis yeddo spruce	TB, P	20-30	14	Prechill 21 days at 3-5° C.
Picea koyamai Koyama spruce	TB	20-30	21	Light.
Picea mariana black spruce	TB	20-30	16	Light.
Picea omorika Serbian spruce	TB	20-30	16	Light.
Picea orientalis oriental spruce	TB	20-30	21	Light.
Picea polita tigertail spruce	TB	20	21	
Picea pungens vars. blue spruce and Colorado blue spruce	TB, P	20-30	16	20° C and 25° C temperatures are also satisfactory.
Picea rubens red spruce	TB	20-30	28	Light.
Picea sitchensis sitka spruce	TB, P	20-30	21	Light; more than 8 hr light may be beneficial to some lots; if dormant add KNO_3.
Pinus albicaulis	P	18 to 22	10-14	Use embryo excision method[a].
whitebark pine	TB, P	20-30	28	Light; prechill 28 days at 3-5° C.
Pinus aristata bristlecone pine	TB, P	20-30	14	
Pinus banksiana jack pine	TB, P	20-30	14	Light.
Pinus canariensis C. Smith canary pine	P	20	21	Light; sensitive to warm temperatures; 1-day soak prior to test helpful.
Pinus caribaea Morelet caribbean pine	C, TB	20-30	21	
Pinus cembra Swiss stone pine	P	18 to 22	10-14	Use embryo excision method[a]. TZ[b] may also be used.
	S, P	20-30	28	Prechill 6-9 months at 3-5° C.
Pinus cembroides Mexican pinyon pine	B, P	20	28	Use embryo excision method[a] for dormant lots.
Pinus clausa (Chapman) Vasey sand pine	TB	22	21	Sensitive to excess moisture.
Pinus contorta lodgepole pine, shore pine	TB, P	20-30	28	Light; more than 8 hr light may be beneficial to some lots. Prechill 28 days at 3-5° C.
Pinus contorta var. *latifolia* lodgepole pine	TB, P	20-30	21	Light; prechill 28 days at 3-5° C.
Pinus coulteri	P	18 to 22	10-14	Use embryo excision method[a].
coulter pine, bigcone pine	S, P	15-25	28	Prechill for 8 or 12 weeks at 3-5° C.
Pinus densiflora Japanese red pine	TB, P	20-30	21	Light.
Pinus echinata shortleaf pine	TB, P	20-30	28	Light; 8 hr light may be beneficial to some lots; sensitive to drying.
	P	22	28	No prechill, and prechill 28 days at 3-5° C 16 hr light (both methods each sample).
Pinus elliottii slash pine	TB, P	20-30	28	Light; 8 hr light may be beneficial to some lots; sensitive to drying.
	P	22	28	Light; no prechill, and prechill 28 days at 3-5° C (both methods each sample).

Table 5. Methods of testing for laboratory germination, TREE and SHRUB SEEDS (continued)

Kind of seed	Substrata	Temperature °C	Test duration days	Additional Directions
Pinus flexilis limber pine	B, P	20-30	21	Prechill 21 days at 3-5° C.
Pinus glabra Walters spruce pine	TB, P	20-30	16	Light; prechill 21 days at 3-5° C.
Pinus halepensis Aleppo pine	TB, P	20	28	Sensitive to warm temperature.
Pinus heldreichii var. *leucodermis* bosnian pine	TB, P	20-30	28	Light; prechill 40 days at 3-5° C.
Pinus jeffreyi jeffrey pine	TB, P S, P	20-30 20-30	21 21	Light; embryo excision method applicable to dormant lots. Prechill for 4 or 8 weeks at 3-5° C.
Pinus khasya Engelmann khasia pine	TB	20-30	21	Light.
Pinus lambertiana sugar pine	P S, P	18 to 22 20-30	10-14 28	Use embryo excision method[a]. Prechill 8 or 12 weeks at 3-5° C.
Pinus luchuensis Mayr Formosa pine	TB	20-30	21	Light.
Pinus merkusii Junghuhn & DeVriese merkus pine	TB	20-30	21	Light.
Pinus monticola western white pine	P S, P	18 to 22 20-30	10-14 28	Use embryo excision method[a]. Prechill 8 to 12 weeks at 3-5° C.
Pinus mugo vars. Swiss mountain pine, Mugo Swiss mountain pine	TB, P	20-30	14	Light.
Pinus muricata bishop pine	TB	20-30	21	Light.
Pinus nigra Austrian pine	TB, P	20-30	14	Light.
Pinus nigra var. *poiretiana* Corsican pine	TB, P	20-30	14	Light
Pinus palustris longleaf pine	P	20	21	8 hr light.
Pinus parviflora Siebold & Zuccarini Japanese white pine	P	18 to 22	10-14	Use embryo excision method.[a].
Pinus patula Schiede & Deppe Jelecote pine	TB, P	20	18	Light; sensitive to temperature.
Pinus pinaster Aiton cluster pine	TB, P	20	28	Light; sensitive to temperature and possibly moisture; some seed sources need prechill.
Pinus pinea L. Italian stone pine	P	20	21	Light; soak 1 day prior to test; some lots sensitive to warm temperatures.
Pinus ponderosa ponderosa pine, western yellow pine	TB, P	20-30	21	Light; prechill 28 days at 3-5° C.
Pinus radiata monterey pine	P	20	25	Light; more than 8 hr may be beneficial; prefers good moisture supply; prechill 21 days at 3-5° C.
Pinus resinosa red pine, Norway pine	TB, P	20-30; 25	14	Light not essential for maximum germination.
Pinus rigida pitch pine	TB, P	20-30	14	Light.
Pinus serotina Michaux pond pine	TB	22	21	

Table 5. Methods of testing for laboratory germination, TREE and SHRUB SEEDS (continued)

Kind of seed	Substrata	Temperature °C	Test duration days	Additional Directions
Pinus strobus eastern white pine	TB, P	20-30	21	Light; more than 8 hr. light may be beneficial to some lots; sensitive to drying; prechill 28-42 days at 3-5° C.
	P	22	28	Light for 16 hr.; prechill 28-42 days at 3-5° C.
Pinus sylvestris scotch pine	TB, P	20-30	14	Light; seed from eastern Mediterranean (Turkey, Greece, Bulgaria) provinces may require prechill 21 days at 3-5° C.
Pinus taeda	TB, P	30-30	28	Light; more than 8 hr light may be beneficial to some lots; sensitive to drying.
loblolly pine	P	22	28	No prechill, and prechill 28 days at 3-5° C. 16 hr light (both methods each sample).
Pinus thunbergii Japanese black pine	TB, P	20-30	21	Light; more than 8 hr light may be beneficial to some lots.
Pinus virginiana Virginia Pine	TB, P	22	21	16 hr light
scrub pine	TB	20-30	21	Light; 8 hr light may be beneficial to some lots
Pinus wallichiana Himalayan pine	TB, P	20-30	28	Light; more than 8 hr light may be beneficial to some lots.
Platanus occidentalis L. American sycamore	TB	20-30	14	
Populus spp. poplar	20-30	14		Light.
Prunus spp. (See Purity Table 1). apricot, cherry, peach, plum	P	18 to 22	10-14	Use embryo excision method.[a]. TZ[b] may also be used.
Pseudotsuga menziesii var. *caesia* grey douglas fir	TB, P	20-30	21	Light; prechill 21 days at 3-5° C. Vermiculite recommended if TB not used.
Pseudotsuga menziesii var. *glauca* blue douglas fir	TB, P	20-30	21	Light; central and southern Rocky Mountain sources not sensitive to temperature. Vermiculite recommended if TB not used.
Pseudotsuga menziesii var. *menziesii* green douglas fir	TB, P	20-30	21	Light; prechill 21 days at 3-5° C. Vermiculite or Perlite (sponge rok) recommended if TB not used.
Pyrus communis L. (See Purity Table 1). pear	P	18 to 22	10-14	Use embryo excision method[a]. TZ[b] may also be used.
Quercus spp. (red or black oak group)	TC, TB	20-30	14	Cut ⅓ off cup scar end of acorn and remove pericarp.
Quercus alba L. white oak	TC	20-30	28	
Quercus muehlenbergii Engelmann chinkapin oak	TC	20-30	28	
Quercus virginiana Miller live oak	TC	20-30	28	
Rhododendron spp. *rhododendron*	C, TB	20-30;25	21	Light.
Robinia pseudoacacia black locust	B	20	21	See footnote[c].
Rosa multiflora multiflora rose	TB, P	10-30	28	Light; prechill 28 days at 3-5° C. TZ[b] may also be used.
Sequoia sempervirens redwood	TB, P	20-30	21	Light.

Table 5. Methods of testing for laboratory germination, TREE and SHRUB SEEDS (continued)

Kind of seed	Substrata	Temperature °C	Test duration days	Additional Directions
Sequoiadendron giganteum giant sequoia	TB, P	20-30	28	Light; sensitive to drying; may prechill 30 days.
Syringa vulgaris *common lilac*	TB	20	21	
Thuja occidentalis northern white cedar, eastern arborvitae	TB, P	20-30	21	Light.
Thuja orientalis oriental arborvitae, Chinese arborvitae	TB, P	20	21	
Thuja plicata western red cedar, giant arborvitae	TB, P	20-30	21	Light; use KNO_3 if dormant.
Tsuga canadensis eastern hemlock, Canada hemlock	TB, P	15	28	Light; prechill 28 days at 3-5° C.
Tsuga heterophylla western hemlock, Pacific hemlock	TB, P	20	28	Light.
Ulmus americana American elm	TB	20-30	14	Light.
Ulmus parvifolia Chinese elm	TB	20	10	
Ulmus pumila Siberian elm	TB	20	10	
Vitis vulpina L. riverbank grape	C, TB	20-30	28	Prechill 90 days at 3-5° C; or use TZ.

[a]Embryo excision method: Embryo excision tests can be placed at the temperatures indicated or at ordinary room temperatures if the maximum temperature does not exceed 24^0 C constantly. Details and literature concerning this method are given in the article: "The excised embryo method for testing germination of dormant seed," Proc. Assoc. Offic. Seed Anal. 45:108-117. 1955 Results are to be reported as percentage viability, as determined by an embryo excision test.

[b]T.Z. Tetrazolium: For procedure see the 1959 International Seed Testing Association Rules and amendments of May 12, 1962, Section 6.0, "Biochemical Tests for Viability." Results are to be reported as percentage viability, as determined by a tetrazolium test.

[c]Hard seed often present; see sections 4.2-d and 4.9-e. The viability of these hard seeds may be determined by clipping or filing the testa, or by a concentrated H_2SO_4 soak for approximately 1 hour followed by washing, and then returning them to test conditions.

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5. TOLERANCES

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5.5 Germination

The following tolerances are applicable to the percentages of germination and also to the sum of the germination plus the hard seed when 400 or more seeds are tested:

Mean	Tolerance	Mean	Tolerance
96 or over	5	70 or over but less than 80	8
90 or over but less than 96	6	60 or over but less than 70.	9
80 or over but less than 90	7	Less than 60	10

When only 200 seeds of mixtures are tested, 2% shall be added to the above germination tolerances.

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APPENDIX I. SEEDLING DESCRIPTIONS

These seedling descriptions are a part of the Rules for Testing Seeds as set forth in section 4.5. * * *

For general instructions on evaluation of seedlings infected with fungi or bacteria see section 4.5 of these rules.

Seedlings difficult or impossible to evaluate because of injury due to chemical treatment of the seeds, exposure to chemicals, or toxicity from germinator trays may be retested in soil or a mixture of soil and sand and the result of this test should be reported * * * .

In general, the following anatomical parts, free from decay, should be present in normal seedling: a well-developed primary root system; a well-developed intact hypocotyl and/or epicotyl; an intact plumule in the Poaceae and an intact terminal growing point in other groups; one cotyledon in monocots and two cotyledons in dicots.

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12. Trees and shrubs

Normal seedling

(a) Seedling possessing those essential structures that are indicative of its ability to produce a plant under favorable conditions.

Abnormal seedling

(a) Weak, rootless or broken.
(b) With poor or stunted radicle growth.
(c) With radicle emerging from the seed coat with apparently normal development of hypocotyl and cotyledons, but radicle failing to develop.
(d) With radicle emerging from the seed coat but growing horizontally or upward.
(e) With radicle emerging from the seed coat but being destroyed by rapid growth of fungus from within the seed coat.
(f) With cotyledons emerging from the seed coat before the. radicle.
(g) Seed split from internal growth with nothing emerging or with only short blunt extension of endosperm and radicle.
(h) With stunted hypocotyl carrying a "collar" of endosperm tissue.
(i) With double embryos fused together. (If two seedlings emerge from a seed and they are not fused, or one is normal or produces a completely normal plant, the unit would not be classed as abnormal).
(j) Without pigment — albino.
(k) Watery — Transluscent in appearance.

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Because the role of tree and shrub seed is indispensable in the renewal of forests and ranges, their identity and quality are critically important. This guide briefly covers recommended practices for maintaining the identity of seeds, for sampling them, and for testing them for quality. Practices associated with the testing and use of tree seed have developed over many years, whereas those for shrub seed are just developing. Selected references, excerpts from official seed testing rules, addresses of seed testing laboratories, and sources of information for shrub seed are included.

Keywords: Seed (tree), seed (shrub), seed testing, seed quality.

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