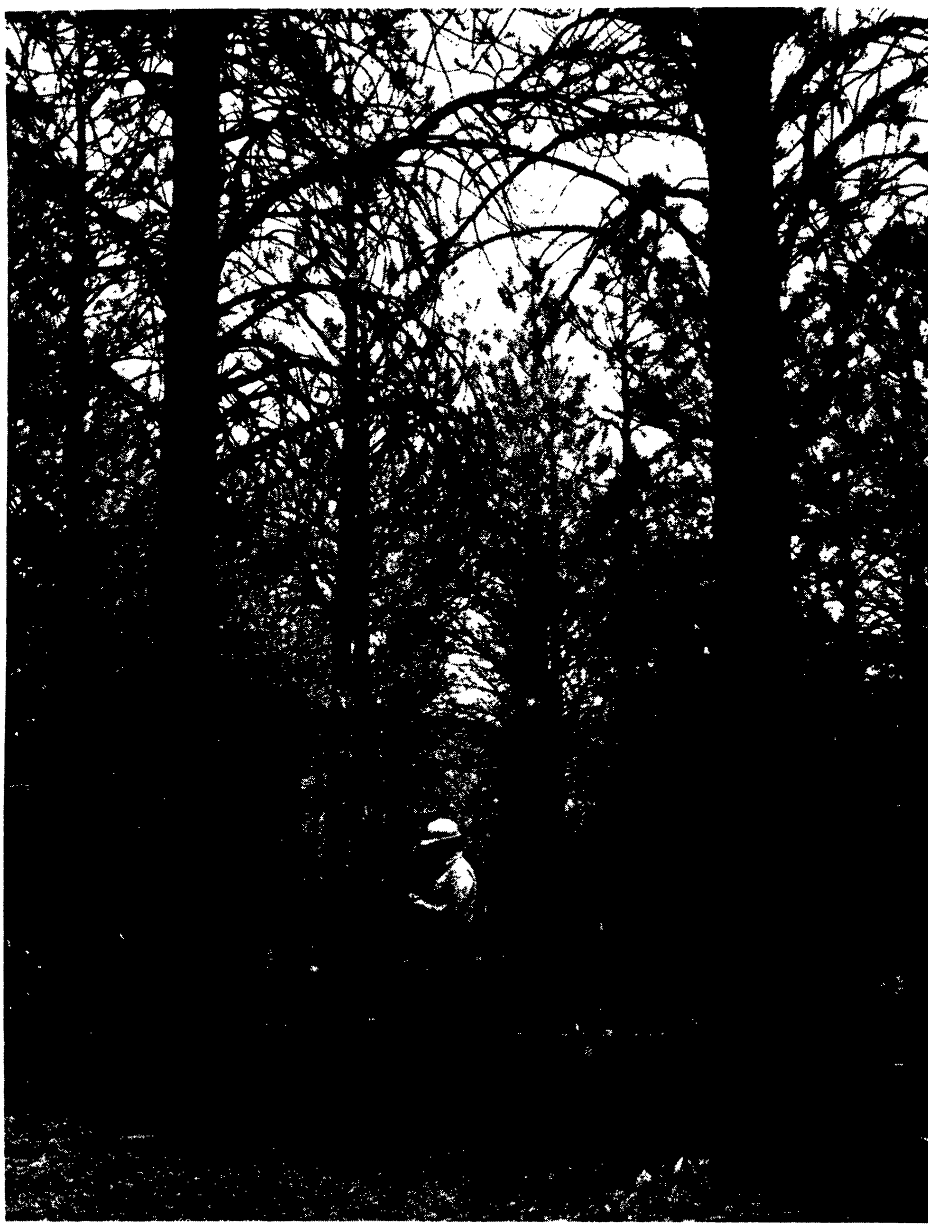
ARTIFICIAL REFORESTATION PRACTICES FOR THE SOUTHWEST



Agricultural Handbook No. 370

U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE

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Rocky Mountain Forest and Range
Experiment Station

PROTECT

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U.S. DEPARTMENT OF AGRICULTURE

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ARTIFICIAL REFORESTATION PRACTICES FOR THE SOUTHWEST

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INTRODUCTION

More than a half-million acres of burned and cutover commercial timberland in the Southwest need to be reforested. Large-scale planting and direct seeding will be required to restore these half-million acres and many newly burned and cutover areas to full productivity. This handbook summarizes valuable information that can be used by foresters and land managers in establishing new stands of trees.

Experience has shown that natural regeneration will not satisfactorily restock these idle acres. Many areas, especially large burns, do not have an adequate seed source. Even in areas with an adequate seed supply, adverse climatic and biotic factors have prevented effective natural restocking except during a few years in the past half century.

Many of the factors that have rendered natural regeneration ineffective also jeopardize planting and seeding. Drought during fall, combined with abundant competing vegetation, is foremost. Most Southwestern ponderosa pine seeds germinate only during the summer wet period. If drought delays germination into August, the seedlings cannot establish deep roots in the remainder of growing season. Many of the shallow-rooted seedlings are then heaved by frost during the fall and spring. Attrition by soil insects, tip moths, birds, rodents, and browsing animals may be severe for as long as 15 years after initial establishment.

Planting, the most successful method of artificial reforestation in Arizona and New Mexico, has several advantages over direct seeding. Seedlings are less subject to destruction by rodents and birds than seed. The larger root systems of the seedlings, placed deeply in the soil, are less likely to suffer damage from a fast-drying surface layer. Furthermore, planted trees (1) can begin their season's growth 2 to 3 months earlier, (2) start with a larger root system which continues to develop faster, to tap more moisture, and to resist frost action better, and (3) can better withstand partial loss of tops and roots by insects, rodents, and browsing animals than seedlings started from direct seeding.

This publication includes instructions in the following areas:

1. Methods for production of planting stock.
2. Site preparation.
3. Planting of nursery grown seedlings.
4. Broadcast sowing on the site to be reforested.
5. Plantation care and protection from fire, insects, disease, rodents, and browsing animals.

SEED REQUIREMENTS

SEED SOURCE

The importance of seed source was officially recognized by the U.S. Department of Agriculture in 1939 (McCall 1939) when a seed policy was adopted directing planters:

1. To use only seed of known locality of origin and nursery stock grown from such seed.
2. To require from a vendor adequate evidence verifying place and year of origin for all seedlots or nursery stock purchased.

[1] The authors are located at the Forestry Sciences Laboratory in Flagstaff, Ariz. The Laboratory is maintained in cooperation with Northern Arizona University, Flagstaff, Ariz. Central headquarters for the Station is maintained at Fort Collins, Colo., in cooperation with Colorado State University.

3. To require an accurate record of the origin of all seedlots and nursery stock used in forest, shelterbelt, and erosion-control planting.

4. To use seeds from local, natural stands whenever they are available.

5. When local seed is not available, to use seed from a region which has the most similar length of growing season, mean temperature of the growing season, frequency of summer droughts, latitude, and other environmental characteristics.

6. To delimit, as early as practicable, climatic zones within which seed of each species may be safely used for forest, shelterbelt, and erosion control.

Some exotic species or hybrids grow better than native species; however, nonlocal seed sources are not recommended for reforestation projects in the Southwest until their compatibility to local environmental conditions is proven. At Fort Valley, Ariz., all ponderosa pines (*Pinus ponderosa* Laws.) from California seed sources have died. Trees from Black Hills and Colorado seed, while as hardy as stock from local seed, are subnormal in size and have abnormal stem form (Larson 1966).

SEED PRODUCTION

Production of seed of the major commercial conifers has been adequate for the needs of an expanded reforestation program in the Southwest. Good ponderosa pine cone crops occur every 3 or 4 years, with lighter crops in intervening years. Although large trees may occasionally yield 10 pounds of seed in a single crop, they average 2 pounds (20,000 to 24,000 seeds) in "good" years and 3 or 4 pounds in "bumper" years. Heavy ponderosa pine cone crops have been observed on the Coconino and Kaibab National Forests in 1913, 1918, 1927, 1936, 1942, 1945, 1954, 1956, 1960, and 1965. Good crops of the other commercial conifers occur at about the same frequency.

Potential cone crops occasionally fail to materialize. Immature seeds may be destroyed by cone and seed insects. In winter and spring, Abert squirrels (*Sciurus aberti* Woodhouse) cut enormous numbers of small branches bearing immature cones. Beginning in early summer, the squirrels feed on green cones until the seeds are shed in the fall. Adverse weather also reduces seed crops. Late-spring frosts may kill conelets, below-average spring temperatures inhibit formation of flower buds, and excessive rain reduces pollination.

SEED COLLECTION

Seed should be collected only from trees with good form and vigor and free of insects or disease. Poor form and excessive limbiness as well as susceptibility to pests may be hereditary. Seeds from isolated dominant trees should not be used because their seeds are very likely self pollinated. Such seeds produce a high proportion of poor-quality progeny. Well-formed trees in plantations that originated from seed of a desired location are good seed sources. Plantations of unknown or questionable seed origin should be avoided.

Cone collections should not be started until the seeds are mature. The viability of mature seeds is usually high and the derived seedlings are normal. In contrast, the viability of immature seeds may be low, or many of the seedlings may be abnormal and worthless (Schubert 1956).

Specific gravity of the cones is one of the most reliable indicators of seed ripeness. Maki (1940) found that ponderosa pine cones were mature when they would float in SAE-30 motor oil or kerosene. The cones were sufficiently mature on a tree when three or more cones from a freshly picked sample of five cones floated in the test medium. Cones on all trees within a stand do not mature at the same time, but tests of individual trees can be discontinued when four of five trees in a stand pass the test.

The specific gravities of mature Douglas-fir (*Pseudotsuga menziesii* (Mirb) Franco), true firs, and spruce cones have not been determined.

Cones may also be collected from squirrel caches and from trees cut during logging. Cone collections from squirrel caches should not start until late fall when the seeds are known to be mature. Cached cones that have opened, usually the top one or two layers, should be discarded. Germination tests have indicated a viability of at least 80 percent for seeds collected from cones cached near Mormon Mountain and the San Francisco Peaks.

Cones collected during logging should be as mature as those collected from standing trees. Since the cones lose moisture rapidly after cutting, the flotation test must be made within a few hours after the tree is felled.

These standard practices should be followed:

1. *Care of cones after collection.* Send cones to a seed extraction site as soon as possible after collection. Allow plenty of air space between sacks, even when they are in temporary storage.

2. *Care of cones during predrying.* Cones can be predried in a heated, ventilated shed that is rodentproof. Spread cones in a thin layer and turn frequently to prevent molding. Cones can be predried outside if placed in burlap bags, hung from an overhead rack, and protected from rain. Fully mature cones require the least predrying, and their seeds are the least damaged during processing.

3. *Extraction of seed.* The quickest method to dry and open the cones is to place them in a cone kiln. The temperature of the kiln should not exceed 130° F. Cones will also open if they are left in a heated shed. Turn cones frequently to obtain uniform opening of the scales. After the cones have opened completely, place them in a tumbler or shaker to extract the seed. Shake or tumble cones gently to minimize damage and to maximize recovery of seeds.

Cones have been successfully opened by spreading them on a large canvas or platform, or by hanging partly filled sacks on special drying racks in the open to air-dry. Cones dried by these methods should be turned periodically and protected from rain, birds, and rodents. When weather conditions are favorable, air-drying is cheap and practical. However, if rains are frequent, drying in a heated shed or kiln is best.

4. *Labeling as to seed identity.* Each sack of cones must be tagged to show at least five facts: (a) Species, (b) geographic location where collected, (c) elevation of collection area, (d) date collected, and (e) collector's name. This information must then be transferred to the seed lot record card and to a seed identification tag.

The card becomes part of the permanent file and must specify: (a) the number of pounds in the seed lot, (b) date of seed extraction, (c) method of seed extraction, (d) number of separate containers holding the seed, (e) storage temperature, (f) seed moisture content, and (g) record of viability tests.

The seed identification tag must be placed on each seed container. A copy should also be placed inside the container as a precaution against loss of the outside tag.

SEED STORAGE

As much as a 4-year supply of seed may be needed to keep long-term projects going between harvests of seed crops. Seeds are actually "in storage" from the time they reach maturity until they start to germinate. Seeds of most conifers can be kept viable during storage if they are mature and properly handled. Ponderosa pine seeds have been stored successfully for at least 10 years. The two most important factors affecting viability of mature seeds are moisture content and storage temperature.

To maintain high viability, seed should be:

1. Dried to a moisture content of 4 to 8 percent.
2. Placed in airtight containers.
3. Stored at 32° F. or less (preferably at 0° F.).

SEEDLING REQUIREMENTS

NURSERY STOCK

There are no forest tree nurseries in the Southwest. Therefore, stock must be grown elsewhere. In any case, foresters should plant only trees that are undamaged, vigorous, properly conditioned, and from the proper seed source.

When to Lift Nursery Stock

Studies pioneered in California have shown that planting stock must be in good physiological condition to survive well (Stone and Schubert 1959a, 1959b). Stock lifted too early in the fall or too late in the spring have a low root regenerating potential and survival rate. Stock lifted in late fall and early winter after the trees have "hardened off" or in early spring before active growth starts have a high root regenerating and survival potential.

Nursery climate governs the time when seedlings are ready to be lifted. Since the climate is usually different at each nursery, the best time to lift stock also varies. The optimum time has not been determined for nurseries supplying planting stock for reforestation projects in the Southwest. Until specific guides are published, the following guidelines should be observed:

1. Stock for fall planting should not be lifted before it has completely hardened off.
2. Stock for spring planting should be lifted before top growth starts.

Planting Stock Size and Quality

All planting stock should meet established size and quality specifications before it is shipped to the field. A good plantable tree should: (1) Have a stem diameter of at least 0.16 inch for the pines and true firs and 0.10 inch for Douglas-fir and the spruces, (2) have a well-developed top and root system, and (3) be undamaged and free of disease. The time needed to produce a tree of this size will vary according to the nursery climate and practices. Trees that remain after proper culling will have a good top-root balance and be of high quality.

Stock Shipment

Trees may be shipped by truck, rail, or air—in refrigerated or nonrefrigerated units. The transportation method used will depend on distances and the availability of particular types of equipment.

For short distances, trees are usually transported by unrefrigerated trucks. For long distances, the trees should be shipped by refrigerated trucks, rail, or air.

During transit, trees must be kept moist and cool (ideally between 34° and 40° F.). These conditions are met when trees are shipped under refrigeration. When shipped by unrefrigerated truck, trees should be covered and ventilation provided. Night shipments may be desirable in hot weather. On long truck hauls, the trees may require more water. If stops are made enroute, the truck should be parked in the shade.

All tree shipments must be carefully planned. The departure time should be scheduled to permit proper disposition of the trees immediately upon arrival. The shipping agent or truck driver should notify the recipient promptly when his trees arrive. The trees must then be examined, watered if necessary, and placed in a cool, moist place until planted.

Stock Storage

Ideal storage conditions require a well-ventilated room, a temperature range of 34° to 36° F., and a relative humidity above 90 percent. Unless good storage conditions are available at the destination, trees should be left in storage at the nursery until needed. Even then, only a week's supply should be shipped to the planting site at one time.

Cold storage with controlled temperature and humidity is preferable for extended storage after delivery from the nursery. Trees can be stored in nursery bales or in packages for up to 1 week in a cool shed or for up to 2 or 3 weeks in a cool, moist cellar if properly tended to prevent heating or drying. If other facilities are unavailable, trees may be stored during the planting season in heel-in beds. These heel-in beds should be located in shaded, moist areas, preferably on north-facing slopes. If artificial shade is required, it should permit adequate ventilation.

The number of trees removed from local storage or from heel-in beds should be limited to 1 day's planting needs. Special precautions must be taken to minimize disturbance of the trees during the storage period. Each additional handling increases the possibility of damage to the seedlings.

WILDLING STOCK

Forest-grown seedlings (wildlings) have been used to some extent for fill-in planting in understocked plantations or in small-scale planting in New Mexico.

Wildlings are usually inferior to nursery-grown trees. They generally do not have the compact root systems needed for successful field planting. Unless the wildlings are readily accessible, easy to lift without serious damage to the root system, and are close to the planting site, they may cost more than nursery stock.

SITE PREPARATION

Neither newly germinated nor newly planted seedlings can compete with an established vegetative cover. With few exceptions, new seedling crops on unprepared areas die during the two seasonal droughts (fig. 1). The late spring drought (May-June) is more detrimental than the fall drought (October-November) because it is more severe and it occurs when seedlings are growing most rapidly.

A dense vegetative cover depletes soil moisture, intercepts light and precipitation, and provides a favorable habitat for insects and animals that feed on conifer seed and seedlings (fig. 2). Overhead shade from tall grasses and weeds is distinctly detrimental to ponderosa pine seedlings. Furthermore, some kinds of vegetation may inhibit seed germination and seedling growth.

Some plant species compete more severely than others for limited soil moisture. For example, Arizona fescue (*Festuca arizonica* Vasey) and black dropseed (*Sporobolus interruptus* Vasey) grow during the spring drought when moisture is critical. However, mountain muhly (*Muhlenbergia montana* (Nutt.) Hitchc.), blue grama (*Bouteloua gracilis* (H.B.K.) Lag.), and most weeds do not begin rapid growth until after the start of the summer rains, when moisture is more abundant.

Site preparation involves removing or reducing established vegetation, preparing a seedbed, and removing obstacles to planting, and renders the site less favorable for destructive

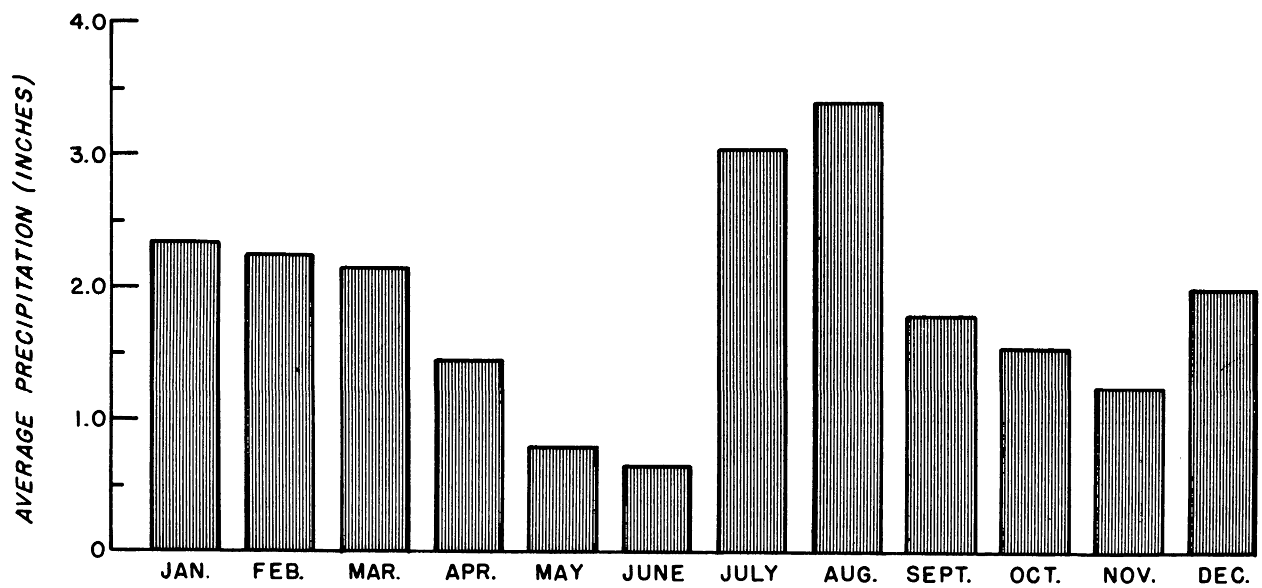

Figure 1.—Fifty-year average monthly precipitation at Fort Valley Experimental Forest (1909-58).

insects and rodents. The most important reason for site preparation in the Southwest is to conserve soil moisture for establishment of tree seedlings and early rapid growth.

The need for site preparation increases with each year's delay in reforesting after fire or timber cutting. Chances for successful establishment of a new stand are greatest the first year after timber removal if the area is not seeded to grass (fig. 3). By the second year, the chances are much less. After 3 years or longer, plantings on unprepared sites are usually complete failures.

CHEMICAL SITE PREPARATION

In the Southwest, a dense, herbicide-killed grassy area is superior to a mechanically prepared area for seedling survival. However, because patches of compact, dead grass may interfere with planting, these areas may be more expensive to plant.

Dalapon, an inexpensive, grass-killing chemical, was successfully used to prepare sites for planting at Fort Valley, Ariz. (Heidmann 1967). Dalapon applied in August as low as 5 pounds active ingredient per acre completely killed Arizona fescue and mountain muhly. Soil remained 2 to 10 percent more moist under dead grass than on denuded plots, and 10 to 15 percent higher than on untreated plots (fig. 5). Dead grass may also serve as a mulch to reduce frost heaving and winterkill of new conifer seedlings. Another advantage of chemical site preparation is that one treatment is usually effective for several years, while mechanically treated areas are invaded by grasses and weeds almost immediately.

Areas should be chemically treated during the summer preceding planting or seeding to allow the herbicides to break down in the soil. By then herbaceous roots are partially decomposed, and more nitrogen may be available to the pine seedlings. Dead grasses are a poor habitat for harmful soil insects.

Most brush species can be killed with 2,4-D or 2,4,5-T. Although dosages and application schedules have not been determined for most species in the Southwest, excellent control was obtained in California with 2 to 4 pounds of the acid per acre applied in the spring before growth started or in the early fall when growth was completed (Schubert 1962). The chemicals are usually applied with a power sprayer or from aircraft.

The cost of site preparation with chemicals depends upon the type of sprayer and condition of the planting area. It costs $10 to $20 per acre to treat most areas. Latest recommendations for chemical treatment should be obtained and followed.

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[2] Identification and description of commercial products in this publication are solely for information purposes. Endorsement of any commercial product by the U.S. Department of Agriculture is not intended and should not be inferred.

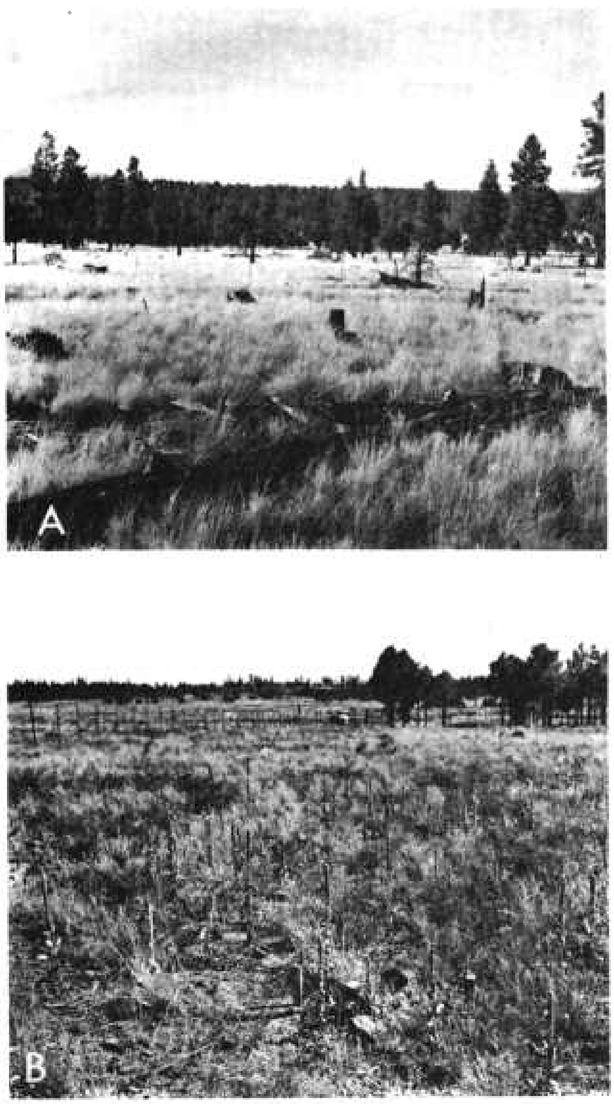

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Figure 2.—Dense vegetative cover (*A*, Arizona fescue and mountain muhly at Wing Mountain and *B*, native grasses and mullein at A-1 Mountain) competes with conifer seedlings for moisture and light and provides a favorable habitat for destructive insects and rodents.

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Figure 3.—A 1-year-old burn (*A*) at time of tree planting in April 1960. The area had been seeded with a mixture of grasses immediately after the fire in 1959. In 1961 (*B*) a heavy stand of orchardgrass overtopped the young trees. The planting failed.

MECHANICAL SITE PREPARATION

Mechanical site preparation is preferred to chemical site preparation in brush, which must be removed or broken up to facilitate planting. Areas to be planted by machine require more thorough site preparation than areas to be planted by hand.

Complete destruction of all competing vegetation over the planting site is preferred to preparation of small, individual planting spots (fig. 6). Earlier literature recommended clearing spots (16 to 24 inches in diameter) or narrow, scalped strips (Pearson 1940) (fig. 7). However, trees planted in these small spots or in narrow strips often failed to thrive. Tree roots quickly outgrew the cleared spots or strips, and roots from the surrounding vegetation rapidly reinvaded the small, cleared areas. Complete eradication of the competing vegetation provides the trees with a longer period in which to become established and a more favorable environment for growth.

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Figure 4.—Native grasses were completely killed by dalapon treatment at Fort Valley, Ariz. in 1961.

Brush, particularly Gambel oak (*Quercus gambelii* Nutt.) and other root-sprouting species, should be uprooted with a brush rake or similar device to remove the root system with a minimum loss of top soil. At times, selective herbicides or fire have been used to deaden the brush or grass before mechanical eradication. Mechanically cleared areas frequently require at least one chemical treatment to kill the new brush sprouts or seedlings.

When bulldozers are used, loss of top soil can be minimized by frequent and sudden jolting of the dozer blade to shake out loose soil from the uprooted brush. This procedure is particularly advisable when brush piles or windrows are to be burned. Loss of top soil may adversely affect growth of the newly planted trees.

In California, complete mechanical eradication of grass and brush on slopes of 35 percent grade and up costs from $25 to $35 per acre (Buck 1959). Planting sites having slopes should be contour furrowed to reduce erosion and retain soil moisture.

Sites should be mechanically prepared during late summer or fall, and seedlings should be planted the following spring. Areas that are not planted on schedule must be reworked to destroy any new vegetation.

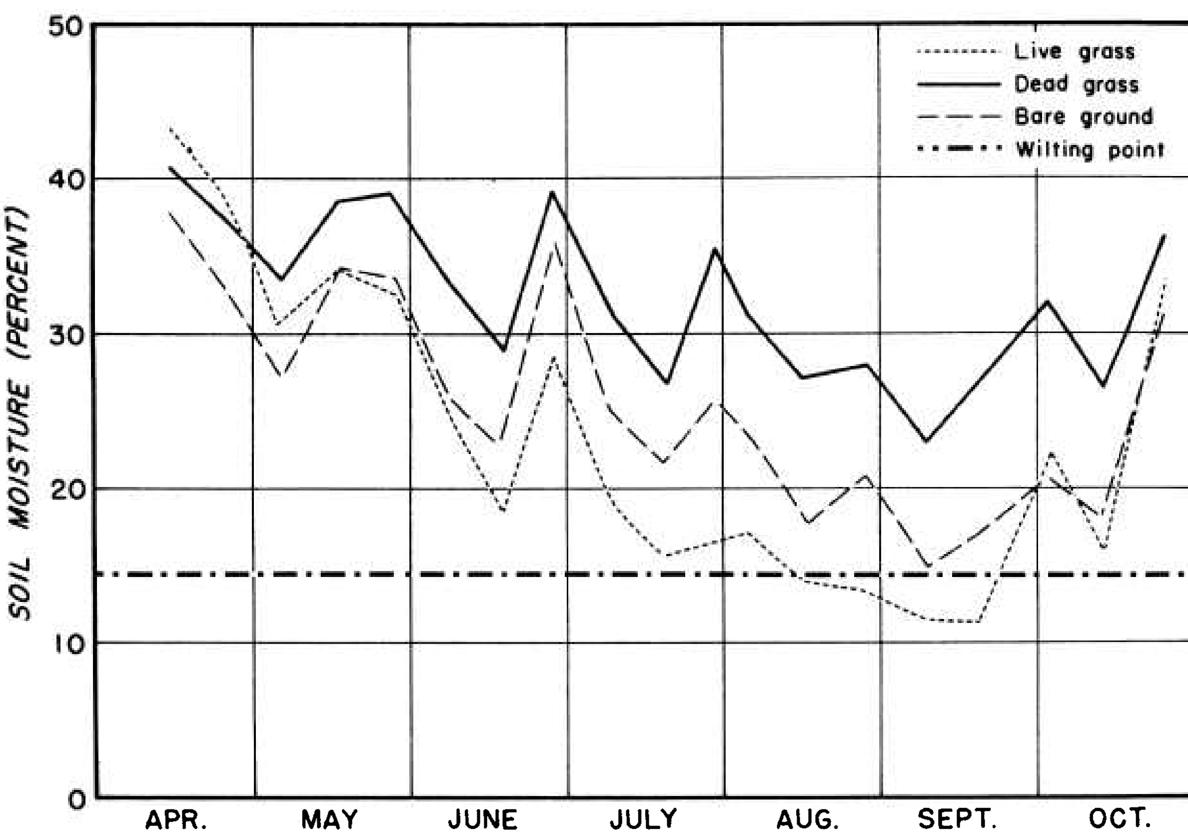

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Figure 5.—Effect of ground surface condition on soil moisture in 1962.

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Figure 6.—Mechanical site preparation on an area formerly covered by dense brush. This area is now suitable for hand or machine planting.

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Figure 7.—Ponderosa pine seedlings being planted in narrow scalped strips in northern Arizona.

Planting sites should never be seeded to grass except in special multiple-use situations where timber is not of primary importance. In these situations, trees and grass may be planted simultaneously.

FIRE FOR SITE PREPARATION

Fire is one of the least effective tools for site preparation. Frequently, the heat generated by the fire stimulates germination of weed and brush seeds stored in the duff. Furthermore, unless the fire is extremely hot root systems and woody stems of perennial vegetation may not be eliminated.

Fire is more effective when combined with chemical or mechanical treatments. After chemical or mechanical treatment, fire is sometimes used to consume dead grass or brush.

PLANTING

Planting forest trees is the most positive way to start a new stand when and where one is needed. However, even planted trees die when the job is not done right. To establish a successful plantation: plant only healthy, vigorous trees that are adapted to the site; plant them on well-prepared planting areas at the right time and in the right way; and then provide proper care and protection. When these requirements are fulfilled, plantations can be successfully established even during dry years.

PLANTING METHODS

Planting may be done by hand or machine. In hand planting, trees are placed by hand in holes dug with handtools or a power-driven auger. In machine planting, trees are placed by hand in a slit in the soil that is opened and closed by the machine. Whether planting is done by hand or machine depends upon the condition of the planting area and the availability of equipment.

Hand Planting

Most planting in the Southwest has been done with handtools. Of the two methods used —hole planting and slit planting—hole planting has several advantages: (1) All sizes of planting stock can be used, (2) roots can be spread out for better contact with undisturbed soil, (3) doubling up of the roots is less probable, (4) moist soil can be packed better around the roots, and (5) the method can be used in any type of soil. The slit-planting method can be used only in light or medium soils. In light, sandy soils, the slit method is faster than the hole method and can be just as successful if done right.

Power-driven hole diggers have been used sporadically for several years in the Southwest. Some important advantages of using hole diggers rather than conventional handtools are: (1) Reduced hand labor, (2) more uniform holes, (3) better planting of trees, (4) faster planting, (5) higher survival, and (6) lower cost per surviving tree. However, there are also several serious disadvantages that must be corrected before power-driven hole diggers are used in preference to hand methods. The main disadvantage is that hole diggers cannot operate on areas with many large rocks and roots. Other disadvantages—noxious fumes from the gas motor, frequent breakdowns, and operator fatigue—have been partly eliminated in newer models.

Two types of hole diggers are used. One is a "casilla" hole digger operated from a power-takeoff unit (fig. 8). The other is a post-hole digger operated from a small, portable power source (fig. 9).

The "casilla" hole digger was field tested in California and found satisfactory on level ground and on gentle slopes relatively free of rocks, roots, and other debris (Schubert and Roy 1959). However, the production rate was only about 480 holes per 8-hour day. Tree survival and growth were better than in hand-dug holes on unprepared areas. The digger eliminates root competition within a 30-inch circle, and the "casilla" traps extra water. The "casilla" digger has been used in Arizona, but no comparative tests were made with other methods. It is not recommended for large planting projects.

Machine Planting

Planting machines (fig. 10) are now used in some parts of the Southwest, and greater use

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Figure 8.—Mechanical hole digger used to prepare "casilla" approximately 30 inches in diameter with a planting hole 9 inches across by 9 inches deep.

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Figure 9.—A 4-inch soil auger driven by a flexible cable attached to a gasoline engine carried on the operator's back can be used to dig planting holes.

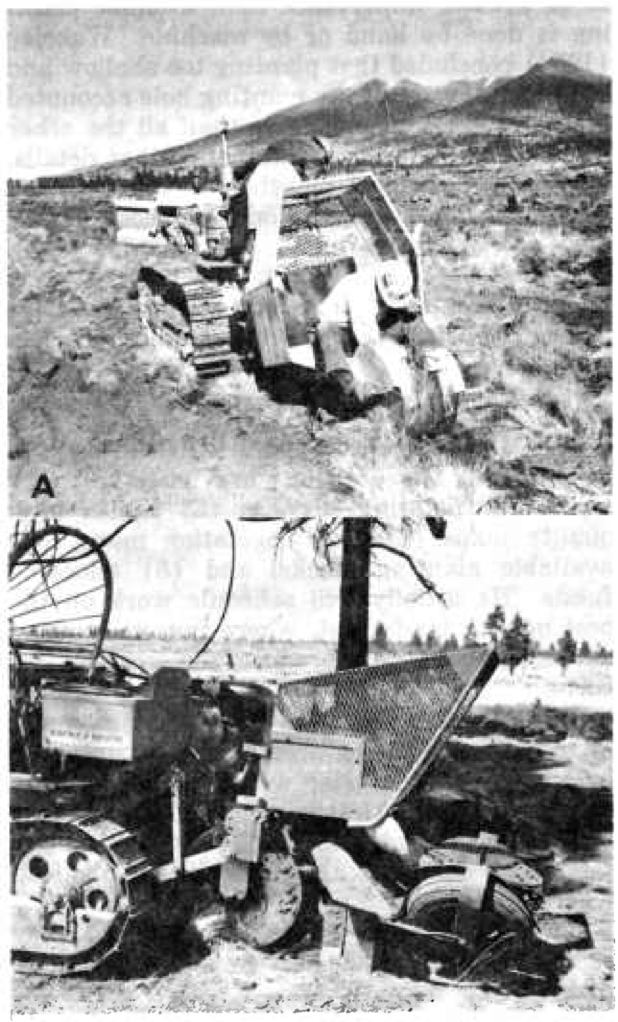

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Figure 10.—Two types of planting machines being used in the Southwest; *A*, the Rocky Mountain planter and *B*, the Whitfield.

is anticipated. New models can be operated on sites that previously were impossible to plant by machine. On fully prepared areas, machine planting is faster, cheaper, and surer than hand planting. Under normal situations, from 2,000–3,000 trees can be planted per machine day on cleared areas. However, machine efficiency decreases rapidly with an increase in rocks, stumps, logs, and other debris. Difficulties are also encountered in attempts to plant trees that are small or extra large, and in soil with a heavy clay content—especially when it is wet. These areas not specifically suited to machine planting should be hand planted.

PLANTING PROCEDURES

Proper attention to details in planting may be of greater importance than whether planting is done by hand or by machine. Wakeley (1954) concluded that planting too shallow and improper closure of the planting hole accounted for more seedling mortality than all the other "errors" of planting. Still, many other details, besides the physical planting of the tree, are important for success. Some of these details are: (1) Where to plant, (2) when to plant, (3) what species to plant, (4) how to plant and (5) how many trees per acre to plant. It is also important to know how to measure success.

Where to Plant

The land manager decides which areas will be planted. His decisions are based on: (1) Up-to-date planting surveys, (2) timber site-quality maps, (3) soil vegetation maps, (4) available planting stocks, and (5) allocated funds. He usually will schedule work on the best quality lands first, where invested money and manpower will produce the greatest returns.

Specifications and guidelines for placement of trees in a planting area should be prepared by a competent forester who has had planting experience. The following guidelines apply mainly to hand planting, but these procedures should be observed also in machine planting where applicable:

1. Select a spot where the seedling may benefit from the shade cast by a stump, log, or rock.

2. Select a spot with good drainage, but do not plant on a hummock. These small mounds often have dry centers and poor moisture-holding capacities. Depressions should also be avoided, except in areas where drainage is good. Trees planted in deep depressions may be buried with silt.

When to Plant

Spring is the best season to plant in the Southwest. The spring planting season normally extends from about April 14 to May 15. In some years planting may be started earlier, but it should not be extended much later than May 15.

Planting during the summer rainy season is not recommended. Air temperatures are too high, vegetative competition is active, and the amount and distribution of summer rains are too uncertain for planting. Furthermore, nursery stock during summer is in its poorest physiological condition for planting.

Fall planting has been successful on several occasions, but failures are common. Fall planting should not be started until the trees have completely hardened off and the fall rains have wet the soil to a depth of at least 1 foot. Nursery stock lifted before the trees become dormant are in poor physiological condition and have a low potential for root production.

The unpredictable fall and winter precipitation makes fall planting more difficult to schedule and less certain to succeed. Winterkill, most common on south slopes, is usually quite heavy in years when the newly planted trees are not covered by snow.

The slope aspect should be considered in scheduling planting in either spring or fall. South- and west-facing slopes should be planted first in the spring. These aspects are the first to be free of snow and the first to become too dry for planting. The reverse schedule should be followed for fall planting; east- and north-facing slopes will be the first to become inaccessible.

What Species to Plant

The general rule is to plant those species that are native to the planting site. Introduced species may not be adapted to the new environment. Nearly all plantings in the past have been with ponderosa pine for wood products. Future plantings may show an increased use of other species for a variety of purposes.

How to Hand Plant

The following procedure is generally accepted as the best way to plant by the hole method, the preferred method of hand planting. The procedure for the slit method differs somewhat, but it requires the same attention to details.

1. *Prepare spot.*—Clear litter and dry soil from a spot 12 to 15 inches square. Omission of this step permits dust and dry debris to fall in the hole, a common cause of failure.

2. *Dig hole.*—Dig the hole deep enough to accommodate the full length of the roots. Roots must not be doubled up in the bottom of the hole.

3. *Remove one* tree from the planting bag or tray *after* the hole has been dug. If more than one seedling is removed at a time, the fine roots may dry out before the seedlings can be planted. The seedling must be removed carefully from the container to prevent damage to the roots. Keep the trees in the planting bag or tray covered and moist.

4. *Set tree.*—Suspend the tree so the roots are against the rear, vertical wall of the hole. Hold the tree so that it will be planted at about the same depth it grew in the nursery, and spread the roots fanwise against the rear wall. Planting a tree too high will reduce survival more than planting a tree an inch or so deeper than recommended.

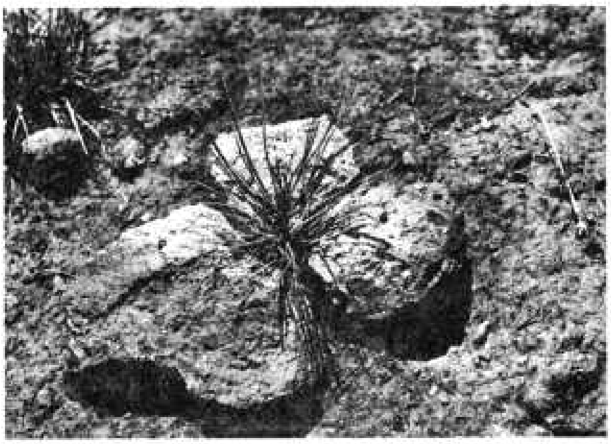
5. *Fill the hole.*—Hold the tree in position with one hand and use the other hand to fill half the hole with moist soil and to firm the soil. Complete filling of the hole with moist soil and tamp firmly in place. Hand tamping is recommended, especially for the lower half of the planting hole. The upper half of the hole can be tamped with the feet or a planting tool, but care must be taken to avoid damaging the tree.

6. *Mulch.*—Push loose soil or litter around the base of the tree to help reduce evaporation of soil moisture. If available, three rocks (fig. 11) or pieces of bark can be placed flat around the tree to reduce moisture loss and to restrict competing vegetation.

How to Machine Plant

Machine planting requires the same strict adherence to detail as hand planting (fig. 12). Some of the more important requirements are:

1. *Prepare area.*—Remove all herbaceous vegetation, litter, slash, and other debris. Vegetation uses moisture needed for tree growth, and interferes with the proper operation of the planting machine. Litter, slash, and other debris also cause improper machine operation and planting.



F–516090

Figure 11.—Three rocks placed around the base of a newly planted tree provide shade and retard loss of moisture.

2. *Check soil moisture.*—Soil should be moist but not wet. Planting machines do not operate properly on muddy soil.

3. *Observe weather.*—The weather should be reasonably calm and humid. Greater care is required to prevent damage to trees planted on hot, dry days.

F–516070

Figure 12.—Trees planted with a planting machine on a well-prepared site.

4. *Set planting depth.*—Adjust coulter and trencher to set trees with roots fully extended.

5. *Pack soil.*—Adjust packing wheels so soil is packed firmly around trees.

6. *Protect trees.*—Remove no more trees from the container at any one time than can be planted before the roots show evidence of drying.

7. *Protect trees in carrier on planting machine.*—Insure that roots are kept moist. Excessive exposure to sun and dry air will kill the trees.

8. *Regulate spacing.*—Place trees in a trench at approximate specified spacing. Avoid setting plants on rocks, roots, or other debris, or in a shallow trench.

How Many Trees to Plant

The present stocking goal in the Southwest is 340 trees with an average diameter of 5 inches per acre. This rate is based on the requirement for stands with an average basal area level of 80 square feet when the trees approach pulpwood size. Current research on stocking levels may suggest different future stocking goals based on site quality and desired wood product.

To achieve this stocking goal, 680 trees per acre should be planted at approximately 8- by 8-foot spacing. This recommendation is based on the current 50-percent mortality experienced in the Southwest. If local success deviates appreciably from the 50-percent average, an adjustment should be made to achieve the specified stocking goal.

HOW TO MEASURE SUCCESS

An accurate estimate of the "success" of planting must be obtained to determine effectiveness of planting methods and whether replanting is needed to develop adequate stocking.

Several methods are used to measure survival. Whatever the method, it is most important that all major site differences and all planters are represented in the sample. To obtain such representation, run the sample lines obliquely to both contours and planting lines.

One method is to stake, immediately after planting, all trees within 3.3 feet of each side of a sample line to provide a basis for future sampling—preferably after the first and fifth growing seasons. Sufficient lines should be run so that the number of staked trees is 10 to 15 times the number of acres planted. For small plantations, sample at least 100 trees. After the first year, natural seedlings should be counted if they stock spots where planted trees have died. Natural seedlings that grow within a 4.5-foot radius (about 64 square feet) of the stake are tallied as stocking the spot. Both survival of planted trees and the percentage of stocked spots can be computed from these data.

The same procedure may be followed to measure success for direct seeding.

DIRECT SEEDING

Direct seeding, while more economical and flexible than planting, is less reliable. With a large seed bank, areas can be seeded promptly when the need arises, whereas planting requires 2 to 3 years to produce planting stock. Total costs for seeding generally average one-fourth to one-half of planting costs.

DIRECT SEEDING METHODS

There are three general direct seeding methods: (1) Broadcast seeding (either from the air or ground), (2) Spot seeding (sowing in prepared spots), and (3) drill seeding.

Broadcast Seeding

In broadcast seeding, seed is simply scattered on the soil. It has been the least effective of the three methods. The main disadvantages are:

1. Broadcast seeding requires a large amount of seed—about 2 to 10 times more seed than the other two methods.

2. Losses of exposed seed to birds and rodents are high.

3. Seed germination is commonly poor—the surface soil dries out too rapidly, even during the summer rainy season.

4. Much of the seed falls on unfavorable spots—rocks, stumps, logs, trash, and other poor microsites.

Broadcast seeding has two advantages over the other two methods—it is easier and faster.

However, some disadvantages of broadcast seeding can be minimized by adequate site preparation, rodent control, and seed coverage. When causes of heavy seed and seedling losses are minimized, broadcast seeding can be a satisfactory method of artificial regeneration.

Spot Seeding

Spot seeding has been the most effective method in the West. It has several distinct advantages over broadcast seeding:

1. Less seed is required—usually less than 5,000 per acre.

2. The seed can be placed in the most favorable spots—the shady side of rocks, stumps, and logs, and where soil is moist.

3. The seeds are covered with soil, giving them the best chance to germinate and develop into thrifty seedlings.

4. Seed destruction by birds is virtually eliminated since birds feed mostly on uncovered seeds.

5. Seeds are easier to protect against rodents because spots can be covered with wire screens. Even if spots are not screened, seed is more likely to be missed than when it is exposed on the surface. However, since rodents are very adept at finding seeds under the soil surface, seed coverage alone does not provide adequate protection.

The main disadvantage of seed-spot sowing is the time required. The method is not much faster than planting.

Drill Seeding

Several types of heavy-duty seed drills can be used to sow forest tree seed. A rangeland drill (fig. 13) was successfully tested in California (Schubert et al. 1960) and has shown promise in the Southwest. Improved special seeders, which may replace the rangeland drill, have been developed in recent years. Drilling the seed is faster and cheaper than spot seeding, and requires far less seed than broadcast seeding. Also, drilled seeds are not as easily found by rodents and birds.

Drills are not satisfactory for use on steep slopes or on areas covered with rocks or debris.

F-516071

Figure 13.—Rangeland drill used for sowing ponderosa pine seed. Seed is sown through the two down drills, and is covered with the chains dragged behind.

DIRECT SEEDING PROCEDURES

The requirements for successful direct seeding have been fairly well established but have not always been achieved. Many of these requirements apply to both planting and seeding (see sections on seed requirements, site preparation, and plantation care). Also, methods and techniques that can be used to improve stocking on seeded areas have been developed.

This section applies mostly to spot seeding, but also contains information useful in broadcast and drill seeding.

Rodent Control

Without effective control, rodents—(mainly mice *Microtus* and *Peromyscus* spp.)—may consume most seed. Three methods are used to reduce losses: (1) Distributing lethal baits over the regeneration area to reduce the rodent population, (2) covering seed spots with screen barriers to exclude rodents from seed, and (3) treating seed with toxic or repellent chemicals to reduce rodent population or to repel rodents from seed.

Lethal bait.—Rodent populations can be reduced by lethal baits, but this method has three undesirable features: (1) Birds and other animals may be killed if necessary precautions are not followed; (2) rodents also eat cutworms, white grubs, and other insects that destroy seedlings, and (3) a population vacuum that is soon filled by rodents from adjacent untreated areas is left.

Extreme precautions must always be taken when lethal chemicals are used in direct seeding; proper clearance *must* be obtained from local authorities.[2]

The most commonly used rodenticides are sodium fluoroacetate (Compound "1080") and thallium sulfate. These lethal chemicals are used as a soaked bait or coating on grain carriers, usually wheat, oats, or corn. Recent studies on the Lincoln National Forest, N. Mex., showed rodent population reductions of 97 percent with "1080" treated oats, 90 percent with endrin, and 94 percent with DRC-714 on 10-acre plots.

The lethal bait is placed in selected spots, such as under logs, stumps, rocks, and other spots where rodents travel, but where the bait

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[2] Personnel of the U.S. Department of the Interior's Fish and Wildlife Service and especially the Service's Bureau of Sport Fisheries and Wildlife have been most helpful in treating the seeds, and they should be consulted for the latest information.

cannot be reached by birds, livestock, and game animals. The lethal bait *must never* be left exposed. A buffer strip 200 to 300 feet wide around the regeneration area is heavily baited to intercept any migrants.

Eighty to 100 bait spots per acre must be placed in the regeneration area, and 160 to 200 must be put in the buffer strip. Each bait spot should have about one-half ounce of treated grain.

The time of baiting is important. Some rodents hibernate (e.g., meadow mice and chipmunks), whereas others do not (e.g., deer mice), but all feed on any available conifer seeds.

The following schedule is suggested for baiting to protect a late-spring or early-summer seeding. At least two bait treatments are needed. The first treatment should be applied about 1 week before seeding, and the second when the seeds start to germinate. Both the lethal chemical and grain should be changed at each treatment date. For example, if the first treatment is "1080" on wheat, the second treatment should be thallium sulfate on oats.

A fall seeding will require at least three and sometimes four bait treatments. The first treatment should be applied about 1 week before seeding; the second in early spring when the area becomes accessible; and the third in late June or early July about a week before seed germination. A fourth treatment, if needed, should be applied in early winter to control deer mice, which do not hibernate during the winter.

Screen barriers.—Seeds can be protected from rodents and birds by placing small hardware cloth screens over the seed spots (fig. 14).

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Figure 14.—Conical screens for protecting seed spots.

The seedlings also appeared to benefit from the shade cast by the screens.

Screen barriers are quite effective, but they do not always insure success. Their effectiveness is often reduced with repeated use in the same area. Large squirrels and other animals will often knock over the screens, and small animals will tunnel under them to get the seeds.

Screen barriers are also expensive to use and, therefore, are used mainly on small-scale operations. The screens, which cost from 75 to 90 cents each, must be (1) transported to the area, (2) distributed to the seeding spots, (3) worked into the soil about 1 inch, (4) removed at the start of the second growing season, and (5) transported back to the warehouse for reuse on the next project.

Seed treatment.—The ideal method to control rodents that seriously threaten the success of a direct-seeding project is to pretreat the conifer seed with an effective repellent or with a sublethal dose of a systemic poison. However, only a few of the several thousand chemicals tried have shown promise, and none of those marketable are effective as repellents.

Endrin-thiram is the most widely used seed treatment.[3] Endrin, a highly toxic insecticide, has been effective as a seed treatment for mice but not for the larger rodents. Thiram (tetramethyl thiuram-disulfide), commonly used as a fungicide, was added (1) to improve the effectiveness against chipmunks and ground squirrels, (2) to repel birds, and (3) to reduce loss from damping-off fungi. This combination of endrin-thiram has been effective [and has been recommended for use] in the Southeast (Derr 1964). However, since the endrin-thiram concentration needed for adequate seed protection exceeds the amount permitted under Forest Service policy, the endrin-thiram treatment *cannot* be recommended for use in the Southwest.

Although endrin is an insecticide, it does not protect the seedlings from insects when it is used as described above. If cutworms, grubs, and wireworms are troublesome in the area to be seeded, the seed spots should be treated with chlordane.

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[3] Recently a new compound, designated as DRC-714 by the U.S. Department of the Interior's Fish and Wildlife Service and the Service's Bureau of Sport Fisheries and Wildlife, at Denver, Colo., facilities, has shown considerable promise in trials on the Lincoln National Forest, New Mex.

Where to Use Direct Seeding

Direct seeding is most successful on moist mineral soil of north slopes where vegetation has been killed or removed to minimize competition for moisture or light, at least during the first growing season. Freshly burned and logged areas sometimes do not require supplemental site preparation.

Rodent populations (particularly mice) are lowest in uncut timber stands and highest in old cutover or burned areas. Therefore, newly cut areas should be seeded the first year before rodent populations build up, and while herbaceous competition is low or absent. Older burns and logged areas should be seeded only after complete site preparation, including destruction of rodent habitat.

Spots for seeding should be selected with the same care used in choosing a spot for planting. The best sites provide the best opportunity for success. Rocky areas that are difficult to plant are often favorable for seeding. The rocks protect the seedlings from frost heaving and animal browsing.

When to Use Direct Seeding

In the Southwest both temperature and moisture are suitable for seed germination only after the beginning of the summer rains in July.

During April and May, there is still adequate soil moisture for germination, but the temperature is usually too low (fig. 15). During June, if the temperature is adequate, the surface of the soil is usually too dry.

Pearson (1950) stated that pine seed can be sown any time between October 1 and the following July when site conditions permit. However, seed sown in late June germinated just as soon as that sown earlier (Larson 1961). Therefore, sowing earlier than necessary exposes the seed unnecessarily long to birds and rodents.

Direct-seeding projects should be planned so they are started as late as possible and are still completed before the end of June. This scheduling reduces the time seed is exposed to rodents and birds, and requires less rodent control for effective protection. It is important

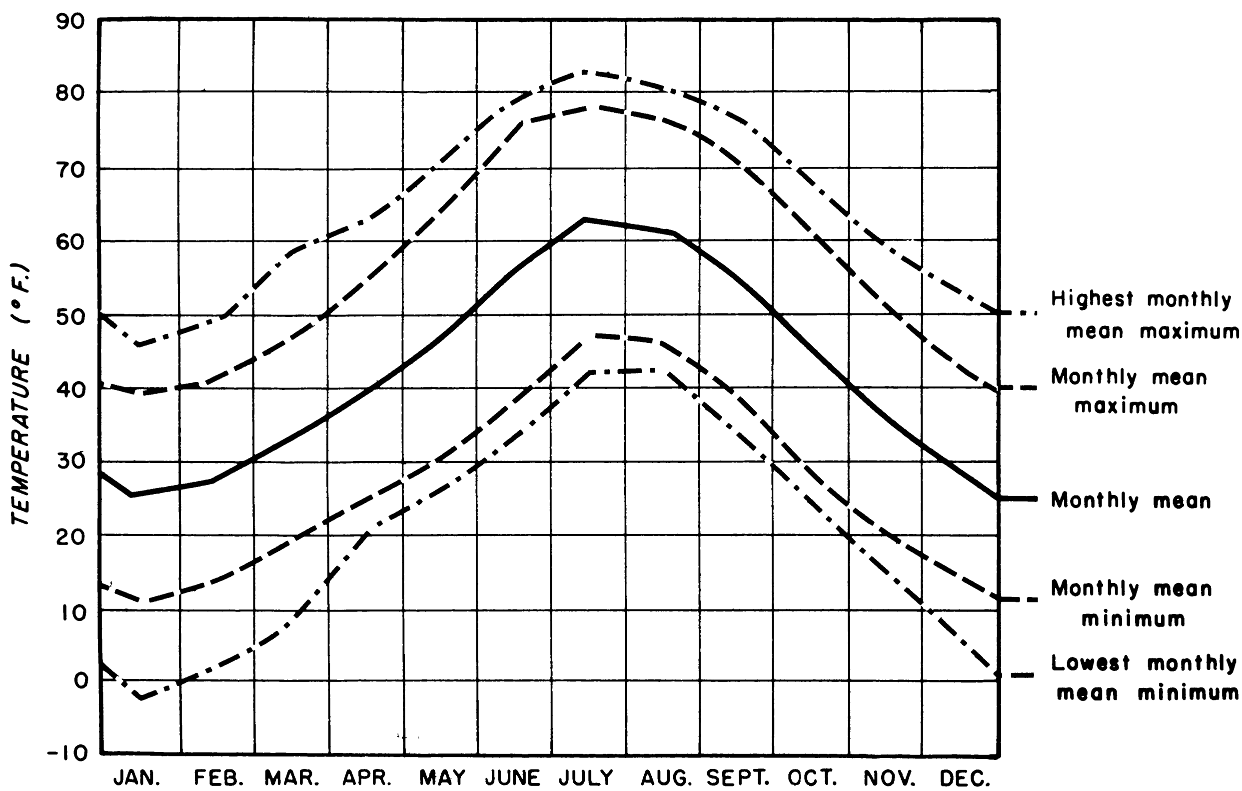

Figure 15.—Mean temperature data for Fort Valley Experimental Forest, 1909-42.

to sow before the summer rains begin so that seeds can germinate at the earliest possible date. Larson (1961, 1963) observed that seedlings that started earliest survived best. Also, seedlings that germinated during the week of July 22 grew roots nearly three times as long by November as seedlings that germinated during the week of August 26 (fig. 16).

The usual germination period for ponderosa pine seed is 2 to 4 weeks. If rains are late or deficient, germination may be delayed until late summer or fall. When this happens, most seedlings die, and resowing will be necessary.

Species for Direct Seeding

Ponderosa pine is the most important timber species in the Southwest; in that area the type constitutes 75 percent of the commercial forest area. Within this pure timber type, it is not difficult to select the species to seed.

In the mixed-conifer types, which occupy about 20 percent of the land (13 percent is Douglas-fir and 7 percent is spruce-fir), a

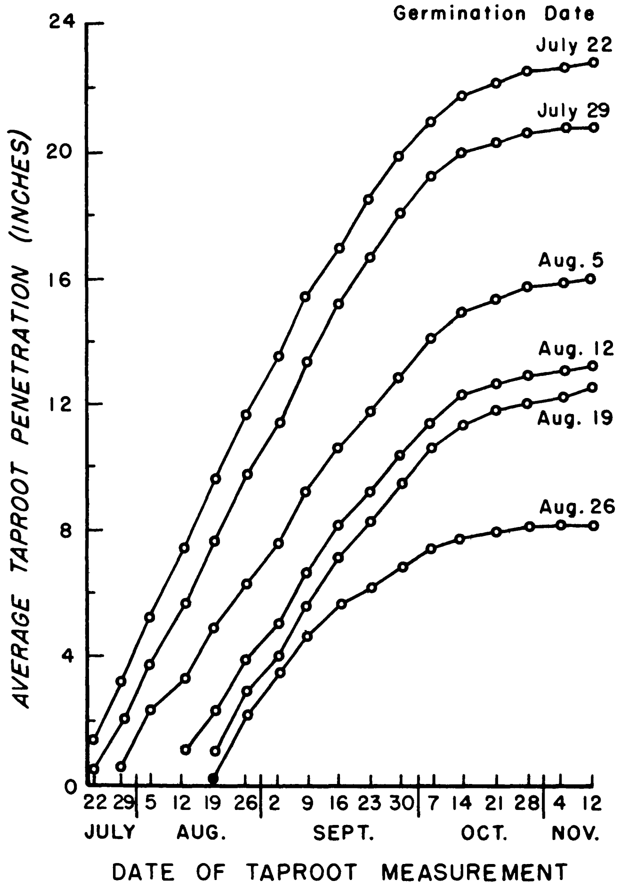

Figure 16.—Average cumulative taproot penetration of seedlings germinating at different dates (Larson 1963).

choice must be made. The choice usually will be based on ecological suitability for the specific environments and on economic desirability. The most logical choice would be to seed the species that already has performed the best on the particular site.

Large-seeded species have been most promising. Among Southwest species, southwestern white pine (*Pinus strobiformis* Engelm.) has been seeded most successfully; ponderosa pine, Douglas-fir, and true firs with intermediate success; and spruce least successfully.

Number of Seeds to Sow

The amount of seed required for direct seeding depends on many variables. Some variables, such as the number of seeds per pound and viability, can be determined with reasonable certainty. However, the effect of weather and biotic agents on seed germination and seedling establishment must be estimated from past performance. At best, these are only rough guides, since the environmental conditions vary from place to place and from year to year.

The amount of seed required also depends on the sowing method. Drill sowing requires more seed than spot seeding, but considerably less than broadcast sowing.

Spot seeding.—Sowing rates previously recommended have been too heavy. Pearson (1950) recommended sowing 10 to 15 seeds per spot and Krauch (1936, 1938) recommended 30 to 40 per spot.

The number of seeds sown in each spot should be just sufficient to insure that the desired number of spots will have at least one seedling and that few will have many seedlings.

A guide was developed in California to determine the number of seeds to sow per spot for different stocking levels (fig. 17). To use the guide, one must know the expected germination and survival ratios. The germination ratio is the number of germinated seeds divided by the number sown. The survival ratio is the number of seedlings alive after two growing seasons divided by the number initially emerged. To obtain nearly optimum effectiveness, the survival ratio should be based on data collected over a period of many years. If no data are available, assume a survival ratio of 0.40 for the first seeding, and then adjust for future sowings.

Use the following procedure to determine the number of seeds to sow per spot (see fig. 17):

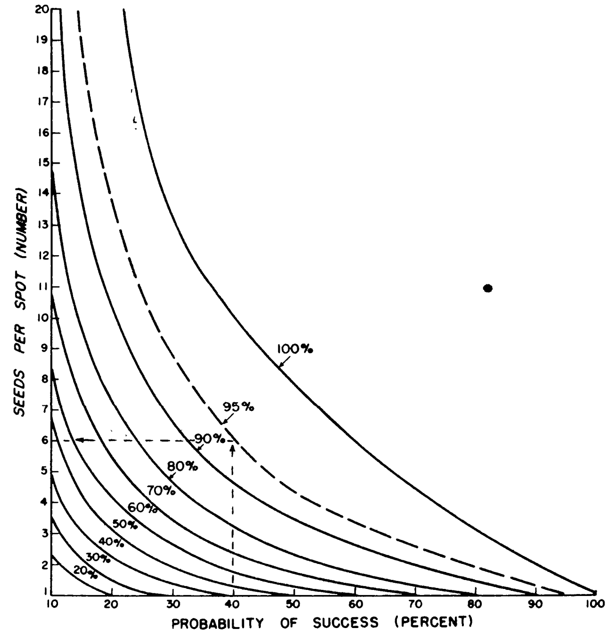

Figure 17.—Stocking curves for various probabilities of success and sowing rates in spot seeding (Schubert and Fowells 1964).

1. Determine the seed germination ratio and the seedling survival ratio.
2. Multiply the germination ratio by the survival ratio to find the probability of success.
3. Locate the probability of sucess on the horizontal axis of figure 17.
4. Extend a vertical line from the probability of success to the acceptable stocking-level curve.
5. Run a line horizontally from the intersection on the stocking level curve to the number of seeds axis.

For example, if the germination ratio is 0.80 and the survival ratio 0.50, the probability of sucess is 40 percent. If you want 95 percent of the spots to have at least one seedling, you should sow six seeds per spot. If you would be satisfied with stocking of 80 percent of the spots, you should sow only three seeds per spot.

Three items must be considered in the application of the seeding guide. First, seed germination in the field may be 10- to 30-percent lower than in the laboratory. If the difference is known, the germination ratio should be adjusted. Second, complete stocking requires two or more times as much seed per spot as 80- to 90-percent stocking. Third, a high sowing rate results in excessive seedlings in many spots.

The survival ratio in the Southwest is likely to be low. Thus, many seeds are needed per spot to obtain a high percent of stocking, and yet many spots (those with a high survival rate) then have far too many seedlings. To avoid these undesirable features, it is advisable to accept a lower proportion of successfully stocked spots, and to sow more spots per acre with fewer seeds per spot. Forty-percent stocking is recommended. In other words, it is better to accept 40 percent of the spots with one or more seedlings. If more than five seeds per spot are required, a lower stocking percentage should be accepted.

Number of seed spots per acre.—The initial stocking for direct seeding should be the same as for planting, usually about 680 spots per acre. Acceptance of a lower stocking percentage requires additional spots to produce the 680 stocked spots. To add the extra spots, reduce the distance between spots in the row, but maintain the 8 feet between rows. For example, for 50-percent stocking, the spots should be set 4 feet apart in the rows. If the recommended 40-percent stocking is accepted, the distance between spots in the rows would be 3.2 feet (8 × 0.40 = 3.2). The following tabulation indicates the number of spots and spacing for different stocking percentages:

Stocking	*Spots per acre*	*Distance between spots in rows 8 feet apart*
(Percent)	*(Number)*	*(Feet)*
100	680	8.0
90	756	7.2
80	850	6.4
70	971	5.6
60	1,133	4.8
50	1,360	4.0
40	1,700	3.2
30	2,267	2.4
20	3,400	1.6
10	6,800	.8

The normal range in seed requirements for spot seeding for the Southwest is 1,700 to 3,400 per acre. This range is based on an assumption of 25- to 40-percent probability of success, when 40 percent of the spots are stocked. A higher acceptable stocking for the same probability of success would require more seeds. For example, to obtain 80-percent stocking, 2,550 to 5,100 seeds per acre would be required.

Drill sowing.—For drill sowing, 10,000–12,000 viable seeds per acre are recommended until experience indicates that a higher or lower rate is needed. Drill sowing requires more seeds than spot seeding because: (1) Many seeds will be dropped on unfavorable spots, (2) a high proportion of the seeds may be buried too deep or too shallow, and (3) some seeds may be damaged by the metering mechanism or by the packing wheel.

The distance between rows should be established by specifications. A single-drill unit can be operated to space rows at any prescribed distance. Some multiple-drill units have fixed distances between drills, whereas others permit adjustments within limits of the machine or obstacles on the seeding area.

The sowing rate in each row will depend on the distance between rows and on the probability of success. For drills set 8 feet apart, the metering mechanism should be set to drop seeds at double the frequency needed with 4 feet between drill rows. The seeds should be sown about one-fourth inch deep; for ponderosa pine, they should never be sown more than a half inch deep.

Broadcast sowing.—Seeding rates will be governed by severity of site conditions. From 16,000 to 32,000 *viable* seeds per acre are recommended for moist, north slopes. On the Dudley Lake burn, Sitgreaves National Forest, about 2 pounds (approximately 22,000 seeds) of ponderosa pine were sown per acre, but stocking was adequate only on north-facing slopes.

Much higher rates—possibly impractical ones—may be required for dry, south slopes. Suggested rates for south slopes are 32,000–48,000 *viable* seeds per acre. Heavy seedling mortality on south slopes results from high soil surface temperature and low soil moisture, which often cannot be corrected economically. Intermediate aspects should be seeded with about 32,000 viable seeds per acre.

The recommended rates for north slopes reflect seedling to viable seed ratios of 1:8 to produce the required 2,000 first-year seedlings. This goal can be achieved only where: (1) A moist mineral seedbed has been provided, (2) competition has been eliminated, and (3) the seeds are protected from birds and rodents. Seeds should never be planted on unprepared areas.

PLANTATION CARE

Successful seeding or planting is only the first step in reforestation. New plantations must receive care and protection. A mortality of 30 to 40 percent may be expected during the first decade. Mortality may be caused by such physical factors as climate and environment, including fire, or by such biotic factors as insects, diseases, animals, or other vegetation. Proper management can greatly reduce the adverse effect of many of these factors.

CLIMATE AND ENVIRONMENT

Young seedlings are particularly susceptible to heat, drought, freezing, frost heaving, and winterkill. Shade and litter can reduce seedling losses from all these causes (Krauch 1956, Larson 1960, Pearson 1950).

The benefits of shade or litter depend upon:

1. *Amount.*—Light shade improves survival of newly planted trees of all Southwestern species. However, any kind of dense overhead shade is harmful. Ponderosa pine seedlings require less shade than Douglas-fir, white fir (*Abies concolor* (Gord. and Glend.) Lindl.), or Engelmann spruce (*Picea engelmannii* Parry).
2. *Type.*—Dead shade furnished by rocks, logs, or stumps is better than live shade for initial survival of ponderosa pine and Douglas-fir seedlings.
3. *When.*—Both shade and litter are usually beneficial, if not too heavy, during the first few years. After the seedlings are well-established, the need for shade is reduced.
4. *Where.*—Shade is most beneficial for seedlings on warm, south-facing slopes, especially at the lower elevational zones of the species. Shade is less beneficial and even harmful on cold, north-facing slopes. At higher elevations, new seedlings of many species must have at least partial shade.

FIRE

Fire, even so-called light fire, is lethal to seedlings and saplings of Southwestern conifers. Grazing, if carefully timed, may effectively reduce the fire hazard due to dry grass without excessive pine browsing. Cattle cause most damage during the spring and fall droughts, and little damage during the summer rainy season. Bunchgrasses grazed to a height of 6 inches by the end of the season will maintain an adequate vegetative cover on moderate slopes without contributing unduly to the fire hazard.

BIOLOGICAL FACTORS

Diseases

The most important diseases of young conifers in the Southwest are dwarf mistletoe (*Arceuthobium vaginatum* f. *cryptopodum* (Engelm.) Gill), root rots (*Armillaria mellea* (Vahl.) Quel. and *Fomes annosus* (Fr.) Cke.), and the western gall rust (*Peridermium harknessii* Moore).

Prevention, avoidance, and direct control methods for these and other important diseases vary considerably depending on several factors. For this reason, advice and assistance by qualified pathologists should be requested as necessary.

Insects

Cutworms, white grubs, and tip moths are the most serious insect pests of young trees in the Southwest. Cutworms (*Noctuidae*) and white grubs (*Phyllophaga* spp.) are most abundant on areas with a heavy cover of grass and weeds. They feed on the roots of seedlings. Tip moths (*Rhyacionia* spp.) often kill terminals and deform trees—from seedlings to small-pole sizes. Slower growing trees usually are more seriously injured and deformed than fast-growing trees.

These harmful insects can be controlled. Cutworms and white grubs can be killed with chlordane applied to the soil at a rate of 3 pounds per acre, or their number can be greatly reduced by complete site preparation that eliminates their main food supply. Tip moths can be killed by chemical sprays. Pine terminals should be sprayed before May 1 with an emulsion containing 1 quart of Dimethoate (CYGON) emulsifiable concentrate containing 4 pounds per gallon in 100 gallons of water. Early detection and control are important.

Competition

Young trees compete with all other vegetation and with each other to obtain those items necessary for survival and growth. Pearson (1942) clearly demonstrated that competing vegetation, particularly grass, is a major deterrent to the establishment of pine seedlings. His studies strongly emphasize the importance of adequate site preparation.

Spring-growing grasses, such as Arizona fescue, compete more severely than summer-growing grasses, such as mountain muhly and blue grama. Spring-growing grasses use much of the available soil moisture during the severe spring drought—a critical time for survival of young tree seedlings. The competition for light and nutrients was considered secondary to the competition for moisture.

Some grass species produce chemical inhibitors (Jameson 1961) that reduce seed germination and seedling growth. The importance of these inhibitors has not been fully evaluated.

Methods to destroy competing vegetation were discussed in the previous section on "site preparation." Regenerated areas may be grazed to reduce the grass competition after the trees are tall enough to be safe from browsing. Pines taller than 3 feet are seldom browsed by cattle.

Small Animals

Many species of small animals seriously damage young forest trees. Mice, squirrels, rats (*Neotoma* and *Dipodomys* spp.), and chipmunks destroy small seedlings. Pocket gophers (*Thomomys* spp.) feed on their roots. Rabbits (*Lepus* and *Sylvilagus* spp.) and porcupines (*Erethizon* spp.) girdle and cut stems of larger seedlings (fig. 18). In fact, entire plantations have been destroyed or deformed by these animals!

Control methods differ. Complete removal of the vegetation before planting helps to reduce the number of small animals by lessening their food supplies and cover. These animals also may be killed by poison. Repellents, such as TMTD and ZAC,[4] have been effective against rabbits. Porcupine damage is most frequent

[4] TMTD = tetramethyl thiuram disulfide (arasan); ZAC = zinc dimethyl dithio carbamate cyclohexylamine complex.

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Figure 18.—Young ponderosa pine recovering from severe injury caused by porcupine.

along streams, around meadows, and in areas adjacent to rock outcrops suitable for dens. Trapping, shooting, and poisoning have been used to reduce porcupine populations.

Browsing Animals

Cattle (fig. 19), sheep, and elk (*Cervus* spp.) (fig. 20) have severely damaged and killed young conifer reproduction in many localities throughout the Southwest. On the Coconino National Forest, Ariz., domestic livestock frequently have browsed or trampled up to 90 percent of the small trees in new plantations. In a recent study, covering a 3-year period on three 40-acre plots from which domestic livestock was excluded, all ponderosa pine seedlings more than 3 years old and less than 4 feet tall were browsed by deer.

F-516065

Figure 19.—Cattle damage to ponderosa pine seedling. Most of the surviving trees in this plantation were browsed and in poor condition a few months after planting.

F-516091

Figure 20.—Ponderosa pine seedlings badly "hedged" by repeated browsing by deer.

Livestock damage on coniferous reproduction varies by (1) kind of animals, (2) season of grazing, (3) intensity of grazing, and (4) size of the trees. Sheep are by far more destructive than cattle or horses. Even under light to moderate sheep grazing, conifer seedlings have suffered heavy damage. Pearson (1950) reported that sizable areas of the 1919 reproduction suffered a loss of 50 to 75 percent of the seedlings under 3 years old. After 5 or 6 years, very litle damage was caused by cattle. In general, cattle seldom browse trees taller than 3 feet, whereas sheep may seriously damage trees up to 5 feet tall.

Cassidy (1937a, 1937b) found browsing by cattle and sheep were related primarily to conditions causing thirst. Damage was most severe during the May-June drought, but it also occurred during short, rainless periods in the summer and drought during the fall. Livestock browsing during the May-June drought was confined mainly to the terminal leaders; during the fall drought, needles were eaten, primarily by sheep (Parker 1948). Damage by cattle and sheep could be appreciably reduced by providing an adequate, accessible supply of water, and by stocking only on the basis of the volume of green feed.

Plantations should not be grazed for the first 5 or 6 years. Even after this initial period, cattle grazing should be deferred until about July 15, until seedling terminals are out of reach. If grazing is deferred regularly until mid-July, cattle could be used effectively in older plantations to: (1) Utilize the bunchgrasses without seriously damaging the pines, (2) encourage pine regeneration by relieving grass competition, and (3) lower the fire hazard by reducing the volume of dry grass carried over into the succeeding fire season.

For sheep, Pearson (1950) suggested enforcement of a 1-night bedding rule, with bed grounds at least one-half mile apart. Grazing need not be deferred after seedlings have grown 3 to 5 feet tall, which may be 10 to 15 years after planting.

Deer begin to browse pine shoots earlier than domestic livestock. Heidmann (1963) found that shoot damage can be greatly reduced by treatments with either of two chemical deer repellents, TMTD or ZAC (fig. 21). Only 8 or 9 percent of repellent-treated shoots were

F-516092, 516093

Figure 21.—Heavily browsed ponderosa pine seedlings (A) treated with ZAC in 1958. Five years later (B) most terminals are out of reach.

browsed, compared with 56 percent of untreated shoots (fig. 22). Since browsing occurred only during active terminal growth in June and July, the repellent should be applied in May before growth starts, until the trees are out of the reach of deer. Planted or natural seedlings, 3 to 4 feet tall may be released from deer browsing with one repellent treatment. Nursery stock may be treated before lifting for about $0.80 per M.

SUMMARY OF MAIN POINTS

More than one-half million acres are in need of reforestation in the Southwest. Both experience and research have demonstrated that

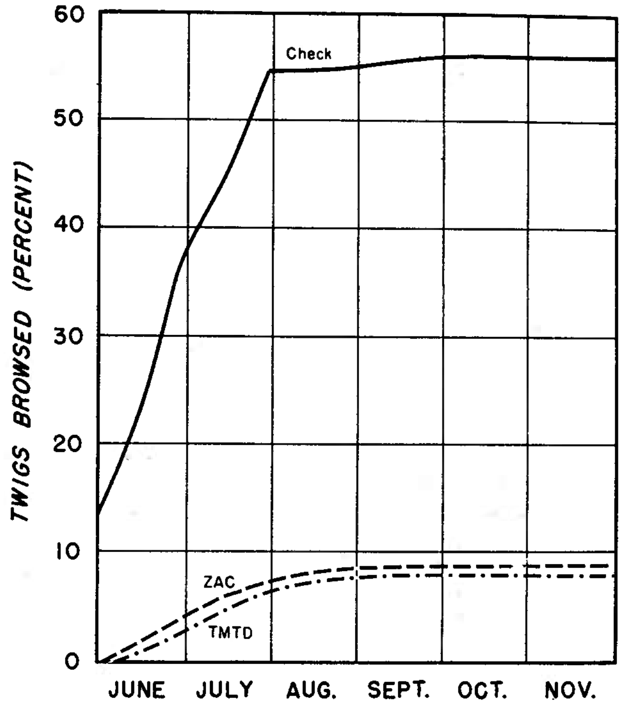

Figure 22.—Cumulative percentage of ponderosa pine twigs browsed by deer during the first year after treatment at Fort Valley, 1958.

successful plantations are possible if the job is done right (fig. 23). This manual summarizes the important points that should guide the land manager in establishing new stands of trees.

SEED REQUIREMENTS

Seed Source.—Use local seed when possible. If none is available, use seed from a source with a similar climate.

Seed Production.—Good seed years occur about once in 3 or 4 years, and a bumper crop occurs about once in 7 to 10 years. Potential seed crops may fail to materialize due to the activity of insects or squirrels, or to adverse weather.

Seed Collection.—Maintain at least a 4-year seed supply. Collect only mature seed from trees with good form and vigor. Plantations from a known seed source may be good collection areas.

Seed Storage.—Seed should be dried to a moisture content of 4 to 8 percent, put into air-tight containers, and stored at 0° F.

SEEDLING REQUIREMENTS

Lifting Nursery Stock.—Do not lift trees in the fall until they are hardened off. Spring

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Figure 23.—Successful ponderosa pine plantation established in 1917 at Fort Valley Experimental Forest.

lifting must be completed before top growth starts.

Size and Quality.—A plantable tree should have a stem diameter of at least 0.16 inch for the pines and true firs and 0.10 inch for other species. It must be undamaged, have a well-developed top-root system, and be free of disease.

Stock Shipment.—Trees must be kept cool and moist, and must be shipped by the fastest available means.

Stock Storage.—Trees should be stored in a moist, cold room (34° to 36° F.) either at the nursery or the forest headquarters, or in heel-in beds at the planting site.

Wildling Stock.—Extreme care must be taken to minimize damage to roots and to keep them moist. Nursery-grown stock is preferred.

SITE PREPARATION

General.—For best results from seeding or planting, all competing vegetation must be removed. Dense vegetation depletes soil moisture, intercepts light, and provides a favorable habitat for some seed- and seedling-eating rodents and insects.

Chemical Site Preparation.—Brush can be controlled with 2,4-D or 2,4,5-T, and grass can be controlled with dalapon. Dead grass helps conserve soil moisture. Follow recommended dosages and timing to obtain the best kill. Be sure to follow all precautions given on the container label.

Mechanical Site Preparation.—Complete removal of vegetation over large areas is preferred to small patch scalping. Sites should be prepared in late summer or fall prior to planting.

Fire for Site Preparation.—It is not effective when used alone, but it can be useful in combination with other methods.

PLANTING

Planting Methods

Hand Planting.—Most trees are now planted in holes dug with handtools. Several types of power augers are available for hole digging. Use of these augers may speed the planting, reduce the hand labor required, and improve survival.

Machine Planting.—On suitable areas, machine planting is the easiest, quickest, and most economical method of planting. The machines operate best on level or gentle slopes where the soil contains few large rocks, roots, stumps, and other debris. Steeper slopes can also be planted by machine if contour trenches are dug before or during planting.

Planting Procedures

Where to Plant.—The most favorable areas should be planted first. Select individual planting spots that offer the best chance for success: spots where there is no competing vegetation and where the soil is deep and well drained. Also, take advantage of dead shade from stumps, logs, and rocks, but do not plant in vegetated places or in places closer to living trees than one-half the height of the trees.

When to Plant.—Spring planting is better than fall planting. Spring planting should begin as soon as the site is open and should end about May 15. Fall planting should be delayed until the ground is thoroughly moistened to a depth of 1 foot and the trees have hardened off. Plant south slopes first in the spring, and north slopes first in the fall.

Species to Plant.—Plant only species known to be adaptable to the site and climate.

How to Hand Plant.—Careful attention must be given to the following steps: (1) Preparing the spot, (2) digging the hole, (3) handling the seedling to prevent root damage, (4) keeping the tree roots moist, (5) placing the tree in the hole, (6) filling the hole, and (7) mulching the planting spot.

How to Machine Plant.—Strict adherence must be given to the following steps: (1) Preparing the area, (2) checking the soil moisture, (3) planting when weather is reasonably calm and moist, (4) setting the tree at correct depth, (5) packing soil around the roots, (6) keeping the roots moist, and (7) placing the trees in the trench.

How Many Trees to Plant.—It is recommended that 680 trees per acre be planted on an 8- by 8-foot spacing. This number is required to achieve present stocking goals of 340 trees per acre with an average diameter of 5 inches.

How to Measure Success.—Run simple lines obliquely to both contour and planting lines. Stake all trees within 3.3 feet of the sample line. Make survival counts at least at the end of the first and fifth growing seasons. Compute the percentage of survival and that of stocked spots. The same procedures may be followed to measure success for direct seeding.

DIRECT SEEDING

Seeding Methods

Broadcast Seeding.—Although fast and flexible, broadcast seeding has been the least effective method and has required the most seed. However, if it is done on properly prepared sites, it may be the best way to seed large areas to keep timberland productive.

Spot Seeding.—This has been the most effective method. It requires the least seed and the seed can be placed in the best locations and covered with soil to improve chances of germination and early survival.

Drill Seeding.—This method has not been tried in the Southwest, but it has many of the advantages of seed-spot sowing, requires less seed than broadcast seeding, and is faster than spot seeding.

Seeding Procedures

Rodent Control.—Rodents must be controlled to make any method of direct seeding feasible. The use of wire screens has been the only consistent way of protecting the seed on experimental plots, but the method is expensive. An endrin-thiram repellent is widely used, but it is not always successful. Poisoning has been effective in many places.

Where to Direct Seed.—Fresh timber burns and logged areas are most promising for direct seeding. Frequently these areas can be seeded without additional site preparation.

When to seed.—The best time to seed is during the last half of June. This is shortly before the summer rains needed for seed germination, and thereby lessens the time seeds are exposed to damage by rodents and birds.

Species to Direct Seed.—The best species to sow are ponderosa pine, limber pine, and Douglas-fir. The species should be adapted to the area.

Number of Seeds to Sow.—Seeding rates will vary considerably, depending on sowing method, seed quality, and specific site. Per-acre rates with good seed range from 1,700 to 4,800 for spot seeding; from 10,000 to 12,000 for drill seeding; and from 16,000 to 48,000 for broadcast seeding on moist, well-prepared areas.

PLANTATION CARE

Climate and Environment

Young seedlings are particularly susceptible to excessive heat, drought, and cold. Light to moderate dead shade has a beneficial effect on seedlings and transplants during their period of establishment. After trees are well established, shade is no longer required and may even be harmful.

Fire

Provide an adequate firebreak, and reduce the amount of heavy fuels on the regeneration area. After trees are free from browsing danger, grazing may be used to reduce the amount of grass fuel.

Biological Factors

Insects.—Cutworms, white grubs, and tip moths are the most damaging insects to seedlings and young trees. Cutworms and white grubs can be controlled through complete site preparation and insecticide treatments. Damage by tip moths can be reduced by use of insecticides and by maintaining vigorous trees.

Diseases.—The most common diseases of young plantations are dwarf mistletoe, two species of root rot, and western gall rust. All dwarf mistletoe- and rust-infected trees should be eliminated in and adjacent to the regeneration area before planting. Areas with root rot should be avoided.

Competition.—Competing grasses can be killed with dalapon without damage to ponderosa pine. Herbicides have been used in other areas of the Nation to release conifers from brush, but they have not been tested in the Southwest. Generally, 2,4,5-T has been the best to use.

Small animals.—Rabbits, gophers, and other small rodents may destroy small trees by girdling the stem or by cutting the roots. Populations are controlled by poisoning or by removing their protective cover and food supply. Porcupines girdle trees from seedlings to those of pole size. Shooting and poisoning are the most common methods of control.

Browsing animals.—Livestock should be restricted from regeneration areas, especially during droughts. However, grazing can be used to reduce both the fire hazard and the competition from herbaceous species. Deer browsing can be reduced by spraying trees with repellents.

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PRECAUTIONS

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when these is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

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Endrin is being examined and reevaluated; do not use endrin unless it is cleared for a specific project.