UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 475

Contribution from the Forest Service.
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Washington, D. C. | PROFESSIONAL PAPER | May 28, 1917

REFORESTATION ON THE NATIONAL FORESTS.

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CONTENTS.

INTRODUCTION.

The National Forests are scattered from Alaska to Porto Rico and contain within their boundaries all sorts of timberlands, from those which produce only cordwood to those which support the finest and most valuable stands of timber in the world. Sometimes natural regeneration of the forest fails or a forest not yet producing seed needs to be increased in density. There are also in the National Forests about 5,600,000 acres now bearing little or no tree growth which are capable of producing valuable timber and are suitable for no other purpose. It is the object of reforestation to improve the stands which are too thin and to make the bare lands productive. Reforestation operations on the National Forests now cover from twelve to fifteen thousand acres yearly.

NOTE.—This bulletin supersedes Forest Service Bulletin 98, "Reforestation on the National Forests," by W. T. Cox, on which the material relating to seed collecting and direct seeding is largely based. It represents the results of the study and experience of many different members of the Forest Service. The author's part has been to compile, weigh, and harmonize these results and to present the reforestation work of the Forest Service as a whole.

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The greater portion of the area which it seems advisable to reforest consists of old burns, where recurring fires have completely ruined the former forest and have left a scanty, sterile, and dried-out soil, often littered with charred down timber and stumps. Some of these old burns are grown up to brush, some to fern, and some to grass and fireweed. Many have been badly eroded; and there are large areas where most of the vegetable soil has been burned. Among the easiest to reforest are those which have recently suffered from light fires, so that the mineral soil is exposed, but which are not so badly eroded or grown up to brush as to make the establishment of tree growth very difficult.

REFORESTATION AN ESSENTIAL FEATURE OF NATIONAL FOREST ADMINISTRATION.

The two chief objects of the National Forests are the production of timber and the protection of water sources. The timberlands of the National Forests are now producing from five to six billion board feet of wood a year. The complete restocking of the areas now denuded or sparsely timbered will increase the annual production of wood at least 3,000,000,000 feet. Probably still greater advantages will be secured eventually through improved conditions for streamflow on many watersheds. This is a public benefit of immense importance because of its relation to the supply of water for cities and towns, the protection of water sources for irrigation and power, and the navigation of large streams. Restocking can be brought about in part by the protection of the forests from fire, which permits the natural extension of tree growth. The rest can be accomplished only by forest planting.

In selecting sites for artificial reforestation preference is usually given in the following order: First, watersheds of streams important for irrigation and municipal water supply, such as those which supply water to Colorado Springs and Salt Lake City; second, lands which will produce heavy stands of quick-growing trees of high commercial value, such as those in northern Idaho and western Washington; third, regions where the supply of timber is limited and more wood is needed for local uses, as in western North and South Dakota; and fourth, sites which offer good opportunities for object lessons in the practice of forestry, such as the sand hills of western Nebraska (Pl. I), where there is practically no natural woodland, and the inferior sandy lands of the Lake States, where the original forest wealth has been largely destroyed by cutting and fire. Some areas combine several advantages. For instance, a burned-over tract may be suitable for sowing to some rapid-growing timber species and may be so situated that the plantation will serve as an excellent object lesson.

The economic importance of field planting or sowing, the expense attending it, the even greater proportionate expense of replanting or resowing parts of areas where the first operation failed, and the high percentage of mortality which is almost sure to attend ill-advised and hasty work have led to two stages in reforestation work on the National Forests; first, experiments conducted on a small scale; and, second, extensive field operations. Successful field planting or sowing on a large scale is not a simple operation. The task of planting or sowing so many acres to forest trees or seed in a given period of time is merely a matter of providing the seed or nursery stock and employing a crew of sufficient size, but the success of the operation depends on much more than this. The object of experimental planting and sowing is to determine the factors which make for success or failure. These in turn serve as a guide for reforestation operations on a large scale. Experimental planting or sowing is usually intensive and necessarily expensive. Practical reforestation on a large scale takes advantage of the facts learned through experimental work, and the foremost consideration is to make the costs reasonable and yet secure success.

COLLECTION OF SEED.

SEED CROPS.

All planting and sowing must begin with the collection of seed. Trees, unlike some other plants, do not bear a good crop of seed every year. Conifers in particular are very irregular about this. A few cones are produced every year, but with most species it is only at intervals of from two to five years, or more, varying with the species and the climatic conditions, that a heavy crop occurs. Years when seed of any species is produced in abundance are known as "seed years" for that species, and the intervening years are called "off years." During "off years" seed is produced only in small quantities; it is difficult to obtain because of the concentrated demand for it by rodents and birds, and there is a smaller yield per bushel of cones.

In a "seed year" the seed crop of any species is usually abundant throughout the tree's range, though much better in some places than in others. Even during an "off year" a species may produce somewhere within its range a fair crop over a limited territory. The season of 1910 was an "off year" for both Douglas fir and western yellow pine, the two most important trees of the West, yet cones of sufficient quantity were collected in widely separated localities to furnish 30 tons of clean seed of these species. Studies made to determine what constitutes a good crop for different species have given the following figures:[1]

TABLE 1.—*Amount of seed per acre produced by different species.*

Species.	Trees per acre.[1]	Cones per tree.	Seeds per bushel cones.	Seed per acre.
		Bushels.	*Pounds.*	*Pounds.*
Douglas fir	10	3.50	1.00	35.00
Western yellow pine	5	4.00	1.50	30.00
Lodgepole pine	40	.50	.40	8.00
White pine	7	1.00	1.00	7.00
Red pine	5	.80	1.00	4.00
Engelmann spruce	12	1.25	.80	12.00
Sugar pine	8	7.00	1.60	[2] 89.60

[1] Bearing seed in appreciable quantities.
[2] The sugar pine seed is large, so that this weight does not indicate a greater number of seed per acre than is produced by some of the other species.

GATHERING THE SEED.

Before beginning the actual work of collecting the seed of any species, information regarding the seed crop in various portions of the tree's range must be obtained. Knowledge of the relative abundance of cones and the possibility of economically collecting seed in the different localities makes it possible to concentrate the work where the best results can be had at the least expense. Small, scattered operations are the most costly.

Cones of most of the pines take two years to mature. Those of some of the junipers and cypresses also take two years, and a few require three years. It is often possible, therefore, to predict a crop of any of these species in advance. Other conifers ripen their cones in one season.

Careful examination of both the cones and the seed is necessary to determine when collecting should begin, because cones ripen at different times in different parts of a tree's range and at different altitudes and localities in the same region. The external appearance of the cone is not a sufficient indication of the condition of the seed; a number of cones should be cut open and the seed themselves examined. So long as the seed are soft and milky they are immature. When the squirrels begin to cut off cones for storing, collecting should begin at once. Hard frosts, followed by warm days, hasten the ripening and opening of cones, and for most species the period of collection is short if the cones are taken directly from the trees. Therefore, when once collection is begun it should be pushed forward with all possible haste.

Cones are collected from felled trees, from standing trees, and from squirrel hoards. Where logging is going on it is often pos-

[1] U. S. Department of Agriculture, Forest Service Bulletin No. 98.

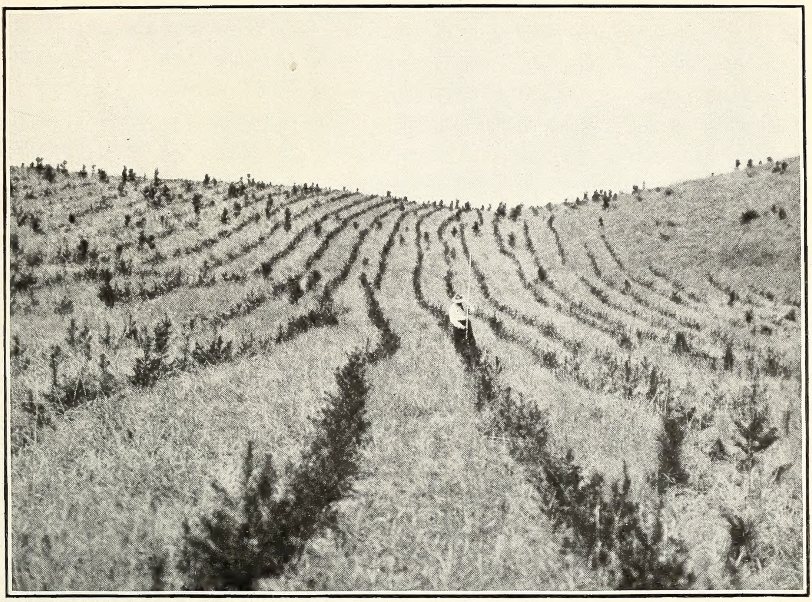

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FIG. 1.—JACK PINE PLANTED ON NEBRASKA FOREST, APRIL, 1911. PHOTOGRAPHED MAY, 1914.

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FIG. 2.—PORTABLE FIELD CAMP ON NEBRASKA FOREST PROVIDING ACCOMMODATIONS FOR 34 HORSES AND 50 MEN. THIS CAMP IS MOVED EVERY TWO YEARS.

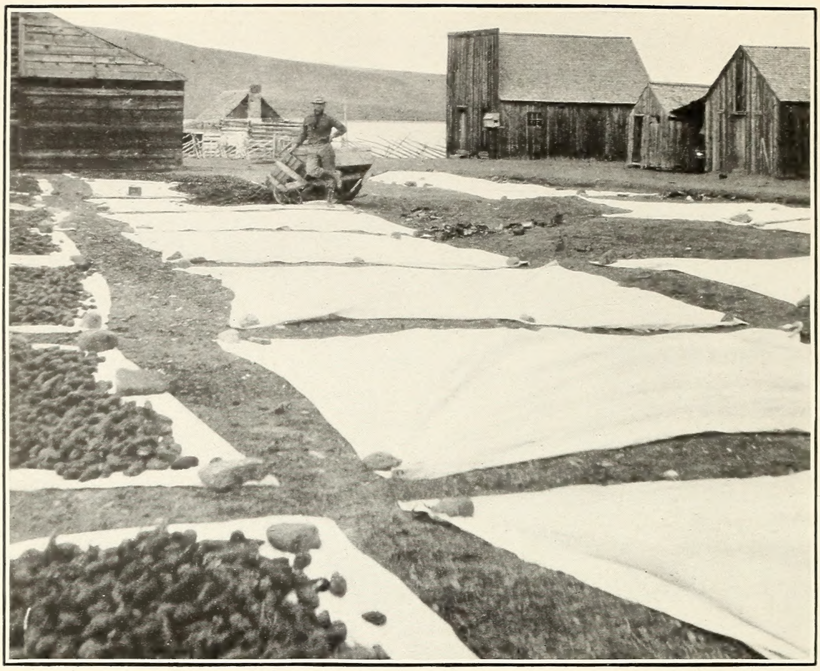

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FIG. 1.—DRYING CONES IN THE SUN.

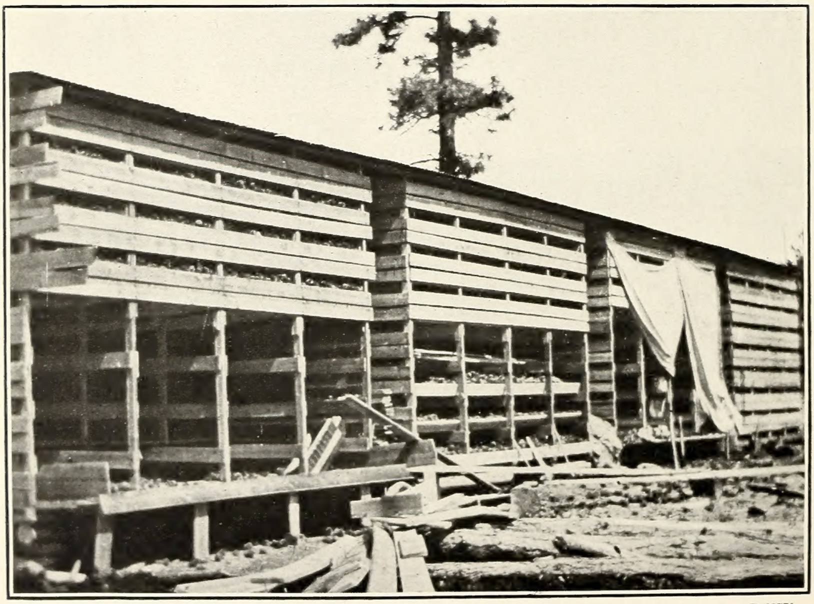

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FIG. 2.—BINS FOR STORING CONES. BITTERROOT NATIONAL FOREST.

sible to pick the cones from the felled trees and from the ground after the brush is piled. This is a good, rapid method, provided a large number of trees are felled each day.

In collecting from standing trees it may or may not be necessary to climb them. Cones can often be stripped from short-limbed trees by hand or by the use of sharp-edged hooks fastened to poles. When climbing is necessary, the cones are stripped or picked off by hand or by means of similar hooks with short handles. It is best to begin work at the top of the tree, because the branches are shorter there, and the cones can more easily be seen. Occasionally it is advisable to cut down heavily fruited trees, but only when the tree itself can be utilized.

Squirrel caches are usually by far the best places from which to obtain cones. Pine squirrels collect large quantities, and chipmunks and mice lay by smaller stores. These rodents do not put by seed sufficient for the winter only, but collect as long as the supply lasts and the weather permits. In consequence they frequently lay by quantities out of proportion to their need.

The small red squirrels are the greatest collectors; and it is not uncommon to find in one of their caches from 8 to 12 bushels of good cones, though the average quantity is about 2 bushels. The caches are sometimes buried at a considerable depth near old rotten logs, in springy places and muck, in duff, under bushes and felled tree tops, along streams, and beneath overhanging stream banks. Their presence is often indicated by heaps of cone scales and chips where the squirrels have been feeding. Sometimes, however, they are carefully covered with leaves and humus, making it difficult to locate them, though the squirrels' well-beaten trails often guide the collector. The squirrels do not confine their collecting to a few species, but appear to relish a large number. Some of the species of cones which are often obtained from caches are Douglas fir, Engelmann spruce, western yellow pine, lodgepole pine, and western white pine. Usually the cones of but one species are found in a single cache. In collecting from squirrels' hoards it is well to have a pack horse for immediate transportation; for if cones are dug out and left loose or in sacks on the ground for any length of time they will be carried away and cached again by the industrious animals.

Collecting from squirrel hoards has important advantages over the other methods; it is usually cheaper; it can be carried on after the cones on the trees are open; and a high grade of cones is obtained. In one instance 610 bushels of lodgepole-pine cones were collected from squirrel caches on the Targhee National Forest, at an average cost of 18 cents a bushel, one man collecting 16½ bushels a day. During the fall of 1908, 1,137 bushels of yellow-pine cones were collected from caches on the Boise National Forest after the cones on the trees had opened.

Burlap sacks with a capacity of about 2 bushels of cones have been found very suitable for collecting operations. After sacking, the cones should be put in a cool, dry place to prevent their opening and the escape of the seed, and to prevent their molding, which results in deterioration of the seed.

DRYING THE CONES.

It is exceedingly important that the cones be air-dried promptly after collection; and it is the usual practice to extract the seed soon after collection is completed. If the cones are placed in well ventilated bins and thus kept dry, immediate extraction is unnecessary. It often happens that collecting and extracting can be carried on simultaneously. Promptness is often necessary to prevent molding and heating of the cones. Good drying weather does not continue in most parts of the West very long after the cones are ripe, and fresh seed is desirable for fall sowing or nursery operations.

Drying with Natural Heat.

The plan commonly followed in drying western yellow pine, Douglas fir, and spruce cones is to spread the cones on canvas sheets of 8 oz. material, 12 feet by 14 feet in size, to dry in the sun (Pl. II, fig. 1). Ordinarily 1 bushel of cones should be spread out to occupy 20 square feet of canvas. This is usually much cheaper than transporting the cones to the drying house and opening them by artificial heat. Furthermore, experiments with western yellow-pine seed at the Priest River Forest Experiment Station show that the viability of seed extracted without artificial heat is much greater than of that extracted with it.

The time required for cones to open varies greatly with climatic conditions and somewhat with different species. A succession of clear, sunny days and frosty nights, with brisk winds, will open cones very rapidly. In such weather mature western yellow-pine cones open in from three to five days. Under ordinary weather conditions, from 4 to 10 days are required, and in damp, stormy weather, often as many as 15 days. Douglas fir and Engelmann spruce usually require a day or two longer under the same conditions. Lodgepole pine takes so much longer that sun drying is seldom attempted. Cones picked early in the season before they are thoroughly ripe open much more slowly than those picked later. If the drying is likely to continue until the ground becomes cold and wet, it is well to keep the canvas off the ground by means of brush or a slightly raised platform. At night and during damp weather the canvas sheets should be drawn up by the corners and either tied in bundles or one side thrown over the cones. When this is done, the cones retain to some extent the heat absorbed during the hours of sunlight, they are not wet by night dews, and they are somewhat protected against nocturnal rodents.

On the Bitterroot National Forest, western yellow-pine cones have been very successfully dried and opened in bins of the type shown in Plate II, fig. 2. These are 16 feet wide by 14 feet deep and are covered, in sections of three, by a single tin roof. There are 8 floors spaced 18 inches apart in each bin. The bottom floor is built to retain any seed which may fall from the cones, and is of solid matched boards. The other floors are of loose 6-inch boards, which can be removed successively from the lowest to the highest. This allows all the cones to fall to the bottom floor, from which they are easily removed during the course of the extracting operations. The side walls consist of successive pairs of 6-inch boards, each pair being separated from the next by a 6-inch open space. The lower edge of each pair is flush with one set of floor boards. The bins are, accordingly, a series of boxes inclosed on the sides for only two-thirds of their height. Each bin is divided into four compartments 4 feet wide and 14 feet deep, and the total capacity of the four compartments is 640 bushels of unopened Idaho western yellow-pine cones. The bin is designed to secure as much free circulation of air over and around the cones as possible and to protect them from rain or snow. Canvas sheets are used to protect the walls during driving storms. Western yellow-pine cones open well in the bins without artificial heat in from four to six weeks, the time required depending upon the weather.

Drying with Artificial Heat.

The cones of lodgepole pine must always be opened by means of artificial heat. It is necessary to open those of other species by this method only when weather conditions are unfavorable for drying by natural heat. Artificial drying is a quicker method than the other and is not dependent on the weather; but it is more difficult and more expensive, and ordinarily does not yield as good seed.

DRYING PLANTS.

Permanent type.—Some of the artificial drying is done at large, fully equipped, permanent plants, to which cones are shipped from a large area (Pl. III, fig. 1). At these plants the cones are put on cars, which are run into kilns resembling in construction those in use at hardwood distillation plants (Pl. III, fig. 2). Here seed extraction is reduced to a science and is done at a low cost, provided large quantities of cones have been gathered. There are smaller drying plants designed for use only on the National Forest where they are located. These are quite simple in their plan and of relatively cheap construction.

Figure 1 shows the plan of a small cone-drying plant on the Arapaho National Forest, Colo. It has been used exclusively for the extraction of lodgepole-pine seed and has proved quite satisfactory. The pine cones are collected in October and held in a storage bin from 12 to 15 months before the seed is extracted. This bin holds approximately 6,000 bushels of cones and is divided into several compartments. A passageway between these permits the removal of the cones to the drying room. The sides and end of the bin are constructed of 4-inch boards spaced a short distance apart to facilitate the preliminary air-drying of the cones. The kiln or drying room proper is constructed within the main building and is located directly over the furnace in the basement. This kiln is 11 feet by 9 feet in size, outside dimensions, and is made as tight as possible.

When the cones are to be opened, they are placed in shallow trays 2 feet 10 inches by 7 feet in size, which have one-fourth inch mesh hardware cloth bottoms. The capacity of each tray is 1 bushel of unopened cones. The trays are braced at the four corners on the bottom with 2-inch pieces of wood, so that when they are piled in tiers the air may circulate freely between them. Three tiers of trays, 12 per tier, constitute a charge for the kiln. The trays are loaded on a truck, wheeled to the kiln door, and in one lot shoved into the kiln on rolls. Each charge of cones is dried for eight hours, and the plant is run continuously, except Sunday, in three eight-hour shifts daily.

The kiln is heated by means of four hot-air flues coming from the furnace and terminating at the floor of the kiln. Opened cones exclusively are used for fuel. When removed from the kiln, the cones are placed in a large hopper and gradually fed into the drum of the "shaker." As the shaker revolves, the seed are separated from the cones and fall upon a canvas spread on the floor. The open cones from which the seed has fallen pass through the shaker and out the open end down a chute to the furnace room.

The capacity of this plant is 108 bushels of cones, or about 40 to 45 pounds of seed, per day.

Temporary type.—Where there is only a relatively small quantity of cones, resort is often had to temporary plants which are handled by less experienced men with simple appliances. The first essential in such cases is some sort of shelter which will protect the cones from weather and be sufficiently tight so that the temperature can be raised to at least 110° F. An empty room in a cabin may serve the purpose and often makes as satisfactory a substitute for a regular kiln as can be obtained. It must have tight walls and plenty of space 'orest, Colorado.

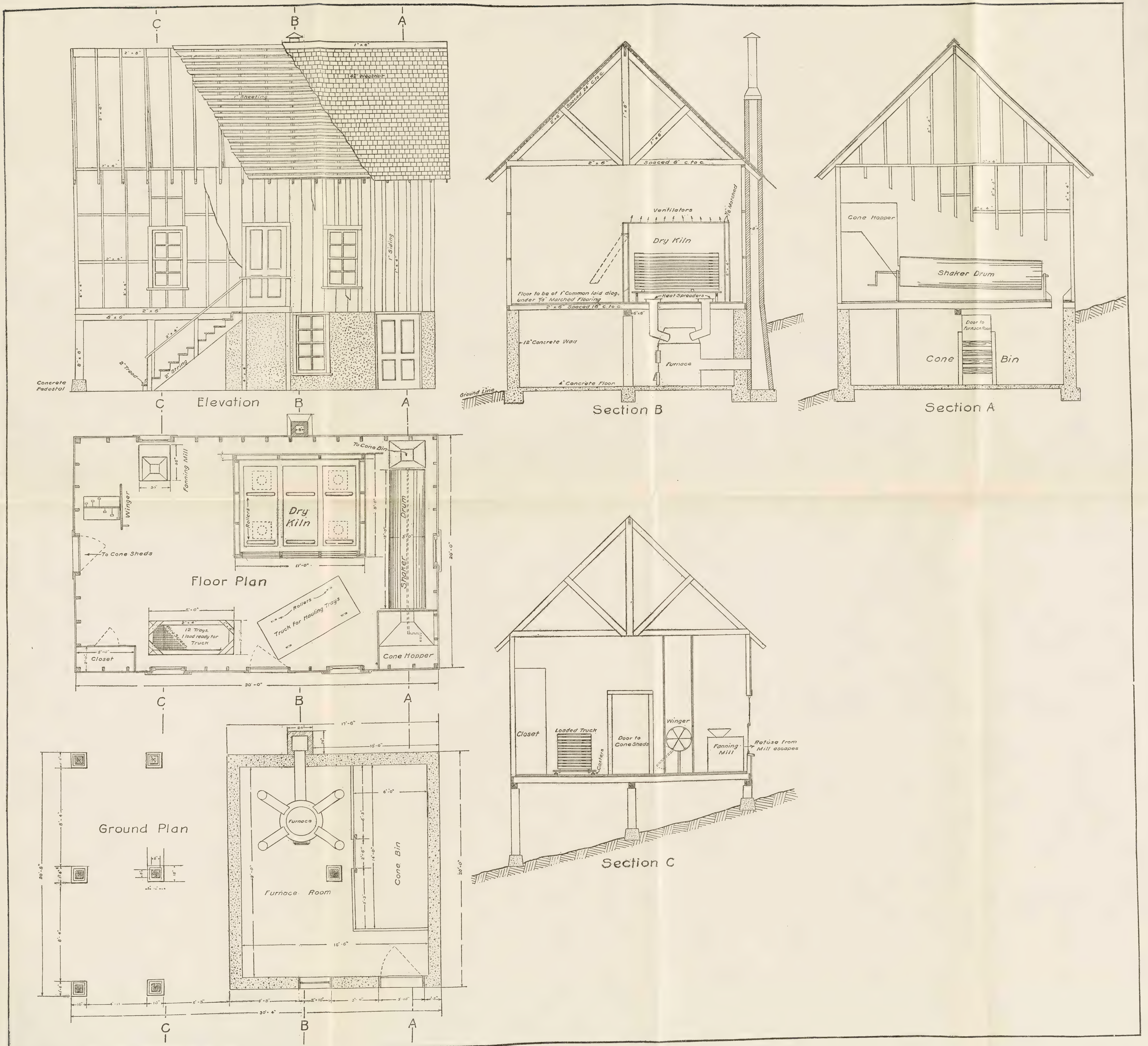

FIG. 1.—Plan of Idlewild Seed Extractory. Arapaho National Forest, Colorado.

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for a stove and for trays around the sides. Often one room of a cabin is used for drying and another for storing and extracting.

Large tents with high walls make fair dry rooms; 12 by 16 foot or 16 by 20 foot tents, with 5 or 6 foot walls, may be used, but the larger tents have given the most satisfactory results. Drying is more difficult in tents than in buildings, but the tents have the great advantage of being readily transported from place to place where cones are collected. Ordinarily, the largest tents are used for drying and smaller tents for storing and extracting.

Small, temporary drying rooms are almost invariably heated by stoves. In buildings, box stoves equipped with drums have been generally used with satisfactory results. In tents, low, conical stoves have been more frequently used because they are cheap and easily put up. They require constant attention, however, and empty cones will not burn well in them. These are serious drawbacks, and the use of box stoves with drums is preferable.

The cones are usually spread in trays arranged in racks along the sides of the room or tent. Trays are generally made of 2 by 4 inch material, and vary in size from 2 by 3 to 3 by 4 feet. The larger trays are difficult to handle, especially where space is limited, and are used only with light cones. The bottom of the tray is wire netting, usually with a one-half inch mesh for lodgepole pine and a three-fourths inch mesh for larger cones. A tray space of 12 square feet holds approximately 1 bushel of cones spread thinly.

Cones may also be spread on pieces of wire netting stretched horizontally between racks at intervals of 6 or 8 inches with a vertical strip at each end to prevent their falling on the floor when raked. Handling the cones is more difficult with this method, and the apparatus is less easily transported from one place to another. With either method a strip of canvas is spread on the floor to catch the seeds as they fall through the netting, unless the floor is so smooth that seed can readily be swept from it without the use of canvas. It is essential that the trays be far enough apart, commonly from 6 to 8 inches, to permit ample circulation of air. There should be a liberal supply of high registering thermometers to keep an accurate record of the temperature in different parts of the drying room.

On account of the high temperature and dry air prevailing in the kiln room, extreme precaution must be taken to prevent fire. Where water pressure is available, a hose should always be connected and ready for use. Chemical fire extinguishers should be secured as additional safeguards. If neither of these measures is practicable, several buckets should be kept filled with water, to be instantly available.

Heating.—One of the most difficult problems in running an improvised kiln is to maintain a constant supply of heat and distribute it evenly through all parts of the drying room. The first step should be to make the room, whether in a building or tent, as tight as possible, except for the openings required for ventilation. All chinks should be closed completely. Wherever practicable as hot a fire should be kept up at night as during the day. This is particularly necessary in a tent, where any dying down of the fire at night causes the air to cool rapidly, with consequent delay and loss of time and labor.

The stove is usually placed in the center of the room and approximately level with the lowest tiers of trays. This results in much slower drying of the cones which are near the bottom of the room and at a distance from the stove. Attempts have been made to obviate this difficulty by dividing the stovepipe into sections and carrying it through as much of the room as possible, but without complete success. Better drying is secured in the farther ends of the room, but the bottom remains much cooler than the top. This difference is especially marked in tents, where cold air constantly passes in under the walls. With only one stove even distribution of heat is impossible. With stoves set at opposite ends of the tent and connected by a single stovepipe conditions are but little better. In one instance where this arrangement was used a difference of from 20° to 30° F. was found in the temperature of the air at the highest and lowest trays in a six-tier stack.

One method of hastening the opening of the cones in the lower trays is to raise them as the drying proceeds and the cones in the upper trays are removed. This, however, requires additional handling and loss of time. A better method, wherever space is available, is to place the lowest tier of trays somewhat above the stove. Room for air circulation is essential. The tiers of trays should be at least 6 inches apart vertically, preferably 8 inches, and the same distance from the walls.

The best method of securing even distribution of heat, although not always practicable, is to have the drying room heated from below. If conditions permit, an excavation should be made under the building and the stove placed below the floor. This not only heats the room above more evenly, but furnishes additional space for spreading cones. The stovepipes should pass through as many parts of the dry room as possible. Still better results are obtained if hot-air pipes can be conducted from the drum of the stove into the room above, and even more heat can be made available by inclosing the stovepipes in jackets, which need not extend farther than the openings where the pipes pierce the floor.

Maximum temperatures and duration of heating.—The degree of heat and the length of time required to open cones vary somewhat with different species, but still more with the conditions under which the drying is done. In a well-equipped plant drying may be finished in less than half the time required in a tent, even with the same temperature. It is therefore impossible to cite average figures of general application. Ordinarily, the higher the temperature the quicker the drying can be accomplished. Dry heat, however, is more effective than moist heat, and heat that is too intense is very apt to impair the fertility of the seed. This is particularly true of intense moist heat. Often this injury to seed is not appreciated at the time, since the deterioration does not become apparent until several months later.

The maximum temperature which should ordinarily be applied to all species except lodgepole pine is 120° F. This can be raised safely to 130° F. if the air is dry and good ventilation provided. Lodgepole-pine cones should not as a rule be subjected to a temperature of more than 140° F., although this can be raised safely to 150° F. under favorable conditions. Lodgepole-pine cones are hardest to open; then come, in order, western white pine, western yellow pine, Engelmann spruce, and Douglas fir. Douglas fir cones can often be dried satisfactorily at a temperature of 110° F.

Assuming that the cones are mature and moderately dry when put into the kiln and that the room is evenly heated and well ventilated, lodgepole-pine cones should be thoroughly dried in from 8 to 10 hours at a constant temperature of 140° F. and other species in from 10 to 15 hours at a constant temperature of 120° F. Under less favorable conditions these periods may be greatly increased. In one instance lodgepole-pine cones dried in a tent at 140° F. took 44 hours to open. The difference was due mainly to uneven distribution and loss of heat in the tent. Preliminary drying of the cones for a few hours at from 80° to 100° F. has been found an advantage. Opening will also be hastened by spreading the cones thinly in the trays and stirring them frequently to make the drying more uniform.

Ventilation.—The proper ventilation of drying rooms, while less difficult than the even distribution of heat, is fully as important. All undried cones contain some moisture. As this is driven off the air becomes more and more saturated. Saturated air not only prevents rapid drying of the cones, but may injure the seed embryos. German experiments indicate that damp, cold air is much more harmful to seeds than dry, warm air. Some method of ventilation (letting in fresh, dry air and letting out moist air) is, therefore, essential.

The method usually employed is to insert one or two ventilators in the roof of the building or tent and also in openings near the floor for the entrance of fresh air. The amount of air taken in and let out can be regulated by adjustment of the ventilators. Tents are usually so open at the bottom that it is not necessary to make special provision for fresh air. Where the drying room is heated from below fresh air can be admitted through dampers or ventilators in the jacket surrounding the stove. Vents to maintain circulation should also be provided in the roof of the drying room.

Though they are usually the best that are practicable, these methods of ventilation are necessarily crude and wasteful. As the air cools and absorbs moisture it becomes heavier and sinks to the floor. Vents in the roof carry off much of the hot, dry, light air which should be retained. A certain amount of heavy, moist air is, however, carried out with the current, and the circulation of air, so essential to drying the cones, is maintained.

An improved method removes the saturated air directly from the floor by pipe ventilators extending from the floor through the roof. In one kiln fresh air is admitted directly under a small box stove with a heating drum placed near the center of the room. As this air becomes heated it rises to the ceiling, where it spreads to the side walls, and, cooling slightly, descends in a steady stream over the cones. The trays thus catch the descending current of hot air, which flows over them. They are slightly tilted toward the center of the room, so that as the air cools and absorbs moisture from the cones it runs off the lower edge of the trays like water from a roof. The saturated air is sucked up by pipe ventilators having inlets at the floor level and passing through the roof.

WETTING CONES.

Wetting cones before drying apparently does more harm than good with any species except lodgepole pine. Lodgepole-pine cones dipped in very hot water for not over one minute have, in some cases, been found to open more readily and to give a higher yield than unmoistened cones. This treatment, however, should be applied only to very tight cones and should not be of sufficient duration to add appreciably to their water content. Its only advantage is that it loosens the sealed tips of the cone scales. Experiments have also shown that live steam applied under a pressure of one-half pound for 30 seconds assists in opening cones without impairing the fertility of the seed. Such treatment, however, is possible only at fully equipped extracting plants.

Even with lodgepole pine a preliminary wetting is not essential, and good results are obtained without it. Continued soaking of cones has almost uniformly lessened the ease of extraction and injured the seed. As a general rule, the cones should be as dry as possible before they are put into the kiln. Preliminary drying in the open or in well-ventilated storerooms will hasten opening after artificial heat is applied.

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FIG. 1.—LARGE SEED-EXTRACTING PLANT OF THE KILN TYPE AT WYETH, OREG.

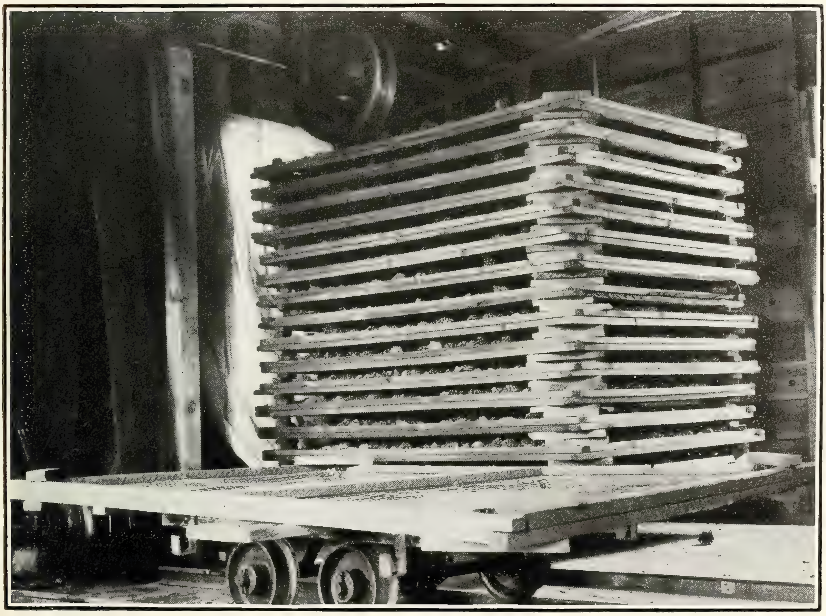

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FIG. 2.—CAR OF CONES REMOVED FROM THE DRY KILN AT A LARGE PERMANENT SEED-EXTRACTING PLANT.

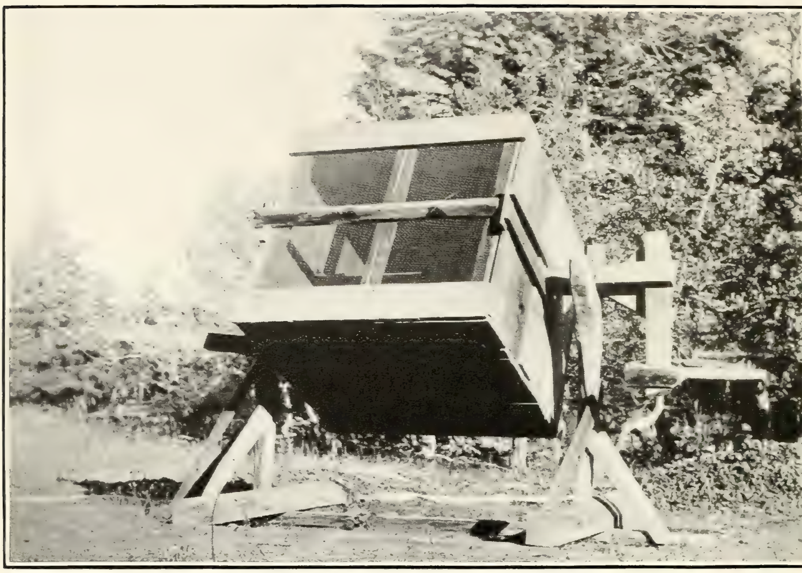

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FIG. 1.—CHURN FOR REMOVING SEED FROM OPENED CONES.

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FIG. 2.—CHURN FOR REMOVING SEED FROM OPENED CONES.

EXTRACTING THE SEED.[1]

After the cones have been thoroughly dried, the next step is to extract the seed. Merely to rake over the cones as they are drying in the sun or kiln is the simplest but least efficient method. It is most successful with western yellow pine, but even with this species better results can usually be obtained by shaking. The practice of placing cones in sacks and beating them with clubs to loosen the seed has also proved unsatisfactory. It requires too much time and yields only a little additional seed, which is apt to be of poor quality.

Cone Shakers.

To secure the maximum amount of seed, therefore, some method of shaking to release the seed from the opened cones must be used in nearly every case. Several kinds of cone shakers have been devised by members of the Forest Service. One in common use is made from a large dry-goods box, about 4 by 3 feet, provided at one end with a door made of slats so spaced as to permit only the closed cones to fall through. (Pl. IV, fig. 1.) This door is fitted also with a removable wire screen of such sized mesh as to permit only the seed to escape, ordinarily $\frac{1}{2}$ inch. The box is built on a pole as an axis and swung between two trees, or else mounted on a windlass. By a crank attached to one end of the axis the apparatus may be revolved and the seed loosened. Slats nailed lengthwise inside the box, or loose blocks of wood placed in the box with the cones, increase the jarring effect. After the seed has escaped to a sheet of canvas placed beneath the shaker, the screen should be removed and shaking continued in order to separate the still closed cones from the larger sized open ones. The closed cones can then be returned to the house for further drying.

The cone shaker shown in Plate IV, figure 2, is a modification of the common potato sorter. It has been used extensively for yellow-pine cones, and, with slight modifications, for lodgepole-pine cones. The shaker is composed of a parallelopiped 16 feet long and about 4 feet square at the ends, constructed on a shaft of 2-inch pipe long enough to provide for the supports at either end and for a crank with which to revolve it. Poultry net of $\frac{3}{4}$-inch mesh for yellow-pine cones and hardwood cloth of $\frac{1}{2}$-inch square mesh for lodgepole cones is stretched over the frame. The whole apparatus is made with a fall of about 6 inches, the end of the hopper being elevated that much to cause the cones to travel automatically through the shaker to the other end, where they fall out. The contrivance may either be operated by hand or by a gasoline engine. Cone shakers

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[1] For more complete details, see Forest Service Circular 208, "Extracting and Cleaning Forest Tree Seed."

of this type may be made to "take down," so that they can readily be transported from place to place in the woods.

SEED CLEANING.

After the seed is separated from the cones there is still mixed with it a good deal of foreign matter, such as small twigs, pieces of cone scales, and membranous wings. Much of this foreign material can be screened out, but to loosen the wings from the seed requires further treatment. Removal of the wings may decrease the germinative power of seed to a small extent, but so greatly increases the ease with which they can be handled that the practice is almost universal.

Wing Removing.

One of the oldest and commonest methods of removing wings is to work the seed over in seamless sacks, the mouths of which are securely tied. The wings are more readily removed from pine seed, to which this method is particularly applicable, if the seed are slightly moistened with cold water. This may be done by putting the seed in a box, adding a little cold water, and stirring. The entire wing may be readily detached from the seed of all the pines except longleaf; but the wings on the seed of other species form part of the seed coat and can be removed only by actually breaking them off, so that moistening the seed is of doubtful value. The sacks are beaten with light flails, usually of leather, or kneaded with the hands and knees. Sometimes the sacks are tramped under foot for a few moments, but this impairs the quality of the seed.

Another process is to pile the seed 6 or 8 inches deep on a cement or plank floor, sprinkle it lightly with water, and then beat it energetically with leather flails. The wings can often be removed completely with the use of very little water. The wings of pine seed may be removed by moistening them slightly and then churning the mass in a cylindrical drum.

Whenever a wet process is used the seed must be dried immediately, so that its vitality will not be impaired. The relative merit of dry and wet processes depends partly upon whether the seed is to be stored for some time or used within a few months. In the latter case a wet process is ordinarily safe. If the seeds are to be stored for a year or more, a dry process should be used.

Another method of removing wings is to churn the seed, together with a number of small wooden blocks, in a box or barrel mounted on an axle so as to be rotated; or the box may be kept stationary and friction applied by rotating brooms nailed to a spindle running through the center. In the latter case, if the box is tilted at a slight angle and a hole cut in the lower end, the seed will gradually work out with the wings broken off.

Still other methods depend wholly on the use of screens. The simplest of these is to rub the seed as it comes from the extractor over a fine screen fastened on an empty box or stout frame. The rubbing may be done with a stiff scrubbing brush, a block of wood covered with corrugated rubber, a piece of tough carpet, or the hands covered with rough gloves. As the wings are rubbed off the seeds gradually drop through the screen, leaving a large part of the wings and all of the coarser impurities on top. One-sixth inch mesh is the best size for screening yellow pine and Douglas fir seed; for lodgepole pine and Engelmann spruce one-eighth inch mesh is preferable. The wings are more easily removed if the seed are moistened slightly with cold water before screening.

The first screening ordinarily does not remove the wings completely. To get rid of what is left, the seed and small chaff coming through the first screen may be churned, together with several small pieces of wood, in a small, cylindrical drum, covered with very fine-meshed wire. This removes the rest of the wings, which with other small particles of dirt, fall through the screening, leaving clean seed behind.

A somewhat similar method, preferable when the work is done on a large scale, makes use of a mechanical cleaner or wing crusher. This consists of a rotating cylinder bearing upon the outside several scrubbing brushes with stiff bristles, which, during about one-third of each revolution, press firmly against a wire screen of mesh fine enough so that the seed itself will not pass through it. The screen against which the brushes press as they revolve may be adjusted to regulate the pressure of the bristles against it. The seed is dropped into the space between the screen and the brushes, and the wings are removed as they pass under the brushes; the fragments of wings and chaff drop through the wire screen. When using such an apparatus with pine seed, a slight moistening of the seed with cold water is advisable before putting them into the hopper.

A device designed by Forest Ranger William Kerlee of the Bitterroot National Forest is both rapid and effective with western yellow pine. It consists of a rectangular churn 2 feet by 2 feet by 7 feet 8 inches. Longitudinally placed through its center there is a cylinder which is revolved in one direction by means of a belt. Upon this cylinder the churn itself is revolved in the opposite direction. From two opposite inner surfaces of the churn, wooden teeth project toward the cylinder, and on the cylinder similar wooden teeth project toward the periphery of the churn. The two sets of teeth overlap by several inches and clear each other by from one-fourth to one-half inch. (See diagram of cross section, fig. 2.) The churn turns at the rate of 52 and the cylinder 168 revolutions per minute. One side of the churn is fitted with a hinged door to permit the reception of unwinged seed and their removal after churning. Three bushels of seed can be put through at a time, and about 80 bushels in a day. Each bushel will yield 10 or 11 pounds of clean seed, so that the daily capacity of the churn is from 800 to 900 pounds. This device has been found unsatisfactory in only one respect. Refuse mixed with the seed occasionally breaks out one of the teeth and this in turn is quite likely to break out several others. It is thought that this defect can be remedied by the use of teeth of spring steel.

Screening and Fanning.

The final cleaning of seed is done by screening and fanning. Where no fanning mill is available, fairly clean seed may be obtained in the following manner: First, pass the seed through a wire screen to remove the coarser particles, such as pieces of cone scales, twigs, and

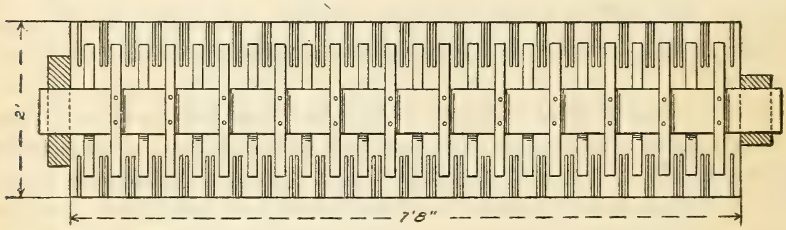

Fig. 2.—Cross section of wing-removing churn.

needles, and then through a screen of smaller mesh to remove the finer chaff and pieces of broken wings; second, winnow the remaining seed in the wind or by bellows or other mechanical devices.

Seed may be fanned in one of the ordinary farm machines for cleaning grain (Pl. V). They remove practically all broken and empty seed as well as much of the resin and other impurities, if the draft is properly regulated and the screens with the right-sized mesh are used. It is essential that the wings be removed from seed before fanning, otherwise many good winged seeds will be lost. Not infrequently, particularly with poorly adjusted machines, the seed must be fanned more than once before it is thoroughly cleaned.

By the use of a grain-grading machine, the extracting plant at the Trapper Creek Nursery divides the seed into four different classes. The grading is accomplished by means of a fan, so that the classification is by weight. Germination tests of western yellow pine carried on for 45 days gave a germination of 13½ per cent for seed of class 1, the heaviest seed; 1 per cent for seed of class 2, the next

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RUNNING SEED THROUGH A FANNING MILL TO REMOVE DIRT AND CHAFF.

heaviest; and one-half per cent for seed of class 3. Seed of class 4 was not tested; but this class is mostly débris and broken seed.

YIELD FROM CONES.

There is great variation in the yield of seed from a bushel of cones. The amount depends upon the quality of the cones, the thoroughness of the drying and extracting, and the manner of cleaning. The cones of any species fill better during a "seed year" than during "off years," so that in the former there is greater bulk, and especially greater weight of seed. Table 2 shows by species about the average quantity of seed per bushel of cones or fruits.

TABLE 2.—*Quantity of seed per bushel of cones or fruit of different species.*

[Quantity varies considerably in different regions or years.]

Species.	Number of pounds.	Species.	Number of pounds.
CONIFEROUS.		CONIFEROUS—continued.	
Incense cedar	2.50	Engelmann spruce	0.80
Western red cedar	.75	Sitka spruce	1.25
Douglas fir	1.00		
Amabilis fir	3.00	HARDWOOD.	
Noble fir	2.50		
White fir	3.00	Black walnut (husked)	40.00
Western hemlock	1.00	Butternut (husked)	40.00
Western larch	.50	Chestnut (clean)	50.00
Lodgepole pine	.40	Bitternut hickory	40.00
Norway pine	1.00	Pignut hickory	40.00
Sugar pine	1.60	Shagbark hickory	30.00
Western white pine	.75	Red oak acorns (clean)	50.00
Western yellow pine	1.50	White oak acorns (clean)	70.00
White pine	1.00		

COST OF SEED.

Many factors influence the cost of seed, such as the quantity and quality of the crop, the species, the remoteness of the area from a railroad, the method and scale of collecting, the character of the weather during collection and extraction, and the method of extraction. Some costs per pound of seed gathered in fairly large quantities by the Forest Service are shown in Table 3:

TABLE 3.—*Cost of seed.*

Species.	Cost per pound.	Species.	Cost per pound.
Incense cedar	$0.70–$2.25	Jeffrey pine	$0.42–$0.84
Western red cedar	2.00	Lodgepole pine	1.70– 2.00
Douglas fir	.66– 1.36	Norway pine	2.63– 3.19
Amabilis fir	.36– 1.13	Sugar pine	.50– .65
Noble fir	.38– 1.13	Western white pine	2.43– 2.83
Red fir	.53– .83	Western yellow pine	.41– .67
White fir	.23– .63	Sequoia (redwood)	1.63
Western larch	2.43	Sequoia ("Bigtree")	.66– 1.22
Jack pine	3.41	Engelmann spruce	1.00– 2.41

NUMBER OF SEED PER POUND.

In Table 4 is given by species the approximate number of seed per pound.

TABLE 4.—*Number of seed per pound.*[1]

Species.	Number of seed.	Species.	Number of seed.
Bigtree	75,000	Maritime pine	9,450
Increase cedar	17,000	Mexican white pine	2,700
Western red cedar	400,000	Norway pine	54,000
Arizona cypress	100,000	Scotch pine	69,000
Douglas fir	43,000	Sugar pine	2,400
Amabilis fir	9,300	Western white pine	28,000
Grand fir	28,900	Western yellow pine:	
Noble fir	[2] 15,400	Pacific Coast	9,100
Red fir	[2] 67,000	New Mexico	16,000
Austrian pine	24,000	Black Hills	13,500
Jack pine	150,000	White pine (New York)	26,000
Jeffrey pine	3,100	Engelmann spruce	175,000
Lodgepole pine	120,000	Sitka spruce	400,000

[1] The number may often be more or less by from 5 to 20 per cent than the figures given.
[2] Not Forest Service tests.

SEED STORING.

Wherever possible clean seed should be stored in air-tight receptacles of glass or metal. Seed retains its vitality under any conditions of temperature and moisture much better in such receptacles than in any others, except when placed in cold storage, which is seldom available. Where neither of these methods of storage is available the seed should be thoroughly dried and stored in a dry and cool place. Some deterioration will take place under these conditions, but ordinarily not sufficient within one year to be of serious consequence. The storing of seed in cement cellars with the wings attached has been found by Austrian experimenters to give better results than storage with the wings removed. It is doubtful, however, whether the slight saving in vitality offsets the advantage of handling and using clean seed. In every case the seed should be thoroughly protected from rodents, by the use of poison, by being stored in rodent-proof buildings, or by being hung in sacks out of reach.

SOWING AND PLANTING.

STATUS OF THE WORK ON THE NATIONAL FORESTS.

DIRECT SEEDING.

Of the two methods of artificial reforestation, direct seeding and the planting of seedlings, the former where it can be practiced successfully offers the easiest and cheapest solution of the reforestation problem. The seeding itself is a much simpler operation than planting, and with inexperienced labor, which is all that is generally obtainable, it can be carried on in conformity with the most approved practice better than planting. A far greater proportion of the Forest Service reforestation operations has been conducted by direct seeding than by planting. Of a total area of 124,732 acres covered up to June 30, 1915, 84,320 acres were seeded directly and 40,412 acres were planted. Practically all of the most important western species of trees and a number of exotics have been given a trial, a wide range of conditions has been covered, and a great variety of methods tested.

In many localities direct seeding has not been successful. In some instances when success or partial success was at first reported it has developed later that, although good germination was secured, the seedlings were killed by drought, birds, frost, or severe winters. Efforts in direct seeding have strongly emphasized the fact that the success of plantations so started can not be judged until they have passed through a period of at least three years. The results obtained already indicate that if rodents are controlled and two or three favorable years in succession follow sowing, direct seeding can be made to succeed on the more favorable sites. No final conclusion, however, has yet been reached regarding the merit of the direct seeding method, and investigations are now being carried on in a more intensive manner on smaller experimental areas.

Consistent success in direct seeding has been obtained with lodgepole pine on the Arapaho National Forest in Colorado. Here, on northerly slopes at altitudes between 8,000 and 10,500 feet, broadcasting on the snow and seed spotting, both being done in the fall, have quite regularly given good results. Broadcasting has been conducted only on areas where the soil was exposed—that is, not covered with duff or a heavy growth of grass—while seed spotting is employed even where such ground cover exists.

Direct sowing of maritime pine on the Florida National Forest appears promising when the seed is broadcasted on plowed ground and covered by means of a brush drag. Plantations started in this manner have passed successfully through a three-year period. Sowing on plowed strips three furrows wide and on harrowed strips, the seed being covered in each case with a brush drag, also gives promise of success. Seed spotting is the least successful method tried, except broadcasting without preparation. All of these operations must be carried on in October after fall rains have started; and rodents must be eradicated or greatly reduced to obtain success.

Planting.

On the greater portion of the National Forest areas in need of forestation it is probable that planting is ultimately more successful and cheaper than direct seeding Results in plantations which have not yet passed through the three-year trial period tend to show that success may be expected on from 75 to 100 per cent of the areas covered, provided the operations are conducted during the right season and suitable stock is used. To determine these points, as in direct seeding, intensive experimental work is being conducted on the National Forests in addition to extensive forestation operations.

As the Forest Service nurseries have developed and planting stock has been produced more abundantly, planting operations have gradually increased in scope. During the fiscal year ending June 30, 1914, 9,400,000 seedlings or transplants grown in Forest Service nurseries were planted, the operations covering 14,063 acres in western United States and being carried on under a wide range of conditions.

SOWING AND PLANTING METHODS.

The methods followed in forest sowing and planting should be governed, first, by the success, and, second, by the economy which attends them. When the Forest Service began this work in the West, there was no experience to indicate how operations could be successfully conducted. Numerous methods have been tried, with varying degrees of success; but it can not yet be said that those best adapted to the several regions and many different soil and climatic conditions in the West have been entirely worked out. A good start has been made, however, and a number of these methods will, accordingly, be discussed.

Sowing.

BROADCASTING.

In broadcasting, seed are scattered by hand or by the use of a mechanical sower in much the same manner as grain. The best practice is to go over the whole area and sow half the seed; then to traverse it again at right angles to the previous courses and sow the other half. This insures a more even distribution of the seed. Large or medium-sized seed, such as sugar pine or western yellow pine, can be sown by hand; but small seed, such as lodgepole pine, larch, and spruce, can be handled better with a mechanical seed sower. When very small seed are used, they can be scattered more uniformly by mixing them with fine, dry earth.

In general the rugged topography of the country, the inaccessibility of the planting sites, or the presence of dead and down timber makes preparation of the ground by such methods as plowing or harrowing impossible. In only a comparatively few cases has it been done. In deciding upon the best method of preparing the ground for sowing, the surface, slope, and character of the ground cover, as well as the species to be sown, must be considered. Some of the

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FIG. 1.—BROADCAST SOWING OF DOUGLAS FIR SEED ON SNOW. SIUSLAW NATIONAL FOREST, OREG.

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FIG. 2.—PLANTING WESTERN YELLOW PINE SEED ON LOLO NATIONAL FOREST, MONT., BY MEANS OF CORN PLANTERS.

FIG. 1.—PLANTING ON NEBRASKA NATIONAL FOREST, WITH PLOW AND FIELD TRENCHER.

FIG. 2.—PLANTING ON OREGON NATIONAL FOREST, NEAR MOUNT HOOD.

methods which have been used are burning, harrowing with an ordinary spring-tooth or disk harrow, dragging tree tops or stumps over the ground, and plowing. An area thoroughly trampled by sheep or which has been used as a sheep driveway, the soil of which has become loose, is usually in good condition for sowing. Covering broadcasted seed by harrowing or otherwise is not usually practiced. Where it has been tried, better germination has sometimes been secured on experimental areas, but the final stand has been little, if any, better. On a successful broadcasted area of Douglas fir on the San Isabel National Forest the seed were raked in by hand.

The best results with broadcast sowing may be expected where the soil is loose and moist at the surface, where some protection is afforded seedlings against heat and drought, and where rodents can be controlled. Burned areas covered with down timber, aspen, or brush of not too dense a character, and without much leaf litter, offer good sites for broadcast sowing without preparing the ground or covering the seed.

Broadcasting has in general proved the least successful of direct seeding methods. It requires large quantities of seed; it is expensive, particularly so where some method of preparing the ground or covering the seed is followed; the seedlings are likely to come up in groups because of the erosion of the soil and destruction of the seed by rodents; and it must be largely confined to sites where the mineral soil is exposed, usually burned or logged over areas. On the other hand it is a simple and rapid method, one man being able to cover from 20 to 40 acres in a day; and operations can be conducted during winter, the season when other work is not pressing. (Pl. VI, fig. 1.)

SOWING IN STRIPS AND BLOCKS.

Strip sowing and block sowing are modifications of the broadcast method. Sowing in strips has the advantage that it does not require the covering of the entire area. Narrow strips, 3 feet wide or less, are sometimes prepared in various ways, such as plowing, harrowing, or raking. Sometimes no preparation at all is given. On hillsides the prepared strips should run along contour lines, not up and down. Strips so run catch and retain the precipitation, and also prevent the soil and seed from being washed down by rain. In a flat country they should run east and west, and when a plow is used, the furrows should be turned toward the south. This will give the seedlings some protection from the sun during the first year. Less seed per acre is required in strip sowing, but the seed is sown more thickly per square rod on the strip seeded than on the area broadcasted. Strip sowing is a method particularly adapted to quick-growing species which will soon bear seed and thus seed up the intervening areas.

REGULAR SEED SPOTS.

In the seed-spot method small spots quite regularly spaced over the area are more or less prepared for the reception of the seed by loosening the soil with some tool. After the seed are sown on each spot they are usually covered with soil to a depth of about one-half inch and often with an additional mulch of needles or leaves. On the Arapaho National Forest, where the most consistent success with direct seeding of lodgepole pine has been achieved, the seed when sown in this way are simply pressed into the soil and not covered. Meager success in direct seeding by seed spotting is probably due in many cases to the planter covering the seed too deeply. When the seed is not covered at all this danger is obviated.

The size of the spot and the depth to which the soil is loosened depend upon the character of the ground cover and the species to be sown. The spots are usually from 10 to 20 inches square. Where the ground cover consists of strong growing plants, such as grasses, which will compete with the seedlings for moisture, wide spots are prepared and a portion of the competing vegetation thus destroyed. Where a shade-enduring species is sown on a moist situation, the competition does not become so critical and the smaller spots are satisfactory. In locating them, advantage is taken of any shelter on the ground, such as brush, logs, or rocks, which will serve to shade the soil and seedlings during a portion of the day. For the same reason, on level ground the turf is thrown upon the southern side of the spot. On slopes the soil is thrown upon the lower edge of the spot. This aids in holding moisture and precludes washing of the soil from above, with the consequent burying of the seed too deeply or the covering of the seedlings. As too deep covering of the seed through the filling in of soil from above is doubtless often the cause of loss, it is better on slopes to prepare seed spots simply by loosening the soil, but not making any depression at all in the slope. The chief functions of the spot are to make sure that the seed reaches the mineral soil and partially to eliminate for a time competition of grass and other plants.

SIMPLE SEED SPOTS.

The simple seed-spot method differs from the regular seed-spot method principally in that the spot is smaller and somewhat deeper. It is usually prepared with one stroke of the mattock. Its chief claim to merit was that on account of its depth it was thought that the earth surrounding the hole would both shade the seedlings and protect them from winds. It would accordingly be especially suited for seeding on very dry, barren, stony ground or in hot or windy situations. A serious objection to this type of seed spot is that soil is likely to wash or crumble in from above and cover the seed so deeply that the germinating seedlings can not push through. Leaves and other litter are also likely to collect in these spots and smother any seedlings which may get a start.

CORN PLANTER SEED SPOTS.

In the corn-planter method seed are distributed at fairly regular intervals by means of corn planters which are regulated to drop the desired number of seed in each spot. More ground can be covered per man by this method than by any other, except broadcasting. In experimental work on the Uinta National Forest from 5,000 to 6,000 spots per man per day have been covered, but from 2,000 to 3,000 is a more common rate. This method has in a number of instances proved fairly satisfactory; but none of the corn planters covers the seed well, and as it is bunched in a mass, it is easily located and destroyed by rodents.

CHOICE OF METHODS.

The results from the use of all of these methods have been so uncertain that none can be positively recommended, nor has any one proved distinctly superior to the others. Over a broad range of conditions, however, it is thought that the "regular seed spot" method offers the best possibilities because a good seed bed is prepared, the seed comes in contact with mineral soil and can be covered properly; only a small amount of seed is required per acre, and the resulting stand is quite likely to be evenly distributed. This method can be used over a greater variety of sites than any other with better chances of success.

PLANTING.

SLIT METHOD.

The slit method consists simply of opening a wedge-shaped crevice in the ground by driving a spade, mattock, or axe into the soil and moving the handle backward and forward or sidewise a little (fig. 3). A hole 2 or 3 inches broad at the top, as wide as the blade of the tool, and tapering to an edge at the bottom is thus formed. Into this crevice the roots of a plant are thrust and shaken down as well as possible. The soil on each side of the hole is then compacted against the roots by means of vigorous tramping and stamping with the foot or by inserting the tool into the soil again on the far side of the plant and prying the soil toward it. Before making the slit the surface soil and sod is scraped away sufficiently to remove débris or dry soil which may fall into the hole when the tool is removed. Further, when the mattock is used, the soil over an area 6 or 8 inches square is ordinarily loosened to the depth of the mattock blade and the cleft is then made in the center of the loosened area.

The principal advantage of this method is that it is rapid, and, where it can be practiced successfully, correspondingly economical. Moreover, it makes possible the covering of large areas during a planting season. On the other hand, it can not be followed to good advantage except in soil which is fairly loose and free from rocks, because it is difficult to make a deep enough cleft in heavy or rocky soil; and, what is still more important, a cleft in such soil can not be properly closed by tramping after the seedling is inserted. Where the cleft is not properly closed air spaces are left around the roots, causing them to dry out; and the death of the plant follows. Further, careless or rapid planters often will not take the trouble to see that the roots are not bent, and that the root tips are not near the surface

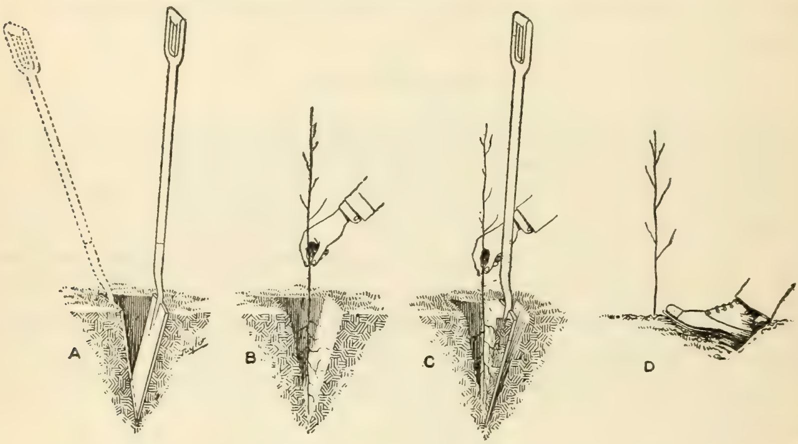

FIG. 3.—Slit method. A, Open slit with spade; B, insert tree and hold with hand until set; C, close slit by thrust of spade; D, close entire hole by thrust of heel.

of the soil where they will soon dry out. Such planting is almost certain to result in failure. The method has been followed successfully, however, particularly on the Nebraska National Forest in the sandhill region, where a crew of two men will average about 2,000 plants per day of eight hours.

A modification of this method is sometimes called the "grub-hoe method." In this the grub hoe or mattock is driven into the soil to the depth of the blade; the tool is pulled slightly toward the operator; the roots of a plant are thrust into the opening thus formed back of the tool; and the blade is then lifted in such manner that the loosened soil slides off upon the roots of the plant. This soil is then well tramped about the roots. The method is simple, easy to perform, and rapid; and the soil is not scattered. Planting can be carried on at an average of from 600 to 800 trees per man per day, and as many as 1,000 under favorable conditions. On good soils and in regions very favorable to tree growth, as in Washington, Oregon, and western Idaho and Montana, this method has proved very successful. It is not yet known, however, that it will be successful in regions or on sites not particularly favorable to tree growth. The hole opened up is not large enough or deep enough to allow the proper distribution of the roots; it usually does not remove much of the competing herbaceous growth; and it does not permit especial attention being given to the packing of the soil around the roots.

TRENCHER METHOD.

The trencher method is simply a modification of the slit method. One of its best features is breaking up heavy sod or herbaceous growth and thus freeing the seedlings from root competition and excessive shading. The field trencher and its use have been described as follows:[1]

The trencher consists of a heavy V-shaped shoe fastened on an ordinary steel plow beam and supplied with handles similar to plow handles. The shoe is 24 inches long, 12 inches deep, and is made V-shaped by riveting plates of steel together at the bottom and separating them 3 inches at the top. These plates are welded and drawn out into a thin sloping edge in front, the lower part of which is widened into a broad nose. The nose draws the shoe into the soil, and a small horizontal plate attached to the bottom of the shoe serves to hold it to an even depth.

With a strong slope from the nose to the top of the shoe in front, roots and trash in the soil that are not severed when the shoe strikes them are inclined to be raised above it and then slide off at one side of the beam without injuring the trench. The length of the shoe is such as to cause the sides of the trench to be sufficiently troweled to make them stand up until the planter comes along to put in the tree. The use of a short shoe results in the trench caving down and half filling in many places almost immediately after the trencher has passed.

The trencher is drawn by three horses, and in its use on the Kansas and Nebraska National Forests the trench is usually made in a furrow turned with a sidehill or ordinary plow. A man with a planting basket follows the trencher and puts trees into the trench, being careful to have the roots well extended toward the bottom. As the crowns of the trees are brought to the proper height, the planter sets his foot at a slight angle to the trench, caving the side in against the roots. Men with long-handled tampers follow, setting the soil firmly against the trees, and close the trench between the trees to reduce the chance of evaporation. A gang of 10 to 15 men is required to keep up with the trencher and can plant from 12,000 to 20,000 trees per day.

On the Kansas National Forest this scheme was brought nearer to perfection by the use of a riding trencher, which combines a lister plow with a trencher and thus saves the expense of one driver and two horses.

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[1] Mast, William H. *In* American Forestry, Vol. XVIII, No. 5.

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Up to the present this method has been followed only on the Kansas and Nebraska National Forests; it has proved rapid on both and successful on the Nebraska (Pl. VII, fig. 1). The method, however, is limited in its scope. It can not be followed on very steep hillsides, in soil that is rocky or filled with large roots, or on areas covered with brush or considerable down timber; and it is questionable if it would be successful in very heavy soil. In short, the method is not suitable for the greater proportion of the lands in the West on which forest planting will have to be conducted.

SQUARE OR DEEP-HOLE METHOD.

A square hole seven or eight inches across and about a foot deep is dug, either with a spade or a mattock; and for utility in planting, the soil removed is placed adjacent the hole (fig. 4). Properly,

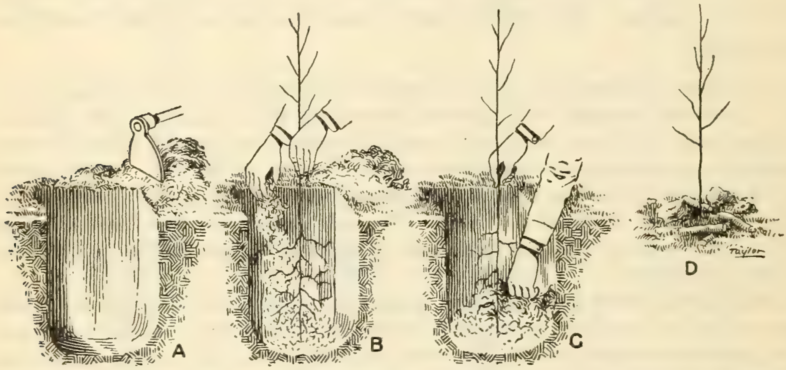

FIG. 4.—Deep-hole method. A, Digging hole; B, partially cover roots with loose moist dirt; C, tamp dirt firmly about roots before filling hole full; D, place objects about tree to prevent erosion and trampling.

the soil removed should be kept in two separate piles; the moister, richer soil of the upper layer in one pile, and the lower subsoil in the other. The depth of the holes depends upon the size of the stock; they should be deep enough so that the roots may hang straight down in their natural position when the tree is set at the same depth as in the nursery. The tree is held by the root stock with the fingers between the different ramifications of the roots so as to spread them apart. This is done with the left hand, while the dirt is filled in with the right. The moist, better soil is first drawn in over the roots and packed well around them with the fist; then the remainder of the soil is thrown in and part of it well packed, a portion lying on top being left loose to serve as a mulch. On slopes, the aim should be to leave the surface of the soil at the same angle as the slope of the planting site instead of leaving a depression in the soil. Where a depression is left, soil from above is apt to wash into it, or leaves may drift in and partly or entirely cover the plant. The drifting in of leaves has caused considerable loss where the planting has been done under a stand of aspen.

This method is the most applicable to all species and sites; it removes part of the competing growth of sod; and it (or a modification of it called "side-hole method") will undoubtedly continue to be the one in most general use in the future. It is only fairly rapid, from 250 to 350 trees per man per day in rough country constituting an average day's planting, and there is the possibility of poor planting if the crew is not careful to spread the roots during the operation.

In the side-hole method the trees are set against one side of the hole instead of in the middle. It is a little more rapid than when the trees are set in the middle of the hole; and, experimentally, in operations on the Siuslaw National Forest and at the Fort Valley Experiment Station, it has proved almost as successful. It can not be given unqualified indorsement, however, without further trial, though with the ordinary planting crew it will probably prove just as successful in the majority of operations as planting in the center of the hole.

CONE METHOD.

The cone method is another modification of the square-hole method. The square hole is dug as in the other method; a mound of earth is then built up by the planter in the bottom of the hole, and the roots of the plant are spread over this mound. Thus they come in contact with a greater amount of soil, from which moisture and other plant nourishment can be drawn. After spreading the roots, the soil is filled in as in the square-hole method.

This method unquestionably has merit for planting under very unfavorable conditions; for, if it is properly conducted, the losses are usually smaller than where other methods are used. On the other hand, it has disadvantages. It is not applicable to species which do not have a ramifying root system; unless given close supervision, the average workman will not be particular to form a good cone or to spread the roots well over it; and it is slow and expensive. Under average conditions one man will plant only from 200 to 250 trees per day.

PLOWING AND MATTOCK METHOD.

Single furrows are plowed from 8 to 10 feet apart, and holes are then dug with a mattock to receive the plants. It has been found that just about twice as rapid progress can be made as where no plowing is done, both in digging holes and in planting, because digging is easier in the broken sod and more loose dirt is provided for filling in around the trees.

Like any other method where a plow is used, this is subject to limitations; but on account of its rapidity and the success which has attended its use, it is worthy of trial, particularly in grassy or sagebrush land where the plow can be used. On steep, grassy sidehill areas open to grazing by cattle there is a serious drawback to this plan; the animals follow the furrows as paths and are likely to tramp out a large proportion of the planted stock.

PIT METHOD.

The pit method is designed particularly for use in regions which, following the planting season, become particularly hot and dry. It has been used by the Forest Service mostly in fall planting in southern California. It consists in partially preparing the holes in advance of the planting operations. Spots are cleared about 16 inches square and the surface soil stirred to a depth of about 8 inches. Then in a spot about 8 inches square in the center the soil is removed to a depth of from 12 to 16 inches in order to loosen it up thoroughly. It is then replaced and a depression left on top. Where the original method is adhered to, the work is finished a month or more before the time of planting.

Rain which will saturate the hard ground only to a depth of 2 or 3 inches will be sufficient to penetrate from 12 to 16 inches in the soft soil of the pits. This is one of the most important points in their favor. Soil when moist to a depth of 12 inches is suitable for planting. Thus, when the contiguous land is not ready for planting and may not be for some time, the soil in the pits is moist enough to make planting feasible, so that operations may be finished before the advent of cold weather. The plants will then have a better opportunity to become partially established during the fall.

The other most valuable feature of pits is that their soil, before it becomes packed by rain or snow, will remain moist two or three weeks longer than the untilled adjacent soil. Accordingly, trees in pits should not, under dry conditions, suffer from lack of moisture as soon as those planted on untilled land. Another advantage is that the soft earth can be very easily removed when the planting operation is in progress, enabling more rapid work and the covering of a greater area during the most favorable planting season, which is often of short duration.

Advance preparation of pits in some particulars has decided disadvantages. Crews have to be assembled to prepare the spots, and again later on for planting: the holes have to be dug twice, which makes the operation expensive; and when the planting is in progress some of the spots previously prepared may be missed. In Forest Service operations this method has been discontinued: because although theoretically it seemed destined to assure better results, practically it has not done so. Fully as good results have been achieved by preparing the holes at the time of planting as by preparing them a month before.

POT PLANTING.

Sometimes stock which has been grown in paper pots is planted. The whole pot is planted either in a hole or a pit. The pot is set in the hole and the loose soil thrown in and firmed closely around it and piled up enough to cover its top.

Pot planting is particularly designed for arid and semiarid regions or for summer planting. The roots are not disturbed or exposed during the operation, and good soil is retained around them. This is decidedly conducive to success, particularly in dry regions. It permits of summer field planting, because the plant, which is growing, is not disturbed to any appreciable extent during the process.

When tried in Arizona the method was not especially successful. Better results at a much lower cost were secured through planting vigorous, sturdy bare-rooted stock. In southern California developments up to date indicate that the method may prove the most suitable in reforestation operations in that region. The greatest success through its use has been secured largely in experimental work with incense cedar and western yellow and Jeffrey pine.

Some objections to the method have developed. The planting stock itself is unduly expensive because of the cost of the pots and the individual attention which must be given to each plant in producing it. Moreover, it is difficult and expensive to transport and distribute the pots over the planting site. The pots form a ready line of cleavage with the soil and have in some instances been heaved up with the plant out of the ground during periods of alternate freezing and thawing weather. Further, the best root development is not secured, and after the pots are set out in the field there is a decided tendency for the roots to remain confined to the good soil of the pots rather than to reach out into the surrounding soil.

BALL METHOD.

The ball method consists in removing each tree from the nursery with a ball of the nursery soil surrounding the roots and planting it in the field in this condition. Almost the same advantages would result from this as from pot planting, but it is obviously impracticable thus to remove the small trees used in forest planting.

Care in Planting.

In planting operations there are a number of points to be kept in mind. Special attention must be called to the susceptibility of conifers to mortal injury through the drying out of their roots. A short period of exposure may bring this about, such as when they are dug from the transplant beds, while they are being counted or heeled in, while en route to the planting site, or during the operation of planting. Drying out may occur at any one of these times; and yet if the roots are afterwards moistened there will be no evidence of the injury, because coniferous tops will remain fresh, green, and bright for some time after the death of the roots, and will reach the hands of a planter apparently in a perfectly vigorous condition. When field planted, however, they will lose their color and shed their leaves in a month or so.

When the crated trees arrive at their destination on the railroad they should be removed at once to the planting site. Wagon transportation is the most effectual over roads and pack animals over trails. When it is necessary to use pack animals the practice of unpacking the trees from the crates and repacking them in the ordinary alforjas or panniers carried on pack saddles should not be followed. This involves an extra handling of the stock, which means both expense and possible harm from exposure. It is a practice which should be discouraged. It can easily be obviated by packing trees at the nursery in boxes of a size which can be readily carried by a pack horse; that is, boxes which, when filled with trees, will not weigh more than 75 or 100 pounds each. While en route the crates should be covered to protect them from the sun and wind.

On arrival at the planting site, the trees should be heeled in (Pl. VIII, fig. 2). This is a simple but effective means of keeping the roots moist. In a cool, moist, shady situation a trench is dug about the depth of the spade, from 10 to 12 inches, with one of its sides slanting at an angle of about 45 degrees. Against this side a layer of trees is placed with their tops projecting above the surface of the ground and their roots extending down this slanting side to the bottom of the trench. From 4 to 6 inches of moist earth should then be thrown against the roots, worked in around the stems, and then firmed by foot pressure. If needed, another trench can be dug in front of this and the process repeated. If it is necessary for the stock to remain heeled in for a considerable period, the soil about the roots should be kept moist by watering. Ordinarily, the trees can be heeled in in bundles as they come from the nursery, but it is preferable at all times to spread them out in a thin layer not over 1 or 2 inches in thickness. As they are needed they can be dug up and used in the planting operations. When plants are to be heeled in during the fall to await spring planting, experience has shown that they should never be heeled in in bundles, but should by all means be spread out in a thin layer. Moreover, where the snow accumulates to a considerable depth, stock heeled in over winter should be so placed that the tops of no two successive layers overlap. Wholesale losses from heating and molding, induced apparently by pressure of the snow, have occurred where the tops have overlapped. Fall heeling in for spring planting has in a number of instances proved very unsatisfactory, and it is a practice which should not be followed if avoidable. At no time, in fact, should plants be heeled in for a long period because loss of vitality results.

For spring planting on the Gunnison National Forest, crates of Douglas fir trees received from the nursery before planting could be

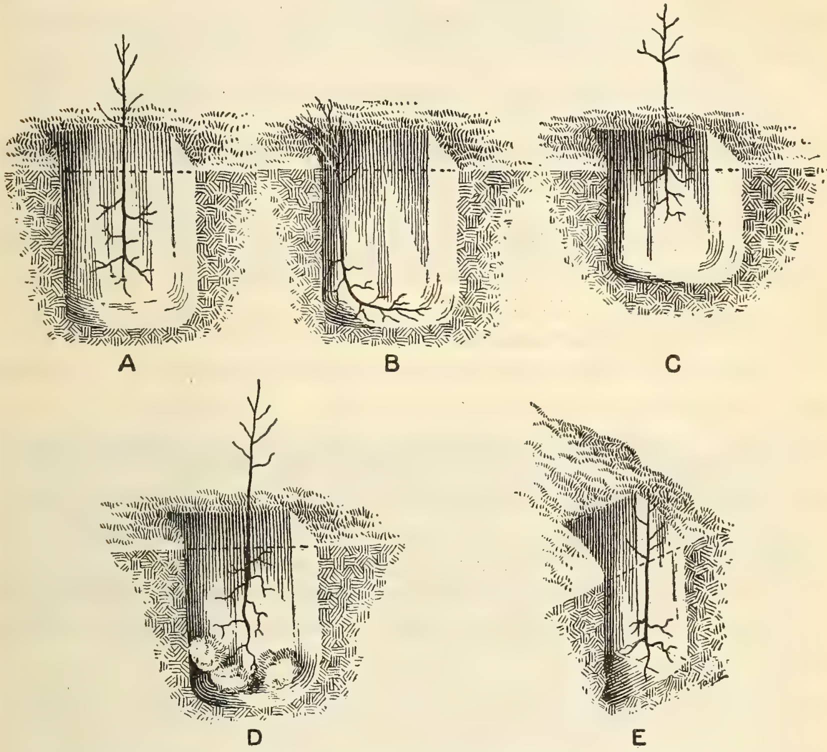

Fig. 5.—Reforestation on the National Forest. A, Good planting (tree will live if firmly set); B, careless planting (tree set too deep and roots crowded; will very likely die); C, very careless planting (tree set too shallow; will surely die); D, careless planting (sod, grass, etc., tamped around roots; will dry out and tree will die); E, careless planting (tree set too deep on side hill; will be covered by soil rolling from above).

conducted were buried in snow. This stock kept in excellent condition until it could be planted.

Too often, without a doubt, failures in planting are ascribed to improper methods of planting, inhospitable sites, etc., when in realty they are due to exposure of the roots at some time during the period following digging at the nursery. Every care must be taken, therefore, to guard against this. Care must also be taken against heeling in the trees in hot, exposed situations and against their heating in the bundles, crates, or while heeled in.

Pains should be taken during the actual planting to observe the following: The planting holes should be deep enough (10 to 12 inches) and broad enough (8 inches or more) to accommodate fully the roots of the planting stock; the planting should be neither too deep nor too shallow; the soil packed around the roots should be moist and well firmed; the more fertile upper layers of soil should be packed around the roots, but sod should be excluded because it leaves air spaces and causes the drying out of the roots and the death of the plant; and depressions should not be left around trees planted under aspen or deciduous brush or on steep slopes (fig. 5).

QUANTITY OF SEED AND NUMBER OF PLANTS PER ACRE.

In the forest nature produces seed abundantly, depending upon quantity to offset possible adverse conditions. In artificial sowing it is not practicable to be so lavish; and conditions that will permit the germination of the seed and enable the plants to grow must, so far as possible, be insured. One of the chief problems is to get the seed into direct contact with the soil. An old grove of Douglas fir trees may shed 25 pounds of seed to the acre, or 1,250,000 individual seed; yet, because of needles and litter covering the ground, very few seed reach the mineral soil, germinate, and grow. With Douglas fir direct light is, of course, an important factor also. By removing the heavy shade, burning the litter, and exposing the mineral soil, and by poisoning destructive rodents, conditions may be so improved that 3 pounds of seed to the acre, sown broadcast, or 1 pound sown in seed spots, will produce a full stand of young trees. Areas sown by the seed-spot method suffer more damage from birds than do those sown by other methods. A thicker sowing in the spots is therefore necessary.

TABLE 5.—*Approximate percentage of germination of fresh seeds of different species under greenhouse conditions.*[1]

Species.	Germination.	Species.	Germination.
	Per cent.		*Per cent.*
Bigtree (Sequoia washingtonia)	33	Norway pine (Pinus resinosa)	89
Arizona cypress (Cupressus arizonica)	22	Scotch pine (Pinus sylvestris)	44
Amabilis fir (Abies amabilis)	[2] 42	Sugar pine (Pinus lambertiana)	51
Douglas fir (Pseudotsuga taxifolia)	55	Western white pine (Pinus monticola)	57
Grand fir (Abies grandis)	[2] 34	Western yellow pine (Pinus ponderosa)	75
Noble fir (Abies nobilis)	[2] 23	White pine (Pinus strobus)	55
Red fir (Abies magnifica)	[2] 65	Western red cedar (Thuja plicata)	67
Austrian pine (Pinus austriaca)	67	Engelman spruce (Picea engelmanni)	60
Jeffrey pine (Pinus jeffreyi)	86	Norway spruce (Picea excelsa)	48
Lodgepole pine (Pinus murrayana)	83	Sitka spruce (Picea sitchensis)	51
Mexican white pine (Pinus strobiformis)	47		

[1] Individual lots of seeds vary greatly in their germinative ability. Under field conditions, germination is usually less than in the greenhouse.
[2] Tests not made by the Forest Service.

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FIG. 1.—PLANTING WESTERN YELLOW PINE ON BURNED-OVER AREA. LOLO NATIONAL FOREST, MONT.

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FIG. 2.—WIRE-PACKING CRATES AND METHOD OF HEELING-IN PLANTS AT PLANTING SITE.

With a suitable area well prepared, the amount of seed of the more important species required per acre is about that shown in Table 6. The amounts are based on the average germination per cent given in Table 5. These quantities should be varied, as germination tests differ from those shown in this table or as spacings of seed spots differ.

TABLE 6.—*Number of seed required per acre.*

BROADCAST SOWING OVER THE WHOLE AREA.

Species.	Seed per acre.	Species.	Seed per acre.
	Pounds.		*Pounds.*
Western red cedar	1½–2½	Mexican white pine	8–10
Douglas fir	4–5	Norway pine	4
Amabilis fir	8–10	Scotch pine	7–8
Grand fir	8–10	Sugar pine	10–20
Noble fir	8–10	Western white pine	8–10
Red fir	8–10	Western yellow pine	6–8
Austrian pine	8–10	White pine	8–10
Jeffrey pine	18–24	Engelmann spruce	2–4
Lodgepole pine	2–3	Norway spruce	5–7
Maritime pine	10–20	Sitka spruce	2–3

SEED-SPOT SOWING.

[Spots spaced 7 by 8 feet; approximately 10 to 12 good[1] seed per spot.]

Bigtree	1	Maritime pine	2
Western red cedar	⅜	Mexican white pine	1½
Arizona cypress	1½	Norway pine	4/8
Douglas fir	⅜	Scotch pine	1⅓
Amabilis fir	1½	Sugar pine	3
Grand fir	1½	Western white pine	1⅓
Noble fir	1½	Western yellow pine	1⅓
Red fir	1½	White pine	1⅓
Austrian pine	1½	Engelmann spruce	⅜
Jeffrey pine	4	Norway spruce	1
Lodgepole pine	⅜	Sitka spruce	⅜

[1] For example, if the germination tests showed 50 per cent germination, 24 seed would have to be sown to have 12 good seed.

A standard stocking of about 800 trees per acre has been adopted for nearly all of the planting operations on National Forests. This stocking is undoubtedly not the most desirable for all species or sites, but is considered the best to adopt as a general standard. As more becomes known about the various species, different spacings will doubtless prove more suitable. Uniform stocking has the advantage of facilitating calculations and making comparisons of different planting operations. As a matter of fact, because of the roughness of the country, the rocks, logs, and brush on the planting areas, uniformity in stocking is not attained. The number of trees planted per acre varies from 600 to 1,000 or more.

COSTS.

The elements which have a material bearing upon the cost of sowing or planting are many, and are sometimes unforeseen. The topographical features, soil, and cover of the area, the distance of the site from the railroad and base of supplies, the character of the transportation necessary to convey the stock and supplies to the camp, the wages paid crews, the efficiency of the crews, the method followed in sowing or planting, the species and amount of seed or stock used per acre and its cost, the size of the operation, and the nature of the weather during operations all are important. Small operations are consistently more expensive per acre than large ones because the former do not continue long enough for the men to become expert in their work. Inclement weather which causes an interruption in operations often materially increases costs, because the men while idle are furnished food. The variation in these factors is so great that it is difficult to do more than estimate approximately the cost of any individual operation. That some idea may be obtained, however, the actual cost of a number of representative Forest-Service operations are shown in Tables 7 and 8.

TABLE 7.—*Cost per acre and per 1,000 spots of sowing different species in different regions by various methods.*

Region.	Species.	Method.	Cost per acre.	Cost per 1,000 spots.
Northern Idaho	Western white pine	Corn planter	$2.16	$3.18
Southern Montana	Lodgepole pine	do	11.07	9.15
Do	do	do	12.49	4.59
Southwestern Montana	do	Broadcast and harrowed	20.78	....
Do	do	Broadcast on snow	9.87	....
Do	Western yellow pine	Broadcast	14.30	....
Do	do	Corn planter	1.59	1.75
Do	do	Seed spot in plowed strips	20.15	16.65
Do	do	Mattock seed spots	19.37	7.12
Do	do	Corn planter on plowed strips	7.21	10.60
Western Idaho	Black walnut	Seed spot with pointed stick.	9.10	7.52
Do	Western white pine	Corn planter	3.18	2.63
Central Montana	Western yellow pine	Broadcast	4.68	....
Western Montana	Western white pine	do	4.83	....
Do	do	Corn planter	2.92	2.83
Do	do	Hoe seed spots	4.67	4.53
Central Colorado	Western yellow pine	Broadcast on snow	3.06	....
Southwestern Colorado	Douglas fir	Plowed strips and harrowed.	5.61	4.64
Do	do	Broadcast and harrowed	5.91	....
Do	do	Corn planter	2.05	1.70
Northwestern Wyoming	do	Broadcast	12.26	....
Do	do	Seed spot	14.09	5.18
Southern California	Western yellow pine	Broadcast and dragged	8.35	....
Do	Jeffrey pine	Broadcast and double harrowed.	7.90	....
Do	do	Seed spot	8.52	7.04
Eastern California	Sugar pine	do	4.65	6.84
Eastern Oregon	Norway spruce and European larch.	do	3.42	2.82
Northwestern Washington.	Douglas fir	do	2.91	4.28
Northern Oregon	do	Broadcast	5.68	....
Western Oregon	do	Seed spot	4.77	3.94

TABLE 8.—*Cost per acre and per 1,000 trees of planting different species in different regions by various methods.*

Region.	Species.	Class of stock.	Method.	Cost per acre.	Cost per 1,000 trees.
Southern Montana	Douglas fir	1-1	Spade hole	$15.01	$12.40
Do	do	2-0	do	15.58	12.88
Southwestern Montana	Western yellow pine	1-1	Mattock holes	4.61	9.53
Do	Western larch	2-0	Ax, slit method	7.45	13.85
Do	Western yellow pine	2-0	do	3.36	6.94
Do	do	1-1	do	10.04	16.60
Do	Western larch	2-1	do	10.22	18.77
Central Montana	Douglas fir	2-0	Pick holes	12.15	15.62
Southern Montana	do	1-1	Mattock holes	9.71	12.63
Do	do	2-0	do	5.10	7.01
Western Montana	Western yellow pine	1-2	do	9.97	12.93
Do	Engelmann spruce	3-0	Ax, slit method	5.10	7.55
Do	do	3-0	Mattock holes	7.15	9.41
Southern Montana	Lodgepole pine	2-0	do	15.25	10.00
Do	Douglas fir	2-0	Mattock holes, slit method	4.08	8.16
Central Montana	Western yellow pine	1-1	Pick, slit method	7.04	10.35
Do	do	2-0	do	5.35	7.87
Southern Montana	Douglas fir	2-0	Mattock holes in plowed furrows.	16.16	8.40
Nebraska	Jack pine	1-1	Field trenches	9.61	7.69
Do	Western yellow pine	2-1	do	15.41	9.78
Do	do	1-1	do	10.09	6.40
Southern Idaho	Douglas fir	2-0	Mattock holes	11.39	11.59
Central Utah	do	2-1	do	12.77	12.77
Southern Idaho	do	2-0	do	14.05	11.67
Southern California	Jeffrey pine		do	16.70	16.70
Northern California	Western yellow pine	1-1	do	19.10	27.28
Northern Oregon	Douglas fir	1-1	do	8.25	12.20
Northern Washington	do	1-1	do	8.78	12.91

For the greater proportion of reforestation operations conducted on a large scale, the cost of direct seeding can be kept within from $4 to $6 and planting within $10 per acre, provided a spacing of 8 by 8 feet is followed. Under more favorable conditions these operations have been carried on at a lower cost.

Further reductions will be brought about in the future. The production of nursery stock will undoubtedly be cheapened. The development of more rapid but efficient methods of sowing and planting or of trees better suited for planting by the rapid methods already in vogue, is quite possible. In many cases the speed of planting can be increased through the use of more adaptable tools kept in the best working condition. Reductions may also be effected through larger assignments which will permit more thorough organization of the work; through confining the planting on a particular Forest at a certain season, to an individual watershed rather than conducting it on several, thus avoiding the duplication of camps, crews, and supervision; and in some cases through allotting fewer species and kinds of stock for use during a particular season.

SEASON.

Planting.

The chief factor governing the choice of the planting season is the climate, and this principally in its relation to the soil moisture at the period of and for a time following the planting operations. Lack of sufficient soil moisture during the period closely following planting and before the stock becomes well established is responsible for a large proportion of the mortality which occurs in plantations on the National Forests. This is particularly true for species natural to the region and normally hardy on similar sites. When planting operations are extensive, it is often necessary to conduct them during both fall and spring because the period suitable for planting is not long enough in either season for their completion.

SPRING PLANTING.

Where sufficient rainfall occurs during the spring and early summer months, the spring is almost unquestionably the logical time for conducting planting operations. The soil is in good condition; the planting operations will not normally be hindered for any great length of time by newly fallen snow; the plants will be in no danger of heaving or winter killing; and they will have a considerable period in which to become partially established before the advent of hot, dry weather. On the other hand, the stock for planting may have started growth in the nursery before the planting site is in a condition to receive it; and labor is more difficult to obtain than at other seasons of the year.

SUMMER PLANTING.

Summer is the rainy season in some parts of the country, and as the soil is in the best condition for the growth of plants it might be thought that this would be a favorable time for field planting. Up to the present, however, summer planting has been found to have few points which make it commendable. Under normal conditions trees are in an active growing state during the summer, and the field planting of growing stock is almost certain to meet with failure. It would seem that stock held in cold storage or held back in the nursery by mulching might be planted successfully, but such plantings with western yellow pine in Arizona and New Mexico have been unsuccessful on the whole. The trees have usually died during the following fall and winter. Field planting of potted trees during the summer has been partially successful with 1½–0[1] western yellow

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[1] The first figure indicates the number of years plants remain in seed beds; the second figure, the number of years in transplant beds.

pine in New Mexico and probably offers the only reasonable chance of success in summer planting. As such plants are unduly expensive to grow and plant, the possibilities of successful planting during the other seasons should be exhausted before resort is had to this method. If summer planting could be carried on successfully in such regions, it would have the decided advantage of favorable weather conditions for a considerable period of time.

FALL PLANTING.

The possibilities of fall planting are governed largely by soil and climatic factors. Loose, friable soil, not subject to serious heaving, or even heavier soils which will be covered with a heavy fall of snow all winter, may be safely planted in the fall, provided the soil moisture conditions make this season seem the best for planting. Labor is usually readily available, and in some regions the weather continues fair and is better suited to planting than any other season. Further, the stock is in the ground, the soil becomes well packed around the roots, and the tree is ready to begin growth early in the spring. In consequence, it becomes fairly well established before the advent of the dry, hot season. On the other hand, on heavier soils or where heavy snowfall does not prevail, particularly on south and west slopes, the plants are liable both to heaving and to winter killing, and in some regions the work is very likely to be interrupted or entirely stopped by premature heavy snowfall or freezing of the ground.

One serious objection has arisen to fall planting of Douglas fir at high altitudes in Utah, where the snowfall is very heavy. The weight of the snow has crushed down the planted stock and resulted in its blackening and rotting as though attacked by a fungus. Where the plantations are under an aspen cover, the aspen leaves fall upon the small plants, become matted over them, and contribute to their destruction.

WINTER PLANTING.

Where the winter is accompanied by snowfall or by cold, freezing weather, planting is obviously impracticable. It is practiced somewhat in southern California during December and part of January before freezing occurs, along the coast region of Oregon until January 1, and during January and February in southern New Mexico.

SEASON FOR PLANTING IN DIFFERENT REGIONS.

Experience gained so far in the Forest Service indicates that early spring planting should be followed in Montana, Idaho, Colorado, Wyoming, Nebraska, South Dakota, Michigan, Minnesota, Arizona, New Mexico, northern California, Washington, Oregon, and Utah. In southern California only, on account of the long, dry season so closely following the spring planting season, planting in the fall after the beginning of the rains is considered best.

SOWING.

The time of year when seeding should be done varies with the climate and, to a less degree, with the species. The important thing is to vary the time of sowing with climatic conditions, so that the seedlings will get the greatest possible supply of moisture. In general, tree seed should be sown immediately preceding or at the beginning of the characteristic period of precipitation in the region. Exception to this rule may be necessary on account of peculiarities of certain tree species or local abundance of rodents.

FALL SOWING.

Fall sowing is advantageous for species whose seed normally germinate slowly, such as white pine, the true firs, Douglas fir from the Pacific coast, western yellow-pine seed from Idaho or California, and seed which deteriorate rapidly, such as incense cedar. In regions where part of the precipitation comes in the form of snow and where after its disappearance in the spring a hot, dry period of several weeks or more follows, fall sowing is advisable. Fall-sown seed germinate earlier in the spring than others, and the plants have a better chance to establish themselves before the drought becomes severe. Danger of destruction of seed by rodents is not so great, because there is usually an abundance of natural foods during this season, but subsequent depredations by rodents during the winter may be very severe. In general, fall sowing is preferable on areas which will be snow covered all winter.

WINTER SOWING.

Sowing on the snow in late winter and early spring has the same effect of inducing early germination as fall sowing. Its chief disadvantage is that broadcasting is the only feasible method. Further, seed when first sown on snow are conspicuous and likely to be eaten by birds, though after a day or two of sunshine they disappear. They also sometimes slide along the surface of the snow, and, consequently, can not be distributed evenly.

SPRING SOWING.

Spring sowing has the advantage of not exposing seed to premature fall germination, to unfavorable winter weather conditions, or to destruction by birds and rodents for a period longer than is necessary.

It has the disadvantage that the seed often fail to germinate until the following year, or until about the beginning of the dry season, when the seedlings have little chance of surviving.

SUMMER SOWING.

Summer sowing is very generally inadvisable, except possibly in those regions, such as Arizona and New Mexico, which are characterized by a rainy period beginning in July. Even in these regions summer-sown seed have only a short growing period after germination and are very likely to be harmed by early frost.

SEASON FOR SOWING IN DIFFERENT REGIONS.

While sowing has not proved satisfactory in general at any particular season, experience gained so far in Forest Service operations indicates that the best results may be expected from early spring sowing in Montana, Wyoming, and Colorado east of the Continental Divide, the Black Hills of South Dakota, and possibly the Lake States. Similarly, the indications point to fall as the best period in Colorado, Wyoming, and Montana west of the Continental Divide, Idaho, Arizona, New Mexico, Utah, California, Washington, and Oregon.

FIELD ORGANIZATION.

The sowing of a certain area or the planting of an assignment of trees involves the problem of doing a definite amount of work on selected sites while certain conditions prevail. In the fall, planting must be done after the soil has become sufficiently moist and before winter sets in; in spring, shortly after the snow goes off and before the summer begins. It is important, therefore, to learn beforehand just what field organization will be necessary to complete the work in the time that is available.

Crew.

The number of men desirable will depend largely upon the scope of the operations, the length of the season, the method followed (whether it be a slow or rapid one), the topography and cover of the site, and the nature of the supervision possible. Because of the limited length of the planting season, the possible interruptions through short spells of bad weather, and the deterioration of the planting stock when heeled in at the planting site for any considerable period, the crew should be as large as is consistent with efficiency and proper supervision. Crews generally consist of from 6 to 24 men each, although much larger ones may be employed. In very rough, mountainous country or on areas covered with much brush or down timber, where difficulty is experienced in getting around, the crew, in order to be worked successfully as a unit, should be small; but in open, rather gently rolling country, much larger forces may be worked and still be given the supervision necessary.

If possible, local men should be employed in the work. As a rule, they are not only more industrious than the transient laborers but more efficient, and they take an interest in the success of the operation. If the same men can be secured year after year, it will be found that they will become more rapid and efficient and more and more interested in the success of each year's operations. Men continuously indifferent or careless, who evince no disposition to improve, should be dismissed from the crew.

The wages will necessarily have to follow pretty closely those offered for other classes of work in the region. A graduated scale will sometimes prove effective in holding men for a longer period than they would otherwise stay. Thus they may be paid at the rate of $2 per day if they work for from one to two weeks, $2.25 if they stay for from two to four weeks, and $2.50 if they remain until the work is finished. If it can be avoided, wages should not be at the rate of so much per day and board, or at least the board should be deducted for days or portions of days that the men do not work. If this precaution is not taken, there will be found men in nearly any camp who will lay off from work at the slightest provocation as long as they obtain free meals.

Assignment of Crew.

In seed spotting, where a portion of the crew prepares the spots and the other portion sow the seed, it is almost always true that one man sowing can keep pace with two or more men preparing spots. On the Arapaho National Forest, the ideal crew is considered to be 2 seeders to 10 men with hoes. One of the seeders is in charge of the crew and keeps the men moving. They are worked in just as long rows as can be laid out across the seeding areas in order as much as possible to avoid the delay which occurs each time that a crew reaches the end of a row. Following this system, a crew of 12 men average from 2,200 to 2,300 spots each per day. On the Black Hills National Forest it has been found that if each man prepares seed spots and sows the seed also, about one-fourth more ground can be covered per day than with any other scheme tried there.

In planting, crews are worked in a number of different ways. When the field-trencher method of planting is followed, two men handle the team and plow and pay attention to getting the rows spaced properly and parallel to each other. They are followed closely by the teamster with the trencher, who takes care that the trench is plowed to the full depth and is so located in the furrow that dry top soil does not fall into the trench and thus come into contact with the roots of the trees. The planting crew follows and put the trees into the trench before it has an opportunity to dry out.

When the planting holes are prepared by hand, one man may do the digging and be followed by another man who plants; one man may prepare the holes for two planters; two men may prepare holes for one planter; or one man may do both the digging and the planting. Standardization of methods is hardly possible because of variations in the nature and condition of soils, and difference in personal adaptation, and in the character, size, and root systems of the stock. The practice of having certain men dig and others plant gives the officer in charge the opportunity to assign to these tasks the men best qualified for them. In soil easily worked and in country where little difficulty is experienced in getting over the ground, a combination of one digger to a planter or even one digger to two planters when the planting is carefully done will be found to work very well. In very rough country where the preparing of the holes is difficult and slow, one planter may be able to follow two diggers. In general, however, it is thought that in such country or where there is a dense ground cover of logs or brush, each man should prepare the holes and plant the trees also. This obviates the necessity of two men traveling over the same course; and actual practice in Districts 1 and 6 has shown it to be by from 25 to 30 per cent the most rapid method under such conditions.

The practice is sometimes followed of having one or more people carry the trees and distribute them to the planters as they are needed. Boys can be employed at this task at a lower wage than the men receive, or the man in charge of the crew can perform this duty. Men engaged in distributing only will be idle part of the time; they will have calls for trees from two or more planters at the same time and obviously can not supply all of them at once, and if the trees are distributed in advance of the planters the roots may be exposed long enough to dry them out. Under most circumstances, one man can carry his own trees and plant as fast as another man can dig, the trees are at hand just when he wants them, and the roots are not exposed until they are ready to go into the hole.

When some of the men are assigned to planting and others to digging, it is well to have them change off two or more times a day if it can be done without impairing the quality of the work. It will relieve the monotony and may promote the rapidity of the operation.

One man who acts as the leader of a crew should set the pace and direct the course of the rows. The others keep abreast of him, and, to facilitate rapid work, merely estimate the proper distance between the holes. Considerable latitude should be allowed in locating the holes in order to take advantage of any shade offered by rocks or brush or of small areas where the soil is particularly good. These points are of special importance on inhospitable sites.

The planter should follow the digger closely, since this will promote rapidity of work and lessen the possibility of the holes drying out or of missing some of them entirely. The planters should carry their trees in a manner which will preclude the possibility of the roots drying out. Carrying the trees in a bucket with the roots immersed in a puddle made of clay and water is not desirable. The puddle so mats the roots together that they are not well distributed in the planting hole. If the roots are immersed in clear water the effect is somewhat the same. At present the most common, and it is thought the most effective, plan is to carry the trees with the roots surrounded by wet burlap or covered with damp moss. Only lots sufficient to last from one to two hours should be packed around. Large lots are burdensome, the burlap becomes dry, and then the roots. Larger lots of trees, properly stored, should be available at different points on the planting site, from which the planter can replenish his stock when necessary. Water should be on hand also, so that the burlap or moss can be wet occasionally.

Supervision of Crews.

The necessity of constant supervision in field planting and seeding can not be emphasized too strongly. Unless it is given, the efforts spent in producing and planting the trees may be entirely lost, for in no other part of the work does the result of carelessness show so clearly. If any of the essential points for successful planting are slighted, the chances of success are greatly reduced at the outset. The technical men can well be employed in supervision only, and the better and more experienced workmen may be made foremen at a higher wage and be charged with supervision. Experience indicates that there should be one man charged with supervision for each crew of from 6 to 10 men. Forest officers, however, should inspect the quality of the work and direct the foreman as to the details.

Equipment.

Field planting and sowing necessitates the carrying in stock of considerable equipment for use in actual operations and of tools necessary to keep this equipment in shape.

SOWING TOOLS.

The tools most commonly used in preparing the ground for sowing are the mattock, grub hoe, garden or some slightly heavier and more strongly constructed rake, and hazel hoe. The mattock and grub hoe are best where the soil is heavy or rocky or where it is desired to stir it to a considerable depth; the rake is good in loose soil where there is not a heavy cover of grass and where deep cultivation is not necessary; and the hazel hoe is good where the soil is not very rocky or exceptionally heavy.

Another seed planter (Pl. IX, fig. 1) has recently been designed which gives promise of being a good tool for this work where the sod is not too heavy. Its construction in principle is that of a removable soil-preparing tool such as the mattock, rake, or hoe, attached to a hollow iron handle, which serves as a receptacle for seed. Through a system of openings at the lower end of the handle which are opened and closed by means of a sliding rod and lever operated by one hand of the worker, the seed are distributed on the spot as it is prepared with the rake or hoe attachment. By continuing the operation of raking or hoeing, the seed can also be covered. In an experimental trial it has proved more rapid than the common garden rakes, but not quite so rapid as the corn planter. One man prepared 4,830 spots per eight-hour day. When using small seed (lodgepole pine) it has proved much more economical of seed than the corn-planter method or that of scattering seed by hand on the seed spots. Its weight of about 5 pounds when empty of seed is an advantage in preparing spots in heavy or sodded soils, but becomes burdensome to the operator. Fairly clean seed is necessary, as the presence of foreign matter larger than the seed itself is likely to prevent successful operation of the tool.

In the trials which have been made of the tool some imperfections have been noted. A portion of the large seed is likely to be cut. In a trial given it with maritime-pine seed, about 5 per cent were injured in this manner. Small seed are injured very little, if any. The tool has not been found as satisfactory as the mattock in heavy turf. It has been found that the seed can not be scattered satisfactorily at the same time as the tool is being drawn toward the operator, unless it is carefully handled, because the seed before striking the ground is struck by the tool itself and scattered outside of the prepared spot.

Numerous corn planters have been tried, and there are several objections to the use of those commonly found on the market. Some have a soft snout, which is knocked out of shape by rocks and is constantly in need of repair, some can not be adjusted to sow the proper amount of seed or to sow it at the right depth, some are not strongly enough constructed to hold together under the rough usage which they get, and some are so heavy as to be cumbersome.

PLANTING TOOLS.

The planting tool most commonly used on the National Forests is some type of the grub hoe or mattock. The spade, ax, and field trencher are used only slightly. Various modifications of the common type of mattock and grub hoe found on the market have been tried. The blades have been narrowed and lengthened; they have been bent so as to form a right angle with the handle, which has been thought desirable for planting on slopes; handles with a slight S curve have been used instead of the common, straight ones; mattocks, one of whose blades is a pick, have been found efficient in heavy, rocky soil; and tools with shortened handles have proved satisfactory in loose soils, where each man of a crew digs the hole and plants the tree also. In most planting operations a mattock with a blade from 10 to 12 inches long seems desirable. For all varieties of soils and conditions encountered these are unquestionably the most efficient planting tools. They are sufficiently heavy to be used without bending or breaking in any soil where planting is at all practicable, and they can be used in the hole, slit, or grub-hoe method of planting. The mattock has a cutting edge which is useful in severing roots, and its blade is efficient for tamping the soil around the plants.

The spade is the next most efficient planting tool. In very loose soil it serves better than any other, either in the slit or the hole method of planting. On very hard, heavy, rocky, or gravelly soils it can not be used to good advantage and sometimes not at all. The short-handled tools are preferable, but any of them are likely to break eventually either in the blade or in the shank.

On the Pike National Forest a planting bar has been devised for work on rocky areas where the grub hoes could not be used advantageously. The bar consists of a steel shank 10 inches long ½ inch thick, 2 inches wide at the point, and 4 inches wide at the shoulder inserted in a 1¼-inch hollow handle. The entire weight is 12 pounds. After one season's work it is declared to be, for such areas, a decided improvement on the grub hoe.

The ax can be used only in the slit method of planting in loose soil or in heavier soil which is free from rocks and not covered with turf. It can not be used successfully in rocky soils. It is not considered desirable nor recommended under any circumstances because the cleft made with it is not sufficiently deep to accommodate fully the roots of most stock used in field planting. Where this method has been followed, the handle has been cut off to a length of about 20 inches.

Weight is an important consideration with any tool in securing efficient work, and especially in increasing the rate of work. A certain number of motions are necessary in clearing off the surface of the ground, digging the hole, and working up the soil, whether

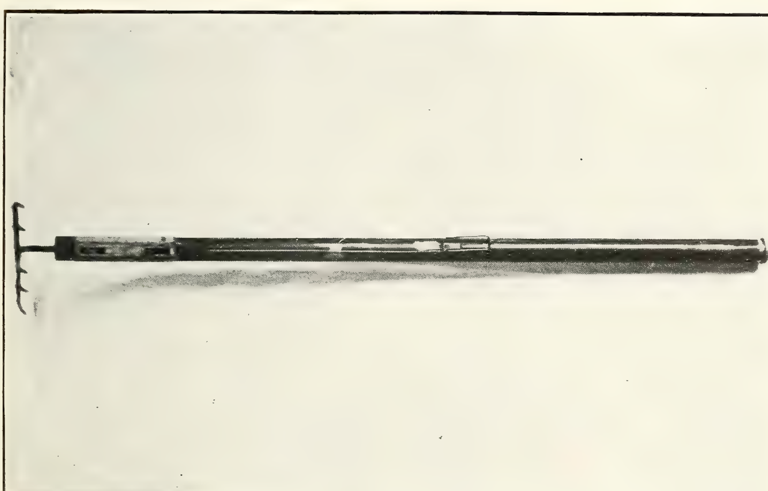
F-13000A

FIG. 1.—ECKBO SEED PLANTER.

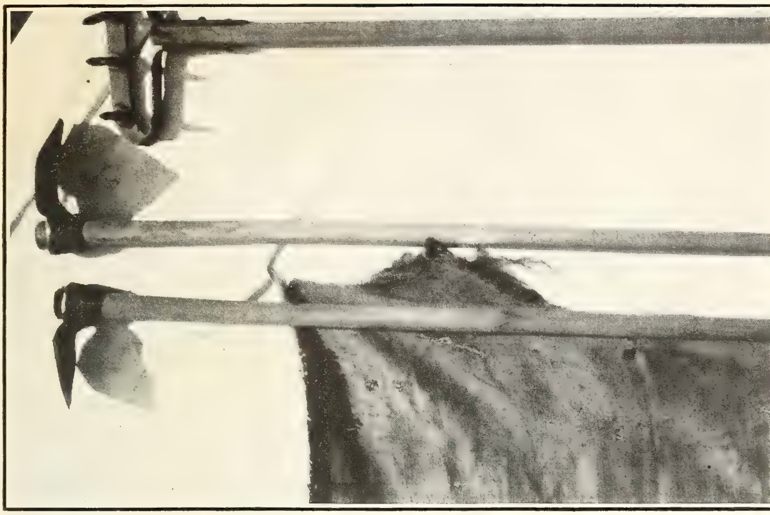
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FIG. 2.—PLANTING AND SOWING TOOLS: HAZEL HOE, GRUB HOE, AND HEAVY RAKE.

a heavy or a light tool is used. The extra energy exerted with a heavier tool can well be expended in performing more work, and under most conditions met in planting it will be found that a tool of medium weight, about 4 or 4½ pounds, will be preferable to a heavier one. Short-handled grub hoes, 2½ to 3 pounds in weight, are now being used successfully in some of the Idaho planting.

OTHER EQUIPMENT.

A very serviceable basket for field planting has been devised at the Nebraska Forest. This is described as follows:[1]

> The Besley planting basket is 12 inches wide, 20 inches long, and 8 inches deep and made of light, galvanized iron, having two handles, as a market basket, and four short legs, consisting of stove bolts 1 inch long soldered in the corners. The top is rolled over a No. 12 wire to give strength. For the inside of the basket several thin quilted pads are furnished. These are fastened on vertical wires at one end, and the trees are placed in layers between the moistened pads. This provides perfect protection for the lower layers while the upper layer is being used.

A modification of this basket has been constructed at the Bessey Nursery. The basket is made collapsible by using canvas instead of galvanized iron. It is of about the same weight, but can be packed about more readily than the first-described type.

Bags made of waterproof cloth and equipped with shoulder or belt straps have been designed in District 6 for carrying stock. The tops of the stock protrude from the bags where they can be grasped by the planter, while the roots are surrounded with wet burlap or moss. In District 1 the specifications for a similar bag are as follows:

> Fourteen inches long, 11 inches deep, with a pocket 8½ inches long and as deep as the bag, sewed on the outside. Material of heaviest duck. Waterproof lining on inside of main pocket. Two rings sewed on ends of bag for inserting ¼-inch rope to tie around waist of planter to keep bag from swinging. Adjustable shoulder straps sewed at one end of bag and fastened with snap at other end.

One of these bags will hold about 1,000 2–0 or 600 1–2 western yellow pines. The plants are readily drawn from the small pocket sewed on the outside, which holds about 100 trees. The main pocket is used to carry the surplus.

Common 2-gallon water pails, in which the roots are immersed in water or covered with damp moss, are also used. The chief objection to them is that on slopes they tip over very readily.

The common wet burlap cover is not so good as the others mentioned, both because it rapidly becomes dry and because in pulling out one seedling for planting the roots of others are very commonly pulled out also and exposed.

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[1] *In* American Forestry, Vol. XVIII, No. 5.

REPAIRS AND EXTRA EQUIPMENT.

That all tools be kept in good working order is essential because it increases the amount and efficiency of the work. A portable forge with an anvil and a grindstone or a supply of files should, if possible, be kept in the planting camps for this purpose. A number of extra tools should also be kept on hand for use while others are being repaired. If pails or baskets are used by the planters for carrying the trees, a surplus of these should also be kept on hand.

CAUSES OF FAILURE AND LOSSES, AND METHODS OF PREVENTION.

Some losses must be expected, but these will be materially reduced when the species, class of stock, sites, methods, and seasons most suitable have been more thoroughly worked out. The only factor that it will never be possible to foresee or guard against is unfavorable weather. The weather being left out of account, the important factors upon which the success of plantations depend are as follows:

Species and Class of Stock.

The safest guide in the choice of species is the trees already growing on the site or on similar sites in the same locality. The introduction of other species or the extension of natural range is always accompanied by high probability of failure. So long as there are in the aggregate such large areas in need of reforestation, the best plan at present is to rely upon the native species. The introduction of others should not be attempted unless upon a very small scale for experimental purposes. While thriving at first, such species may after a few years become very inferior in form and rate of growth.

In some instances seedlings have given better results than transplants in field planting and vice versa. Time will undoubtedly develop the fact that on some, probably the better sites in the more favorable regions, seedlings will succeed admirably. As their use will reduce costs, they should be planted under such conditions. Upon by far the greater portion of the area needing planting, however, two or three year old transplant stock, by virtue of its better developed root systems and somewhat dwarfed stocky tops, offers much better assurance of success in field planting. Even with such stock consistently heavy grading should be followed to eliminate the weak trees.

Source of Seed.

The source of seed also exerts its influence upon the final success of the plantation. Experiments have demonstrated clearly that stock from seed locally collected succeeds better than that produced from seed collected either in a more southern or in a more northern region. The former produces trees which do not harden rapidly enough to escape danger from frost and the latter produces stock of less rapid growth.

Handling of Stock.

The manner of handling the stock from the time it is lifted in the nursery until it is planted in the field is all important. The fatal effect of allowing the roots to become dry or the tops to heat and mold has already been shown. Too much emphasis can not be laid upon this point.

Quality of the Site.

Unfavorable sites, such as those with very thin or very rocky and sandy soils, those with a dense cover of grass or other herbaceous growth which will compete with the plants for soil moisture, wind-swept areas, or those with intense insolation, are often responsible for failure. The most favorable sites should first be chosen so far as possible; and, again, the place for each tree or seed spot should be carefully selected with reference to shelter from the sun or live stock or to take advantage of the better patches of soil.

Time and Method of Planting or Sowing.

The time of planting or sowing has much to do with success. The climate of a region may be such as practically to insure the failure of operations conducted at a certain season. This makes the study of local climatological data of considerable importance when extensive operations are to be conducted. These will indicate the seasons when the weather conditions will normally be favorable. If the soil is moist at the time of planting or sowing and the work itself is followed by a favorable season, the probabilities of success are good; while if an unusually dry summer or very open, cold winter follows, the greatest success can not be expected. This is one of the factors governing success which can not be foreseen and over which no control can be exerted. A good deal of dependence must accordingly be placed upon the quality of the site itself, and in controlling the other factors so far as possible.

The virtue of the different methods of planting and sowing has already been discussed somewhat, and it can readily be seen that where the methods employed are not suitable to the site, soil, or the stock, losses are certain to occur. Experience gained from experimental work and the character of the native stands of timber will be the best guides in determining the proper methods.

Efficiency of Crews.

Careless work may be wholly responsible for failure in planting operations. Planting holes not dug deep enough, failure by the planters to distribute the roots well, bending the roots, insufficient packing of the soil or the packing of dry soil around the roots, undue exposure of the roots during planting, poor supervision—these and possibly other factors will contribute largely to failure. Speeding up the operation in order to make a record is often directly responsible for carelessness. No worse mistake can be made. A planting crew should not be allowed to loaf, but neither should it be urged to such efforts that the thoroughness of the work will suffer. Much loss in past planting has without question been due to this cause. Excessive speed will result in the planting of a larger acreage, but not in its successful planting, and judgment concerning an operation must in the end be based upon its success. Further, where partial failure follows such work the expense of replanting the area plus the first expense will much more than equal the expense of more careful initial operations. Good, efficient crews doing careful and conscientious work at a reasonably rapid rate will do much to make a planting successful and to keep the costs within reasonable limits.

PROTECTION.

Plantations can easily be killed by fire and damaged by stock, insects, disease, and rodents. Fire danger is, of course, always possible, and where it is very acute, reforestation should not be attempted unless adequate fire patrol can be afforded. Reforestation, moreover, need not yet be carried on where roads or trails do not make the area easy of access by fire-fighting crews.

FIRES.

Fire guards are constructed to assist in protecting plantations. On the Nebraska National Forest (Pl. X) these consist of two strips of plowed ground each 12 furrows wide paralleling and separated from each other by a strip of unplowed ground about 2 rods wide. The cost of construction is about 50 cents per mile per furrow. These plowed strips are harrowed when necessary to keep down subsequent growth and the intervening strip of unplowed ground is burned over. Under most conditions met in reforestation, fire-breaks around plantations will be unduly expensive and therefore impracticable. Ordinarily, fire is a risk which will have to be assumed in any plantation.

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FIRE LINES ON THE NEBRASKA NATIONAL FOREST.

STOCK.

If large areas are to be reforested, stock should be excluded, and, if possible, sheep should be excluded from any plantation as they do more damage to coniferous plants than any other animal, goats excepted. As a rule, cattle do not damage plantations much, provided the ground is not plowed, the area is not close to salting and watering places, and the stock is not permitted to concentrate too much in particular localities. Fencing against live stock is seldom advisable, and where exclusion is necessary it should be based upon natural boundaries.

INSECTS.

The pine-tip moth has damaged plantations in Nebraska, and the white grub of the June beetle cuts off the roots of young planted stock in the southwest. No practicable method of combating these insects over large areas has been devised.

Grasshoppers have destroyed whole plantations on the old Kansas National Forest, attacking both hardwoods and conifers. Methods of control of these insects through burning, poisoning, and trapping have been worked out in California,[1] but it seems that certain methods are effective only with certain species, and control measures must accordingly be worked out for each region.

DISEASES.

Diseases in plantations on the National Forests have not been at all serious. Were dangerous diseases to appear it might be impractical as well as impossible to stamp them out. It is well, therefore, to warn against the planting in one general region of nursery stock grown in another unless there is absolute certainty that it is not affected by diseases which may prove harmful to the native timber where the stock is to be planted. White pine grown in regions where the white-pine blister rust is prevalent should not be planted in the western white pine and sugar pine regions; and western yellow-pine nursery stock produced in a region where mistletoe is present should not be shipped, for instance, to the Black Hills where this disease does not occur. Great economic losses are possible through the shipment of diseased or insect-infested stock.

RODENTS.

Young planted stock is often damaged by rodents, and tree seed is very attractive to them. In many cases it is their natural food, and

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[1] Cal. Agri. Exp. Sta. Bul. 170, "Studies in Grasshopper Control."

they are wonderfully diligent and expert in searching it out. Many experiments in the direct seeding of hardwoods and conifers have failed because nearly all of the seed was eaten by mice, chipmunks, and other animals. Where tree seed attractive to rodents is to be sown it is necessary, therefore, to consider the systematic poisoning of the area as an essential operation. In numerous experiments conducted by the Forest Service, seed spots have been sown and then covered with small portable screens which effectively protected them from rodents and birds. The successful germination in these spots and the absolute failure in similar unprotected spots adjacent showed how important an adverse factor animals, and possibly birds, are in reforestation.

In the spring of 1910, in cooperation with the Bureau of Biological Survey, intensive studies of the damage from rodents were conducted at a number of places where direct seeding was in progress, and on many other sowing areas observations were made by forest officers. In nearly every case a different species of animal was found to be the chief cause of damage. There are, of course, a great many species of mice, chipmunks, and ground squirrels, and a number of different kinds of tree squirrels. Each species appears to have distinctive habits, and the food and activities of the same species differ greatly with the time of year. The kind of poison bait and the manner of applying it must therefore be adapted not only to the species of animal to be destroyed, but to its taste and activities at the time the poisoning is done. The latest approved methods of poisoning rodents shown below are those developed by the United States Biological Survey.

The poison preparation which most nearly meets all requirements is as follows:

Mix 1 heaping tablespoonful of gloss starch in ½ teacup of cold water and stir with 1 pint of boiling water to make a thin, clear mucilage. Remove from the stove. Mix together 1 ounce of powdered strychnine (alkaloid)[1] and 1 ounce of powdered bicarbonate of soda and stir with the starch to a smooth, creamy mass. Stir in 1 tablespoonful of glycerine, and finally ⅛ ounce of saccharine. Apply to 20 quarts of good clean oats or wheat and mix thoroughly to coat each kernel.

This poison is effective in destroying chipmunks, kangaroo rats, pocket mice, the smaller species of ground squirrels, and, at times, kills many white-footed mice.

Oats are generally the most successful bait. On account of the skill of chipmunks in "hulling," wheat is more effective for these animals. Barley, in the proportion of 16 quarts to each ounce of

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[1] If strychnine sulphate is used, dissolve in the boiling water before adding the starch; also dissolve the bicarbonate of soda before adding to the poisoned starch. Care is necessary that the resulting mixture does not greatly exceed a pint.

strychnine, has given best results in destroying the larger "digger" ground squirrels, and is most effective during the dry summer season.

A second process of applying the poison described below is an improvement over that just described in that it delays the taste of strychnine, the intense bitterness of which is the greatest factor detracting from success in poisoning certain rodents. During the present season this poison has been used with great effect against rodents which have hitherto exhibited marked aversion to strychnine baits. The fact that the poison coating readily separates from the bait is also of importance to the success of this preparation, especially for such rodents as habitually "hull" grain. In the process of hulling, sufficient strychnine to kill the animals flakes off in their mouths. Grain poisoned in this way must be handled carefully to avoid loosening or grinding off the poison coating. It should be freshly prepared in small quantities, for use each day, as follows:

Mix together ¼ ounce of powdered strychnine (alkaloid), ¼ ounce of powdered bicarbonate of soda, a scant ½ teaspoonful of saccharine, 2 heaping tablespoonfuls of dry powdered starch; and stir with enough cold water to make a thin paste of the consistency of cream. Apply gradually to the material to be used as bait, mixing vigorously to distribute the poison as evenly as may be and to prevent the formation of lumps.

Oats, wheat, cracked corn, and dry coarse meal of all kinds may be so poisoned. For ground squirrels, chipmunks, and medium-sized rodents generally, one-fourth ounce of strychnine is sufficient for 4 quarts of bait; for white-footed mice the amount of bait may be doubled. Among baits especially attractive to the white mice may be mentioned pine seeds (both whole and crushed seeds), roasted peanuts, crushed to a coarse meal; crushed wheat; and mixtures of crushed or chopped grains.

In the work as usually done on woodland planting areas, each quart of the poisoned grain is sufficient for 60 or more baits. The baits should be placed in slightly scattered form along logs, on stumps, on clean hard places on the surface of the ground about burrows, along the animals' trails, and especially in the dry sheltered places beneath logs, and in other locations not exposed to rain or moisture, that they may retain their effectiveness for a long time.

Poisoned baits of sweet potato almost invariably kill pocket gophers if placed in the underground runs without too much disturbance of the latter. Baits of carrot or parsnip may be substituted, or corn, poisoned as in the first formula described, but none of these are so completely successful as sweet potatoes.

The baits of vegetables should be cut about 1 inch long and one-half inch square and washed and drained. From a pepperbox slowly sift ⅛ ounce of powdered strychnine (alkaloid) and one-tenth of this quantity of saccharine (ground together in a mortar) over about 4 quarts of the dampened baits, stirring to distribute the poison evenly.

The runways, which are usually from 4 to 8 inches beneath the surface, can be located by means of a probe made of any strong handle an inch in diameter and 36 inches long. One end should be bluntly pointed. Into the other should be fitted a piece of three-eighths-inch iron rod, protruding about 12 inches, and bluntly pointed. A foot rest aids in probing hard soils. By forcing down this iron rod near gopher workings, or a foot or two back of fresh mounds, the open tunnel can be felt as the point breaks into it. The blunt end of the instrument is now carefully used to enlarge the hole, a bait or two is dropped into the run, and the probe hole closed.

One soon becomes expert in locating the runs, and a man can treat from 300 to 500 gopher workings in a day. Baits need be placed at only two points in each separate system or group of from 10 to 30 mounds, which is usually the home of a single gopher. Baits placed in open underground runs have invariably killed the gophers, and the method has found great favor wherever it has been introduced.

At the Converse Nursery, in California, wood rats or "pack" rats (*Neotoma*) have been found responsible for a considerable part of the damage to transplants usually ascribed to rabbits.

Wood rats eat little or nothing of the trees they cut, but carry the green tips into their nests to store away, as they do many other things for which they apparently have no real use. These animals are rarely killed by any of the baits which have been described, though they pack away such baits readily enough. Effective results were obtained by dusting baits liberally with finely powdered strychnine, as the rats were killed in packing them. Dry oatmeal biscuits one-half inch square and one-fourth inch thick, cut from a stiff dough of oatmeal and water after rolling it in sheets, proved to be especially successful baits. Raisins and whole corn may also be used.

Though both cottontails and jack rabbits fall victims to poisoned oats during periods when their natural food is scarce, this poison can not always be relied upon to destroy them when it is most important to check their depredations. Green or ripening grain heads of barley or wheat are among the most attractive baits in summer. Soaked for 48 hours or more in a solution of 1 ounce of strychnine sulphate and one-eighth ounce of saccharine in 2 gallons of water, such baits have occasionally proved very successful. They should be used only in locations where live stock is not endangered.

Investigations on the Pike National Forest by Forest Expert H. S. Reinsch have developed the fact that on that Forest hulled oats is the grain most relished by mice and hulled barley is the most desirable grain for poisoning all species of rodents. On the Arapaho National Forest groats is considered superior to wheat for use in poisoning.

Fencing has been tried in southern California to protect planted stock from rodents, but is quite expensive, and has not been found efficient. It has been found impossible to rid the inclosed area of them, and all destructive types of rodents, especially pack rats, can not be kept out even by fencing. Rabbits have been successfully combated on the Kansas National Forest by inserting a few grains of strychnine in garden beets and placing these on small upright stakes throughout the planted area. On the Wasatch National Forest alfalfa hay poisoned with a solution of strychnine and water has proved effective. Rabbits can also be destroyed in early spring by baiting with poisoned twigs cut from fruit trees or native brush. The twigs should be scattered a few hours before sundown along the rabbit trails or in openings on the plantations.

In distributing any kind of poisoned grain it is important to put it out of the reach of birds. Ordinarily this is not difficult. Cavities among shallow piles of stones or under roots or logs or burrows of animals will be entered by rodents and ignored by birds. Lacking these, cover made from pieces of bark, boards, or flat stones, with a low runway left beneath, will fill the purpose. Barley is usually attractive to rodents and is the grain least relished by birds. To cover an area thoroughly requires 1 bushel of poisoned barley or oats to every 40 acres, a pinch of the grain being dropped at intervals of 15 feet in rows 40 feet apart.

Red lead has been tried in protecting acorns and nuts from rodents. Its use delays germination only slightly, but the protection it gives is not thorough. Sometimes it appears even to attract birds and certain rodents. It is applied by placing the wet nuts or acorns in a bag containing red lead, and shaking thoroughly. Carbolic acid solutions and petroleum injure seed and are of doubtful value as protection from animals.

SOWING OR PLANTING BY REGIONS.

Selection of Sites.

The selection of sowing or planting sites for operations on a large scale is of great importance and should be governed to some extent by the local economic development of the country, the accessibility of the sites, the labor and transportation facilities, the need for reforestation, the protection which can be given from fire, and the suitability of the sites for the operation.

The suitability of the site for sowing or planting can best be determined by experimental work, but in the absence of this by a number of other factors. Among these are the natural growth on the area, the precipitation, the exposure, the altitude, the length of the growing season, the soil moisture, and the depth and character of the soil.

The suitability of an area is very strongly indicated by the natural growth present. This is a pretty fair criterion of the quality of the site, and it points out the species which are most likely to succeed—either those which naturally occupy the area or others whose demands upon soil and climate are quite similar. A heavy growth of trees on similar adjacent sites will indicate that the area is quite probably suitable for sowing or planting; while a sparse growth of a drought-resistant species of tree on such sites will indicate that the area is only suited to reforesting with very drought-resistant species and that even then success will be uncertain.

Locally, the amount of precipitation over various sites will differ very little at the same altitude, but regionally and at different altitudes it will vary considerably both in amount and distribution, and thus be of considerable influence in determining the suitability of a site. Precipitation in conjunction with the soil depth and character will largely determine its moisture content. This, in turn, is most influential in determining the success of properly conducted reforestation operations, provided the stock used is otherwise climatically adapted to the site. The total precipitation is not alone important. A total of from 12 to 15 inches will support a tree growth if it is distributed rather evenly throughout the growing season; but if it comes mostly during winter, for instance, and the other seasons are characterized by extreme drought, planted stock is not likely to succeed. Drought of moderate duration can be withstood by plants after they have become firmly established, but for two or three years following planting they are less able to withstand any protracted dry period.

The depth and character of the soil are important in conjunction with precipitation. Deep, fine, retentive soils, by virtue of their water-holding capacity, or even looser surface soils with retentive subsoils at a depth of from 2 to 3 feet, offer better conditions for planting than loose, sandy, gravelly, or rocky soils which drain rapidly and soon become dry, or even soils of finer texture which are very shallow and soon dry out for that reason.

Exposure is of influence chiefly in its relation to soil moisture. South and west slopes become much hotter than north and east slopes; and, other conditions being equal, evaporation is much greater from the former and drought condition more prevalent. Further, on south and west slopes the snow may melt during the winter and planted stock will be in danger of drought or winter killing during that period. Moreover, on these slopes growth starts earlier in the spring and continues later in the fall, thus subjecting the plants to greater danger from either early or late frosts.

The relation of altitude to the suitability of a planting site is found in its influence upon precipitation, humidity, evaporation, soil moisture, accessibility, and length of the growing season. With increase in altitude, there is normally an increase in and a better distribution of the precipitation, the relative humidity is greater and evaporation less, the soil moisture is greater, the region is usually less accessible, and the length of the growing season is shorter. The intermediate altitudes within the natural limits of any particular species of tree offer the most favorable climatic conditions for its successful planting. High altitudes are usually difficult of access; and unless the stock for planting is grown at a similar elevation it will not be in a condition for setting out at the time when the operation should be conducted. Stock grown in nurseries at a lower altitude will start growth in the spring before planting can be carried on at higher altitudes, and it will not be hardened sufficiently for fall planting by the time it is needed.

The immense total acreage on the National Forests in need of planting, the cost of the operation, and the necessity of securing satisfactory results make it highly desirable to plant the better sites first. Planting at best, under the conditions encountered and with the employment of unskilled and usually uninterested laborers, is always of doubtful success. The selection of the better sites, however, will mean that a larger proportion of the planted trees will live; they will make better growth after becoming established and form a better stand at maturity; and much experience in regard to methods of planting and the most desirable classes of stock will be gained. The poorer sites can be planted later when cheaper stock, cheaper labor, and better methods make it more feasible.

Although results do not yet permit a final judgment in regard to the comparative suitability of different sites on the National Forests of the West for planting or sowing or of the best class of stock to be used, an attempt is here made to classify them in the order of their favorableness. It must be remembered that in this classification of sites the altitudes given are not exact; that they change with latitude; and that the best planting and sowing sites are almost without exception found at elevations somewhere between the extremes.

Experience will undoubtedly lead to a change in the order in which these sites are listed and may prove some of them unfitted for planting or sowing. There are other sites which because of their unfitness or for other reasons are not considered for reforestation.

Among these are areas either above or below timber line, rock slides, very shallow-soiled south slopes, wet alpine meadows, very dense brush fields where it is a physical impossibility to conduct planting operations, and areas now barren but which it is almost certain will eventually be stocked from surrounding seed trees.

Montana and Idaho.

East of the Continental Divide no direct seeding is recommended, except possibly on the most favorable north slopes, with the best quality of soil, and here only on an experimental basis. West of the Continental Divide direct seeding is not generally recommended; but the best chance for success is thought to be with white and yellow pine on cool north slopes. Recent burns are preferable, since there the loss from rodents and damping off is diminished.

In general, planting may be carried on with success practically anywhere within natural altitudinal limits west of the Continental Divide. East of the Divide sod-covered areas should not be planted.

EAST OF THE CONTINENTAL DIVIDE.

Western yellow pine: (1) South slopes, altitude of from 3,500 to 6,500 feet; (2) west slopes, altitude of from 3,500 to 5,500 feet; (3) east slopes, altitude of from 3,000 to 5,500.

Such ground cover as grass, weeds, brush, and fire débris have an appreciable effect on success by reducing transpiration; but the greatest cause of success or failure east of the Continental Divide is believed to be porosity of soil. Soil with clay content enough to make it pack hard invariably results in heavy loss. The best sites are those with soil which contains particles of rock large enough to prevent close packing. Such soil is usually indicated by a thin broken sod.

Douglas fir: (1) North slopes, altitude of from 5,000 to 7,500 feet; (2) east slopes, altitudes of from 5,000 to 7,500 feet; (3) west slopes, altitude of from 5,000 to 6,500 feet. The effect of ground cover on the success of Douglas-fir plantations is greater than on those of western yellow pine.

Lodgepole pine: (1) North slopes and high divides, altitude of from 6,000 to 7,500 feet; (2) east slopes, altitude of from 6,500 to 7,500 feet; (3) west slopes, altitude of from 6,500 to 7,500 feet.

WEST OF THE CONTINENTAL DIVIDE.

Western white pine: (1) North slopes and flats up to 4,500 feet in elevation (on the Bitterroot Mountains up to 5,000 feet); (2)

east, northeast, and northwest slopes up to about 4,000 feet. On either of these situations the best results are obtained in deep, loose soils, free from rock.

Western yellow pine: (1) South slopes up to 4,000 feet (on the Bitterroot Mountains up to 5,500 feet); (2) southeast and southwest slopes up to 3,500 feet.

Douglas fir: North slopes up to 6,000 feet.

Western red cedar: Favorable north and northwest slopes in mixture with western white pine up to 4,500 feet.

Engelmann spruce: (1) North slopes from 4,000 to 5,500 feet. In mixture with other species on north slopes from 3,500 feet upwards; (2) east and west slopes from 4,000 to 5,500 feet.

Western larch: (1) North slopes from 4,000 to 6,000 feet. In mixture with other species on north slopes from 3,500 feet upwards; (2) south, east, and west slopes from 4,000 to 6,000 feet.

Colorado, Wyoming, South Dakota.

Western yellow pine: Between altitudes of 5,300 and 8,500 feet, the sites in order of their favorableness are: (1) all aspects of burns or cut-over areas, for the most part devoid of vegetation, which have failed to restock naturally even though soil and moisture conditions are normal; (2) all aspects of burns and cut-over areas with a well defined cover of aspen; (3) all aspects of burns and cut-over areas of long standing, with or without aspen, where moisture and soil conditions are normal, though such sites are almost invariably overgrown with a heavy cover of sod, grass, and weeds; (4) all aspects of open, grassy parks without trace of any former timber, where moisture conditions are normal and the soil is of good depth; (5) north and east aspects of open parklike areas without traces of former timber, often found in the yellow pine and in the lower limits of the Douglas-fir types, supporting dense stands of oak brush and occasionally lone, stunted balsams but with moisture both of air and soil deficient; (6) north aspects of low foothill, brush, and sagebrush areas in the lower limits of the yellow-pine type where yellow pine, pinon, juniper, and sagebrush may be associated.

Sowing should be attempted only on the north and east aspects of sites 1, 2, and 3 in the Black Hills region of South Dakota.

Douglas fir: Between altitudes of 8,200 and 9,400 feet, the sites in order are: (1) all aspects of burns or cut-over areas, for the most part devoid of vegetation, which have failed to restock naturally even though soil and moisture conditions are normal; (2) all aspects of burns and cut-over areas with a well-defined cover of aspen; (3) north and east aspects of burns and cut-over areas of long standing, with or without aspen, where the moisture and soil conditions are normal, though such sites are almost invariably overgrown with a heavy cover of sod, grass, and weeds; (4) north and east aspects of open grassy parks without trace of any former timber, having normal moisture conditions and soil of good depth; (5) north aspects of open parklike areas without trace of former timber, often found in the yellow pine and lower limits of the Douglas-fir types, supporting dense stands of oak brush and occasionally lone, stunted balsams.

Sowing should be attempted only on north and east aspects of sites 1 and 2.

Lodgepole pine: Between altitudes of 8,500 and 10,300 feet the sites are: (1) All aspects of burns or cut-over areas, for the most part devoid of vegetation, which have failed to restock naturally even though soil and moisture conditions are normal; (2) all aspects of burns and cut-over areas with a well-defined cover of aspen; (3) all aspects of burns and cut-over areas of long standing, with or without aspen, where moisture and soil conditions are normal, though such sites are almost invariably overgrown with a heavy cover of sod, grass, and weeds; (4) all aspects of open, grassy parks without trace of any former timber but with normal moisture conditions and soil of good depth.

Sowing is advisable only on sites 1 and 2, and planting is usually necessary only on sites 3 and 4.

Engelmann spruce: Between altitudes of 9,500 feet and timber line, the planting sites in order are: (1) All aspects of burns and cut-over areas, for the most part devoid of vegetation, which have failed to restock naturally even though soil and moisture conditions are normal; (2) all aspects of burns and cut-over areas with a well-defined cover of aspen; (3) all aspects of burns and cut-over areas of long standing, with or without aspen, and usually overgrown with a heavy cover of sod, grass, and weeds; (4) all aspects of open grassy parks without trace of former timber but with soil of good depth and with normal moisture conditions. Only one site is thought possible for sowing, that being the north aspect of site 2.

Northern Minnesota and Michigan.

Eastern white pine: Only one type of area is considered as a planting site for this species, namely, all aspects of burns and cut-over areas with natural white pine reproduction wanting, with numerous species of deciduous trees and shrubs present and with normal moisture conditions and soil of good depth, usually composed of light sand over a heavy clay subsoil.

Norway pine: The only type of area considered for this species is all aspects of burns and cut-over areas with natural reproduction of desired species wanting, usually with numerous species of deciduous trees and shrubs, and with soil of nearly pure sand to a great depth and somewhat lacking in moisture. Dry rocky ridges and exposed slopes are included.

Jack pine: Only one type of site is considered for this species, namely, all aspects of dry areas of pure light sand of unknown depth which may or may not have previously borne commercial species. It may bear a light cover of grass and weeds or may include undesirable deciduous trees and shrubs. The soil may become very dry.

Sowing is not considered advisable with any of these species.

Nebraska Sand Hill Region.

Jack pine: Only on the south slopes of the sand hills is it considered advisable to plant this species, not because it will not succeed on other sites, but because these are favorable to more desirable species.

Western yellow pine: The sites in order are (1) north slopes of the sand hills; (2) ridge tops; (3) the bottoms or depressions between the hills.

Norway pine: Only the north slopes of the sand hills are considered as well adapted to the planting of this species.

No direct seeding is thought advisable in this region.

Arizona and New Mexico.

Western yellow pine: Approximate altitudinal limits from 7,000 to 8,500 feet. The sites in the order of their favorableness for planting or sowing are:

1. Old cuttings on western yellow-pine land. Usually such areas are practically denuded of tree growth and bear a dense growth of grass.
2. Brush land showing evidences of having been at least partly forested with western yellow pine but now occupied by a moderately dense growth of brush, such as oaks, mountain mahogany, and buck brush or cliff rose.
3. Untimbered parks or prairies within the range of the species.

Douglas fir: Approximate altitudinal limits from 8,000 to 9,500 feet. The sites in the order of their favorableness are:

1. Old burns grown up to moderately dense stands of aspen.
2. Old burns bare of aspen or other shrubs but strewn with down logs.
3. Open grass lands.

Engelmann spruce: Approximate altitudinal limits from 9,500 to 11,000 feet. The sites in the order of their favorableness are:

1. Spruce burns grown up to aspen.
2. Spruce burns not grown up to aspen but strewn with down logs.

UTAH AND SOUTHERN IDAHO.

Western yellow pine in Utah: (1) Burned-over areas in the natural yellow-pine types; (2) areas covered with brush, mainly of oak, maple, and service berry; (3) areas covered with open stands of scrubby aspen; (4) sagebrush areas.

Western yellow pine in southern Idaho: (1) Those sites producing yellow pine naturally; (2) brush areas within the limits of yellow pine and adjoining stands of that species; (3) open grassy areas in the neighborhood of timber stands.

Douglas fir: (1) Burns within the fir type; (2) sites covered with aspen of moderate density; (3) burns in the Engelmann spruce type; (4) areas covered with brush of oak, maple, service berry, cherry, and other deciduous species; (5) open grass land and mountain meadows. The planting of this species naturally centers mainly around the aspen type, particularly in Utah. The last two sites are not considered favorably for planting at present.

Engelmann spruce: (1) Burned-over, nonrestocking Engelmann spruce and balsam-fir cuttings; (2) the denser and better stands of aspen occurring at high altitudes; (3) lodgepole-pine burns.

Lodgepole pine: (1) Lodgepole-pine burns which are nonrestocking; (2) nonrestocking Engelmann-spruce burns; (3) aspen-covered areas at higher altitudes. This species is not thought suitable for planting on brush areas nor on open grassy land where sheltering objects are missing.

CALIFORNIA.

Planting has not yet progressed far enough to warrant a thorough and final classification of the sites. It has been thoroughly demonstrated, however, that sowing is a failure throughout the State and that planting can not be undertaken with any degree of success in the foothill region of southern California. At higher elevations in southern California, within the timbered belt, western yellow and Jeffrey pine are being grown successfully on open land free from rodents. The typical planting sites in this region, however, are covered with heavy brush frequented by rodents. So far the depredations of these animals have not been successfully controlled, and from present indications these depredations can not be controlled at a reasonable cost.

The planting of western yellow pine in the brush fields of northern California gives promise of very good success, and it is thought that white fir and incense cedar will also do well there. Climatic conditions during the growing season are very variable in this State and influence the degree of success in planting to a large extent. Long

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FIG. 1.—BURNED AREA IN SIUSLAW NATIONAL FOREST, OREG. PLANTED TO DOUGLAS FIR.

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FIG. 2.—PLANTING CAMP, SIUSLAW NATIONAL FOREST, OREG.

periods of extreme drought may occur at any time between April and November. Such a condition inevitably means a large degree of failure in new plantations. Rodents also cause heavy loss, but indications are that spring planting, use of large stock, or planting on an area immediately after it has been burned will minimize the rodent danger. Shade is of extreme importance, since it assists in preserving soil moisture.

Western yellow pine has been most successfully used between 3,500 and 5,500 feet elevation. The highest degree of success is attained under full brush shade, and a classification of planting sites may be made largely upon the basis of the shade characteristics of the brush species. The most favorable brush types are as follows, arranged in the order of their value:

1. Manzanita and snowbrush type.
2. White thorn and manzanita type.

These types are generally found at elevations over 4,000 feet. The oak and open-brush types found at lower elevations are more difficult sites, in which success can only be obtained in very favorable years.

Washington and Oregon.

DOUGLAS FIR.

1. Areas covered with a dense growth of herbaceous vegetation in which fern usually predominates, indicating good soil and moisture conditions, mostly on the west side of the Cascades and in the Coast region at altitudes below 2,500 feet; in the Coast region of the Siskiyou Mountains at elevations under 1,500 feet. The north slopes are the best.

2. Slopes covered with a medium growth of herbaceous vegetation indicating fair soil and moisture conditions, second only to class 1; mostly on the west side of the Cascades and in the Coast region below 3,000 feet; in the Coast region of the Siskiyou Mountains between altitudes of 1,500 and 5,000 feet.

3. Sites between 3,000 and 4,500 feet in altitude on east and west slopes of Cascade Mountains. On these sites the soil may be thin and rocky, but the moisture conditions are usually good. Douglas fir should be planted in mixture with noble fir on the west side of the Cascades, and with western white pine or Amabilis fir on the east side.

4. North slopes at moderate altitudes in the Blue-Mountain region, typically cool and moist.

5. Areas below 3,000 feet on the west side of the Cascade Mountains and in the Coast region with only a scant ground cover, indicating a dry exposed situation.

6. Dense salal or brush-covered slopes in the Coast region indicating good soil and moisture conditions, but keen competition.

7. Brush-covered, northerly slopes in the eastern part of the Siskiyou Mountains at elevations of from 1,500 to 5,000 feet with soil moisture conditions variable but usually fair, and cover of California black oak, Oregon grape, manzanita, ceanothus, and willow on the better sites, and tan oak, chinquapin, huckleberry, live oak, and ceanothus on the poorer sites. Douglas fir should be planted in mixture with western yellow and sugar pines.

NOBLE FIR.

(1) Sites between 2,500 and 4,500 feet on the west side of the Cascade Mountains, except in southern Oregon. On these sites the soil may be thin and rocky, but the moisture conditions are usually good. Noble fir should be planted in mixture with Douglas fir.

(2) Sites above 4,500 feet on the west side of the Cascade Mountains. On these sites the soil is usually thin and rocky, but the moisture conditions good. Noble fir should probably be planted in mixture with Amabilis fir.

WESTERN YELLOW PINE.

(1) Occasional north slopes at moderate altitudes in the Blue Mountains, with good soil and moisture.

(2) Light brushy south slopes in the eastern portion of the Siskiyou Mountains with fairly good but rather warm and dry soil and a cover of tan oak, chinquapin, huckleberry, live oak, and ceanothus. Sugar pine may be planted with western yellow pine on the better soils.

(3) South slopes at low altitudes in the Blue Mountains, typically hot and dry.

(4) Serpentine slopes in the Siskiyou Mountains at an elevation of from 4,000 to 5,000 feet, with typically dry and infertile soils and a cover usually of tan oak, saddler oak, manzanita, huckleberry, knob-cone and lodgepole pines. Such sites are very difficult to plant, and it is impracticable to plant them for many years to come.

Classes of stock for planting by regions and site classes.

Region and species.	Site class No.	Classes of stock for planting in order of their preference.[1]
1. Montana and northern Idaho:		
(a) East of Continental Divide—		
Western yellow pine	1	2-0
	2	1-2
	3	1-2
Douglas fir	1	3-0
	2	2-2
	3	2-2
Lodgepole pine	1	2-0
	2	1-2
	3	1-2
(b) West of Continental Divide—		
Western white pine	1	2-0
	2	1-2
Western yellow pine	1	2-0
	2	1-2
Douglas fir	1	2-2 3-0
Western red cedar	1	2-2 3-0
Engelmann spruce	1	3-0
	2	2-2
Western larch	1	3-0
	2	2-2
2. Colorado, Wyoming, South Dakota:		
Western yellow pine	1	2-1 1-1
	2	2-1 1-1
	3	2-1
	4	2-1
	5	2-1
	6	2-1
Douglas fir	1	2-1
	2	2-1
	3	2-1
	4	2-1
	5	2-2
Lodgepole pine	3	2-1
	4	2-1
Engelmann spruce	1	2-1
	2	2-1
	3	2-2 3-1
	4	2-2 3-1
3. Northern Minnesota and Michigan:		
Eastern white pine	......	2-1 2-0 1-1
Norway pine	......	2-1 2-0 1-1
4. Nebraska Sand Hill region:		
Jack pine	......	2-1 1-1
Western yellow pine	1	2-1 1-1
	2	2-1 1-1
	3	2-1 1-1
Norway pine	......	2-1
5. Arizona and New Mexico:		
Western yellow pine	1	1½-1 2-1
	2	1½-1 2-1
	3	1½-1 2-1
Douglas fir	1	2-1 3-0
	2	2-1 2-2
	3	2-1 2-2
Engelmann spruce	1	2-1 2-2
	2	2-2
6. Utah and Southern Idaho:		
Western yellow pine in Utah—Utah seed.	1	3-0 2-1 2-0
	2	3-0 2-1 2-0
	3	3-0 2-1 2-0
	4	3-0 2-1 2-0
Western yellow pine in southern Idaho—Idaho seed.	1	2-0 2-1 3-0
	2	2-0 2-1 3-0
	3	2-0 2-1 3-0
Douglas fir	1	2-2 3-0 2-1
	2	2-2 3-0 2-1
	3	2-2 3-0 2-1
Engelmann spruce	1	2-2 3-0
	2	2-2 3-0
	3	2-2 3-0
Lodgepole pine	1	2-1 3-0 2-0
	2	2-1 3-0 2-0
	3	2-1 3-0 2-0
7. California:		
Incense cedar	......	2-1 1-2
Jeffrey pine	......	2-1 1-2 1-1
Sugar pine	......	2-1 1-2
Western yellow pine	1	2-1 1-2 1-1
	2	2-1 1-2 1-1
8. Washington and Oregon:		
Douglas fir	1	1-1 2-0
	2	1-1 2-0
	3	1-1
	4	1-1 2-1
	5	1-1
	6	1-1
	7	1-1
Noble fir	1	2-1 1-1
	2	2-1 1-1
Western yellow pine	1	2-1 1-1
	2	2-1 1-1
	3	2-1
	4	2-1

[1] The first figure of each pair indicates the number of years the stock remains in seed beds; the second figure the number of years it remains in transplant beds.

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