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HENRY S. GRAVES, Forester.

EXTRACTING AND CLEANING FOREST TREE SEED.

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HENRY S. GRAVES, *Forester.*
ALBERT F. POTTER, *Associate Forester.*
HERBERT A. SMITH, *Editor.*

BRANCH OF SILVICULTURE.

W. B. GREELEY, *Assistant Forester in Charge.*
EARLE H. CLAPP, *Forest Inspector.*

SILVICS.

RAPHAEL ZON, *Chief.*
S. T. DANA, *Assistant Chief.*

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EXTRACTING AND CLEANING FOREST TREE SEED.

The extraction and cleaning of seed from cone-bearing trees are essential steps in artificial forestation. Economical methods and devices for doing this work have not yet been fully developed or standardized in the United States. Even the fundamental conditions necessary to prevent overheating, crushing, molding, and other injuries to seed, in extracting and cleaning, are not thoroughly understood. This is particularly true where small quantities are handled with simple appliances. The following directions, compiled from the experience of a number of members of the Forest Service, are designed to meet the needs of Forest officers and others who extract and clean seed in small amounts, without the facilities of a fully equipped plant.

STORING CONES BEFORE DRYING.

It is always preferable, especially when only natural heat is to be used, to begin drying cones at the earliest possible opportunity. When artificial heat is to be used finally, preliminary drying keeps the cones in good condition and enables them to be opened more readily later. The best method of handling cones is to spread them on canvas drying sheets in the open as soon as they are received. In fair weather this should always be done. If the weather is unfavorable, cones should be spread on canvas sheets in a dry building where plenty of air is circulating. Where there is not enough space to do this, they should be dumped into bins separated from each other by slat partitions set about one-half inch apart. Ventilating pipes, through the center of each bin, will increase the air circulation.

A fair makeshift for these methods is to pile the cones in heaps in the open or in a well-ventilated room. If in the open, they should be covered during wet weather in order to keep them as dry as possible. In any event, the cones should be shoveled or raked frequently to provide ample ventilation and prevent molding or mildewing. They should not be left in tied sacks, but if this is not avoidable they should be stored only in a dry, cool room. They should never be stored in dark, damp, or ill-ventilated rooms. Such conditions almost invariably cause molding and mildewing, and may lead to premature germination. If mildewing starts, the cones should be spread on sheets in the sun and dried as thoroughly and rapidly as possible.

Every precaution should be taken to keep away squirrels, chipmunks, and other rodents. This can ordinarily be done by the use of poisoned grain.

HANDLING CONES IN TRANSIT.

In transporting cones to the place of extraction similar precautions should be taken to keep them dry and to prevent heating. Ordinarily the best method of shipping is in sound gunny or sugar sacks, closely tied to prevent loss of loose seed. When shipped in carload lots stock cars should be used if possible, since these afford the best circulation of air. If box cars must be used, the small doors or windows in the ends of the cars should be left open. The sacks should be stacked in rows with air spaces between them and between the outer rows and the sides of the car. Ample space for circulation of air should be left also between the tops of the stacks and the roof of the car.

Seed which has ripened naturally and which has been extracted without having been subjected to dampness or overheating is better than that extracted from mildewed or moldy cones. Any precautions taken to avoid these unfavorable conditions will produce seed of higher quality.

DRYING CONES BY NATURAL HEAT.

WHERE NATURAL DRYING IS PRACTICABLE.

With favorable weather conditions the seed of nearly all coniferous species, except lodgepole pine, can be extracted by the heat of the sun. Where this method can be used it gives the best and cheapest, though not always the quickest, results. In the southern Rocky Mountains it is nearly always practicable because of the clear skies, slight precipitation, and drying winds usually prevalent from October to December. In the central and northern Rockies sun drying is possible in normal seasons until about October 20. Thereafter it is uncertain and not to be depended upon as a method of extraction. Sun drying is impracticable on the west side of the Cascades in Oregon and Washington because of frequent rains. It can be used in the eastern parts of these States only under particularly favorable weather conditions. Sun drying can be used in southern California, but in the Sierras its success is doubtful, except in particularly dry seasons. In any locality this method may be precluded by an unusually wet fall, or it may be stopped in the midst of the season by unfavorable weather.

EQUIPMENT.

To extract seed to the best advantage by sun drying the work must be thoroughly organized in detail and the necessary equipment must

be on hand as soon as the first cones are received. The short period during which sun drying can be employed makes any delay in starting the work inadvisable.

The first requisite is a supply of 12 by 14 feet, 8-ounce canvas drying sheets. These are used both for spreading and covering the cones. If canvas sheets are not available wagon covers, tents, tent flies, burlap, and heavy muslin are substitutes. A sufficient number of drying sheets at the outset is essential, and their shortage has heretofore been one of the greatest drawbacks to successful work.

If trays or raised platforms are to be used in drying, in connection with sheets, these should also be ready when the cones are received. One or more shovels and wooden rakes should be available.

SELECTION OF SITE.

The site for open-air drying must be carefully selected. An open place on top of a low ridge or bench is usually preferable. Small openings surrounded by bodies of timber are not suitable, because the trees prevent good circulation of air. The ground should be level, or, preferably, sloping gently toward the south, and should be thoroughly cleared of brush, weeds, stones, and other rubbish before work begins. If no favorable site can be found in the neighborhood of the collecting area or if it is anticipated that drying can not be completed before wet and cold weather sets in it may be best to select a site at a lower altitude, where drying will be more rapid and can be continued until a later date. The facilities for transporting the cones must, of course, be considered.

SPREADING THE CONES.

Before spreading cones for drying it is advisable to run them over a coarse screen to separate loose sticks, twigs, stones, dirt, needles, and other débris. If this is not done such material becomes mixed with the seed and makes future cleaning more difficult.

After the cones have been cleaned they should be spread on the canvas sheets in a thin layer, ordinarily not more than one cone deep, so that all are exposed to the air. They should be raked over at least once a day in order that all parts of the cones may be exposed to both sun and wind. If lack of space makes it necessary to spread to a greater depth, the cones should be raked or shoveled at least four times a day. Cones should never be piled deep. Considerable seed is usually obtained from the cones by raking while drying, especially during the hottest part of the day, but further extraction is nearly always necessary.

Keeping cones off the ground.—In continued dry weather good results can be obtained by spreading the sheets directly upon the

ground. If this is done, trenching around the sheets is essential to avoid flooding if rain occurs. Drying will, however, be much more rapid and satisfactory if the sheets are spread on brush or platforms raised 8 inches or more above the ground. This allows the air to circulate beneath the sheets and prevents their drawing moisture from the ground after a storm. In unfavorable weather it is imperative that the sheets be raised above the ground. Platforms can be easily constructed from refuse lumber, unedged boards, or poles. The top of the platform can be made of boards, with or without canvas stretched over them, or of canvas alone nailed to a framework. A still better device is to make platforms of wire-mesh screens, with sheets spread on the ground below to catch the seeds as they fall through.

Drying racks.—A development of this method is to build a larger frame containing wire trays and canvas sheets below them. In one case where this appliance was used successfully frames were constructed of 2 by 4 inch material, 8 feet wide, 16 feet long, and set 4 feet off the ground. The tops of these were covered with 1-inch mesh wire netting. One foot below this was stretched a sheet of muslin or canvas to catch the seeds as they fell through. A similar but improved device consists of a 6 by 12 foot frame made with posts driven into the ground and standing from 3 to 4 feet high. This frame holds two movable trays, supported by 2 by 2 inch cross-pieces. The upper tray is 5 feet long and 12 feet wide by 4 inches deep; it has a wire-screen bottom, with $\frac{3}{4}$-inch or 1-inch mesh. This is to hold the cones while drying. The lower tray, which is also 4 inches deep but 8 inches wider and longer than the upper, has a cloth bottom which catches the seeds as they fall through the wire screen above. With species whose cones open readily, such as yellow pine, it is often possible to extract all of the seed in this apparatus by stirring the cones frequently as they dry. The empty cones are thrown out with a potato shovel. At the close of the season the racks can be removed readily and placed under shelter. The frames are so inexpensive, however, that they can be reconstructed each year if necessary. They are also light enough to be moved easily from place to place.

Drying platforms or racks should, when possible, slope slightly to the south or southwest. This will expose them to the direct rays of the sun during the middle and latter part of the day, when the air is warmest.

Protecting the cones.—Cones which are being dried out of doors must be protected from dew and rain. At night and in bad weather they may be heaped together in the center of the sheet on which they are spread, and the pile covered with the ends of the sheet. This is done most effectively by taking hold of each corner of

the sheet successively and throwing the cones toward the center. One corner of the canvas is then thrown over, nearly covering the cones; next, the corners to the left and right of the first are folded over; and finally the remaining corner, opposite the first, is drawn over all and tucked under the farther edge of the pile. The four thicknesses of canvas help to retain the heat absorbed by the cones during the day and furnish good protection from rain. As an additional precaution the canvas folds may be weighted with rocks and an extra sheet thrown over the pile. A sheet more than 14 feet square is not easily handled by one man.

When cones are dried on platforms or in trays protection must be afforded by covering with sheets of canvas, which should be large enough to overhang the racks and protect the seed in the lower tray. With cones spread directly upon the ground, the use of cover sheets requires less time and labor in respreading the cones, but makes many more sheets necessary.

Covering cones at night protects them from nocturnal rodents, as well as from dampness. It is usually necessary, however, where rodents are abundant, to protect the drying areas by poisoned grain. Birds may often be frightened off by cloth streamers on small stakes, or wires, around the sheets. When racks are used for drying, squirrels may be kept out by tacking sheets of tin sloping downward on each leg of the frame. Care must also be exercised to prevent seeds which have fallen from dried cones from being blown away by high winds. This is best done by catching the seeds in a canvas-bottomed tray with 4-inch sides.

Space required.—The space required for spreading cones varies so much with different species, and even with the same species in different localities, that it is hard to give specific definite figures. The following table indicates the average number of square feet of drying surface per bushel for each of the four species most commonly collected, as well as the capacity of a 12 by 14 foot canvas sheet. This applies to green cones spread thinly. As they dry their volume will expand at least 50 per cent, bringing the cones into closer contact and making more frequent raking necessary.

Species.	Square feet per bushel.	Bushels per 12 by 14 feet drying sheet.
Western yellow pine	12 to 16	14.0 to 10.5
Douglas fir	16 to 20	10.5 to 8.4
Engelmann spruce	22 to 28	7.6 to 6.0
Lodgepole pine (seldom dried out of doors)	18 to 22	9.3 to 7.6

For yellow pine and Douglas fir, the two chief species handled, 16 square feet per bushel will usually be needed, making it possible to spread 10.5 bushels on each 12 by 14 foot drying sheet. To allow

sufficient room for expansion, however, it is safer, in planning on the number of drying sheets needed, to allow only 8 or 9 bushels to each sheet.

Time required.—The time required for cones to open varies greatly with climatic conditions and slightly with different species. A succession of clear, sunny days and frosty nights, with good winds, will open cones very rapidly. In good weather mature yellow pine cones will open in from 3 to 5 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.

Number of sheets needed.—An estimate of the number of drying sheets needed for 1,000 bushels of western yellow pine cones may be made as follows: Ten bushels of cones can be spread on each sheet; if it takes 5 days to open each batch of cones and there are 20 good drying days in the fall each sheet can be used four times. In other words, 40 bushels can be handled on each sheet. Dividing 1,000 by this gives 25, the total number of sheets needed for the work. Bad weather or the need of additional sheets for covers may make this number insufficient. It is always well, therefore, to make the estimate liberal, since lack of a few drying sheets at a critical time may cause serious delay and even the loss of much seed.

DRYING CONES BY ARTIFICIAL HEAT.

With lodgepole pine, and with other species when weather conditions are unfavorable, artificial drying must be used. This method is quicker than drying by natural heat and is not dependent upon the weather. It is, however, more difficult, more expensive, and ordinarily does not yield as good seed; therefore it should not be used except when outdoor drying is not practicable. Most of the artificial drying is done at permanent, fully equipped extracting plants to which cones are shipped from a large area. This circular is designed for the smaller, temporary plants which must be handled by less experienced men with simple appliances.

EQUIPMENT NEEDED.

Cabins.—The first essential in drying by artificial heat is some sort of shelter which will protect the cones from weather and be sufficiently tight to make it possible to raise the temperature 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 for trays around the sides and for a stove. Often one room of a cabin is used for drying and another for storing and extracting.

Tents.—Large tents with high walls make fair drying rooms; 12 by 16 foot or 16 by 20 foot tents with 5 or 6 foot walls may be used, but larger tents have given the most satisfactory results. Drying is more difficult in tents than in buildings, but the former 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.

Stoves.—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, but, as a rule, with poorer results. They are cheap and easily put up, but require constant attention. Empty cones will not burn well in them. These are serious drawbacks, and the use of box stoves with drums is prefareble.

Drying trays.—The cones are usually spread in trays with wire bottoms 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 used only with lighter cones, since they are more difficult to handle, especially where space is limited. The bottom of the tray is wire netting, usually with a $\frac{1}{2}$-inch mesh for lodgepole pine and with a $\frac{3}{4}$-inch mesh for species with larger cones. Twelve square feet of tray space hold approximately 1 bushel of cones, spread thinly.

Cones may also be spread on pieces of wire netting stretched horizontally between the racks at intervals of 6 or 8 inches, with a vertical strip at each end to prevent them from 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 should be 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 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.

FIRE PRECAUTIONS.

With 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.

DISTRIBUTION OF HEAT.

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 vents required for ventilation. All chinks in a building should be closed completely. The next precaution is to secure as constant temperature as possible. 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 has ordinarily been 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 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.

Heating the dry room from below.—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, excavate under the building and place the stove below the floor. This will not only heat 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 will be 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.

IDEAL DRY HOUSE.

An ideal dry house contains three stories, built in the side of a hill to take advantage of gravity, and to utilize the earth which partly surrounds the building to prevent the escape of the heat. The cones are unloaded into the third story from a road on the hillside. From this storeroom, or preliminary drying room, the cones are dropped to the second floor or kiln room. The ground floor contains the extracting room, furnace, and other equipment. The furnace may consist merely of a large box stove, burning long sticks of wood, inclosed in a galvanized-iron jacket packed with mineral wool or asbestos to prevent radiation of heat. From this jacket the heat is conducted through two pipes into the drying room or kiln. The heat is thus used where it is most needed, and its escape into the space about the furnace prevented. The building can be built, if necessary, only two stories high, in which case the cones are either unloaded directly into the second story or kiln room, or stored on the ground floor until ready for drying.

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.

While usually the best 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 trays. Each tier of trays is set a little nearer the wall than the one above. 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 passing through the roof and having inlets at the floor level.

APPLICATION OF MOISTURE BEFORE DRYING.

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 in loosening 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 yielded seed of poorer quality. As a general rule, the cones should be as dry as possible before they are put in the kiln. Preliminary drying in the open or in well-ventilated storerooms will hasten opening after artificial heat is applied.

TEMPERATURE REQUIRED.

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 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 finally Douglas fir, which can often be dried satisfactorily at a temperature of 110° F.

TIME REQUIRED.

At well-equipped plants lodgepole pine cones should be thoroughly dried at a constant temperature of 140° F. in from 8 to 10 hours, and other species at a constant temperature of 120° F. in 10 to 15 hours, assuming that the cones are mature and moderately dry when put into the kiln and that the room is evenly heated and well ventilated. 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 loss of heat in the tent and its uneven distribution. Preliminary drying of the cones for a few hours at 80° to 100° F. has been found an advantage. Opening will also be hastened if the cones are spread thinly in the trays and stirred frequently, to make the drying more uniform.

EXTRACTING SEED FROM DRIED CONES.

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.

TRAY SHAKERS.

In nearly every case, therefore, to secure the maximum amount of seed some method of shaking must be used to release the seeds from the opened cones. One of the earliest and simplest devices is a tray

or frame with a wire-screen bottom, in which the cones are shaken or worked over. The framework is usually of 6-inch boards, varying from 3 by 6 feet to 5 by 7 feet in size. One-half inch mesh woven wire is used for the bottom. The tray may be stationary, supported on legs; or equipped with handles at both ends, so that it can be shaken by two men; or equipped with handles at one end and suspended by ropes from a tree at the other, so that it can be shaken by one man. Either of the last two devices is more satisfactory than the first, since much more thorough shaking of the cones is possible. A canvas sheet should be spread beneath the shaker to catch the seeds as they fall through the screen bottom. A similar shaker, but of different size and shape, consists of a box 30 by 18 by 18 inches, without a top and with wire screen bottom. This, too, is hung from the limb of a tree and is shaken in the same way. It contains about a bushel of cones and has a capacity of 50 bushels a day. Wooden blocks are often put in tray shakers to increase the jarring effect.

BOX SHAKERS.

All of these devices, while crude, can be used to advantage when other methods are not practicable. Better results can be obtained by the use of revolving cone shakers. These may be either box-like or cylindrical in shape and are often known as "churns" or "drums." The box shaker has been more generally used. It may be constructed readily from a dry-goods box of proper size. It should be large enough to hold from 2 to 4 bushels of cones when half full. Four feet long by three feet square in cross section is a common size, although both larger and smaller boxes are used with good results. One or more sides of the box should be composed entirely of wire screen. A frame is needed for support, and the extracted seeds fall through to a canvas placed beneath. With most species a $\frac{1}{2}$-inch mesh is most satisfactory for the screen. With lodgepole pine a $\frac{1}{3}$-inch mesh lets the seed through as readily and keeps out more rubbish.

Half of one side of the box should be made into a hinged door through which the cones can be placed in or dumped out of the shaker. Lengthwise through the center of the box should be run an axis of 2 by 4 inch or 3 by 3 inch lumber, or 2-inch iron pipe, projecting through the box and supported at both ends like a windlass. By attaching a crank to this axle the whole box can be revolved. The efficiency of the shaker may be increased by placing small cleats inside the box or by adding small wooden blocks to the cones to increase the jarring effect. The additional devices are unnecessary and undesirable, however, with species such as western yellow pine, which give up their seeds readily, since it breaks up the cone scales and makes cleaning of the seed more difficult.

CYLINDRICAL SHAKERS.

A convenient size for the cylindrical shaker is 3 feet in diameter by 4 feet long. The ends are of wood, but the sides consist of heavy wire screening, usually with ½-inch mesh, supported by a wooden framework, and a hinged door. An axle is put through the center of the cylinder, a handle attached, and the entire machine set on a sawhorse or windlass.

Of these types of shakers, the box is more easily constructed, and is more effective with cones from which the seeds are extracted with difficulty, since the shaking is more violent. On the other hand, this is a disadvantage in the case of easily extracted seed, since it breaks up the cones and increases the amount of rubbish to be removed. Small cones, furthermore, like those of lodgepole pine, are apt to collect in the corners of box shakers.

Shakers of both types should be revolved at a rate which will just bring the cones to the top of the mass and then allow them to fall straight to the bottom. The speed necessary varies with different species, as does also the number of revolutions required to extract all of the seed. From 20 to 40 revolutions is ordinarily sufficient to get practically all of the good seed. Too much time should not be spent in trying to secure every seed, since those at the extremities of the cones, which are extracted with the most difficulty, are often imperfect, and their presence in good seed lowers the quality of the whole.

BARREL SHAKERS.

A barrel may be used for seed extracting in practically the same way as the devices already described. One and a half inch iron pipe, with a crank at one end, is run through the center of the barrel. With this as an axis the barrel is mounted on a box about 4 feet long, 2½ feet wide, and 3 feet high. Both ends of the barrel are screened, with one screen movable to permit filling and emptying. For convenience in handling the seeds a tray may be fitted into the box to catch them as they fall from the barrel. The large box is useful not only as a means of support but also to keep the seed from blowing away. A 40-gallon barrel, filled about two-thirds full, will hold from 2½ to 3 bushels of well-opened Douglas fir cones. Seed can ordinarily be extracted thoroughly by revolving the barrel about five minutes.

INCLINED SHAKERS.

Where seed extraction is to be conducted on a more extensive scale a shaker capable of handling a larger quantity of cones should be built. This is hardly worth while for less than 250 bushels of cones. A model which has been used successfully with yellow-pine cones consists of a wooden frame 3 feet square at the ends and 16 feet long,

over which wire screening is stretched to form a long oblong box. The frame is held rigid with four internal X-shaped cross braces about 5 feet apart, connected at the ends by horizontal slats or strips. The screening is stretched horizontally from end to end of the frame and should never be wound round the frame. The framework may, of course, be constructed to fit any width of screen. The ends of this long screened box or shaker are left open to allow the free passage of cones. Holes are bored through the center of the four cross braces before they are put in the frame, and when the whole box is assembled a 2-inch iron pipe, bent at the upper end so as to form a crank, is thrust through these holes and firmly fastened to the frame, the lower end projecting beyond the shaker for a short distance to form a support. This pipe is then set in two wooden frames so as to allow the shaker to revolve. The lower end of the churn should be mounted from 3 to 6 inches below the upper end, where the cones are inserted. A chute should be constructed at the upper end, so that cones dumped into the chute will roll directly into the shaker. When in operation the whole machine should be set on canvas sheets to catch the seed as it falls through the wire screens. One man is required to revolve the shaker, another to pour in the cones, and a third to remove the empty cones at the lower end. The total cost of this apparatus is about $5. It has a capacity of approximately 40 bushels of yellow-pine cones per hour. With other species which give up their seed less readily a modification of this design is necessary to secure a more violent shaking of the cones.[1]

SORTING CONES.

Various appliances to separate opened from unopened cones have been devised. These consist of slats so spaced as to permit the small, unopened cones to pass through while retaining the larger, opened cones, the principle being similar to that used in machines for grading fruit by size. Such devices generally give poor results on account of the irregular size of both opened and unopened cones. It is usually preferable to sort cones by hand. The small amount of seed, however, ordinarily obtained from cones which do not open in the first drying does not justify much expenditure for sorting.

SEED CLEANING.

IMPURITIES PRESENT.

After extraction from the cones, the seed contains impurities which must be removed. Aside from wings, these consist mainly of broken cone scales and needles, broken and empty seeds, resin, and dust.

[1] Illustrations of this machine and of a box shaker are given in Plate IV of Forest Service Bulletin 98, "Reforestation on the National Forests."

The amount of broken cone scales depends partly on the species and partly on the treatment to which the cones are subjected during extraction. Seed of species whose cones are very brittle naturally contains more extraneous matter of this character. With most species, however, it is possible to avoid breaking the cones badly if they are shaken out rather than crushed out. The common method of putting heavy blocks of wood in the shaker with the cones is excellent for species whose seed is hard to extract or whose cones are tough. For other species, however, this method is undesirable, since it not only increases the difficulty of cleaning the seed, but is apt to injure it. It is advisable, therefore, to use no more violence than necessary, even if this makes extraction slower. The loss of time will be more than offset by the greater ease of cleaning. Twigs and broken needles can be largely kept out by screening the cones before drying is begun.

The presence of broken seeds depends chiefly on the treatment of the cones, which has been discussed. Empty seeds are also present in nearly all samples. Their proportion depends partly on the species, but mainly on the season. In a poor seed year empty seeds are usually abundant; in a good seed year comparatively rare. They can be separated from good seed only by fanning.

The presence of resin in seed depends mainly upon the species. It is probable, however, that crushing or overheating the cones increases its amount. It is certain that overheating, by softening and melting the resin, makes it much harder to remove. When the cones are heated to such an extent that resin sticks to the seed, it is practically impossible to remove it. Dust is always present to a greater or less extent.

REMOVAL OF WINGS.

The seed of all western conifers commonly handled have wings, which are usually, though not necessarily, removed when the seed is cleaned. Removal of the wings probably decreases the germinative power of seeds to a small extent. It so greatly facilitates the ease with which they can be handled, however, that the practice is almost universal. In the pines, the entire wing may be detached from the seed with comparative ease, particularly if the seeds are first moistened slightly. With other species, however, the wings form part of the seed coat, and can be removed only by actually breaking them off. Moistening the seed is therefore of doubtful value.

By flails.—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 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 method impairs the quality of the seed. With the pines, to which this method is particularly applicable, the wings are more readily removed if the

seed is slightly moistened with cold water. This may be done readily by putting the seed in a box, adding a little cold water and stirring with a shovel.

Another application of the wet 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. A similar method of removing the wings from pine seeds is to moisten them slightly and then churn the mass in a cylindrical drum until the wings become detached.

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

By churns.—Another method of removing wings is to rub the seeds together with a number of small wooden blocks. This may be done by churning the seeds and wooden blocks in a box or barrel mounted on an axle so as to be rotated, or by keeping the box stationary and applying friction 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 seeds will gradually work out with the wings broken off.

By screens.—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, or 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; with lodgepole pine and Engelmann spruce one-eighth inch mesh is preferable. The wings of the seed are more easily removed if the seeds are moistened slightly with cold water before screening.

With most species the first screening ordinarily does not remove the wings completely. To secure this final removal the seeds and small chaff coming through the first screen may be churned in a small cylindrical drum, covered with very fine-meshed wire, together with several small pieces of wood. This process removes the remainder of the wings, which, with other small particles of dirt, fall through the screening, leaving clean seed behind.

By mechanical cleaners.—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 fine mesh. 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 the seeds 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 seeds with cold water is advisable before putting them into the hopper.

FINAL CLEANING OF SEED.

The final cleaning of seed is done by screening and fanning. Thoroughly clean seed can not be obtained without fanning. Where no fanning mill is available, fairly clean seed can be obtained by passing the seeds through wire screens of different sized mesh to remove first the coarser particles, such as pieces of cone scales, twigs, and needles, and then the finer chaff and pieces of broken wings; and finally by winnowing the remaining seed in the wind or by bellows or other mechanical devices. A blacksmith's rotary blower has been used effectively in winnowing lodgepole pine seed.

Seed may be fanned in one of the ordinary farm machines for cleaning grain. It removes practically all broken and empty seed as well as much of the resin and other impurities if the draft is properly regulated and 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.

Before purchasing grain-cleaning machines their adaptation to cleaning coniferous seed must be fully determined. Many of the ordinary machines have yielded but poorly cleaned seed with low fertility, even after running the seed through the mill six or seven times. This increases cost of power and labor and adds the expense of storing and handling a considerable amount of refuse with the seed. Two machines have proved satisfactory. One of the important points in selecting a fanning machine is to secure screens properly perforated for the species which is to be handled.

Certain impurities, such as pieces of cone scales, resin particles, and twigs of the same size and weight as seeds, can not be removed ordinarily by screening or fanning. The only way to get rid of these is to pick them out by hand, and this is seldom warranted. Such

foreign matter usually composes a very small proportion of the total weight of seed, and its presence does little if any harm.

SEED STORING.

Wherever possible, clean seed should be stored in air-tight receptacles of glass or metal. Seed stored in such receptacles retains its vitality under any conditions of temperature and moisture much better than in any other except 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, either by the use of poison, by being stored in rodent-proof buildings, or by being hung in sacks out of reach.

SUMMARY.

STORING CONES.

Make all arrangements to begin drying the cones as soon as they are received. This is necessary on account of the short season when outdoor drying is possible.

If storage is necessary, take every precaution to prevent the cones from heating or molding. Never store them in damp or ill-ventilated rooms.

DRYING BY NATURAL HEAT.

Use outdoor drying whenever practicable with all species except lodgepole pine.

Screen the cones before drying to remove needles and other foreign matter.

Do not spread the cones too thickly on the drying sheets.

Protect the cones while drying from rodents and from moisture.

DRYING BY ARTIFICIAL HEAT.

Make every effort to secure even distribution of heat and good ventilation.

Avoid sudden or extreme fluctuations in temperature.

Never let the temperature rise above 150° F. with lodgepole pine or above 130° F. with other species.

Do not wet cones before drying, except lodgepole pine, and then only superficially.

Do not pile the cones too thickly in the trays.

Have the best available apparatus for putting out fires always ready for use.

EXTRACTING SEED.

Do not break the cone scales in raking or shaking more than is absolutely necessary.

Extract the seed as thoroughly as possible, but do not attempt to secure every single seed.

CLEANING SEED.

If moisture is used in removing wings, dry the seed as thoroughly and quickly as possible.

Do not use moisture in cleaning any but pine seed.

Do not consider seed clean until wings, impurities, and empty and broken seeds have been removed.

STORING SEED.

Store clean seed whenever possible in air-tight receptacles.

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