# NATURAL AND ARTIFICIAL REGENERATION OF LODGE-POLE PINE (PINUS CONTORTA) IN THE CENTRAL ROCKY MOUNTAIN REGION

Thesis for the Degree of M. For.

Huber Copeland Hilton

1917

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# NATURAL AND ARTIFICIAL REGENERATION OF LODGEPOLE PINE

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## METHODS

An analysis of the present methods followed upon the National Forests in the Central Rocky Mountain region, for the securing of reproduction of Lodgepole Pine by natural and artificial means, and results secured, both the number of seedlings and the cost of producing them being considered.

## LOCATION AND DESCRIPTION

The observations and experiments noted throughout were made upon three National Forests, the Medicine Bow of southern Wyoming, and the Arapaho and Colorado of northern Colorado. The Medicine Bow Forest occupies the higher mountainous country extending along and tributary to the Medicine Bow or Snowy Range. The Arapaho Forest occupies the higher areas along the western slope of the Continental Divide and the various slopes of the tributary or spur ranges adjacent, or the Vasquez and Williams Fork Ranges. The Colorado Forest occupies in its southern division, the eastern slope of the Continental Divide; it occupies in its northern division the several slopes of the Mummy and Medicine Bow Ranges adjacent to, and abutting from the Continental Divide.

The location as outlined represents a region most important considering the commercial range of the species. Here Lodgepole Pine furnishes by far the greater part of the commercial timber of the section and makes its best development. This region varies from extremely rough and mountainous sections to areas of gentle topography for a

Lodgepole Pine burn, scattered stand of Lodgepole Pine reproduction coming in satisfactorily.

Near Flattop mountain, Continental Divide, Estes Park, Coloardo National Forest.

mountainous region but yet Lodgepole Pine occupies the entire crests of some ranges at certain altitudes.

Lodgepole Pine is found in this region at altitudes varying from 7000 feet to timberline, at 11000 to 11500 feet. The commercial stands in this region are usually found at from 8000 to 9500 feet. The species rarely forms commercial stands except within an altitudinal belt from 2000 to 2500 feet in width. The Forests are usually confined to the mountains while the lower valleys between the ranges are occupied by meadows or sagebrush. Some of the valley country is used for ranching and the production of forage crops.

The usual soil of this region is a gravelly decomposed granite somewhat moist but well drained. The best developement of the tree is made upon a moist gravelly loam soil found in the bottoms of the valleys, and at the foot of the slopes. The majority of the stands however are found upon the poorer classes of soil.

The climate of the region is comparatively dry. The species is rarely found where the average precipitation is less than 18 inches. The best developed stands are located where the precipitation exceeds 21 inches, altho the amount of available moisture determines the growth of the tree. It is likely that the precipitation over the areas described usually exceeds 24 inches. The growing season is very short, usually not exceeding 3 or 4 months. Frosts frequently occur throughout the growing season but rarely affect or influence the development of the tree. Extremes of temperature are frequent in this region and Lodgepole


Lodgepole Pine and Engelmann Spruce burn. Scattered stand of Lodgepole Pine coming in satisfactorily.

Near Longs Peak, Estes Park, and along Continental Divide, Colorado National Forest.

Pine occasionally endures temperatures of 100°F and -55°F for short periods.

## CLASSIFICATION OF NATURAL AND ARTIFICIAL REPRODUCTION

For the purpose of this thesis, natural reproduction is that reproduction secured either with or without the assistance of man as he may make use of silvicultural systems or other agencies to assist nature. In short it is all reproduction secured in which man has not directly handled the individual seed or product of the seed.

Artificial regeneration is considered to consist of reproduction secured from seed sown directly in the Forest or in the nursery and later transplanted to the Forest.

## NATURAL REGENERATION

### CHARACTERISTICS OF THE TREE

Lodgepole Pine characteristically forms dense, even-aged stands of tall slender trees of narrow crowns. The species frequently occurs also as a woodland form either from poor soil conditions or as a result of a fire that destroys the majority of the seed and seed trees so that only a few trees are produced and they take on a woodland form because the large growing space.

### HABIT OF GROWTH

Lodgepole Pine is one of the smallest pines which reach commercial size, altho of fairly rapid growth considering the soil and growing conditions found in its range. The tree is usually from 60 to 90 feet in height

Lodgepole Pine on third quality soil, stand fairly open, yet forest is not only devoid of groung cover but also of reproduction probably due to fact that soil is very poor and that seed is also destroyed by rodents.

Bald Mountain region, Colorado Forest.

altho specimens of 103 and 105 feet in height have been noted, An occasional tree over 100 feet high and up to 24 inches in diameter has been noted in this region upon site 1 quality soil.

For District 2, in which this region is located, three site classifications are made. Site 1 is found in the bottoms of draws and at the foot of mountains adjacent where a gravelly loam soil has accumulated. Here Lodgepole Pine makes its best development unless crowded out by its more tolerant associates, Engelmann spruce and balsam fir at the upper end of its altitudinal range and douglas fir at the lower. The area occupied by site 1 is comparatively small.

Site 2 consists of the main body of Lodgepole Pine and is found upon the wide benches and varying slopes of this region. It occupies all slopes at certain altitudes altho more uniformly confined to the north and west slopes in abrupt country. The observations and experiments noted were made upon site 2 quality soil.

Site 3 consists of those areas along the exposed tops of ridges, of areas of shallow soil, and areas of south and east slopes, usually very dry and exposed. This site occupies a very small area of the timbered section of this region.

The tree uniformly has a straight bole which is clear of limbs from one-half to two-thirds of its height. The majority of mature timber is from 10 to 14 inches in diameter at breast height and under 85 feet in height. The taper is usually very gradual for trees grown in the usual crowded condition but in open grown stands is often rapid, where trees take on a woodland form and the branches extend to the ground.

The crown varies in shape and in size with the position of the tree. In a close grown stand the crown is small and irregular; in open stands it becomes more regular and often extends to the base of the tree.

The usual stands are from 125 to 175 years of age althe the largest trees are frequently 200 years old. A few may even reach 250 to 300 years of age.

The bark is thin, usually less than one-half inch in thickness.

The maximum water content of the soil for Lodgepole Pine is 35% in loam and about one-half that in sand and gravel. The optimum is usually between 12 and 15 inches, rises to 20% where decay of needle cover makes the amount of non-available water greater. The minimum may fall below 5% without injury to the tree except in rate of growth.

## ROOT SYSTEM

The tree is characterized by the lack of a tap root but has a well developed lateral root system. A tap root is frequently found in young trees but this fails to develope, usually because of shallow soil.

## TOLERANCE

Lodgepole Pine is very intolerant. It is more intolerant than Engelmann spruce, balsam fir, blue spruce, douglas fir and yellow pine with which it is sometimes associated, It is classed with limber pine as to intolerance. Lodgepole Pine altho extremely intolerant has ceratin characteristics of tolerant trees, as it grows in dense stands and frequently does not clear itself even in stands of greatest density.

The manner of origin of the tree however is distinctly intolerant.

Lodgepole Pine often shows remarkable ability to live for long periods in a suppressed condition beneath trees of the same species, The question of whether Lodgepole Pine can recover from suppression is a debatable one. At present it is believed that the tree does recover in many cases but not in every case.

## CONE AND SEED PRODUCTION

Lodgepole Pine begins bearing cones very early in the life of the tree. Trees of five years of age have been found bearing cones. Seed in quanity is not produced however until the tree is 20 years old, or even older in dense stands. The cones are asymetrical, due to the non-development of scales on one side and base, because of lack of light. Cones are usually produced in fair quanity every year. It is believed that the tree has a periodicity of heavy seed production every 2 or 3 years but this has not been confirmed. Just why such a regularity should be assigned trees alone is unknown and may prove to be a false assertion. A bushel of cones usually yields about one-third of a pound of clean seed.. Cone production is very heavy upon trees grown in the open altho the trees yearly produced in close grown stands is greatly in excess of any possible requirement for natural reproduction did development take place, Cones are frequently produced upon trees growing in very unfavorable conditions as in very exposed and rocky situations. A Lodgepole Pine was found growing alone, miles from another of the same species and exactly at timberline on the Colorado Forest in a tangled

Reproduction of all ages which has come in under a douglas fir stand in which the burned trees are still standing. Stocking is very satisfactory. Stagnation of growth is not likely to occur and trees will eventually clean well.

Danner Hill, Colorado National Forest.

mass of dwarfed spruce and balsam. The altitude was approximately 11500 or 11600 feet. Several cones were found upon the tree which to all appearance were fully developed and undoubtedly contained fertile seed.

## SEED DISSEMINATION

Lodgepole Pine cones open in late August or early September of the second year. Cones borne at the top of the tree often open immediately at maturity and release the seed. The majority of the cones open in the first few years after ripening or at least when 10 years of age when the pedicel dies and no moisture is secured from the tree. A number of cones on each tree remain closed for a longer period and some of these open each year afterward. This characteristic is distinctive for the species altho jack-pine (Pinus divaricata) acts quite similarly. Seed retained in closed cones of 75 years of age has been found to be viable. Sealed cones of 75 and 80 years of age have been found attached to the parent tree. Board specimens from sawmills have been secured in which the cones were found completely imbedded in the wood.

Quite contrary to the old opinion that cones open as a result of fire, recent observations and studies show that cones open normally as a result of drying out assisted by temeperature changes, and extremes. Trees of the same age and in the same stand may show all cones open in one case and all closed in another. Without the action of fire cones open in consequence of weathering and by the solution of the resin which holds the scales together; followed by changes

Stub Creek ranger station in foreground. Note typical stand of young Lodgepole Pine(40 to 45 years) in background. Stand not as thick as usual in this vicinity yet probably too closely spaced for proper development.

Lower end Glendevey Burn, Colorado National Forest.

in moisture content which cause the scales to bend back. The chief value of fire in reference to seed dissemination is in the removing of resin and releasing the scales, but it also dries out the scales. Experiments have shown that fire does not seriously impair the germinative power of seed unless the cones are thoroughly charred.

Seed is rarely distributed more than 150 to 250 feet by the wind at the maximum. Seed is frequently found upon the snow after a snowstorm followed by a change in temperature and a heavy wind.

The natural and uneven process of the opening of cones has two important results-it means the almost complete consumption of the freed seeds each year by the animal population of the Forest, but it insures on the other hand an adequate seed supply whenever a fire makes reproduction possible. Seed is distributed primarily by the wind but also by animals, gravity and washing.

Because of the manner in which cones are retained upon the tree, dead tress often serve as seed trees both on burns and in the unburned forest.

## SEED GERMINATION

The germination percentage of Lodgepole Pine is usually high running from 60 to 85 per cent and averaging about 80 per cent. Seed has been found to germinate rapidly in cones from 50 to 75 years of age.

## REQUIREMENTS FOR NATURAL REPRODUCTION

As Lodgepole Pine is intolerant of overhead shade, it will not reproduce satisfacorily without considerable

Lodgepole Pine timber before cutting. Note reproduction in openings at left of picture.

Near Wyocola, Colorado National Forest.

direct light. The seed will often germinate with a very small amount of light but the young seedling dies without it. Unless a heavy thinning has been made and the crown density reduced about one half, the seedlings in the average stand are few in numbers and very spindling in form.

The most favorable seed bed for Lodgepole Pine is a mineral soil with plenty of heat and available moisture. The presence of needles and humus is unfavorable as it dries out rapidly in the spring before the roots of the seedlings have reached the mineral soil. Mineral soil is not always necessary for germination and proper development of the seedling as areas upon the Arapaho and Colorado Forests are quite frequently found which are unburned and which have a heavy stand of reproduction. This condition is particularly striking in the Beaver Lake region of the Colorado Forest where the old slash from lumbering operations had reseeded the areas both in the skid trails and upon the undisturbed forest floor. In full sunlight the mineral soil may dry out so rapidly that many seedlings are killed by drought. Young stands are usually more dense upon areas lightly shaded by standing dead timber than upon exposed sites. This undoubtedly accounts for the condition of large burns which have not reseeded altho it is possible that the fire may have been so severe as to entirely consume the supply of seed.

Competition with native vegetation such as huckleberries (Vaccinium) and kinnikinnick (Arctostaphylos) often reduces the amount of reproduction because of the conquest for light and moisture. Aspen is usually a hindrance to


Lodgepole Pine stand in which about 40 per cent of the volume has been removed. Note lack of young growth except the balsam fir. Brush piling and burning not completed.

Near Wyocola, Colorado National Forest.

reproduction through its more rapid growth when young trees of the two species start upon the same area. A light overhead aspen cover may sometimes be benificial by benefiting the soil. Rodents reduce the seed supply to a certain extent altho it is likely that more than enough seed remains were other conditions favorable.

Since light values in mature forests range from .12 to .05 in density, using sunlight as a standard, with an average of .08 or .07, and Lodgepole Pine needs .10 for development it is not to be expected that seedlings will be found in these stands. Seedlings are often found but usually only in moderately open stands in restricted groups and in small openings. The seedlings are almost without exception small, stunted and spindling in appearance. Full sunlight will result in the best development provided soil moisture is available and the area is not exposed to drought.

## METHODS OF SECURING NATURAL REGENERATION

### WITHOUT THE AGENCY OF FIRE

The question of the proper method of handling Lodgepole Pine from a standpoint of silvicultural management has long been a debated one. It is certain that without the agency of fire or the assistance of man, the areas now occupied by Lodgepole Pine would in large measure be taken over by the more tolerant species such as by Engelmann spruce and balsam fir at the upper altitudinal ranges and by Douglas fir upon the lower. It is likely however that Lodgepole Pine would continue as a permanent type in a nar-

of soil and climate are more favorable to it than to the competing species.

A great many silvicultural practices have been attempted and given up in an effort to establish some system for Lodgepole Pine whereby the facts of poor market facilities for small material and the small amount of reproduction secured, could in some measure be compensated for.

The methods of cutting which have been tried out in Lodgepole Pine usually aim to increase the yield as well as to secure reproduction. During the first sales, cutting followed the practice of selection cuttings and the variation of the single tree system. Later square groups of trees were left in varying proportions of total stands and the remainder cut clean. These remaining groups were lightly th thinned and as a result the trees were blown down. Another system used was the cutting in strips. The usual plan was to leave about one-third of the area in seed strips 100 to 150 feet wide. These were left intact, and windfall reduced to a small amount. This method however required later some plan of artificial reforestation over the cut portions over the majority of the area and at the same time the soil was left unprotected.

The seed tree, seed group, and strip systems did not consider the watershed protection nor silvicultural and market conditions. The present system followed depends largely upon market conditions. In overmature timber, clean cutting to a certain diameter is practiced in some places in which 35 to 60 per cent of the stand is removed. This is based on the assumption that ample reproduction will be

secured from the trees left and from the seed scattered from the tops of trees felled. In mature stands the system is the same, but only from 25 to 40 per cent of the trees of merchantable size are usually removed. The smaller trees are left for further growth. Reproduction is not here the principal object but should be secured in the frequent small openings. A second cutting is planned in from 20 to 40 years. A variation of this system is often used for overmature stands especially where the market demands only large timber. This is followed quite uniformly in all stands in Colorado and Wyoming. The brush except in areas where the fire danger is negligible is always piled and burned, as a protective measure. This plays no part in the securing of reproduction, as far as results to date in the stands have shown.

## RESULTS SECURED

While it is certain that the present plan of management for the Lodgepole Pine forests is a makeshift proposition, it is believed that satisfactory results will be secured from the standpoint of watershed protection, from the standpoint of securing increased growth and sufficient reproduction will be secured. The reproduction secured however will be of uneven age and the forest will eventually take on the appearance of an all aged stand. Very little windfall occurs under the present system and altho the plan has not been in operation lang enough to determine the results to be secured, it is the best which can be used and must necessarily be used until market conditions are such that the areas can be clear cut and reproduction later

secured from the slash remaining, with or without the agency of fire, or by some artificial means. Upon the Arapaho Forest plats were counted within an unburned stand in which one-half of the timber had been removed, six years ago. Six thousand seedlings per acre were found of which thirty five hundred had started since the cutting was made.

In addition to the areas handled by the Forest Service, areas located outside the Forests or upon private lands within them upon which cutting has been conducted, are very interesting. Slashed areas upon which the brush has not been burned and over which reproduction in varying numbers has come in, are very frequent. These conditions were noted upon all the Forests concerned. A particularly good example is found upon the Colorado Forest in the vicinity of Beaver Lake. Upon this area all trees of merchantable size had been removed, skid trails made across it, and tops and brush left as they fell. Here reproduction had come in running from 400 to 500 per acre up to 3000 per acre and furnishing a stand of as great a density as is desired. Little difference was apparent in the number of seedlings found in the skid trails where the mineral soil had been exposed compared with the number found upon the undisturbed soil. The number of seedlings on certain areas compared with other areas seemed rather to be due to the presence of cones either upon the ground or hanging to the tops of brush. The ground cover is made up of huckleberries and weeds, which did not seem to have affected the amount of reproduction in this case. Several tops were rolled over and the number of seedlings


Typical burn which has not reforested. Note manner in which all limbs upon the trees have been destroyed.

Glendevey burn, Colorado National Forest.

found beneath them was surprising. It was noted that neither directly under the tops nor upon the areas as a whole, were the seedlings even aged, indicating that fresh seed was constantly being liberated from the brush and tops as well as from the standing trees. It appears that if it were not necessary to burn the brush as a fire protection measure, that reproduction might well be secured without fire in practically all clean cut over areas if tops are left.

WITH THE AGENCY OF FIRE

Fire has not yet been used by the Forest Service as an aid in securing reproduction upon the National Forests except for small experimental areas. The results from these experiments are not yet available.

Forest fires have in the past served largely in the establishing of Lodgepole Pine Forests. Because of the protection now afforded the National Forests, fire is unlikely to play any large part in the establishment of future Lodgepole Pine forests.

Forest fires in reference to the securing of Lodgepole Pine reproduction, serve five purposes;-

1. The opening of closed cones, and thus making a large number of seeds suddenly available.

2. The removal of the herbaceous and scrubby ground cover, thus preventing competition.

3. The forming of a favorable seed bed, exposing mineral soil.

4. The renewal of proper conditions of sunlight.

5. The removal for a time of the seed eating rodents, or the population of squirrels, chip munks and birds.

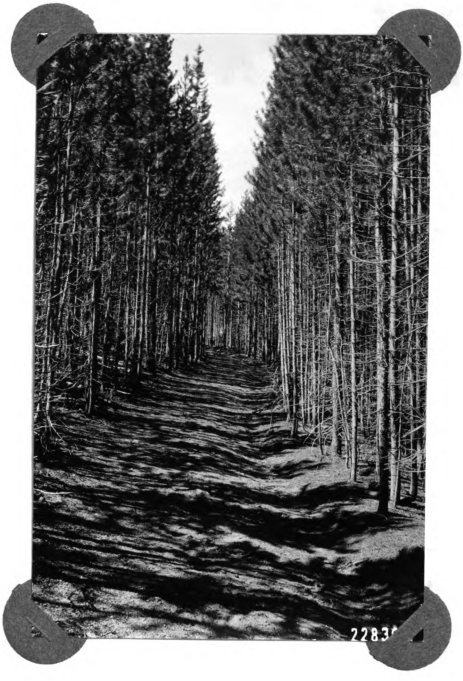

Entire mountain side covered with reproduction, 40 to 45 years of age. Reproduction largely in stagnant condition because of excessive numbers, Lighter areas are aspen groves and rocky slopes. High mountain in center is part of upper Glendevey burn which has not reforested.

Colorado National Forest.

It will be noted that a cut over area, especially under present practice, differs from a burned over area in practically every condition as noted and that optimum reproduction can rarely take place in cut over areas. Areas which have burned over are almost uniformly stocked soon after burning, by Lodgepole Pine. This is not the only tree found in the burns but of the competing species, Engelmann spruce, balsam fir and Douglas fir, a few seedlings are usually found. Areas which have not restocked are usually "double burns" or "triple burns". Some cases are found however where reproduction has not come in since the original fire. This is sometimes due to the severity of the fire which burns all the seed or may have been due to soil and moisture conditions following the fire.

RESULTS SECURED

While reproduction is usually secured in large numbers after fires the conditions are usually not satisfactory from the standpoint of density. Because of the difficulty which Lodgepole Pine has in clearing itself of limbs, young trees must be very closely spaced to secure a first quality stand at maturity. The correct density is often lacking over large areas and very frequently is too dense upon others. Reproduction after fires frequently runs as high as 55000 per acre. Upon one location, 300000 seedlings were found upon an acre, one year after the fire. Other counts have shown 175, 000 seedlings per acre after eight years, and 44,000 seedlings after twenty two years. This capacity of the tree to live for long periods under a suppressed condition is often



Forty year old stand of Lodgepole Pine. Note stagnation of growth and varying size althe the stand is even aged. Note persistency of limbs and small trees. Timber will probably not develope into commercial importance.

Lower end, Glendevey Burn, Colorado National Forest.

called "smothering back" and results from the checking of growth because of the density and poor growing conditions. Counts have been made upon seventy year old stands in which 101,000 "live" trees" and 79,000 dead were found. These "trees" could be pulled up like weeds and the stand will probably never develope into merchantability. The right density of course for Lodgepole Pine is that at which the lower branches become suppressed and die while small, but without overcrowding of the trees and the consequent decrease in rate of growth. Eight thousand seedlings per acre have been considered as required to produce clean stems at maturity. It has been shown however that altho this stocking would secure natural pruning that this would be done at a sacrifice to diameter growth. Experiments have been carried on to determone the proper density and it is likely that the number will be in the vicinity of one thousand per acre, since the uses to which Lodgepole Pine are put to do not require absolutely clear material.
In the reconnaissance work, "normal" stocking is often considered to be one thousand seedlings evenly distributed and in planting results, five hundred or more seedlings per acre are considered satisfactory. Even with a stand of one thousand seedlings per acre, it is certain that the proper spacing through the rotation will not be secured. Thinnings must be given the stands if proper development is to be secured in most cases. While these thick stands have a good appearance, it is easy to see what the result will be in fifty years unless thinnings are made. The proper stocking for Lodgepole Pine should be something like the


Burn which has reseeded completely. Unburned pole timber in background. Seedlings have come in so thick that stagnation of growth has resulted. Note persistency of limbs and suppressed condition of trees. Stand 30 years of age.

Buckhorn region, Colorado National Forest.

following in this region;-

At ten years- 1000 per acre.

At thirty years- 500 per acre.

At ninety years- 300 per acre.

At one hundred and forty years- 250 per acre.

Stands in which the fire has not been severe enough to release vast amounts of seed, and has killed the trees and placed the soil in good condition, usually develope reproduction of less density and of better condition than the more severe burns. This is brought out upon what is locally called "Danner Hill" upon the Colorado Forest. Upon this burn very little of the dry timber has fallen down. A large amount of reproduction came in after the fire but not in a heavy or dense stand. As a result, from 1000 to 2000 seedlings per acre were established, during the first two or three years. At the present time as more dry trees fall and more seed is liberated, the first seedlings have sufficient start over the later ones so that the younger seedlings will die out in the same manner as in mature stands from lack of sufficient light.

Reproduction does not always follow burns nor are all barren areas caused by "double" or "triple" burns. Upon the Glendvey burn upon the Colorado Forest, a large area of 10000 acres, only an occasional Lodgepole Pine is now found forty five years after the fire. No other fires have followed the original one. It is hard to determine the exact cause of this condition but it is no doubt due to one or more causes or combination of causes. The trees were of large size on this burn and while the fire did not

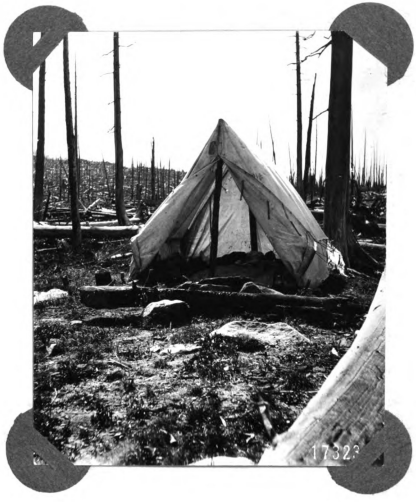

Close view of young seedlings which are growing in an opening near a scattered stand of wood land Lodgepole Pine. Seedlings growing on moist situation which also supports willows. Note small puddles of water around trees.

Lower end, Glendevey burn, Colorado National Forest.

consume them, it was probably of sufficient intensity to burn all needles and cones of the trees located upon the higher elevations at least, so that little seed was released. The soil and moisture conditions may also have been unsatisfactory following the fire. This burn is located along the Medicine Bow range over which the winds constantly blow down the slope. Along the upper portions of this burn no reproduction of any kind has come in, but farther down toward the valley a partial stocking took place and still farther down, heavy and excessive stocking resulted. The particular causes which made this differentiation upon parts of this burn cannot be determined at this time.

In connection with the portion of the area which is partially stocked, it is interesting to note that these trees commenced to reseed at an early age and in this belt a complete stocking has now been established, with trees of all ages from one to forty five years of age. The older trees have limbs extending to the ground and the timber produced will of course be of poor grade. In this particular place a peculiar phenomenon was noted in relation to the seed bed upon which Lodgepole Pine usually germinates. Seedlings of varying ages were found upon an area supporting also lichens and mosses. In the spring of the year this area is partially covered with water for a month at a time and the soil often saturated with water for a longer period. These seedlings were in good condition.

While reproduction comes in best after fires, cases have been noted where the fire exposed the soil so to wind




Temporary camp in foreground. Note absence of any reproduction upon burn in background, and manner in which tops have been completely burned from trees.

Glendevey burn, Colorado National Forest.

and sun that the seedlings after germination often died. The best conditions are secured when there is some slight amount of debris upon the ground which furnishes a little shade.

## ARTIFICIAL REGENERATION

### REQUIREMENTS FOR SUCCESS

The requirements for securing artificial regeneration by means of direct sowing are practically the same as those stated under natural reproduction. In the direct sowing work, the selection of a site is most important. Burned over areas without grass cover, or with a scattered cover of aspen are usually suitable but the question of exposure to wind and sun is also very important. Successful operations to date have usually been secured upon north and west slopes as contrasted with south and east slopes.

The requirements for planting are not severe as planted stock will grow well at any place trees have formerly grown and also in some places where it is doubtful if trees were formerly found. The results secured are largely determined by the care used in planting, the class of stock used and prevailing weather conditions.

### METHODS OF ARTIFICIAL REGENERATION

Direct sowing consists of the use of the seed directly in the sowing operations as contrasted with planting in which stock grown in forest nurseries from seed sown or pulled stock secured in the forest is used.

### DIRECT SOWING

#### METHODS

## BROADCAST SOWING

Broadcast sowing consists of scattering seed broadcast either by hand or by means of some mechanical device by which the seed is uniformly scattered. The Cyclone seeder has been quite commonly used and has the advantage over hand sowing in that the seed is uniformly distributed.

Seed sown broadcast may be sown either upon the soil direct, usually in fall, and before or after the soil has been prepared by some raking process or may be sown upon soil which has had no preparation. Seed is often sown upon the snow during early spring.

## SLIP AND DIBBLE SOWING

Slip and dibble sowing consists of sowing in hills at certain distances, small amounts of seed. In the slip sowing a mattock is inserted almost horizontally and seed inserted. In dibble sowing, a hole is made with a bar or dibble, seed dropped into it and the hole closed by the foot.

## SEED SPOT SOWING

Seed spot sowing consists in sowing a quanity of seed in a spot which has been prepared by a hazel hoe or similar instrument. Regular seed spots consist of holes made from two to four inches deep and about one foot square. Simple seed spots consist of spots usually from two to four inches deep in the form of a wedge, and about five inches square.

## CORNPLANTER SOWING

Cornplanter sowing consists of sowing seed with a specially made cornplanter worked with one hand and

which makes the hole and drops the seed at points selected by the operator. The seed is covered by the foot in pressing down the soil.

## Broadcasting

Of any of the methods of direct seeding, broadcasting has been the most frequently used and most frequently incorrectly used. The usual plan of broadcasting is for the man doing the sowing to take a strip of certain width back and forth across the area until the area is completely covered. It is sometimes recommended that one half the seed be sown in strips one way across the tract and the remainder across the other way. This not only doubles the expense but is particularly unnecessary when a mechanical seeder is used and when proper markers are employed. In broadcasting upon unprepared soil, the actual sowing constitutes the only work. The sowing should be done in the fall that the seed may work into the mineral soil and that it may also have absorbed water from the melting snows and early germination favored. Upon prepared soil seed is sown after the soil has been raked or harrowed, or may be sown first and the harrowing follow. In the mountain regions a rake or similar instrument is the only tool which can be used. The preparation of the soil is nearly always prohibitive in cost, for the mountain regions. Areas which have been tramped by sheep are sometimes used but it has been proven that when reproduction by broadcasting can be secured, that it can be practically as well secured without prepartion of the soil as with it.

Broadcasting may reasonably be expected to be

successful when the soil is loose and moist at the surface, where some protection is offered against heat and drought and when rodents can be controlled. In all cases of direct sowing, poisoning of rodents is always included as a part of the sowing operation. Seed sown broadcast often comes up in groups because of the effect of erosion or rodents in bunching the seed into pockets. Areas covered with down timber, some brush and debris, with soil exposed often afford suitable areas for broadcast sowing. Modifications of sowing broadcast are often practiced in which strips and blocks are sown. The method is best adapted to quick growing species. In broadcast sowing in Lodgepole pine from two to three pounds of seed per acre are usually used. The advantages of the method are that the seed is easily scattered and that no soil preparation is usually necessary. The cost of labor is very low but the seed cost is high. The principal difficulty with broadcast sowing is that only particular areas are suited to the method.

## RESULTS SECURED

Broadcast sowing has been successful upon several Forests in the western states. Upon the Arapaho Forest on the Arrow Burn and upon the Williams Fork, the results have been very gratifying. Germination has not only taken place in large numbers but the seedlings have withstood the climatic changes. The areas used were particularly suitable. They were rather clean burned but had a light stand of aspen and very little ground cover. These areas had an exposure to the north and west. Upon the Colorado Forest on the


Broadcasting Lodgepole Pine prior to first snowfall.
Note absence of reproduction over this area.
Glendevey Burn. Colorado National Forest.

slopes of Flattop Mountain very good results have also been secured where the conditions were similar to those found upon the Arapaho Forest. The seed often germinates in large numbers but unless some shade and protection is afforded, the seedlings continue to die during the first second and third years, after sowing and considerable loss always results. This has been repeatedly borne out by the broadcasting work upon the Colorado Forest.

In addition to the general Forest sowing, experimental plots were sown at different seasons by several methods. In this experiment seed was sown broadcast at the rate of one good seed per square foot upon an area eighty by eighty feet square. The area was later raked after sowing the seed. This experiment was located upon the Glendevey Burn, an area burned over 45 years ago and upon which no reproduction had come in. The altitude was 9500 feet. The soil was exposed, some ground cover present but not sufficient to influence results. The soil is a dry decomposed gravelly granite. Frequent winds visit the area during the summer. The region was formerly occupied by Lodgepole Pine, Engelmann Spruce, and Balsam Fir.

During the experiment, one block was sown in the spring, another in the summer and another in the fall. The summer season was a normal one and altho rain falls frequently in the summer, the soil dries out very quickly. Again in 1914 the operation was repeated for two plots sown in the spring and summer.

Counts were made in the spring and fall following. Results secured the first season were of no value since seed

uniformly lays over in the ground for one year before germination at this altitude. This method in this experiment proved as adaptable as any direct method tried but the mortality was very excessive.

Germination of the seed took place after the seed had lain in the soil for some time but but the drying winds, erosion and drought killed large numbers of seedlings. The experiment definitely proved that no methods of direct seedlings could be compared with planting results because of the great mortality in seedlings.

In broadcast sowing, from two to three pounds of seed per acre are used which costs from $2 to $4 per pound. The total cost of the work varies generally from $4 to $7 per acre. Eight areas on the Williams Fork Burn upon the Arapaho Forest, totaling 391.70 acres braddcasted on the snpw either in fall or spring cost from $4.05 to $9.02 per acre. The average cost was about $4.50 per acre. The amount of seed used varied from 1.50 to 2.40 pounds per acre. This particular area was a fourteen year old burn at an altitude of from 9000 to 9500 feet, and having a small amount of aspen, buck brush and weeds upon it. Seven of these areas are successful and the eighth is partially so.

Upon Flattop Mountain upon the Colorado Forest where broadcasting has also been successful, costs were from $7.23 to $17.32 per acre for the small areas sown. From 2.33 to 3.00 pounds of seed per acre were used.

SLIP AND DIBBLE SOWING

Slip sowing in which seed is inserted into a slip

made horizontally, is not suited to as small seed as Lodgepole Pine. The method is suited particularly to grassy areas if the seed sown can produce strong seedlings. Lodgepole Pine seed becomes too deeply buried in the soil to allow of germination or else the seedling is unable to compete with the grass.

Dibble sowing is unsuited to Lodgepole Pine because of the smallness of the seed and the fact that the seed is usually covered too deeply.

The usual method followed in slip sowing is to line up a bunch of men in a row across the area who are equipped with mattocks. Each man sows the seed into a slip as he makes it. A string of eight or ten men can conveniently work together in this way. The first man keeps the lead and makes the line to which the others work at the proper distance away. Slips are usually made with spacing 2 x 4 or 4 x 4 feet.

Dibble sowing is usually done in the same manner but a dibble or planting tool used which makes a small opening and into which seed is dropped. The spacing is 2 x2, 2 x 4, or 4 x 4 feet depending upon the number of seed used.

## RESULTS SECURED

These methods have been little used in general Forest reforestation work in Lodgepole pine.

Slip sowing was tried out upon the experiment previously mentioned upon the Glendevey Burn. The spacing used was 2 x 4 feet, and eight good seed per slip sown. No germination took place the first year and but from 24 to 41 seedlings were found in each of the 80 foot plots in the

second year. The seed which did germinate were found to have been but lightly covered. The plots were located upon an exposed loose soil and as a result, the seed was covered too deeply. The method is unsuited to the average condition of burns in this region.

The costs of this method are very small because of the small amount of seed used but the method is of little value upon the National Forests.

## SEED SPOT SOWING

This method next to broadcasting has been most extensively used in reforestation work with Lodgepole Pine. In making the regular seed spots, four to eight men with mattocks or hazel hoes are used. These men line up one back of the other but in adjoining rows, the head man keeping the line. Spots are made by loosening the soil 2 to 4 inches deep or the competing vegetation is removed and the soil little disturbed. The seed spots are usually about one foot square and are spaced 4 x 4, 5 x 5, or 6 x 6 feet apart. A man usually follows each group of four men and drops the required number of seed into each spot. Ten good seed per spot are usually used as a basis. The seed is covered lightly by kicking over them, a small amount of soil.

In the simple seed spots the general lineup is the same. Holes are made in the form of a wedge and five inches in depth. The seed is dropped into the hole and covered as in the regular seed spots.

The method is adapted to all areas which can be broadcasted and to other areas supporting a heavy stand of grass and weeds not suited to broadcasting. The soil is exposed

and loosened, and competition with other vegetation reduced. The method has a further advantage in that less seed per acre is used. The cost of the work is high. In case good germination takes place and the seedlings live, a number of trees develope in the same spot whic must be thinned out at some future time. The young seedlings are also exposed to the full effect of wind and sun in the spots. Birds often do considerable robbing of seed in the spots since they can be easily located.

The average cost using ten good seed per spot and with spacing about 5 x 5 feet is from $5 to $7 per acre. An area of 185 acres upon the Colorado Forest cost $5.87 per acre in which .328 pounds of seed per acre was used. Three areas upon the Arapaho Forest on the Williams Fork, totaling 132.76 acres, upon which from .75 to 1.07 pounds per acre of seed was used, cost from $6.61 to $15.33 per acre.

## RESULTS SECURED

In the experiment upon the Glendevey Burn, spots were made 4 x 4 feet apart, 4 inches deep, one foot square and 16 good seed per spot were used. Soil was then placed on the seed not to exceed one-quarter inch in depth. After the seed had laid over in the ground for a year, excellent germination took place. The counts showed from 90 to 240 seedlings per 80 foot plot. The same results were secured here as with the other methods in that excessive losses occured and the plot with 240 seedlings was reduced to 50.live seedlings. The seed spot area had however more seedlings at the last count than any of the plots sown to other methods.

Simple seed spots were also made in this experiment,

in which spots 2 x 4 feet, 5 inches square,and 5 inches deep were made. Eight good seed per spot were used. The method proved of no value since the holes immediately filled with soil and germination did not take place. A few seed which fell outside the spots or in a spot which did not fill up with soil, germinated. Themethodis unsuited because of soil conditions to any areas in need of reforestation to Lodgepole Pine.

The areas of regular sowing upon the Colorado and Arapaho Forests usually showed a good germination but the losses in seedlings in the second and third years were enormous, so that the possibility of the method being of real value is questionable.

## CORN PLANTER SOWING

The corn planter has been little used in reforestation work with Lodgepole Pine. The tool is so arranged that a certain number of seed are dropped each time. The machine is operated with one hand, the hole made and the seed forced out with a forward motion. This method is not adapted to Lodgepole Pine because it is practically impossible not to cover the seed too deeply and thus retard germination. It is also difficult to regulate the number of seed dropped because of their small size. Except for covering the seed the method has no advantages over broadcasting since competition with vegetation is not reduced.

## RESULTS SECURED.

The method was not tried out in general Forest work but plots were sown by this method in the experiment upon

the Glendevey Burn. Seed on the average of four per spot were sown 2 x 2 feet apart in holes made by the corn planter. Counts on the plots a year afterward when germination first occured showed from two to thirty six seedlings and the next year the maximum number on any plot was 17 seedlings. The seed which did germinate were found to have been but lightly covered with soil. The method is not suited to the average conditions upon Lodgepole Pine burns.

## PLANTING

Planting is uniformly being practiced now in the reforestation work upon National Forests with Lodgepole Pine except upon particular areas which have given good results from broadcasting or seed spots, and upon which these methods a are being continued with small acreages. Planting is adapted to,practically any condition found in Lodgepole Pine burns. The only disadvantage is the cost of the trees and the high labor cost. It is usually necessary to use a mattock or similar tool in all the planting operations carried on in this region because of the rocky soil. This adds greatly to the cost of the work as contrasted with planting with planting tools in furrows. The spacing is now uniformly 8 x 8 feet. The exact application of the men making the holes or doing the planting varies from area to area.

## RESULTS SECURED

Satisfactory results are uniformly secured in planting Lodgepole Pine except under unusual conditions. No difficulty has been encountered in securing a survival of from 70 to 85 per cent even upon rocky dry exposed situations.

One area was planted upon the Glendevey Burn as a con-

Forest Ranger completing the planting of a transplant By tamping the soil about the tree.

Colorado National Forest.

trast with the direct sowing operations upon the detailed experiment there. Upon this 80 x 80 foot plot, 425 Transplants were to have been planted but the number was considerably reduced because of poor trees since it had been necessary to heel in the stock for six weeks prior to planting it. The planting was done in the spring and at the count made in the fall, 64.2 per cent were alive based on the original number of 425. The planted area had then cost less than the seed spot area and but little more than the broadcasting. Results were of course much better in the planted plat. Transplants can usually be grown for about $6 per thousand in the mountain nurseries and the actual planting cost is from $ 4 to $5 per acre, making the total cost about $10 to $11 per acre, depending upon the size of the operations, the accessibility of the area, the kind of soil and ground cover, the class of men available and the cost of stock used. The actual labor cost of the work, upon an average spacing of 8 x 8 feet is from $2.50 to $2.75 per acre in which mattocks are used.

## SUMMARY

### NATURAL REGENERATION

Fire has played an important part upon areas now occupied by Lodgepole Pine and it is certain that without fire as an assisting agent that large areas in particular now occupied by young stands of Lodgepole Pine would be held by the more tolerant species, Engelmann spruce, balsam fir, and douglas fir with which Lodgepole Pine associates.

In cutting Lodgepole Pine timber, the first methods followed the selection system and variations of the single


Fortyfive year old stand of Lodgepole Pine upon lower portion of Glendevey Burn. Stub Creek ranger station in middle ground. Sagebrush land in foreground.

Colorado National Forest.

tree method. A later practice was to cut clean except for square groups of trees left, which were lightly thinned. Clean cutting in strips was also practiced. The methods did not consider watershed protection nor silvicultural and market conditions. Under the present practice of Forest Service timber sales, the system followed depends largely upon market conditions. In mature stands only from 25 to 40 per cent by volume of the stand is removed and this amount consists of trees of merchantable size only. Although the plan of cutting does not aim to secure reproduction, it is believed that a large number of seedlings will come in in the openings made.

The system is not ideal but will serve to protect the watersheds and also allow for a second cutting in from 20 to 40 years as well as to secure reproduction which will be of unexen age. The amount of windfall resulting from this system is inconsequential. The small number of cuttings which have been made along this plan indicate that the amount of reproduction secured will be satisfactory in amount.

Areas outside the Forests or upon patented lands within the boundaries, show that satisfactory results in securing reproduction are found where the slash was not burned but left in the timber. Reproduction occurs over these areas both in the old skid trails and upon portions of the areas where the forest floor remained undisturbed.

Forest fires serve as an aid to reproduction by releasing seed, by preparing a suitable germination bed, affording correct light conditions, and causing the removal of rodents. A heavy stand of reproduction usually follows a fire in Lodgepole Pine unless the fire is so severe as to destroy


Lodgepole Pine burn. Scattered stand of Lodgepole Pine coming in. smaller seedlings cannot of course be seen

Near Continental Divide, Estes Park. Flattop mountain, Colorado National Forest.

all cones and seed. The chief difficulty often occurs in that the number of seedlings per acre is so large and the individuals so persistent that stagnation results and the seedlings f fail to develope into valuable timber.

## ARTIFICIAL REGENERATION

Direct sowing follows the method of sowing directly upon the soil which may or may not have received preparation. The usual methods consist of broadcasting, slip and dibble sowing, seed spot sowing, and cornplanter sowing.

In broadcasting seed is sown by hand or by the use of a mechanical seeder upon the exposed soil which may secure some sort of harrowing either before or after sowing; or by sowing upon the snow in fall or spring. The method is only adaptable to particular areas and only successful upon certain locations. Satisfactory results have been secured upon but a few Forests and the use of the method is now confined to a few favorable areas. Broadcasting on snow usually costs about $4.50 per acre when seed secured locally by the Forest Service is used. The cost is slighly higher when the seed is sown upon the bare ground.

In slip sowing seed is sown in slits made by mattocks but is unsuited to Lodgepole Pine because of the small size of the seed. In dibble sowing, a dibble or planting bar is similarly used. These methods have been little used in Forest Service work and are of no practical value. The costs are very low because of the small amount of seed used.

Next to broadcasting, seed spot sowing has been used most extensively. Seed spots are made of regular square shapes or in the form of a wedge. The system is adapted to

Forest Service planting crew using mattocks.

Colorado.

a larger percentage of area than broadcasting but results have not been entirely satisfactory because of the severe mortality after heavy germination once points to success. The cost of the work is usually from $6 to $7 per acre.

Cornplanter sowing is of little value since the method cannot be satisfactorily used because of the small size of the seed. It is practically impossible to use the planter and to sow the proper number of seed and also to prevent covering the seed too deeply.

Planting is now largely practiced upon most of the reforestation work since the method is a success upon all locations if correctly done. The cost of stock used and labor involved is of course high. Mattocks are largely used because of rocky soil. The survival number is usually large running from 70 to 85 per cent. The total cost per acre using transplant stock is from $10 to $11 per acre where mattocks are used and large areas planted.

Of the methods used to secure artificial reproduction, planting is most desirable and successful. Seed spot sowing is next of value followed by broadcasting. Corn planter. slip and dibble sowing are of little value for this species.