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Tree Planting IN Scrub Oak Areas

AFTER SITE PREPARATION WITH HEAVY EQUIPMENT

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CONTENTS

A QUESTION OF PLANTING

PENNSYLVANIA'S forests include many acres of a brushland type commonly referred to as scrub oak or bear oak (SAF Type 43[1]). This cover type is found also in parts of New Jersey, Maryland, Virginia, West Virginia, New York, and southern New England. It is a temporary type of the drier sites, and is practically always associated with a history of repeated fires. The distinguishing and usually predominant species is *Quercus ilicifolia.*

Various other shrubs and sprouts of tree species typically are intermixed. In Pennsylvania, the more common tree species include pitch pine (*Pinus rigida*), red maple (*Acer rubrum*), chestnut (*Castanea dentata*), gray birch (*Betula populifolia*), quaking aspen (*Populus tremuloides*), sassafras (*Sassafras albidum*), and the usual upland oaks such as *Q. alba, Q. prinus, Q. coccinea,* and *Q. rubra.* Among the other shrubs, the most characteristic and ubiquitous ones are low-growing blueberries (*Vaccinium spp.*) and sheep laurel (*Kalmia angustifolia*). Bracken fern (*Pteridium aquilinum*) is a common associate.

The soils are stony to varying degrees. Ridges and upper slopes usually are exceedingly stony, with some ledge rock outcropping. Lower slopes and flats range from land with so few stones that clearing and cultivation are possible, to glacial boulder fields and long narrow stringers of boulders where little or no surface soil is present. Most flat and gently sloping areas fall somewhere between these extremes — too stony for agriculture but having sufficient soil to support forest vegetation. In glaciated sections, the land surface in many places is only a skin of humus and soil overlying a stratum of boulders a foot or so thick; beneath the boulders there may be several feet of fairly stone-free mineral soil. Trees can push

[1] Society of American Foresters. FOREST COVER TYPES OF NORTH AMERICA. 67 pp. 1954.

their roots through such boulder layers into the soil below and grow reasonably well — if they escape fire.

The acreage of scrub oak in Pennsylvania has been variously estimated in the past to be as much as 2 million acres. Estimates have varied widely according to the estimator's concept of the type — according to where he drew the line between scrub oak and other sprout hardwood types in which scrub oak was one element. When the estimate was made is also a factor, for the acreage certainly has shrunk as fire protection has improved during the past three or four decades. In 1951 the Pennsylvania Department of Forests and waters estimated, on the basis of a state-wide survey, that the scrub oak type then occupied about 170,000 acres.[2] In this survey, areas having 100 or more stems per acre of commercial species growing above the scrub oak were not considered as of the scrub oak type. This estimate of 170,000 acres is still the best figure available. Later estimates from the Forest Survey of the U. S. Forest Service are based on much less intensive sampling.

These essentially unproductive areas of scrub oak have long been a challenge to foresters. Could commercial timber be grown on them if fire were controlled? Or did the presence of scrub oak indicate sites inherently too poor to produce commercial timber?

During the early days of forestry in Pennsylvania, a number of small planting trials were made in the scrub oak type, the first one of record being in 1911. Although initial survivals often were good, these plantings generally failed because of inadequate site preparation, failure to release the seedlings from the competing brush soon enough and often enough, or the plantings were lost in wildfires. Nothing conclusive was demonstrated, except that scrub oak areas are difficult planting sites. MacIntyre[3] reviewed the situation in 1928 and concluded that planting in this type was not economically feasible.

In 1948, the Northeastern Forest Experiment Station, in cooperation with the Pennsylvania Department of Forests and Waters, started a long-term watershed study in a scrub oak area on

[2] Pennsylvania Department of Forests and Waters. SCRUB OAK IN PENNSYLVANIA. 21 pp., illus. 1951.

[3] MacIntyre, A. C. THE SCRUB OAK TYPE IN PENNSYLVANIA. Unpublished report, Pa. State Bureau of Forestry. 1928.

the Pocono Plateau. The experimental area, comprising about 2,000 acres, was designated as the Dilldown Unit of the Delaware-Lehigh Experimental Forest; it will be referred to hereafter in this paper simply as Dilldown. The study called for conversion of the shrubby cover to a cover of true tree species after a 5-year or longer period for calibrating the watershed. In some places, where sprouts of tree species were abundant, the conversion was to rely on natural growth under fire protection. Elsewhere — on more than one-half the area — conversion was to be accomplished by planting. Experiments were started in 1948 to determine how the planting should be done. The results and implications of those experiments are summarized in this paper.[4]

Beginning in 1955, conversion plantings on the Dilldown watershed, and subsequently in several other locations, were done by methods developed in the experiments. The results in these action programs also will be briefly described.

THE PLANTING EXPERIMENTS

Four major studies and several smaller supplemental experiments were established during the period 1948-53. The four major studies were: (1) preliminary experiments, (2) bulldozer furrow study, (3) rototiller study, and (4) rootrake study. The studies will be described in only a general way, with but little detailed data. The emphasis will be on the practical aspects of the results.

The primary problem in planting in scrub oak is site preparation. With adequate site preparation, the primary variable to be evaluated is species. Those are the main themes throughout this paper.

[4] These experiments have been described and the results have been summarized periodically in a series of publications issued in 1951, 1953, 1955, and 1961 by the Pennsylvania Department of Forests and Waters as Reports Nos. 1, 2, 3, and 4 under the title FOREST AND WATER RESEARCH PROJECT — DELAWARE-LEHIGH EXPERIMENTAL FOREST. Those reports had only a restricted distribution and, furthermore, were oriented to the watershed study. Therefore, this paper, devoted solely to the tree-planting aspects of the project, seems warranted despite some duplication of previously published material.

Preliminary Experiments

This first study, begun in 1948, involved several site-preparation methods, 11 tree species, 2 sizes or ages of planting stock, slit versus center-hole planting, and post-planting release versus no release. The study site represented easier than average planting conditions: almost level ground, relatively few stones, and a relatively low and open stand of brush. Much of the scrub oak was about 3 feet tall.

At that time the difficulties and importance of the site-preparation problem were not fully appreciated, and — by hindsight — the attack on it appears rather inept. The methods tried were (1) hand-made scalps, (2) furrowing with an old-model Killefer fire-line plow, (3) plowing strips with a brush-breaker plow; (4) chopping up the vegetation with a heavy tandem disk; and (5) no site preparation. None of these methods was satisfactory. The machine methods worked to a degree, but considerable supplemental hand work with a mattock was required to prepare suitable planting spots. Hand scalping was utterly impracticable: the ericaceous understory of blueberry and sheep laurel forms an amazingly tough mat of wiry roots and stolons that defies the puny efforts of a man with a mattock. Planting with no site preparation in this root mat also was impracticable.

This first study taught us one important lesson: that our only hope for an effective practical method of mechanical site preparation lay in powerful heavy equipment.

Eight tree species and one mixture of hybrids were used in the study:

Pitch pine	— *Pinus rigida*	European larch	— *Larix decidua*
Red pine	— *P. resinosa*	Red oak	— *Quercus rubra*
Scotch pine	— *P. sylvestris*	Black locust	— *Robinia pseudoacacia*
Jack pine	— *P. banksiana*	Hybrid poplars	— 5-clone mixture
White pine	— *P. strobus*		

In addition, Japanese Larch (*L. leptolepsis*) and Norway spruce (*Picea abies*) were planted in a few plots outside the formally designed experiment.

The seedlings were ordinary nursery stock, and some of the stock was not of good quality because the state nurseries at that time had not fully recovered from the disruptions of the war period. The stock of some species had suffered from too high density in the nursery bed, improper care after lifting, or other mishandling. Differences in stock quality to some degree confounded the species comparisons.

Age or size of stock was less important than the overall quality characteristics resulting from treatment in the nursery. When seedlings were sturdy and in good condition, small stock survived and grew almost as well as larger stock. Seedling survival and later performance did not differ significantly between the two planting methods.

The hybrid poplars survived only a year or two, even on the plowed strips. All the other species, except Norway spruce, demonstrated a capacity to survive satisfactorily and become established in prepared spots or sites. In the small supplemental trial of Norway spruce, which was on plowed strips, about one-half of the seedlings died out after hanging on for a few years in a state of check. And, in this case, the quality of the stock when planted appeared to be good. Although most of the surviving seedlings eventually overcame the checked condition and made more or less normal growth, the overall performance of this species must be rated as poor.

All of the site preparations that broke up and removed the ericaceous root mat around the seedlings permitted satisfactory survival and establishment. Results were somewhat better in the Killefer furrows than in the other treatments, even though these furrows averaged only about 1 foot wide. On the plowed strips, some mortality occurred that apparently was caused by air pockets in the soil where debris had been turned under.

Survival and growth were not markedly increased by the release treatments (cutting overtopping brush during the second and fourth years); most vigorous seedlings were able to get up above the relatively low brush without help. Had the brush been taller and denser, as it is in many scrub oak areas, the losses caused by suppression on unreleased plots doubtless would have been greater.

Bulldozer Furrow Study

This study, begun in 1950, was our first attempt to adapt heavy equipment to the site-preparation job. After some preliminary experimenting with a medium-sized bulldozer, we hired a D7 Caterpillar equipped with a hydraulically controlled standard blade. The objective was to skin off the ericaceous root mat in furrows of sufficient width and depth that trees planted in them could grow without subsequent release.

By tilting and angling the bulldozer blade to the maximum, fairly satisfactory furrows could be made by lowering just the trailing edge of the blade into the ground. Because of the tremendous side draft on the machine, and the tendency for debris to accumulate on the blade, the operator could not keep going ahead continuously. However, he could commonly make runs of 30 to 50 feet or more during which the soil and debris rolled from the end of the blade in a more or less continuous flow similar to the flow from a moldboard plow. Then debris would pile up, or rocks would force the blade out of the ground, and he would have to stop and back up for a fresh start.

Except where the soils were excessively stony, practically continuous furrows that conformed reasonably well to specifications (3 to 4 feet wide and 5 to 8 inches deep) were prepared. The furrows were spaced 8 to 10 feet apart, center to center. We prepared about 47 acres by this method because we wanted a good estimate of costs on a day-by-day production basis. The charge for tractor and operator in 1950 was $9.00 per hour; the site-preparation cost, based on actual operating time, was $13.21 per acre.

One significant observation made during this job was that the skill of the tractor operator is an exceedingly important element in the cost picture. We had two operators, and one could accomplish about twice as much as the other in a given time.

On the basis of their early performance in the preliminary experiments, red pine and Japanese larch were scheduled to be the major species in this planting. However, Japanese larch stock was not available from Pennsylvania nurseries in 1950, so European larch was used instead. The pine and larch were planted by a

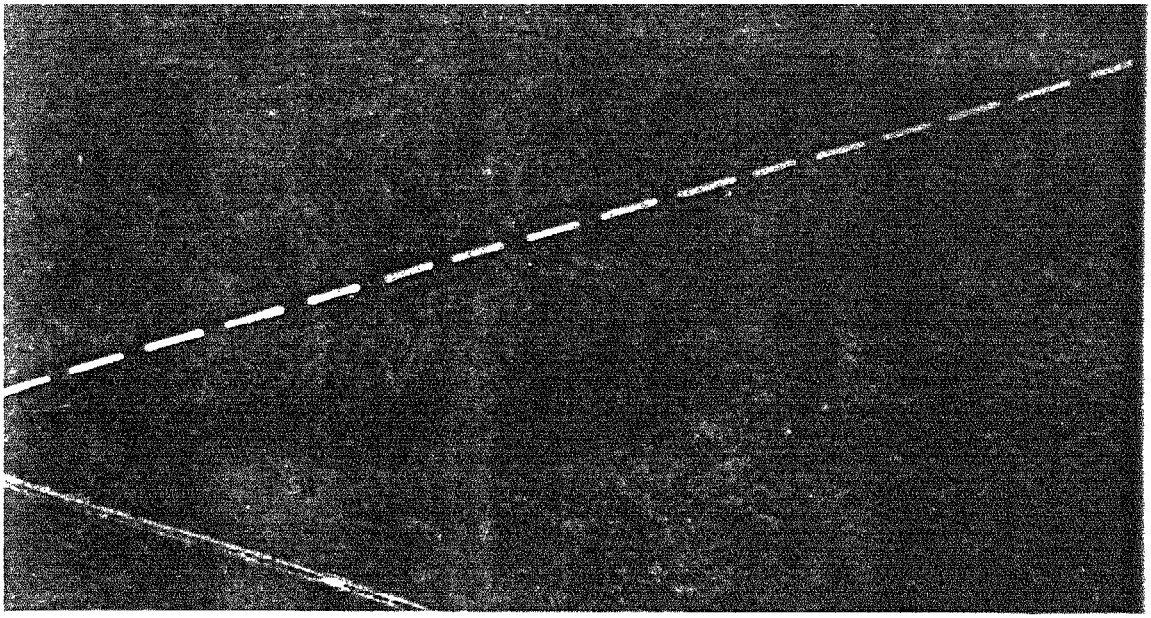


Figure 1. — An aerial view in 1965, showing most of the 47-acre planting made in 1950 in bulldozed furrows. Dark strips are red pine and light strips are larch. The strip of about 10 acres in the foregound (marked by dotted line) was prepared with a rootrake and planted in 1953.

mattock-slit technique in alternating 8-row strips (fig. 1). A few strips were planted to jack pine, pitch pine, and red oak.

Survivals at the end of the first summer were 90 percent or better for all species except red oak. The red oak stock was received in poor condition from the nursery. Its survival was about 70 percent the first summer. Considerable mortality occurred during the next year, and only a few of the survivors exhibited normal vigor. Their fate was not followed after 1953. The other species suffered only moderate attrition during the next few years; survivals after 8 growing seasons (the last sampling for survival) were in the range of 75 to 85 percent.

No release cutting of brush was ever done. A few seedlings were shaded out by brush growing out from the sides of the furrows, but most of these were weaklings that grew poorly from the beginning. Occasional seedlings were clipped by rabbits, were killed by sawfly larvae, or died from undetermined causes.

The European larch seedlings both here and in the preliminary experiments varied greatly in vigor. Some were hopeless runts from the start and eventually died. Others did not develop a real leader for several years, and these trees usually remained among the slower growers.

Rototiller Study

In 1951, an entirely different type of machine was tried on about 8 acres — a heavy model Seaman Rototiller. This machine cultivated strips 6 feet wide. The strips were spaced 10 feet apart center to center, some once over, some twice over, and some thrice over with the tiller. On strips tilled two or three times, the vegetation was well macerated and the soil was in good condition for planting. However, fragments of the stoloniferous species remained in the soil, and promptly gave rise to abundant regeneration. After about 3 years, the low cover had regenerated almost completely.

This experience with the rototiller demonstrated again, as in the preliminary experiments, that machinery designed for farm use is not well suited for site preparation in the scrub oak. After this relatively small job, the tines of the tiller were badly worn, and the machine suffered several breakdowns. It simply was not built ruggedly enough to cope with the stones and large scrub oak root crowns.

Japanese larch was the major species used in this planting. Some double-tilled strips also were planted to red pine, jack pine, and pitch pine. Survival and early growth were good for all species. For Japanese larch, the only species planted under all three tillage intensities, both survival and early growth increased with tillage intensity. In 1954, the spread in average survival from once over to thrice over with the tiller was from 72 to 86 percent, and the spread in average height was from 2.4 to 3.1 feet.

Growth rates began to slow down perceptibly during the third and fourth years after planting. Although dry weather may have been a factor in this, the primary cause was believed to be increasing root competition from the regenerated low vegetation. This planting burned out in 1957, so we don't know how well the trees would have grown in the long run.

Rootrake Study

In 1952, after having observed the use of rootrakes for site preparation in the Lake States, we hired one of these rigs for a trial at Dilldown. The machine we obtained was a D6 Caterpillar tractor mounting a 10-foot rake in the same position as a bulldozer blade. The rake consisted of 10 stout teeth spaced 1 foot apart.[5] One advantage of a rootrake over a solid blade is that some combing action is achieved; that is, less soil is picked up when the shrub crowns and ericaceous root mat are removed from a planting patch or strip. Another advantage is that teeth can be forced into stony ground more readily than a blade.

We first tried complete clearing of lanes as wide as the rake (10 feet), but found this to be excessively expensive. We then devised a zig-zag cross pushing procedure that did a rougher but adequate job of clearing lanes about 10 feet wide. With lanes about 10 feet apart, edge to edge, this cost $14.10 per acre in a 10-acre job at the rate of $10.00 per hour for machine and operator. Thus the cost was roughly comparable to the $13.21 per-acre cost for the 1950 bulldozer furrowing when we allow for the $1.00-per-hour increase in equipment rental in 1952.

The site preparation accomplished by the rootrake was considered to be better than that accomplished by furrowing. The lanes were planned to accommodate two rows of trees at 6- by 6-foot spacing. Although seedlings planted in the lanes might be shaded some from one side, the other side would remain open, and there seemed little likelihood that any appreciable number of the seedlings would be seriously suppressed.

Red pine and Japanese larch were planted in the spring of 1953 in alternating 4-row strips (fig. 1, right side). Within lanes, the spacing was roughly 6 by 6 feet; between lanes, the row-to-row distance was some 12 to 15 feet. Early survival and growth were good. Sample tallies in the spring of 1955 showed 83 percent survival for both species; in 1958, after five growing seasons, the survival figures were 80 and 81 percent. Only an insignificant num-

[5] Some models of rootrakes are a combination consisting of a blade with teeth extending below. The rootrake used in this study consisted only of teeth mounted on a supporting bar.

ber of seedlings suffered any suppression from overhanging brush. As in the furrow planting, no release has ever been done.

Other Studies

Besides the four major studies involving mechanical site preparation, we made smaller trials in 1950 of an acre or so where only a herbicide was used, or where no site preparation at all was done.

Of the herbicides available and tried in 1950, only ammate accomplished any substantial reduction of the vegetation. It killed most of the understory and top-skilled the scrub oak and tree sprouts. Tree seedlings planted in spots far enough from large root crowns to escape being overgrown as the regrowth developed grew about as well as where the site had been prepared mechanically.

The planting with no site preparation was spotted into small openings in the scrub oak and taller brush, and no attempt was made to achieve any particular spacing. Trees were placed only in openings at least 5 or 6 feet in diameter. Thus, except for some slight shading by the low-growing vegetation, they were assured of light from above. These trees survived reasonably well but grew poorly. The poor growth is attributed to the root competition associated mainly with the understory vegetation.[6]

However, planting in either living or dead standing brush is an exceedingly tedious and frustrating sort of work, and it requires conscientious effort to do it well. Such planting would never be practicable on a large scale, regardless of how well the trees might grow.

Species Appraisal

Of the species tried at Dilldown, red pine and Japanese larch are definitely the best choices for planting. The two species differ greatly in growth rate, but each has performed well within the limitations imposed by its natural characteristics. Both species

[6] McNamara, E. F., and Irvin C. Reigner. ROOT COMPETITION SLOWS GROWTH OF PLANTINGS IN UNPREPARED SITES IN SCRUB OAK. U. S. Forest Serv. NE. Forest Exp. Sta. Forest Res. Note 54. 3 pp. 1955.

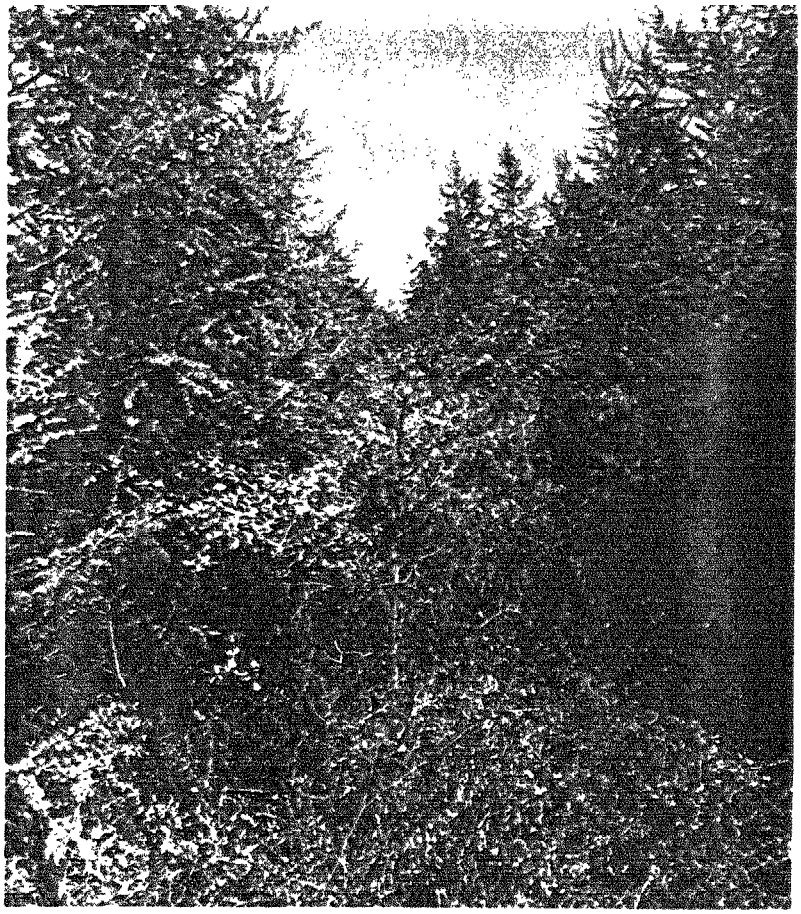


Figure 2. — Japanese larch 12 years after planting in double rows in lanes cleared by rootrake. Central open strip is the 10- to 15-foot space between lanes, occupied by a ridge of debris from the clearing.

survive adequately after planting by routine procedures on prepared sites; both tolerate the rather adverse soil and climatic conditions of scrub-oak areas on the Pocono Plateau; and both have thus far remained free of serious insect or disease pests.

Red pine has been represented in all the studies and has grown about equally well in all of them. The seedlings normally grow slowly for the first few years. In the rootrake study, for example, mean height after 5 growing seasons was 2.9 feet. The growth rate typically increases after about the fifth year and annual height increments of a foot or more become common. In some years the more vigorous trees will put on 2 feet.

No formal sampling to determine mean heights has been done in any of the plantings since 1958. A few sample trees were measured in the spring of 1965 as a check on general estimates by eye. Red pine in the rootrake planting (after 12 years) mostly ran about 10 feet tall. The stronger trees ranged up to 12 or occasionally 14 feet, and the weaker ones down to about 7 feet. Good but not exceptional red pines in the 1950 furrow planting stood 12 to 13 feet tall. In one better-than-average red pine plot planted with 2-2 stock in 1948, most of the trees were 16 to 18 feet tall; one tree measured 19 feet.

Japanese larch is best represented in the rootrake planting. There it averaged 6 feet tall after 5 growing seasons, and has continued to grow very well. After 12 years, the trees that made up the silhouette of the stands were mostly 20 to 25 feet tall, and occasional trees ranged up to 30 feet or more (fig. 2). Although this species does not exhibit the extreme variation of European larch, considerable variation in size and vigor were evident. Trees in the 15- to 20-foot class were not uncommon, and others in the 10- to 15-foot class were occasionally encountered.

Among other species, white pine, scotch pine, pitch pine, and European larch merit some consideration.

White pine, tried only in the preliminary experiments, performed rather erratically: some trees grew well, but a good many grew poorly. It has the further disadvantages of being subject to damage by the white-pine weevil and by blister rust, and seedlings are a favorite food for deer. Under conditions of light deer pressure at Dilldown, white pine was the only species in our plantings that was hurt appreciably by deer browsing.

Scotch pine, also used only in the preliminary experiments, has survived and grown very well; in growth it has slightly exceeded red pine. However, scotch pine can be recommended only with reservations because, in this country, it seldom continues to grow well into pole and sawlog sizes. In fact, some of our trees in 1965 — 17 years after planting — appeared to be slowing down. Many of them had lost their leaders (presumably ice and snow damage) and apparently were not capable of developing a strong replacement (fig. 3).

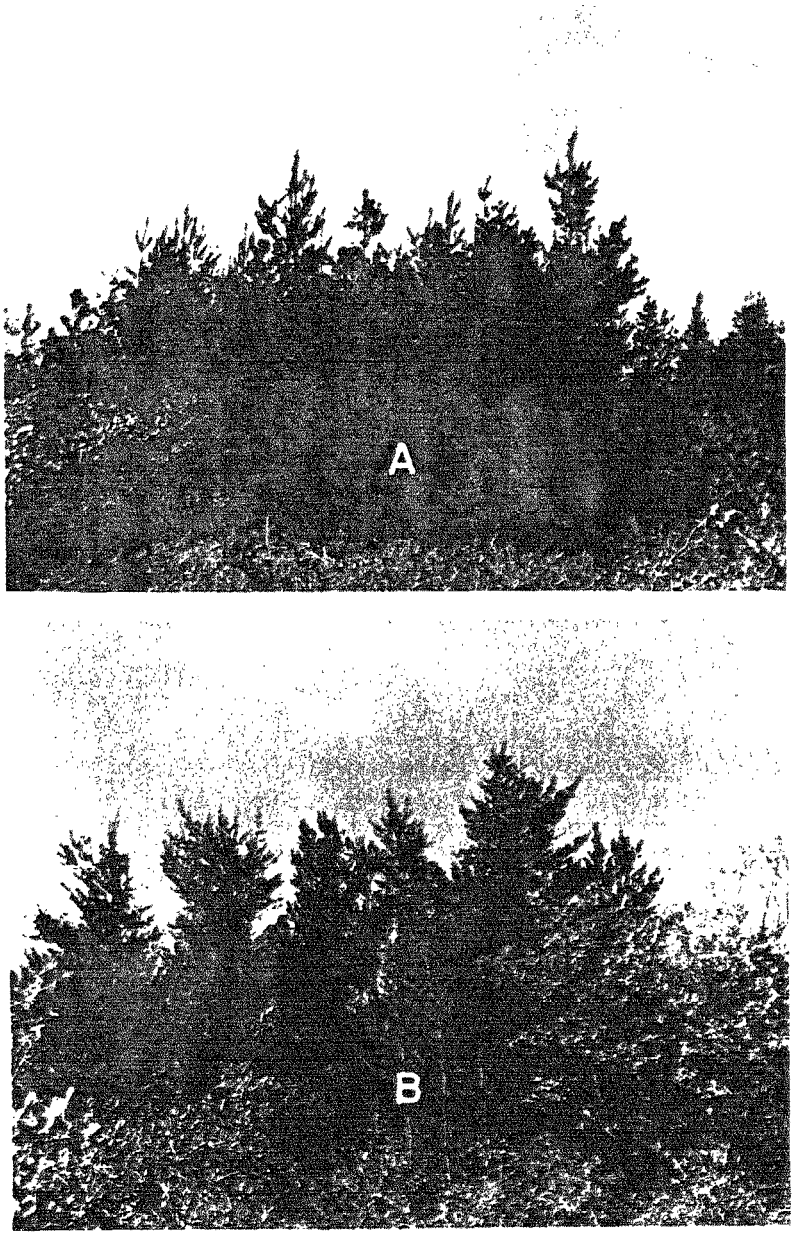


Figure 3. — Two 25-tree plots of scotch pine in the 1948 planting as they appeared in 1965. A, trees still growing fairly well; tallest one is 22 feet. B, most of trees becoming flat-topped; tallest one is 19 feet.

Figure 4. — European larch in the 1950 planting in bulldozed furrows. The two trees in back are among the better ones — 20 to 21 feet tall in 1965. The two trees in the adjacent furrow in front are weaklings 8.5 and 10.5 feet tall (tips marked by arrows).

Pitch pine is an enigma. Probably the species includes genetic stock capable of yielding progeny of good form, but such stock has not been identified and utilized for propagation purposes. None of the pitch pine planted at Dilldown is developing in good form. The best pitch pine is in the bulldozer furrow planting. These trees grew fairly well at first, averaging 6.3 feet tall after 8 years — almost 2 feet taller than red pine in the same planting. Their form looked promising up to that time, but as the trees have emerged above the level of the brush, their terminals have become more crooked and height growth has slowed down. Until pitch

pine seedlings of genetic strains of good form are available from the nurseries, extensive planting of this species would not seem advisable.

European larch, as has often been observed, is an exceedingly variable species, apparently because of diverse genetic origins represented in the imported seed. In our substantial planting of this species in bulldozed furrows, about 25 percent of the trees (based on rough estimates) have done reasonably well and, at the other extreme, at least 25 percent of the trees were congenital runts that have either died or are dying out. The rest of the trees are coming along, but relatively slowly; they seem destined to occupy intermediate and suppressed positions in the final stand. However, the best of the European larch in 1965 was only about 20 feet tall (fig. 4). So, even though 3 years older, these trees had not attained the height of many of the Japanese larches. The latter species seems unquestionably to be the better of the two larches for planting under the conditions represented at Dilldown.

None of the other species tried in the studies are suitable for planting on scrub oak sites. Jack pine, although promising at the start, was not windfirm after it grew above the level of the surrounding brush. Norway spruce in our one small trial went into prolonged check from which only about 50 percent of the trees eventually recovered and grew. Given good planting stock, red oak perhaps would perform better than it did in our experiments; but the scrub oak soils could hardly be expected to support good, quality growth of any hardwood. Black locust and hybrid poplars definitely have no place in scrub oak planting.

CONVERSION PLANTING ON THE WATERSHED

By 1955, the calibration phase of the watershed study had been completed, and the rootrake method had been demonstrated as a practicable way to prepare the less stony areas for planting. The species comparisons, even then, pointed rather definitely to red pine and Japanese larch as first choices, with scotch pine and European larch as the most promising alternates.

Based on a planting survey of the watershed, some 1,100 acres were scheduled for conversion. However, this survey revealed that much more of the area than had previously been realized was so stony that mechanical site preparation was not feasible. These portions supported scrub oak vegetation and, superficially, they appeared plantable. But the humus mat overlaid a practically complete layer of stones a foot or so thick. Beyond a certain density and thickness of this stone layer, a rootrake (or bulldozer) cannot be operated effectively for site preparation. Only about 335 of the 1,100 acres were mapped as suitable for planting.[7]

The plantable areas on the watershed were prepared by a rootrake technique and planted by the Pennsylvania Department of Forests and Waters during the years 1955-57. Only about 285 of the 335 acres mapped as plantable actually were planted; the other 50 acres were in small islands that were by-passed either because of adequate stocking with native trees, or because of excessive stoniness.

A rootraking technique that differed radically from the cross-pushing procedure used in the experimental planting was devised and used in most of the conversion planting. In this later technique, as described by McNamara,[8] series of small, separate planting patches are cleared, rather than lanes. From a given starting point, the tractor progresses backward across the area to be worked, in the following manner:

First, the operator engages the teeth and moves forward until a full load has been accumulated — perhaps 15 to 20 feet. Next, he reverses from the load across the cleared ground and continues 20 feet or so into undisturbed area. Here, he again engages the teeth and moves forward until this load is at the starting point of the first cleared patch. Then he reverses as before across the last cleared patch into undisturbed area, and repeats the process.

The result is a line of cleared patches, each separated from the

[7] Experiments have since been undertaken to develop procedures for direct seeding the stony areas after reducing the brush with herbicides. These offer considerable promise of success. Also, recent re-examinations of the watershed indicate that much of the area originally scheduled for conversion is developing enough natural tall growth so that seeding or planting will not be necessary for purposes of the watershed study.

[8] McNamara, E. F. CONVERTING SCRUB OAK AREAS. Pa. Forests 52 (2): 22, illus. 1962.

Figure 5. — A site prepared for planting with rootrake by the technique developed on the Dilldown watershed. This area is on State Forest land in Dauphin County, Pennsylvania.

next on either end by a mound of soil and debris (fig. 5). Other lines of patches are prepared parallel to the first, spaced about 10 feet apart edge to edge. Each patch is 10 feet wide (the width of the rake), 10 to 15 or more feet long, and will accommodate 4 to 8 trees at spacings of approximately 6 feet.

This method of preparation was devised and adopted for reasons of economy. The cross-pushing procedure, when tried in the conversion job, was costing more than twice as much as in the experimental job because the operators were less skillful, the soil conditions were somewhat more difficult, and the rental rate for equipment had increased ($11.00 an hour for a D6 outfit). The

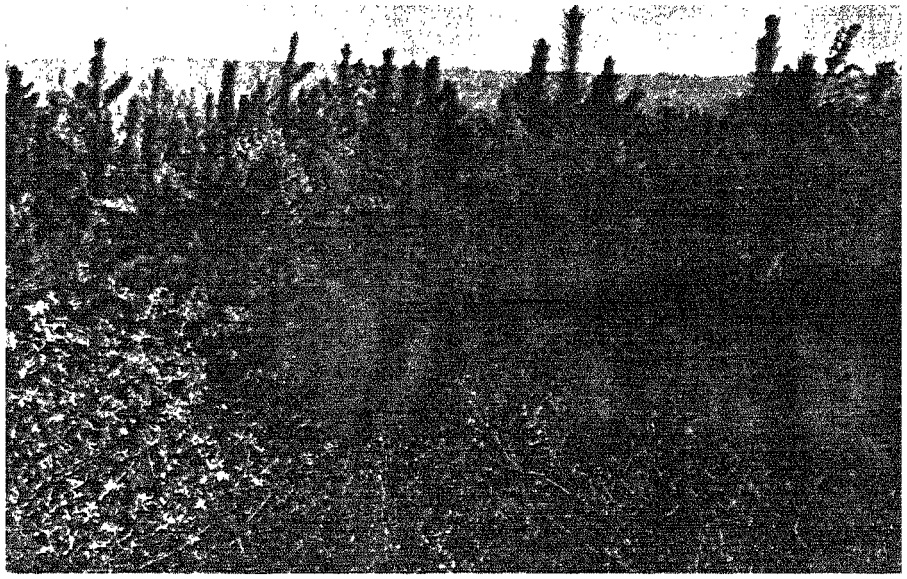
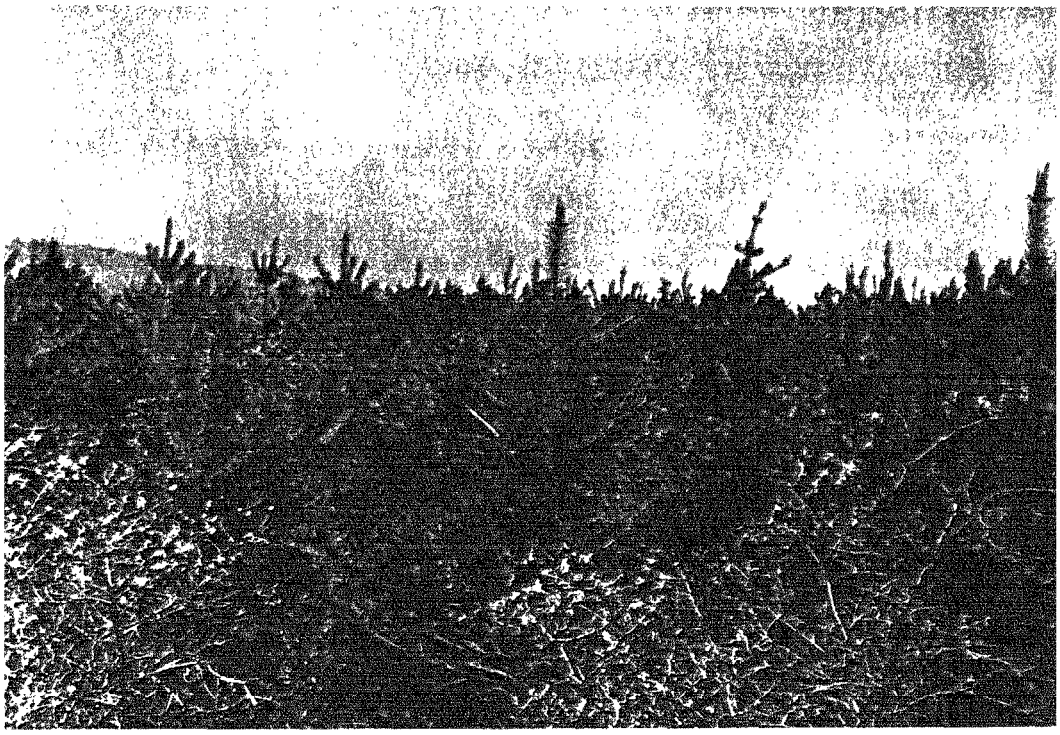


Figure 6. — Red pine planted on the watershed in 1956, photographed in 1965. Trees are mostly 8 to 10 feet tall. This is the site of the first rootrake preparation on the watershed; it was done with the cross-push technique, clearing a continuous lane.

new procedure was simpler to execute because the tractor movements were almost all straight back and forth, with very little turning or other maneuvering required. And, compared to the lanes in the experimental job, the area cleared per acre was less by the amount of space occupied by the mounds of debris. So, the work progressed somewhat faster on an acre basis. But despite the more efficient procedure, costs on the conversion job ran somewhat higher than on the experimental job, probably because ground conditions were generally more difficult. The average cost on 245 acres worked by this procedure was $17.81 per acre.

The lines of separate cleared patches provide somewhat less planting space per acre than cleared lanes. Another undesirable feature is the mounds of debris between the patches: These impede planting to some degree because the men have to scramble over or around them as they move from one patch to another. Nevertheless, this method of site preparation is the most practicable one yet devised for planting the scrub oak lands. It permits the planting of 600 to 800 trees per acre in positions where they will grow without requiring any subsequent release. The number of trees planted will vary according to how well the planters utilize the available space: by placing some trees at or in the toes of the mounds, and by judicious tightening of the spacing where this will

Figure 7. — Scotch pine, planted in cleared patches in 1957, emerging above the brush in 1965. Most of the trees are 9 to 10 feet tall; occasional ones are up to 12 feet tall.



permit planting another tree or two in a patch, 800 trees per acre are possible.

The distribution of the trees within a planted area is, of course, not in the regular pattern of old-field planting, but it is such that we believe closed stand conditions will eventually develop. In general, if the distance between lines of patches does not exceed 10 feet, the distance between clumps of trees should seldom exceed 15 feet.

Red pine, scotch pine, and European larch were the main species used in the conversion planting. Japanese larch, which would have been preferred over the European species, was not available from Pennsylvania nurseries when needed in 1957. The planting, done by contract, cost about $20 an acre. With trees figured at the nursery price of $6 per thousand, the total planting cost for site preparation, planting, and stock was about $44 an acre.

Survival and growth of the trees have generally been good. Survivals for different lots of stock or locations at the end of the third growing season ranged from 83 to 91 percent. Sample measurements in the 1956 planting of red pine and the 1957 planting of scotch pine showed heights predominantly in the range of 8 to 10 feet for both species in the spring of 1965. Two-foot internodes for 1964 were not uncommon. Barring fire, the conversion plantings show excellent promise of developing into thrifty, well-stocked coniferous stands (figs. 6 and 7).

OTHER CONVERSION PLANTINGS

Pennsylvania foresters, particularly those responsible for management of the State Forests, watched with interest as success became evident in the site-conversion experiments at Dilldown. The rootrake offered, for the first time, a machine and a technique that seemed practical and economically feasible for converting at least some of the State's unproductive brushland areas to productive forest. Moreover, the rootrake technique would substantially reduce the risk of disastrous wildfires for a number of years because of the repeated breaks in continuity of the fuel.

The first brushland conversion plantings by the rootrake tech-

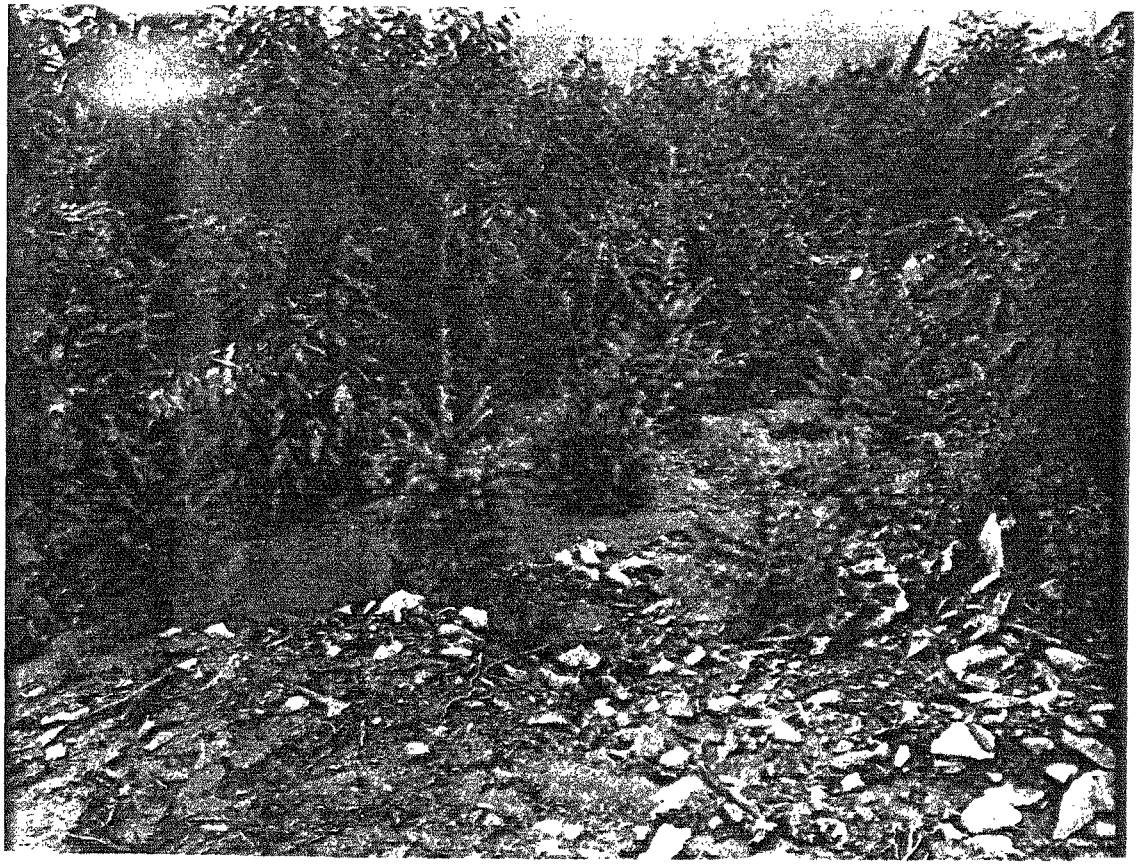


Figure 8. — Japanese larch 2 years after planting in a patch cleared with a rootrake; on State Forest land, Dauphin County. Although the brush here is relatively tall, the larches give promise of emerging above it without difficulty.

nique on areas other than Dilldown were begun in 1957. During that year and since, 567 acres on State Forest land in three forest districts, 47 acres on a municipal watershed, and 20 acres of private land have been prepared and planted. In addition, 140 acres of States Forest land were prepared in the fall of 1965 for planting in 1966.

The practice on all these jobs has been basically the same as in the watershed-conversion planting at Dilldown; that is, to clear lines of small separate patches, usually in the fall, followed by hand planting of 700 to 800 trees per acre the next spring. However, different makes of rootrakes, different makes and sizes of

tractors, different operators of varying degrees of proficiency, differences among the sites, and differences among planters and in number of seedlings planted per acre all conspired to bring about considerable variation in per-acre costs.

The species planted have been Japanese larch predominantly (fig. 8), plus smaller quantities of red pine, pitch pine, Austrian pine, and Norway spruce. Early survivals have ranged from very good to poor. Some of the poorer survivals can be explained by frost damage, an unusually dry summer after planting, fall planting, and use of planting stock that was not in optimum condition. Cost, survival, and other data extracted and summarized from District Foresters' reports on the State Forest plantings are given in table 1. The survival data should be viewed as merely indicative because we do not know the method or intensity of sampling, and we do not know whether the sampling was done the first fall after planting, the next spring, or later.

One private landowner in Monroe County rootraked and planted about 20 acres of scrub oak land in 1960 and 1961. Japanese larch, red pine, and Norway spruce were planted, larch making up 78 percent of the total. We do not have definite cost and survival data. The costs apparently were about in line with those on the State jobs. Survival both years was reported as excellent.

It is of passing interest that this planting qualified for payments under the Agricultural Conservation Program at the approved rate of $19 per acre for site preparation by rootrake.

In the fall of 1964, the Bethlehem Authority rootraked 47 acres of brushland on their holdings in Monroe County. They used a TD-18 tractor, a bigger machine than was used on the other jobs. Site-preparation costs were $28.68 per acre, which the supervising forester felt could be substantially reduced after the tractor operator had gained more experience. About 600 red pine and Japanese larch seedlings per acre were planted in 1965 at a per-acre cost of $16.91. This was a lower rate of planting and a lower planting cost than in any of the other jobs. No survival data are yet available.

By and large, the costs have been higher and seedling survivals somewhat lower in these other conversion plantings than in those at Dilldown. Perhaps this was to be expected because the whole

Table 1. — Cost, survival, and other data on rootrake plantings on State Forest land in Pennsylvania

Location	Year of planting	Area planted	Species	Cost per acre		Survival
				Rootraking	Planting	
		Acres				*Percent*
Dauphin County, District 18	1957, 1958, 1960, 1963, 1964	503	Japanese larch	$18.26[1] ($17.95-18.85)	$40.67[1] ($27.73-54.82)	79[1] (60-95)
Pike County, District 19	1961, 1962	15	Japanese larch Red pine Pitch pine Norway spruce	21.60	33.68	85[2]
Snyder County, District 7	1960	49	Japanese larch Austrian pine	36.73	40.02	70 40

[1] First figures given are weighted averages; figures in parenthesis show the range in values.
[2] 1961 planting only.

procedure was new to both supervisory personnel and tractor operators; they had to gain experience on the job. And the competence of the tree planters probably did not average as high as in the Dilldown crew. Also, considerably more than the recommended 700-800 seedlings per acre were planted in some of the jobs, which would increase planting costs.

Survivals are known to have been adversely affected by drought and frost in some places. Fall planting was done on at least one occasion, and stock that had been heeled-in over winter or longer also was used on two jobs. These practices probably accounted for some of the poorer survivals.

Conversion planting in the scrub oak type will never be easy or inexpensive. But the rootrake technique for site preparation does provide a way to plant such areas successfully at a cost that can be borne, particularly where other values in addition to timber are involved on public lands. One compensation for the relatively high initial costs is that, ordinarily, no subsequent release treatments will be required. Costs can be expected to decline somewhat as supervisory and operating personnel gain experience. And good planting stock, properly handled and planted at the proper time, should assure a high percentage of success.

DISCUSSION

Successful conversion of scrub oak or other brushland types by planting depends upon a practicable method of site preparation. Herbicides are not the answer because planters cannot work effectively in standing dead brush. Furthermore, if only herbicides were used, the tough mat of ericaceous roots and the layer of rocks that often lies at the soil surface would be additional impediments to efficient planting. These obstacles must be broken up and moved aside by mechanical means so that planters can work in cleared spaces. There may still be rocks to contend with, but since the rocks in many places are concentrated near the soil surface, they can be loosened and moved sufficiently to permit planting.

Furrowing with a heavy bulldozer (D7 or equivalent) was the first practicable site preparation method developed in the Dilldown experiments. The 47-acre plantation growing there today demon-

strates its efficacy. This plantation was given no release after planting. However, a few trees were suppressed by brush leaning over from the sides of the furrows. In brush types containing a large proportion of tall-growing, heavy-foliaged sprouts of tree species, greater losses than were experienced at Dilldown would occur unless release treatments were made.

Site preparation by clearing lanes or patches with a rootrake is a better method because the cleared spaces are wider than the bulldozed furrows. All trees planted in these clearings have open space on one side at least, and very few are likely to be suppressed, even by brush that grows taller than typical scrub oak.

Although continuous cleared lanes would be preferable, lines of separate patches prepared by the method developed in the Dilldown watershed planting is a practical concession to cost realities. This method provides space for planting 600 to 800 trees per acre in a pattern that should result in stand closure as the trees reach pole size.

Where planting costs of $50 or so per acre can be justified for converting brushlands to coniferous forest, the rootrake method of site preparation is recommended wherever soil conditions and terrain will permit operation of this equipment. Where a rootrake is not readily available, and where tall-growing, heavy-foliaged tree sprouts are not predominant in the brushy growth, bulldozer furrowing might be considered as a second-choice method.

Mechanical site preparation and planting are, of course, not feasible in much of the brushland of the Poconos and the Northeast as a whole. Rough or steep terrain rules out tractor equipment in many places. Furthermore, thin soils over residual rock, or excessive glacial deposits of loose rock, often rule out mechanical site preparation as a practical measure. The presence of brushy growth does not mean that a site is plantable. Therefore, one of the first tasks facing a land manager when considering conversion planting is to determine the location and amount of area that actually is plantable. Only then can he begin to plan intelligently in terms of acres and costs.

SUMMARY

Tree planting experiments in the scrub oak type of the Pennsylvania Poconos are described. The first experiments in 1948, with hand tools and farm machinery, demonstrated that adequate site preparation could be accomplished only by use of heavy equipment. During the years 1950-53, a D-7 bulldozer, a heavy rototiller, and a rootrake mounted on a D-6 tractor were used in planting trials of 10 to 47 acres.

Fairly good site preparation was possible by furrowing with a bulldozer; trees planted in the furrows generally came through without later release. Double tilling with the rototiller also resulted in good site preparation; but this method was not practical because of the need for two passes over each planting strip, and also because the machine was not rugged enough to stand up under the rigorous operating conditions of the stony brushlands. The rootrake proved to be best suited for the job.

After several procedures were tried with the rootrake, a technique was devised by which separate patches, each 10 by 15 to 20 feet, were cleared in lines about 10 feet apart. Usually 6 to 8 trees were planted in each patch. The planted trees have grown well without follow-up release treatments, and are expected to create closed-stand conditions as they reach pole size.

Red pine and Japanese larch are the most highly recommended species for such plantings. Scotch pine also does well during the first decade or so.

After the original trial of the rootrake in 1953 demonstrated its merits, about 285 acres were prepared by rootraking and were planted in 1956 and 1957 as part of a watershed study. At the equipment rental rates prevailing at that time, the rootraking cost $17.81 per acre. Total planting costs (preparation, seedlings from a state nursery, and planting labor) were about $44 per acre.

Since 1957, almost 800 more acres of brushlands in the Pocono region have been similarly prepared and successfully planted on state forest, municipal watershed, and private land.

This method of site preparation and planting can be recommended wherever the terrain and stone content of the soil will permit a rootrake to be effectively operated.