A FURROW-SEEDER for the Northeast

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U.S.D.A. FOREST SERVICE RESEARCH PAPER NE-150
1969

NORTHEASTERN FOREST EXPERIMENT STATION, UPPER DARBY, PA.
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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INTRODUCTION

ON MANY acres of unproductive wild lands in the Northeast, planting or seeding is needed to establish new stands of conifers. However, planting is very expensive on these lands, and direct seeding has often failed.

Our research on direct seeding over the past several years has shown that mineral soil seedbeds and shade from an existing overstory will provide a microenvironment favorable for germination and seedling survival *(McConkey 1964, Graber 1965 and 1968)*. We have also found that the protective (endrin-arasan) coating used in the South to prevent destruction of seed by birds and small mammals does not offer adequate protection under northern conditions unless the seed is covered with soil *(Graber 1969)*.

Furrow-seeding techniques seem to offer the best means of providing these desired conditions at reasonable cost *(Croker 1967)*. A tractor-drawn furrow-seeder prepares a mineral seedbed, sows and covers the seed, and can be maneuvered so as to leave some existing vegetation between furrows for shade.

Since no commercial equipment was suitable for use under typical northeastern brushland conditions, we adapted existing equipment to suit our needs. From a fireline plow and a beet planter, we devised a furrow-seeder. We tested it over a wide range of site conditions to evaluate its operational efficiency and to determine the stocking of red and white pine seedlings that were established through its use (fig. 1).

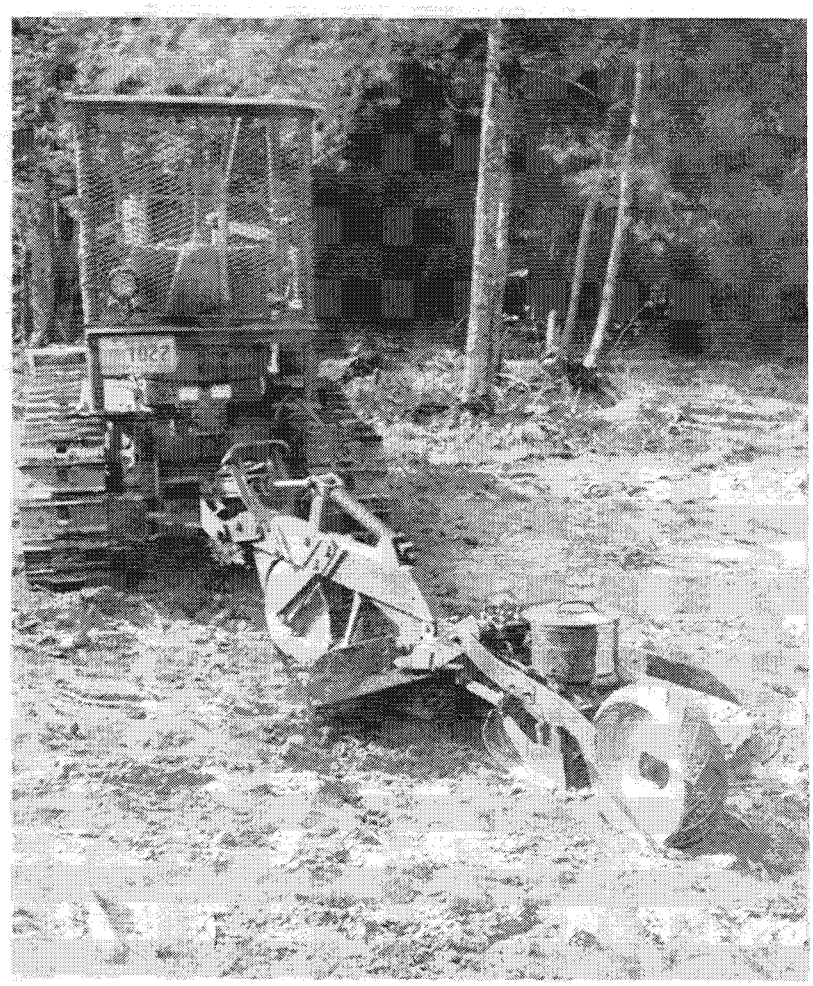

Figure 1.—A furrow-seeder, devised from existing equipment, was used successfully over a wide range of Northeastern soils, vegetation, and topography.

We found that the unit performed satisfactorily and promoted favorable seedling emergence, survival, and stocking at all locations tested. Direct seeding with this equipment costs between $7 and $15 per acre. We believe that this furrow-seeder will provide a reliable means of establishing pine on lands now occupied by brush or low-quality hardwoods—and at about one-third the cost of planting nursery stock.

EQUIPMENT

The equipment used and modifications required have been described in detail previously *(Graber and Thompson 1967)*. The new furrow-seeder consists of a modified International Harvester beet planter, coupled behind a fireline plow (Sieco C154). The rig is pulled by a small crawler tractor (John Deere 1010).[1] The tractor and fireline plow had previously been found capable of producing an excellent mineral-soil seedbed at low cost, and it worked well on the stony, wooded lands commonly encountered in the Northeast.

Modifications made to the seeder included: the use of an oversized drive wheel and a runner opener with a steel ski on the bottom; a new free-floating mount that allowed the seeder to ride up over obstacles such as large stones, stumps, or logs; and general reworking and strengthening of the seeder unit at all points of strain.

METHODS

The furrow-seeder trials were conducted over a variety of field conditions in southwestern Maine, including dominant vegetation ranging from grass to sapling and small pole hardwoods; soil ranging from outwash sands to stony tills; and topography ranging from level land to 30-percent slopes (table 1). Two-acre plots of typical combinations of vegetation, soil, and topography were established at nine locations. At each location, 20 parallel furrows were plowed and seeded in the spring of 1967. The furrows were 400 feet long with a 12-foot interval from furrow center to furrow center.

This relatively wide spacing between furrows was necessary to allow the operator sufficient room to maneuver around obstacles on the more difficult plots. The interior 12 furrows at each location consisted of two six-furrow replications to allow a statistical

[1] The furrow-seeder was developed and tested cooperatively by the Maine Forest Service and the Northeastern Forest Experiment Station, Forest Service, U. S. Department of Agriculture. Mention of a brand name does not imply endorsement by the Forest Service or the Department of Agriculture.

Table 1.—*Description of experimental plots*

Plot name	Dominant vegetation: Type	Dominant vegetation: Mean basal area	Dominant vegetation: Mean d.b.h.	Dominant vegetation: Mean height	Dominant vegetation: Stems/acre	Surface obstacles: Stones 6 inches plus	Surface obstacles: Stumps and down trees	Slope	Soil type
		Square feet	*Inches*	*Feet*	*Number*	*Percent*[1]	*Percent*[1]	*Percent*	
Brandt field	Native and introduced grasses	—	—	—	—	0.6	—	0-8	Gloucester sandy loam
Smith field	Native and introduced grasses	—	—	—	—	5.9	—	0-8	Gloucester stony sandy loam
Ross brushland	Scrub oak[2]	16	0.6	6	5,520	0	0	0-6	Adams loamy sand
Ross brushy hillside	Scrub oak	26	.7	7	7,820	0	0	10-30	Adams loamy sand
Rosen woodland	Quaking aspen[3]	56	1.1	14	7,440	0	0	0-2	Ninigret sandy loam
Smith woodland	Gray birch,[4] paper birch[5]	14	1.7	18	860	3.2	0	0-3	Gloucester stony loam
Smith wooded hillside	Paper birch, black oak,[6] red maple[7]	27	2.0	21	1,020	2.6	3.8	10-20	Gloucester stony sandy loam
Nalf woodland	Red maple, black oak, gray birch	20	2.2	20	638	8.6	2.1	0-3	Paxton stony fine sandy loam
Bachand woodland	Black oak, paper birch, red maple	49	3.1	26	869	13.6	0	0-10	Sutton extremely stony fine sandy loam

[1] Percentage of surface area occupied by obstacles.
[2] *Quercus illicifolia* Wang.
[3] *Populus tremuloides* Michx.
[4] *Betula populifolia* Marsh.
[5] *B. papyrifera* Marsh.
[6] *Q. velutina* Lam.
[7] *Acer rubrum* L.

test of the location effect. The six-furrow replications were divided into two subplots of three furrows each, and to each was randomly assigned a species treatment of either red pine *(Pinus resinosa* Ait.) or white pine (*Pinus strobus* L.)

Seedling emergence, survival, and stocking observations were made at ten randomly selected sample points in each subplot. Seedling data at each sample point were collected on a 6-foot furrow segment that was divided into two 3-foot furrow segments or subpoints.

Analysis of variance was used to test the significance of the location and species effects. When these effects were significant, statistical comparisons among treatment means were made, using Duncan's *(1955)* new multiple-range test.

The site preparation (furrowing) and seeding were carried out in a continuous operation with the furrow-seeder. The seeds were dropped at uniform intervals (approximately 7 inches apart) into a narrow groove cut in the bottom of the furrow by the runner opener. The seed was then pressed into firm contact with the soil by the packing wheel and covered with loose soil by a chain dragged behind the packing wheel.

Before sowing, the white pine seed had been stratified 60 days at 40°F. to break dormancy. The seeds of both species were coated with arasan and endrin.

RESULTS & DISCUSSION

Furrow-Seeder Production

Detailed records of time required for furrow-seeding at each location were kept to provide a measure of productivity under each set of field conditions (table 2). These data are actual operating times on the study area, with no allowance for transportation, for unloading, for moving the equipment to the study area, or for rest breaks.

The effect of location on furrow-seeding time was highly significant (at the 1-percent level). Generally the results (table 2) were quite logical. The almost complete absence of stone at the first four locations listed made possible a significantly faster rate of furrow-seeding. The Brandt field was furrow-seeded very

Table 2.—*Furrow-seeder production, in minutes*

Location	Mean time[1] per 400-foot furrow	Calculated time/acre
Brandt field	1.66	15.1
Ross brushland	3.10	28.1
Ross brushy hillside	3.53	32.0
Rosen woodland	3.62	32.8
Smith field	4.43	40.2
Smith wooded hillside	4.55	41.3
Nalf woodland	5.06	45.9
Smith woodland	5.32	48.3
Bachand woodland	6.14	55.7

[1] Duncan's new multiple-range test. Means not connected by a vertical line differ significantly at the 5-percent level.

rapidly because of the gentle topography, excellent visibility, and the almost complete absence of any obstacles, eliminating any need to maneuver the tractor. This allowed the driver to shift into a high gear and operate at full throttle. The woody plant cover at the Ross and Rosen locations caused a signicant slowing of operations even in the absence of stone. The large amount of stone in the Smith field necessitated frequent maneuvering to avoid collisions, forcing the tractor operator to reduce his speed.

Further reductions in operating speed were necessary when both stone and overstory trees and other obstacles were encountered. The thicker the maze of all obstacles combined, the slower the furrow-seeding, simply because of the time required by the operator to pick a suitable path and maneuver the equipment past the obstacles.

Species composition and size of dominant vegetation caused differences in ease of movement of the equipment. Where the dominant plants were small, with a mean d.b.h. of 1 inch or less, species mattered little. Larger trees—especially species such as oak, maple, or birch—offered much more resistance. Ordinarily it was much quicker to bypass these trees than to push them aside. Soft brashy-wooded species, such as aspen, offered very little resistance, at least in the sizes encountered here.

The influence of slope on rate of furrow-seeding was obscured by other factors that had a greater bearing on operating efficiency. The Ross brushy hillside plot (20 to 30 percent slope) took slightly longer to furrow-seed than the adjacent Ross brushland plot (0 to 6 percent slope), as might be expected; but the differences were not significant. The reverse was true at the Smith locations, where the wooded hillside plot (10 to 20 percent slope) required significantly less time to furrow-seed than the adjacent woodland plot (0 to 3 percent slope). In spite of these contradictory results, a noticeable if unimportant reduction in production did occur, especially where the side slope exceeded 25 percent. It was necessary for the operator to exercise greater caution on these steep side slopes, which reduced production.

Degree of Seedbed Preparation

A rough measure of seedbed quality is the area of mineral soil exposed. After furrow-seeding, the furrow width was determined at 10 randomly selected points in each of the 12 study furrows at each location. The average width of each replication was then multiplied by the combined furrow length, 2,400 feet, to give area. These areas are given in table 3.

Table 3.—*Seedbed area*

Location	Mean area of mineral soil[1] per six 400-foot long furrows
	Square feet
Brandt field	7,440
Smith field	6,240
Ross brushland	6,240
Smith woodland	5,640
Smith wooded hillside	5,640
Ross brushy hillside	5,280
Rosen woodland	4,800
Nalf woodland	3,960
Bachand woodland	3,600

[1] Duncan's new multiple-range test. Means not connected by a vertical line differ significantly at the 5-percent level.

The fireline plow cleared a furrow 6 inches deep and 38 inches wide under optimum conditions. Where stones, roots, stumps, and trees interfered, the furrow was both shallower and narrower; and, under very difficult conditions, a skip occurred.

Differences among the nine locations in the amount of mineral soil exposed were highly significant. Large amounts of mineral soil were exposed in the open fields and on the level Ross brushland tract. Where the equipment was operating on a side slope, there was a tendency for the turned-out furrow slice on the uphill side to fall back into the furrow. This falling-in of the furrow caused low ranking of the Ross brushy hillside tract.

Where furrow-seeding was difficult, as on the Nalf and Bachand tracts, the area of mineral soil seedbed was reduced. The results on the Bachand tract were poor because the soil was so stony that the plow was repeatedly forced out of the soil by subsurface stone, and frequently was lifted by the operator to avoid striking large visible stones. An additional difficulty on the Nalf tract was the presence of dense clumps of prostrate juniper (*Juniperus communis* L. var. *depressa* Purch), less than 3 feet high, that occurred in small openings. The juniper stems were very brittle and broke off, fouling the plow and causing it to ride up out of the ground. The results were a narrow furrow and occasional outright misses. It is likely that a V-blade mounted on the front of the tractor would have helped overcome this difficulty. A similar effect reduced the area of seedbed on the Rosen tract; there the soft and brashy aspen overstory was easily crushed by the tractor, but the tops of the trees broke off and collected in front of the plow, gradually lifting it out of the soil.

Clearing the brush-entangled plow was simple but time-consuming, so the tractor operator was instructed to continue plowing as long as the furrow width did not fall below a minimum of 1 foot. To clear the plow, the operator had only to lift it and the seeder off the ground and reverse the direction of travel. The crawler tracks would then catch the dragging brush and debris, pulling it free. Normally it was necessary to back the machine only 10 to 15 feet to completely clear it of entangling brush and debris.

Seedling Emergence

Seedling emergence as a percent of the viable seeds sown was high: the mean value was 73 percent. No significant differences in emergence were found among the nine locations or between the two species. This was partly because the seed was uniformly buried in a well-prepared mineral soil seedbed at all study locations. In addition, the amount and frequency of precipitation during May and June, when most of the seeds germinated and emerged, was generally favorable.

Though there was a wide range in environmental conditions due to differences in soil and vegetation, the effect on seedling emergence was not significant.

Seedling Survival

Seedling survival, as a percentage of the emerging seedlings living at the end of the first growing season, averaged 70.1 percent over the entire experiment. No significant differences existed among the nine locations included in this study. However, there was a significant difference (5-percent level) between species. Red pine seedling survival was 74.5 percent, while white pine survival was 67.0 percent. This reflects the better adaptation of red pine to the more exposed conditions during the first growing season.

At the end of the second growing season, the species differences were no longer significant. However, the influence of growing conditions (location) was significant at the 1-percent level. Second-year survival as a percentage of seedling emergence ranged from 75.0 to 38.2 percent at the nine locations under study (table 4).

Survival was very good at the Rosen location, primarily due to the high water table at this site, which reduced drought-related losses to one-half of those found on the study as a whole. The major reason for poor survival on the Bachand tract was the heavy losses caused by small mammals soon after seedling emergence, and later trampling by deer. Small mammals at this location caused 14 percent of all losses compared to less than 1 percent on the other locations. Mortality due to deer trampling was five times greater on the Bachand tract (9.5 vs. 1.9 percent) than on the

Table 4.—*Seedling survival at the end of the second growing season*

Location	Seedling survival[1] Percent of emerging seedlings
Rosen woodland	75.0
Ross brushy hillside	64.6
Smith wooded hillside	60.6
Smith woodland	57.0
Ross brushland	53.4
Brandt field	53.4
Nalf woodland	53.2
Smith field	51.8
Bachand woodland	38.2

[1] Duncan's new multiple-range test. Means not connected by a vertical line differ significantly at the 5-percent level.

study as a whole. This, coupled with a heavy litter fall, which caused many seedlings to smother, resulted in significantly poorer survival on the Bachand tract than on any other location.

The major cause of seedling mortality on all locations was drought. Most of these losses took place during and just after germination, before the seedlings became established. Approximately one-half of all seedlings killed during the first growing season died from this cause.

Stocking

A measure of seedling stocking provides a practical evaluation of the success of a seeding operation. Stocking is given as a percentage of 3-foot-long sample segments (subpoints) with one or more seedlings. At the end of the second growing season, average stocking was 70 percent. The effect of location was significant at the 1-percent level. Naturally, the ranking of locations from the best to the poorest was similar to the ranking under survival (table 5).

The Bachand tract was appreciably poorer than any of the other locations because of the seedling mortality discussed in the preceding section. It is our estimate that 50 percent or better stocking is adequate at the end of the second growing season.

This would mean that only the Bachand tract is in danger of a failure, and even here, the linear increment used to measure stocking has a great influence on the data. If a 6-foot furrow increment is used as the basic stocking unit, the Bachand tract value would increase to 72.5 percent stocked.

Table 5.—*Seedling stocking*

Location	Percentage of stocked[1] 3-foot furrow segments
Rosen woodland	87.8
Ross brushy hillside	83.8
Ross brushland	83.8
Smith woodland	73.8
Smith wooded hillside	70.0
Smith field	65.0
Nalf woodland	62.5
Brandt field	61.5
Bachand woodland	45.0

[1] Duncan's new multiple-range test. Means not connected by a vertical line differ significantly at the 5-percent level.

Efficiency of the Furrow-Seeder

A combined measure of the efficiency of the furrow-seeder method is possible by testing statistically the machine time per hundred stocked 3-foot furrow segments. The effect of location was again significant at the 1-percent level (table 6).

This measure of production efficiency indicates that a large difference exists in time expended per unit of stocked furrow. The time-stocking ratio was nearly five times greater on the Bachand tract than on the Brandt field. The four top-ranked locations had dominant vegetation that offered relatively little resistance to the furrow-seeder equipment and little or no stone. The second group of four locations showed the effects of increasing amounts of stone and a heavier stand of dominant trees.

It would appear then, that the best economic choice might be to seed those locations that offer the least resistance to machine

Table 6.—*Furrow-seeder time per 100 stocked 3-foot segments, in minutes*

Location	Time/100 stocked[1] 3-foot segments
Brandt field	14.54
Ross brushland	18.92
Rosen woodland	20.81
Ross brushy hillside	21.22
Smith wooded hillside	32.44
Smith field	34.28
Smith woodland	36.73
Nalf woodland	43.66
Bachand woodland	69.64

[1] Duncan's new multiple-range test. Means not connected by a vertical line differ significantly at the 5-percent level.

Table 7.—*Estimated furrow-seeding costs*

Item	Cost
Crawler tractor (40 hp.) equipped with dozer blade and double hydraulic system, plus operator. (Contract rate: Includes depreciation, maintenance, repairs, profit)	$ 9.50/hr.
Depreciation, maintenance, and repairs on fireline plow and seeder	$ 1.00/hr.
10-percent allowance to cover lost time for rest stops, moving equipment, and breakdowns	$ 1.05/hr.
TOTAL EQUIPMENT COST PER HOUR	$11.55/hr.
Job layout and technical supervision	$ 1.00/acre
Seed — 10,000 viable pine seeds per acre including protective coating and stratification	$ 3.50/acre
TOTAL SUPERVISION AND SEED COST PER ACRE	$ 4.50/acre

operations. However, this approach ignores site productivity, which over the course of a rotation will probably have a much greater effect on profitability of regenerating a given tract.

Cost of Furrow-Seeding

Cost figures that can be obtained from a study such as this are limited by the lack of more extensive practical trials and must be considered only rough estimates of actual operating expenses. However, even a tentative estimate of cost is helpful in evaluating the furrow-seeder method and providing a basis for comparison with other methods of regeneration.

Using our cost estimates (table 7) and the time to furrow-seed an acre (table 2), we calculated the cost of furrow-seeding on a per-acre basis at each of the nine locations (table 8).

We estimated that typical per acre cost will range between 7 and 15 dollars. These figures are much lower than those for planting nursery stock on similar sites in New England.

Table 8.—*Estimated per acre cost of furrow-seeding*

Location	Equipment-operator (cost/acre)	Supervision-seed (cost/acre)	Total (cost/acre)
Brandt field	$ 2.90	$4.50	$ 7.40
Ross brushland	5.40	4.50	9.90
Ross brushy hillside	6.20	4.50	10.70
Rosen woodland	6.30	4.50	10.80
Smith field	7.70	4.50	12.20
Smith wooded hillside	8.00	4.50	12.50
Nalf woodland	8.70	4.50	13.20
Smith woodland	9.30	4.50	13.80
Bachand woodland	10.70	4.50	15.20

CONCLUSION

A furrow-seeder for use under difficult Northeastern conditions has been successfully developed and tested. It performed efficiently over a wide range of soils, vegetation, and topography. From these trials, we estimate that direct seeding can be accomplished at about one-third the cost of planting nursery stock on similar sites. We believe this equipment will allow forest managers to economically establish pine on lands now occupied by brush or low-quality off-site hardwoods.

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