CONVERTING HARDWOODS
on poor sites
TO WHITE PINE
by planting and direct seeding

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COVER PHOTO—*A typical stand of hardwoods growing on a poor site in West Virginia.*

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Increased Returns From Poor Sites

UNTIL RECENTLY, conversion of hardwood stands on poor sites to white pine (*Pinus strobus* L.) was limited mostly to natural white pine reproduction released from a hardwood overstory, either by killing the hardwoods or by removing them through a timber sale. However, in our effort to increase the returns from poor sites in West Virginia (oak site index 45 to 60) we have been introducing white pine where advanced natural white pine is scarce or absent. The results of several conversion studies completed during the past 6 years and the results of pertinent research conducted elsewhere are summarized and reported here.

Background

Research results give substantial evidence that, within the range of site quality we are working with, white pine grows considerably faster and will yield a higher return than the hardwoods. Doolittle *(1958)* found that, in the southern Appalachians, site index 52 for northern red oak (*Quercus rubra* L.)—47 for white oak (*Quercus alba* L.)—is site index 60 for white pine. In terms of volume production, the projected yield for oak stands on site index 57 was about 5.4 M board feet per acre, compared to 24.0 M board feet per acre for white pine.

We know much about natural white pine reproduction and growth that can be applied to sites where white pine must be introduced by planting or seeding. In its early years, white pine is tolerant of light to medium overstory shade. Although optimum growth is not achieved under these conditions, natural seedlings that survive leaf smothering and other hazards the first few years continue to survive and grow slowly in height as long as they receive 20 percent or more of full sunlight *(USDA 1965)*. However, for optimum growth, established white pines grow best under conditions of greater sunlight.

A recently completed study showed that height growth of white pine seedlings grown 3 years in pots was not appreciably greater under full sunlight than under 55-percent shade (table 1). However, height growth was much less under 80-percent shade, indicating that the point where shade began to seriously affect height growth of seedlings was somewhere between 55 and 80 percent (fig. 1).

Table 1.—*Average total height of white pine seedlings at the end of three growing seasons under four intensities of shade*

Treatment	Percent shade			
	0	55	80	90
	In.	*In.*	*In.*	*In.*
Not released	8.1	8.9	6.4	4.3
Released[1]	—	8.5	6.9	4.4

[1]Seedlings moved to full sunlight at the end of 2 growing seasons and grown in full sunlight for an additional year.

Figure 1.—Total height of white pine seedlings grown in pots under 0, 55, 80, and 92 percent shade, after 3 years.

Three-year-survival averaged 85 percent under 0-, 55-, and 80-percent shade and dropped to 47 percent under 92-percent shade.

Lane *(1959)* concluded from a summary of previous research on release of naturally established white pine under hardwoods that:

- Height of the pines at the time of release was important if the pines were to compete successfully with a regrowth of hardwoods. For example, in the Lake States, white pines 8 feet tall competed successfully with aspen (*Populus* sp.) regrowth, and pines 6 feet tall kept ahead of regrowth of vegetation in cutover oak stands. In New England, the optimum release height for pines was 15 feet when they were dominated by aspen and 12 feet when they were dominated by red maple (*Acer rubrum* L.) (However, our observations in West Virginia indicated that, on most of our conversion sites, white pines more than 3 feet tall compete successfully with the growth of the sprouts and other vegetation after the overstory is cut).
- Intensity of competition is usually greater on the better sites than on the poorer sites. In general, this is considered to be

due largely to the greater abundance and more rapid growth of competing vegetation on the better sites.

- In order of competing ability, gray and paper birch (*Betula alleghaniensis* Britton and *B. papyrifera* Marsh.) are weak competitors, aspen and oaks are intermediate, and red maple is a strong competitor to white pine.

Conversion with Artificial Reproduction

Until a few years ago, conversion to white pine by artificial methods in West Virginia was tried mostly in small underplantings or plantings on cutover areas. The results of underplanting studies showed that, on areas of low site quality, introduced pines survived well under hardwood overstories. The results were not so good on cutover areas, where dense clumps of hardwood sprouts and other vegetation soon provided heavy shade that proved detrimental to pine survival and growth. These effects were more pronounced on the better sites.

The greatest drawback to planting is cost. In the mountains of West Virginia, it has been costing $50 to $60 to plant about 700 trees per acre. To get away from high planting costs, emphasis was shifted to direct-seeding. The shift was encouraged by the development of bird and rodent repellents for seeds and by the successes in direct-seeding the southern pines *(Mann 1965)*.

UNDERPLANTING

Probably the oldest documented white pine underplanting study in West Virginia was begun in 1954 on a typical conversion area on Clover Run near Parsons. The seedlings (3-0 stock) were underplanted at a spacing of about 9 feet beneath a 50-year-old oak stand on a southwest slope. Six plots were laid out on three site strata; the lower-slope plots had an oak site index of 59 *(Schnur 1937)*; middle slope, 53; and upper slope, 45. On one of the site-paired plots, the overstory was untreated; on the other, the overstory was girdled immediately after planting.

After four growing seasons, the treated plots were split, and the pines on half of each were given a second release *(Yawney 1961)*. After 15 growing seasons (in 1968), the plots were remeasured and the results were tabulated.

Survival ranged from 80 to 96 percent and averaged 90 percent for all plots (table 2). Only on the released plots on the best site did survival appreciably differ from the average: there it was lower. This can probably be attributed to a greater surge of competing vegetation after release.

Total height of the unreleased pines on the two poorest sites averaged 2 feet taller than the unreleased pines on the best site (table 3, fig. 2), probably because the overstory was denser on the better site.

Released pines on the upper-slope plot (poorest site) were taller than their counterparts on the middle and lower slopes (table 3, fig. 2). After 15 years, this difference was about 5

Table 2.—*Survival of underplanted white pine after 15 growing seasons*

Oak site index	No release	Released[1]
	Pct.	*Pct.*
59	88.2	80.5
52	91.1	96.1
45	90.5	93.6
Average	89.9	90.1

[1] Averaged for once- and twice-released areas combined.

Table 3.—*Average total height and d.b.h. of underplanted white pine at the end of 15 growing seasons by site index and release treatment*

Plot location	Oak site index	No release		One release		Two releases	
		Height	D.b.h.	Height	D.b.h.	Height	D.b.h.
		Ft.	*In.*	*Ft.*	*In.*	*Ft.*	*In.*
Lower slope	59	4.4	0.17	13.3	1.43	18.1	2.47
Middle slope	52	6.1	.43	11.7	1.17	18.2	2.25
Upper slope	45	6.4	.45	18.8	2.30	19.1	2.49

Figure 2.—Fifteen-year average heights of underplanted white pines: *A*, unreleased pine on poor site, *B*, unreleased pine on best site, *C*, once-released pine on the poorest site, *D*, once-released pine on the best site.

feet for the once-released pines and 1 foot for the twice-released pines.

After 15 years, on the lower-slope and middle-slope plots, appreciably more pines were free to grow or likely to get through on the twice-released areas than on the once-released plots. On the upper slope—the poorest site—two releases showed a much smaller advantage over one release (table 4).

Diameter growth followed the same general relationships with site and release as did height growth (table 3).

We may conclude from this study that on sites similar to the study area:

- Excellent survival of underplanted white pines can be maintained for at least 15 years.
- Without overstory treatment, 3-0 underplanted white pines will average between 4 and 6 feet tall after 15 years.
- After 15 years on areas with an oak site index of about 45, 40 percent of the pines will be free to grow if the overstory is killed at planting time; on areas of oak site index 60, only

Table 4.—*Percentage of underplanted white pines by suppression rating and release treatment at the end of 6 (1954) and 15 (1968) growing seasons*

Year	Oak site index	Suppression rating[1]					
		One release[2]			Two releases[3]		
		A&B	C	D	A&B	C	D
1959	59	12	58	30	42	44	14
1968		20	27	53	50	28	22
1959	52	21	48	31	60	35	5
1968		10	26	64	40	31	29
1959	45	37	46	17	74	19	7
1968		39	19	42	47	29	24

[1]A=Pines free to grow.
B=Pines likely to get through.
C=Pines likely to be suppressed.
D=Pines suppressed.

[2]Released at planting time.

[3]Released at planting time and at 4 years.

half as many pines will be in this favorable position. Two releases on the site of highest quality equalled the effect of one on the poorest.

The release treatments probably were not made at the best time. Planted pines usually require 3 to 5 years before they are well established. Because white pines in juvenile stages are quite tolerant of shade, it might be best to wait 5 to 10 years before release. This viewpoint is supported by results reported by Goebel and Cool *(1968)* in the Upper Piedmont of South Carolina. They reported excellent response of severely suppressed under-planted white pines after 20 years. They said that release response appeared to be related to height of the pines; but after a few years, many of the shorter trees had caught up.

Walters *(1959)* reported good to excellent 5-year survival of white pines planted after clearcutting oak stands in southeastern Ohio. He suggested that on the poorest sites many of the pines keep pace with or outgrow the hardwood sprouts, and thus an early release is probably not justified.

Figure 3.—Typical poor-site-hardwood stand with an understory of advanced natural white pine reproduction.

Table 5.—Average number of advanced white pine seedlings per acre and percent of milacres stocked before and after logging on four typical conversion areas in West Virginia

Time	Cut per acre	Height class (inches)					
		0-6	6-12	12-24	24-36	36+	Total
	Cords	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Before	11.8	1,378	394	484	228	494	2,978
After	—	846	305	400	189	428	2,168
Percent loss	—	39	23	17	17	13	27

Geerinck and others *(1954)* reported high survival of white pines underplanted in mixed stands in Maine after 18 growing seasons. Best height growth was obtained under a light canopy, which minimized the growth of understory vegetation and allowed the more tolerant white pines to grow satisfactorily.

Clements *(1966)* reported that underplanted white pines, 4 to 6 feet tall, competed successfully with understory vegetation in thinned aspen sucker stands in Canada.

The risk in underplanting is that the seedlings will be destroyed if the overstory is removed by a logging operation. To determine what portion of the seedlings might be destroyed, we determined the losses from clearcutting on four typical conversion areas in West Virginia (fig. 3).

Before cutting, the four areas averaged about 3,000 white pine seedlings per acre in the understory; 27 percent of these were destroyed in logging (table 5). Milacre plot stocking, which averaged 84 percent before cutting, dropped to 71 percent. The greatest losses were in the 0- to 6-inch height class. Though most of the seedlings were destroyed by logging, some mortality was probably caused by damping-off, leaf smothering, and animal depredations.

DIRECT-SEEDING

Direct-seeding of white pines is not new. In fact, early seeding trials with this species date back 50 years or more *(Baldwin 1965; Roe 1963)*. Some of the trials have been successful, but a consistent level of success with broadcast and spot-seeding methods has not been attained.

Most failures resulted directly or indirectly from:

- Inadequate site preparation.
- Rodent and bird depredation of seed.
- Unfavorable soil moisture and temperature conditions at time of germination and during the critical first year.
- Low viability of seed and subsequent inadequate seeding rate.
- Smothering of first-year seedlings by hardwood leaves.

Broadcast Seeding

It does not appear that broadcast seeding offers much promise in conversion work in rugged mountain country like West Virginia, mainly because of the difficulty of adequately preparing the site. In addition, most conversion sites are on southerly and westerly aspects, which means that seed lying on the surface is subjected to high temperatures and extreme drying. Thus, short periods of drought may be detrimental to seed germination and seedling establishment.

A large-scale trial of aerial seeding in West Virginia in the spring of 1963 failed. An area of 64 acres, consisting of eight 8-acre plots (four clearcut and four uncut), was seeded from a helicopter at an average sowing rate of 9,000 seeds per acre. An intensive survey of seedlings was made at 60 days, 1 year, and 2 years after sowing. After two growing seasons, less than 1 percent of the milacre plots in any treatment had a white pine seedling. Several factors seemed to be responsible for the failure:

- Lack of rainfall during the critical germination period and afterward in the first summer (this was probably the biggest reason for failure).
- Unfavorable seedbed conditions. Even though about 44 percent of the surface on the logged areas was mineral soil or a mixture of mineral soil and humus, a high proportion of this bare surface consisted of severely compacted horse skid trails.
- Two-low seeding rates.

In another local study, seed was broadcast with a hand seeder in a cutover stand and in an uncut stand at the rate of 1¼ pounds per acre. At the end of the first growing season, milacre stocking (based on 100 milacre plots) was only 20 and 24 percent, respectively.

Spot-Seeding

Because of the lack of success with broadcast seeding, efforts were directed to spot-seeding. In appraising the possibilities of this method, several pertinent questions arose:

- When should seeding be done—before or after removal of the overstory?
- How many seed spots are needed to attain a given stocking per acre?
- Does shape of seed spot affect survival of young seedlings when an overstory is present?
- What effect does initial seed size have on survival and height growth of seedlings?
- How does overstory shade affect the height growth of young seedlings?

Several studies were made to answer these questions. One of these was aimed at determining whether the best time to spot-seed was before or after overstory removal.

Though it was obviously easier to seed in an uncut stand, the results of earlier research had shown that, when this was done, hardwood leaves from the overstory trees smothered many newly germinated pine seedlings.

From observations of some spot-seeding done under canopy, it appeared that the configuration of the seed spot was also an important factor: the deeper the scalp, the greater the tendency for leaves to accumulate in the spots and smother newly emerged seedlings. From this observation, it was hypothesized that low mounds might elevate emerging seedlings and thus reduce losses from leaf-smothering.

A study was begun in 1966 to determine the effect of seedspot configuration on the emergence, survival, and growth of seedlings. Under a hardwood overstory on a slightly better than average conversion site, 8 to 10 Arasan-Endrin repellent-coated seeds (see appendix I) were sown during the dormant season in shallow concave seed spots ($\frac{1}{2}$ to 1 inch deep) and on low mounds of mineral soil (about 2 or 3 inches high). An attempt was made to protect half of the seed spots from smothering by manually removing the leaves from them, but the wind usually blew the leaves back into the shallow holes, and the treatment was ineffective. Few of the mounds ever became covered with leaves.

Seed size was also considered in the study to determine whether larger and heavier seeds produced taller seedlings than small seeds.

Maximum stocking for both mounds and holes occurred about mid-July during the first growing season (81 and 76 percent respectively). Thereafter, to the end of the growing season, mound stocking decreased 4 percent and hole stocking decreased 10 percent (table 6). Overall mortality of seedlings during the first growing season was due mostly to damping-off (38 percent)

Table 6.—*Percent of seed spots containing seedlings*
[Each value is based on 200 spots]

Seedspot shape	Initial seed size[1]	Date				
		9/67	7/68	10/68	4/69	10/69
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Mound	1	84	44	41	17	21
....	2	69	43	39	27	28
....	3	79	44	41	24	27
Average	—	77	44	40	23	25
Hole	1	60	17	15	10	13
....	2	82	39	40	22	26
....	3	55	31	23	20	21
Average	—	66	29	26	17	20

[1] 1 = Seedlot run, not graded by size.
2 = Large seed (average weight 23.3 mg.).
3 = Small seed (average weight 17.3 mg.).

and to soil washing away from the roots on mound spots (53 percent).

During the first winter, the number of spots containing one or more seedlings decreased 50 percent in both types of spots. Frost-heaving caused most of the mortality on mounds, smothering by hardwood leaves caused much of it in the holes. The same factors caused additional mortality the second winter. By the end of the third growing season, only 25 percent of the mounds and 20 percent of the holes had one or more seedlings. No statistically significant difference in spot stocking showed up between treatments for any period.

Lack of protection from leaf mulching probably contributed to frost-heaving on mounds. On the other hand, where leaf mulching occurred in the holes, many seedlings smothered. It would seem that level seed spots—those with slightly convex or concave configuration—would be preferable. For best results, these too would need some protection from leaf accumulation.

At the end of three growing seasons, no differences in seedling height could be attributed to seed size.

In contrast to the results of this study of spot-seeding under canopy, a survey of spot-seeded areas where the canopy was removed showed much better results. Surveys were made of 12 clearcut areas that were spot-seeded (hole method) at a spacing of 8 by 8 feet either just before logging or during the first dormant season after logging. Survival tallies made 3 to 5 years after seeding showed that 66 percent of the spots contained one or more living seedlings (table 7). A relatively constant level of success was attained in early establishment of pine in spite of competition from stump sprouts and other vegetation. However, observations indicated that most of the surviving seedlings would require release before they could be considered free to grow (fig. 4).

Table 7.—*Summary of white pine seed-spot trials on clearcut conversion sites on the Monongahela National Forest*

Ranger district	Compartment No.	When seeded	Seedling age	Spots with one or more seedlings	Seedlings per acre[1]
			Yrs.	*Pct.*	*No.*
White Sulphur	A-20	After cut	5	76	517
	A-14	” ”	4	68	462
	D-6	” ”	4	79	537
	D-9	” ”	4	78	530
	A-14	” ”	3	55	374
	D-6	” ”	3	65	442
	A-20	” ”	3	71	483
	D-13	” ”	3	55	374
Potomac	#1	” ”	3	53	360
	#2	” ”	3	44	299
	PR	Before cut[2]	5	77	524
White Sulphur	A-14	Before cut[2]	3	67	456
Average, all areas		—	—	65	447

[1]Based on 680 spots per acre and at least 1 seedling per spot.
[2]Seeded in winter; canopy removed before the end of the ensuing growing season.


Figure 4.—Three-year-old spot-seeded seedlings in need of release.

Discussion and Recommendations

Conversion or partial conversion of hardwoods to white pine on poor sites—site index 45 to 60 for oaks—definitely offers an opportunity to increase the value of products grown. Moreover, once the white pine has been successfully established, it can probably be maintained indefinitely as an important constituent of the stand through the use of judicious cutting practices.

The cost of conversion deserves considerable study because this operation comes early in the life of the stand, and interest charges mount up by the time the pine is ready to cut. For example, \$10 carried 60 years at 6-percent interest amounts to about \$330.

Both planting and direct-seeding have been used to establish white pine in areas of low site quality occupied by hardwoods. Direct-seeding in spots has been most frequently used of late to avoid the high cost of planting and the poor success of broadcast seeding. However, recent research results indicate that spot-seeding should be limited to areas without an overstory, because leaf accumulations smother the young pines. And when seeding is done immediately before or after the overstory is removed, the young pines may have to be released twice before many are free to grow. Moreover, the recent ban on hard pesticides has eliminated the use of Endrin as a rodent repellent, which precludes spot-seeding in areas of high rodent populations. Covering untreated seed with a thin layer of soil has prevented serious depredation in New England *(Graber 1969)*, but has not been tested in West Virginia.

Thus a number of considerations are involved in deciding whether to convert or not and, if conversion is favored, what method to use. Research and observations have given us some basis on which to predict chances of success by the different methods. To illustrate, we assumed a goal of 200 established stems per acre 3 years after planting or seeding. We determined the number of planted seedlings or seeded spots necessary to attain this goal by applying survival figures obtained from various studies (table 8).

Considering the results (table 8), we would probably not consider direct-seeding under a canopy. It is unlikely that we would be willing to accept the costs of preparing and sowing 1,370 spots per acre to get 200 established seedlings. The other three methods offer reasonable possibilities, but the data do not show all of the considerations involved.

For example, if we planted recently cutover land, we would need to plant only about 222 trees per acre to have 200 surviving at 3 years. However under these conditions, we would need to make one and possibly two releases to bring a satisfactory number of pines through. In spot-seeding recently cutover land, we would almost surely have to make two follow-up releases. Moreover, with the ban on the use of Endrin as a rodent-repellent seed-coating, direct-seeding would be a risky proposition in West Virginia.

This leaves understory planting. With this method there would be no urgency to release the pines for 5 to 10 years; during this

Table 8.—*Estimated number of seedlings to plant or seed spots to prepare to attain a goal of 200 established white pine seedlings at the end of 3 years*

Item	Planting		Direct-seeding	
	With over-story	Cutover land	With over-story	Cutover land
Expected survival at end of 3 years (percent)	90[1]	90[1]	20[2]	65[3]
Expected loss (percent) in number of seedlings as a result of logging overstory	27[4]	—	27[4]	—
Approximate initial number of seedlings to plant or spots to prepare	304	222	1,370	308

[1]From table 2, percent of planted seedlings surviving after 15 years.
[2]From table 6, percent of spots with 1 or more seedlings at the end of 3 years.
[3]From table 7, percentage of spots with at least 1 seedling.
[4]From table 5, percent of seedlings destroyed during logging of hardwood overstory.

period we would not expect mortality to be more than 10 to 15 percent. If the pines were 5 to 10 years old when the overstory was cut, we could expect most of them to develop without further release.

In summary, it seems best to plant 100 to 400 stems per acre (depending on how complete a conversion is desired) under canopy and let them grow for 5 to 10 years before the overstory is removed. Expected mortality would be about 35 percent through the overstory-removal period.

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Appendix I

Caution about Pesticides

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife — if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

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