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TREE PLANTERS' NOTES

FOR PLANTERS OF FORESTS AND SHELTERBELTS AND FOR NURSERYMEN

U.S. DEPARTMENT OF AGRICULTURE • FOREST SERVICE

CONTENTS

Cover--Pine seedlings ready for harvest at the Florida Forest Service's Andrews Nursery, Chiefland, Fla.

DIRECT SEEDING MACHINE

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A new type of seeding machine for planting Southern pine performed well in shakedown tests this spring at the Tuskegee National Forest (fig. 1).

Researchers of the U.S. Forest Service Forest Engineering Laboratory cooperating with the Agricultural Experiment Station at Auburn University reported good results when the new seeder planted 90 acres to longleaf pine. Planting was in 9-foot rows using 90 pounds of seed.

The new machine has the advantages of providing positive precision control of seed spacing and preventing damage to seed that often

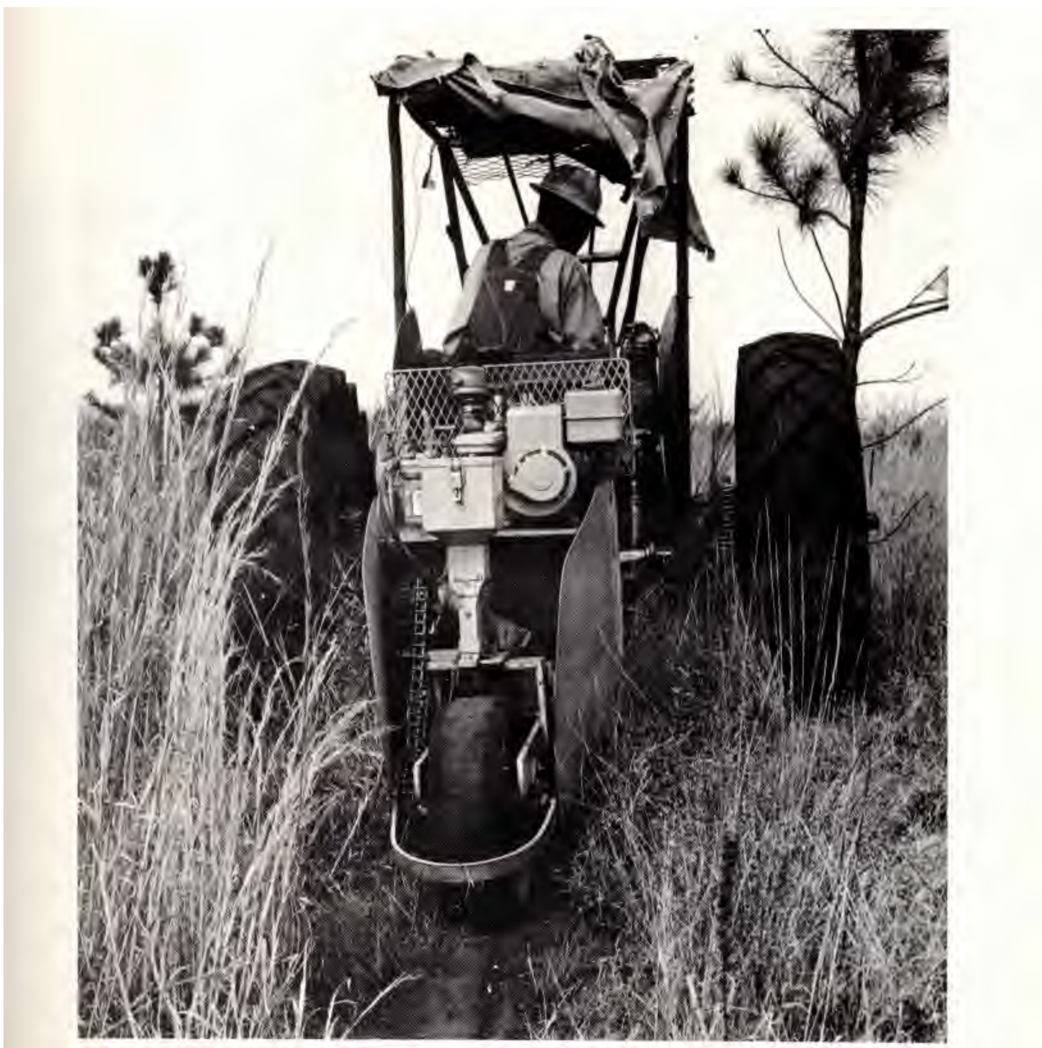

Figure 1.--The new pine seeder, a pneumatically operated seeding system, mounted on a standard furrow seeder, gave good results in pine planting tests. The machine is seeding longleaf pine at the Tuskegee National Forest.

occurs with planters using plate-type mechanisms. Operating under a pneumatic system, the seed pickup is not affected by seed size or shape. This makes it readily adaptable to use with various species of Southern pine, according to Heyward Taylor and Boone Richardson, project leader and agricultural engineer at the Laboratory.

Engineers at the University of Idaho designed the original seeder. It was modified for Southern pine species by the Arcadia Equipment and Development Center of the U.S. Forest Service. The Arcadia Center constructed the prototype machine and tested it in the Laboratory. Engineers from the Auburn Laboratory mounted the penumatic system on a standard Forest Service furrow seeder.

Taylor and Richardson say the Tuskegee tests proved the system reliable and that plans and specifications for a new seeder should be available to landowners by late 1965, Some minor parts were redesigned to reduce wear and improve performance.

SIMPLIFIED PLANTING TECHNIQUE FOR PINUS SPECIES

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In experiments to evaluate the significance of certain mycorrhizae to the incidence of root rot in Pinus radiata seedlings, various methods of isolating the plants from soil influences were used.

One method involved the use of foam plastic (Estafoam). This method of growing Pinus radiata was so successful in a laboratory that it has been used for preliminary trials in fieldwork, and may have wider application.

Method

Rectangular blocks of black foam plastic (fine-celled), 3- by 1- by 1- inch, were cut from sheets using a paper-cutting guillotine.

A diagonal slit 1-1/2 inches in length was made at the top end, and the pine seed dusted with Hexcebunt L. (30 percent hexachlorbenzene with lindane).

The blocks were saturated by squeezing and releasing them under water, and the pine seed was then placed in the slit.

The blocks were stood in aluminum pans in a glasshouse so that half the length of the blocks was immersed in water.

Normal germination occurred after 3 weeks at day temperatures varying from 70° to 75°

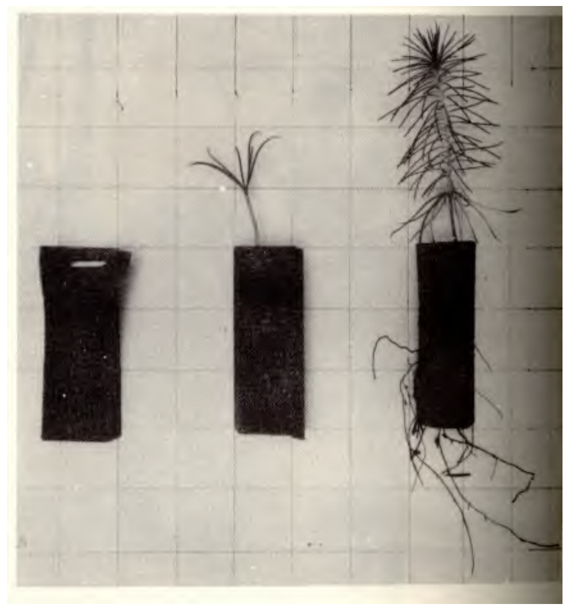

Figure 1.--From germination to 3 months.

Within a week needles had opened out and plants were established (fig. 2).

At this stage the sides of the pans were packed with damp litter from a mature pine stand. Water loss was low initially but in. creased with rise in temperature and increase in size of the seedlings. A good balance of moisture to aeration had to be

Figure 2.--Progressive development of plants in trays.

maintained so that the plastic blocks remained damp but not waterlogged,

A satisfactory water relation was best indicated by an advance of mycorrhizal fungi through the blocks and a strong mushroomy smell, With excess water a putrifying odor developed, caused by bacterial action.

CoroHold outgrowths of mycorrhizae appeared on roots in about 8 to 10 weeks, and at this stage the individual blocks were wrenched apart from each other to accelerate root proliferation.

Promoting top growth was possible by adding nutrient solutions (1), and as a result the seedlings grew from 12 to 18 inches in 12 months. With no nutrition except that provided by the breakdown of the litter by microorganisms, the seedlings would reach 6 inches in the same time. The latter method was considered more acceptable for planting out in the field.

At planting-out time (July-August in Australia), the plastic blocks were broken apart again, and each block was rolled in superphosphate before being "heeled into" the soil.

Survival records are limited because of the few seedlings planted out in this way, but results are promising after 2 years (fig. 3).

Figure 3.--Seedling 14 months after planting out in field (4 months old at planting-out time).

Discussion

The foam plastic begins to rot in the soil in 12 to 18 months, so that a reasonable degree of flexibility in handling it is possible.

The seedlings carry well and will not become dislodged from the plastic despite rough handling.

The method lends itself to mechanisation, and it should be reasonably easy to devise a machine for inserting the relatively large pine seeds into the blocks on a traveling chain.

Roots at a vulnerable stage are protected, and indeed it is possible for a nursery to be a glasshouse.

The criticism that such spoonfed plants will not survive when brought into contact with soil has so far not been borne out, Even plants that have been fed on balanced nutrients without litter grow well, but no one has assessed their performance against that of mycorrhizae-infected plants.

The cost of plastic blocks is a fraction of that of metal tubes, and if recovery of the blocks is deemed worthwhile they can be autoclaved.

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NURSERY FUMIGATION TRIAL WITH VORLEX

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Soil fumigation effectively controls nematodes, soil-borne diseases, and weeds in forest nurseries (3, 5, 7, 8). Methyl bromide (3) and Trizone (1) are good multipurpose soil fumigants that when applied under suitable covers give good control of nematodes, fungi, and weeds.

Many southern nurserymen object to the time and cost of placing and removing these covers. Therefore, a multipurpose soil fumigant than can be used without a cover and that still satisfactorily controls disease and weeds is often preferred.

Materials and Methods

The efficacy of a new fumigant,[4] Vorlex, with and without a polyethylene cover, was evaluated in a Georgia forest tree nurser. Its active ingredients are dichloropropenes, dichloropropanes, and methyl isothiocyanate. The site of the trial was a compartment in the Union Bag-Camp Paper Corporationforest tree nursery at Bellville, Ga. Several slash pine beds showed damping-off and stunted seedlings in the 1963 growing season. Weeds were difficult to control with mineral spirits and hand weeding. An assay of seedlings and soil revealed parasitic nematodes and damping-cff fungi.

Plots in a randomized block design were alined between two riser lines in the compartment. In early April 1964, the soil was disked. Three hundred pounds per acre of gypsum and muriate of potash was harrowed in. After the beds were formed and rolled smooth, 4- by 100-foot plots were arranged on the center four beds between the riser lines, with 20 feet of bed between each plot left untreated.

Soil samples were taken before fumigation, 20 cores 1 inch in diameter to a 6-inch depth in each plot. The soil was assayed for nematodes as described by Jenkins (6).

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[3] The authors thank Don Ryder, Union Bag-Camp Paper Corporation. and C. M. Gates, Morton Chemical Company, for their technical assistance.

[4] The fumigant is manufactured by the Morton Chemical Co.

The following treatments, replicated four times, were made on March 17, 1964:

A. Control
B. Vorlex soil fumigant broadcast at 40 gallons per acre, water seal, no cover
C. Vorlex soil fumigant broadcast at 25 gallons per acre, and covered by polyethylene within 1 hour after application
D. Methyl bromide injected under cover at 290 pounds per acre.

Vorlex was applied to a depth of 8 inches with a piston fumigant applicator with nine injection shanks spaced on 8-inch centers. In treatment B, overhead irrigation followed soil injection to provide a surface water seal. In treatment C, unsupported 4-mil-thick polyethylene sheet was used. In treatment D, MC2 (98 percent methyl bromide plus 2 percent chloropicrin) was released under supported 4-mil-thick polyethylene sheets.

On the application date, soil temperature averaged 59° F. at a 6-inch depth. The covers were removed 4 days after fumigation. The beds were seeded and mulched the following week at a rate to produce 35 seedlings per square foot. Application of ammonia nitrate was delayed until the soil temperature was above 65° F. and the crop well established because fertilizer toxicity may be a problem with soil fumigants.

To check for nematodes, we took soil samples from each plot 2 weeks and 2 months following fumigation and again just before lifting at the end of the season. These samples were also assayed for ammonia by a standard colorimetric procedure (4).

Examinations for damping-off and number of weeds were made at weekly intervals 2 to 8 weeks after planting. Permanent sampling areas were randomly marked in blocks of 4 square feet within the center 50 feet of each plot. Seedlings and weeds were tallied, and the weeds and dying seedlings were removed. In laboratory isolations made from all dying seedlings, finding of Fusarium solani or F. oxysporium was considered to confirm damping-off.

In January 1965, seedling density and height growth were determined within the center 50 feet of each plot. Random groups of seedlings were lifted from these areas and graded. Total green weights of each grade class were also found.

Results

The growth of slash pine seedlings was improved by soil fumigation (table 1). No differences were apparent between any two of the three fumigation treatments in respect to seedling density, green weight, or height growth. A statistical analysis of these data showed no significant difference between means except in height growth. All three fumigants produced height growth significantly better than control at the 1 percent level.

Based on field observations made just before the seedlings were lifted, those in Vorlex-treated plots were more uniformly green throughout the seedbed than under other treatments. The methyl bromide plots had spotty areas of reddish-colored seedlings, and this reddish coloration was rather uniform over all the control plots.

Vorlex, applied both with and without covers, gave excellent nematode control (table 2). Ring nematode (Criconemoides sp.), stubby-root nematode (Trichodorus sp.), and the

TABLE 1.--Effects of fumigation on growth of slash pine seedlings

Treatment	Mean total seedling density per square foot	Mean plantable seedling density per square foot	Mean height	Mean weight plantable seedlings per square foot
	Number	*Number*	*Inches*	*Grams*
Control...........	31.8	26.1	7.88	270.5
Vorlex without cover...........	34.5	27.3	9.35	310.4
Vorlex with cover..	34.2	27.5	9.28	312.6
Methyl bromide.....	34.4	29.8	9.33	335.0

TABLE 2.--Effects of fumigation on nematodes per pint of soil[1]

Time of sampling	Control		Vorlex without cover		Vorlex with cover		Methyl bromide	
	Ring nematode	Stubby-root nematode	Ring nematode	Stubby-root nematode	Ring nematode	Stubby-root nematode	Ring nematode	Stubby-root nematode
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Before treatment (3/17/64)............	9.5	7.1	15.4	11.8	14.2	20.1	20.1	13.0
2 weeks after treatment (4/1/64).............	17.8	33.2	--	--	--	--	--	--
2 months after treatment (5/18/64).......	31.9	66.2	--	--	([2])	--	--	([2])
End of experiment (1/18/65)............	9.5	66.3	--	100.3	--	85.3	--	46.0

[1] Average of four replications.
[2] Trace.

American dagger nematode (Xiphinema americanum) were all reduced by fumigation to undetectable levels during the first 2 months of the growing season. At the end of the growing season, only the stubby-root nematode was present. This was not unexpected because this nematode is known to become quickly reestablished following soil fumigation (2).

In damping-off and weed control, Vorlex under cover apparently was a better treatment than Vorlex without cover (table 3).

Assays of soil samples for ammonia nitrogen showed differences 2 months following fumigation. Determinations made just before the ammonia fertilizer application showed the following average ammonia nitrogen levels in pounds per acre, per treatment: A, 34; B, 45; C, 50; and D, 50.

Conclusions

Vorlex applied without a cover was not as effective as Vorlex or methyl bromide under cover. Thus, Vorlex injected at the rate used in this test and sealed with water may be relatively ineffective against weed seed and damping-off fungi in the top 1 inch of soil. To obtain maximum nematode, damping-off, and weed control with a multipurpose fumigant, plastic covers are needed.

The contrast between fumigation treatments and control might have been sharper if weather in the first 2 months after planting had been different. Probably because of the weather, little damping-off developed in the nursery. Furthermore, nematode populations were never high enough to cause appreciable root damage. The secondary seedling growth benefit mentioned by Foster (3) was present in fumigated beds. This may have resulted partly from an increase in ammonia nitrogen following fumigation.

If Vorlex is used in nurseries, it should be applied under a polyethylene cover. Though not significantly better than methyl bromidein this test, nurserymen may prefer it becauseit is easier and safer to handle.

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TABLE 3.--Effects of fumigation on damping-off and weed control

Treatment	Block	Total damped-off seedlings[1]	Total weeds[1]
		No.	*No.*
Control............	1	20	10
	2	3	24
	3	5	74
	4	4	79
	means	8.0	46.8
Vorlex without cover	1	11	5
	2	7	27
	3	0	61
	4	4	24
	means	5.5	29.3
Vorlex with cover...	1	7	7
	2	3	11
	3	0	15
	4	4	44
	means	3.5	19.3
Methyl bromide......	1	6	7
	2	3	23
	3	5	73
	4	1	231
	means	3.8	83.5

[1]Accumulated numbers of weeds and damped-off seedlings recorded in a 4-square-foot area during the first 8 weeks following planting.

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EFFECT OF FLOOD ON OREGON NURSERY

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The flood-swollen Umpqua River rose rapidly in the predawn of December 22, 1964, to cover the 106-acre Oregon State Forestry Department nursery at Elkton with water up to 10 feet deep. A midnight appraisal had failed to reveal that within the next few hours water would completely incapacitate the nursery during its lifting and shipping season (fig. 1). A month was required to clean up, recondition equipment and facilities, and let nursery grounds dry enough to resume work (fig. 2).

Everyone was surprised--oldtimers had never seen the water rise so swiftly or to such a level. The flood swept in over nursery beds containing about 40 million trees. The water poured into the packing room and tree storage facilities. Fertilizer and seed were also flooded. The equipment storage building, containing tractors, spray equipment, and electric motors, was engulfed.

Floodwaters were calm over the nursery and receded within 24 hours, leaving nearly

Figure 1.-- Floodwaters at the nursery office building at right extend more than 800 yards to the main stream of the Umpqua River.

Figure 2.--Flooding of the equipment storage building ended operation of all nursery vehicles until they were reconditioned. Cedar shingletoe and peat moss were brought in by the current and heaped at the equipment shed as the waters receded.

all the 2- and 3-year-old tree seedlings silted to a depth of 2 to 8 inches (fig. 3). The height of the seedlings protected the ground from erosion and served as a collection point for mud. One-year-old stock was completely covered in many areas. However, not all the nursery was as severely flooded and damaged (fig. 4).

The immediate concern was whether the floodwater had drowned the current season's tree growth. The experience of other agencies indicated that such brief flooding would not

Figure 3.--Seedbeds of 2-0 Douglas-fir in a severely damaged area, January 19, 1965. Depth of the silt averaged more than 6 inches. Lifting these trees was extremely difficult. At least 6 feet of water covered this area.

Figure 4.--Seedbeds of 1-year-old Douglas-fir as they appeared on April 7, 1965. Floodwater depth here was 1 to 4 feet. The silt layer is about 2 inches deep. Prior to bud burst, all these seedbeds were cultivated to break up the crust and mix the silt with the original soil . Practically no trees were lost except on a few low spots.

damage seedlings. This has proved to be essentially correct.

Although no data on silting damage was available, a consensus indicated that as long as seedlings were dormant, they should survive. Under controlled laboratory conditions at the Forest Research Center at Oregon State University, growth trials at 2-week intervals during the lifting season indicated that even the severe silting did not kill the seedlings. However, as normal bud-breaking time neared, seedling vigor noticeably decreased. An exceptionally dry spring in 1965 made good vigor essential to the survival of forest plantings.

The problem of lifting seedlings from nursery beds was increased greatly by the deposit of silt. Production per man-day declined 60 to 80 percent. A lifting crew under contract was employed to speed production. The standard lifting blade was not adequate to break up the overlay of silt around the seedlings. A plow with a long, flat point and short moldboard mounted on a work bar was substituted to lift the seedlings and break up the silt layer row by row (fig. 5).

Crop losses for the current year approximated 1.3 million seedlings; the losses occurred because there was not enough time to lift deeply silted seedlings before growth started. The loss in 1-0 tree seedlings has not been fully appraised. The silt has been removed and growth has begun, and estimated losses of 10 to 50 percent can be seen in scattered individuals and beds throughout the nursery.

Figure 5.--Lifting 2-0 Douglas-fir seedlings, March 2, 1965. Plow is breaking the seedlings loose in heavily silted area. The contract lifting crew is putting the trees in burlap-lined boxes for transport to the packing shed. This is about the same area as shown in figure 3.

EFFECT OF SOIL FUMIGANTS ON SEEDLING DEVELOPMENT

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Introduction

Most nurseries growing trees for reforestation and many commercial landscape nurseries fumigate the soil before sowing or transplanting. The effect of soil fumigants on plant development and mycorrhizae in the soil has been much discussed and studied. In 1952 at the Chittenden Nursery, white pine beds treated with MC-2, methyl bromide, produced larger and better developed 1-0 seedlings than did unfumigated beds. [3]

Very little mycorrhizae was found on the roots from treated beds, whereas roots from unfumigated beds had good mycorrhizae development. At the end of the second year the seedlings from the fumigated beds were still better plants than those from the unfumigated beds. Mycorrhizae had become reestablished in the fumigated beds, and the seedlings had a good growth of mycorrhizae on most of the roots. Anderson (1) found that beds treated with Trizone or Telone produced larger Scotch pine and Douglas-fir seedlings, with root systems much better developed, than did the control beds.

In the past the top/root ratio and dry weight of the roots have been used as one of the measures of seedling development. Dry weight does not differentiate between heavy roots with limited absorbing surface and small fibrous roots with a large absorbing surface. A technique to give a better evaluation of

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[3] Chittenden Nursery unpublished notes.

root quality has been developed by Wilde (3), and Anderson (1), and others. This is the root titration technique and was used in this study.

Procedure

Four soil fumigants--Mylone (50D), Vapam, methyl bromide (MC-2), and Trizone--were used to treat the seedbeds at the Chittenden Nursery in the fall of 1961. All treatments were in early September when the soil temperature at the 6-inch depth was 60° or more.

Mylone was broadcast on the seedbed area with a fertilizer drill at the rate of 560 lb. per acre. The soil was irrigated for several hours immediately following the application and again a few days later. Application was on September 1, and the beds were sown in the latter part of October.

Vapam was applied by two methods:

1. Injected into the soil at a depth of 6 inches and at a 12-inch spacing between shanks. The soil was sealed by floating following injection and then irrigated. Vapam was applied at a rate of 1 pint per 100 square feet.
2. Applied as a drench, at the rate of 21 pints of Vapam in 250 gallons of water. The tarp layer followed the sprinkler cart and covered the beds with polyethylene film. This film was kept on the beds for at least 48 hours.

Methyl bromide (MC-2) was injected under polyethylene tarps, as a hot gas, at the rate of 1 pound of MC-2 per 100 square feet. The tarps were left on the beds for at least 48 hours.

Trizone was injected into the soil at a depth of approximately 6 inches at 140 pounds per acre. A Trizone fumigation rig was used to cover the beds with a polyethylene film.

Red pine from a lower Michigan seed source was sown in late October 1961.

Germination began in late April 1962. Counting plots were immediately established in several beds of each treatment. Counts were made at frequent intervals during the germination period, and annual inventories were taken. All beds received the same fertilizer, water, and other treatments that were standard for the nursery. The trees were root pruned at the beginning of the third growing season. A few seedlings were dug from each treatment at the end of the first and second growing season. Seedling growth, presence of mycorrhizae, etc., were observed.

Samples were taken from beds of each treatment in the fall of 1964. The sampling was made at points where the stand density was about the same (35 to 37 per square foot). The samples were taken by digging a 1 clump from the six interior rows and three trees from each row. The roots of the sample trees were carefully washed and all seedlings with damaged roots discarded. This reduced the sample to 12 to 14 trees. Ten of these were measured and the others photographed, The stem caliper, top length, and root length were recorded for each seedling. The tops were cut off at the root collar, ovendried, and the dry weight determined. As the seed. lings were measured, the root systems were examined for mycorrhizae development.

The roots were air dried, placed in a 0.3 normal solution of hydrochloric acid (1) for 15 seconds, and drained of excess acid for 5 minutes. The roots were then transferred to a beaker containing 250 ml. of distilled water, agitated, and let to stand for

absorbing surface of the root system. An aliquot of 100 ml. of the weak acid solution was then titrated with 0.3 N-NaOH and phenol. phtalin. The absorbing capacity of the root surface, expressed in milliliters of titration, was calculated and designated the titration value of the root system. Two titrations were run on samples from each treatment.

The length of the root system did not give a true picture because of large differences in the length of individual roots. All stock shipped to the field are root pruned to about 8 inches. Seedlings with a mass of short roots are preferred for planting to those with a few long roots.

Results

The effect of the fumigants on seedling development was found to be as follows:

Mylone

The germination in Mylone-fumigated beds was only slightly higher than the control (table 1). The stand remained fairly constant during the 3 years. The seedlings made about the same growth as those in the control beds, having a slightly better stem caliper and top weight (table 2). The root titration value was less than that obtained for the control seedlings (table 2). Little if any mycorrhizae developed on the roots of stock from Mylone-fumigated beds, whereas the seedlings from the unfumigated beds h a d well-developed mycorrhizae over the entire root system of the first growing season. Some mycorrhizae appeared on the Mylone seedlings at the end of the second year. The seedlings in the Mylone beds were slightly off-color, having a yellowish tinge, until late in the third year.

Seedling development was similar to a 1957 Mylone test at the Chittenden Nursery (2).

Vapam

Germination was very good, being slightly more than double that obtained in the control (table 1). During the three growing seasons there were some losses, but still about 100 percent more seedlings per square foot than the control. The method of applying Vapam did not affect the seedling development.

TABLE 1 --Germination and survival, seedlings per square foot, in soil fumigation plots

Treatment	Germination	Survival		
		First year	Second year	Third year
	Number	*Number*	*Number*	*Number*
Mylone....................	26.0	28.0	27.9	29.0
Vapam (injected)..........	51.0	45.0	37.2	41.5
Vapam (drench)............	57.0	45.0	41.9	44.3
MC-2......................	48.8	40.0	33.2	31.0
Trizone...................	54.75	53.0	48.17	52.6
Control...................	24.5	23.0	22.0	22.0

TABLE 2.--Seedling development in fumigated 3-0 red pine seedbeds

Treatment	Tops length	Dry weight	Roots titration value	Stem caliper in 32ds	Mycorrhizae development
	Inches	*Grams*			
Mylone.........	7.625	33.1	2.7	5.3	Very little present and only on upper roots.
Vapam (injected)	8.88	41.3	2.9	5.4	Large masses on upper roots.
Vapam (drench).	7.725	39.1	2.85	5.1	Do.
MC-2...........	11.3	71.8	3.25	6.1	Masses scattered along most of roots.
Trizone........	9.713	58.1	3.5	6.2	Masses along roots, some large.
[illegible]............	12.425	77.0	4.5	6.7	Masses on upper roots.

The seedlings from the Vapam beds were slightly better than the control and had about the same titration (table 2). Some mycorrhizae was present on the upper roots, but the lower roots were without mycorrhizae. There was no mycorrhizae at the end of the first year and only a small amount at the end of the second year.

The needles of seedlings were slightly off-color or at least not as intense a green as those in control and beds fumigated with MC-2 and Trizone. During the 3 years the beds treated with MC-2 and Trizone stood out because of their better color.

Methyl bromide and Trizone

MC-2- and Trizone-fumigated beds produced seedlings that were significantly larger in top length, dry weight, and stem caliper. The root titration value of seedlings from the MC-2 and Trizone beds was over 30 percent greater than for seedlings from the unfumigated beds (table 2). No mycorrhizae was observed on the MC-2 or Trizone seedlings at the end of the first year, but at the end of the second growing season mycorrhizae was well established on the roots. The roots of seedlings from MC-2 beds had masses of mycorrhizae on the upper roots and some mycorrhizae scattered along most of the roots. The roots from Trizone beds had large clumps of mycorrhizae on the upper roots with small amounts scattered along many of the lower roots.

Summary

Fumigation with Mylone and Vapam did not materially affect the development of the seedlings except to produce more uniformity. MC-2 and Trizone both gave a larger seedling, greater stem caliper, and higher root titration value.

Seedlings from the fumigated beds, regardless of the fumigant, were more uniform than the control and not retarded in development, Less than 1 percent of the trees from the fumigated beds would not meet the specifications for plantable stock: 4-inch top, 4/32-inch stem caliper, and 6-inch root. No trees were found in the samples from the fumigated beds that did not meet specifications, Cull from the control beds was about 10 percent.

There did not appear to be any difference in the number of roots on seedlings from fumigated and control beds. There were, however, more root hairs on all the seedlings from fumigated beds.

At the end of 3 years, mycorrhizae was well distributed over the entire root system of seedlings from unfumigated beds, but varied in the fumigated beds. Mylone seedlings had the poorest mycorrhizae development, followed by Vapam. MC-2 and Trizone had well-developed masses of mycorrhizae on the upper roots and some on most of the roots. No mycorrhizae developed on seedlings from the fumigated beds the first year.

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PLANTING BLACK WALNUTS IN TIN CANS

C. N. Henniger[1] and Max D. Bolar [2]

Black walnut, a minor tree associate in several forest cover types in Eastern United States, is highly prized for furniture and paneling. The nuts are also valuable for human consumption. Thus, it is important to develop and maintain forest stands with a favorable amount of this species.

To accomplish this, more research is needed to clarify both the site and silvicultural requirements of the species. It is known that plantings should be made on the deep, rich, well-drained soils most commonly found in draws or on foot slopes, where moisture is plentiful. Black walnut does not grow well on thin, dry, or eroded sites. Also, plantings should be made in openings in the woods to allow plenty of light for the development of new seedlings and where there is limited from other trees or large bushes. Plantings may be made on good deep soils in open fields, but large block plantings of walnuts do not usually develop into successful plantations.

Newly planted nuts must be protected from squirrels. Most black walnut trees in woodlands today probably grew from nuts buried by gray and fox squirrels who intended to dig them up later for food. Because the nuts are so desired by squirrels, many areas planted by landowners have been pilfered of most of the nuts within a few days. Planting seedlings to avoid this problem is possible, but it generally has not been successful or as common as nut plantings.

A method devised for planting nuts in tin cans is recommended in areas where squirrel damage is expected. [3] This way nuts can be safely planted in the fall without the trouble of stratifying them over winter. The technique also can be used in the spring.

[1] Woodland conservationist, Soil Conservation Service, Nashville, Tenn.

[2] Woodland conservationist, Soil Conservation Service, Little Rock, Ark.

[3] Steavenson, Hugh. Seed or Seedlings? An interesting question--and experiment--in the planting of heavy—seeded hardwoods. American Forests, Nov. 1943.

Figure 1.--Cut an "X" in the bottom of each can with a hatchet or other available tool.

Figure 2.--Scalp sod from an area 15 inches in diameter, and dig a hole deep enough to cover the upright can.

Figure 3.--Pour 1 inch of topsoil into the can, holding can at bottom to keep soil in.

Figure 4.--Place walnut in can.

Figure 5.--Cover nut with soil to top of can, and firm lightly.

Figure 6.--Place the can in the hole, bottom up.

Figure 7.--Fill in the hole with topsoil: bend the tips of the lid back with pliers to make a 1-inch opening.

Figure 8.--Firm the soil around the can.

The accompanying eight pictures illustrate the details of the tin can method of planting black walnuts. It is recognized that some kind of portable instrument or template could be devised to more easily punch out and shape the ends of the cans prior to planting. The instrument would replace the hand axe and pliers now required.

Number 2 tin cans are convenient for walnut plantings. This is the size commonly used to can tomatoes, peas, corn, etc. Beer cans, oil cans, and soft drink cans are satisfactory, but they should be burned first to hasten disintegration in the soil after planting.

For fall plantings (October to December), nuts should be "seasoned" for at least 2 weeks in a shady place until the husks start turning brown. For spring plantings (February to March), use nuts that have been properly stratified over winter.

SAND PINE CONES AND SEED

J. P. Barnett and B. F. McLemore
Southern Forest Experiment Station
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Sand pine, a rough tree native to deep sandy soils of Florida, has recently gained favor in regeneration of adverse sandhill sites. Unlike slash pine, which has been planted widely in the sandhills, it grows well on unprepared sites. Two races are recognized--the Ocala, native to peninsular Florida, and the Choctawhatchee, found in the western part of the State (3). Cones of the Ocala race are serotinous, while those of the Choctawhatchee race are not.

A study was undertaken in 1962 to obtain information on cone and seed characteristics of both races. Differences were found in cones per bushel, seeds per pound, requirements for seed extraction, and degree of dormancy. These differences are summarized below. Additional details are reported in U.S. Forest Service Research Paper SO-19 (1).

Cones were collected from Choctawhatchee trees in mid-September and from Ocala trees in early November. Fifteen to 20 trees of each race were represented. Cones were kept separate by individual trees, and specific gravity was determined in the field immediately after cones were picked. Choctawhatchee cones opened readily at a kiln temperature of 105°F. even though specific gravities ranged from 0.85 to 1.11. There was no relationship between specific gravity and seed viability.

Serotinous cones of the Ocala race may be collected at any time after they have turned brown, as maturity is then assured. Extraction methods tested on Ocala cones were: (a) kilning at 130°F. to 140°F., (b) applying a flame directly to the cones, (c) soaking in a 1:2 ethyl alcohol-benzene solution, and (d) immersing in boiling water. The most efficient of these methods is the last. Scales separate in 5 to 15 seconds after immersion, and if cones are removed from the water promptly there is no impairment of seed viability. After the seal on the scales is broken, cones open completely in 24 hours when dried in a kiln at 100°F.

The Ocala race has the larger cones and seeds. Choctawhatchee cones averaged 1,010 per bushel with a range of 630 to 1,310, while Ocala cones averaged 830 and varied from 450 to 1,100. After most of the empties were removed, seeds per pound averaged 56,100 for the Choctawhatchee race and 47,200 for the Ocala. The Woody-Plant Seed Manual (4) reports 75,000 seeds per pound, but does not distinguish between races. Moreover, this last value was probably derived from samples with high proportions of empty seed.

Choctawhatchee cones yielded 0.62 pound of seed per bushel after wings and trash had been removed. New cones from the Ocala race gave 0.58 pound, while those maturing a year earlier yielded 0.77. Such year-to-year variations in production are common in pines (5).

Liquids of varying specific gravities were tried for separating full and empty seeds in small lots. Flotation in 95-percent ethyl alcohol gave excellent results for both races, and soaking for as long as 5 minutes did no harm.

Because Ocala trees typically bear an accumulation of cones of many ages, seed viability was tested for cones of three age classes: current crop, 1 year old, and 2 or more years old. Fifteen trees were represented in these tests. Viability declined with each increase in cone age. Seed from new cones averaged 93-percent germination as contrasted to 83 percent for seed 1 year old and 56 percent for that 2 or more years old. Commercial collections of Ocala cones should exclude those older than 1 year, since their exact age cannot be readily determined by coloration or position, and viability is apt to be low.

Seed dormancy and methods of speeding germination were studied with lots from 10 trees of each race; Ocala seed was subdivided again into the three cone ages for each tree. The pregermination treatments evaluated are shown in table 1, along with their effects. Czabator's (2) germination values, which take into account both speed and completeness of germination, were used in making comparisons.

Choctawhatchee seed was mildly dormant. Stratification for 14 days boosted both rate and total germination, but increasing the length to 28 days gave little added response. Dormancy of Ocala seed varied with cone age. Seed from new and 1-year-old cones germinated promptly without presowing treatment, and none of the treatments stimulated germination significantly. Older seed was slightly dormant. While cold stratification speeded germination, it decreased total viability substantially. Thus, stratification is not recommended for seed from the Ocala race.

Sand pine seed is easily stored. When dried to 10-percent moisture, seed of both races was held for 2 years at 25°F. with no loss in viability.

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TABLE 1. --Laboratory germination of Choctawhatchee and Ocala races of sand pine seed subjected to various pregermination treatments

[Choctawhatchee Race]

Pregermination treatment	Peak germination	Germination value	Final germination
	Day		*Percent*
None	17	15.38	88
14-day stratification	11	26.27	93
28-day stratification	10	27.90	94
24-hour soak in water	13	20.66	92
24-hour soak in H_2O_2	14	18.07	89
[Ocala Race]			
Seed from new cones			
None	10	32.03	94
14-day stratification	9	34.33	90
28-day stratification	8	35.86	93
Seed from 1-year-old cones			
None	10	24.07	89
14-day stratification	10	26.60	90
28-day stratification	10	25.27	84
Seed from cones 2 or more years old			
None	15	10.92	70
14-day stratification	14	8.22	54
28-day stratification	11	5.70	43

1 Germination tests conducted with 100 percent sound seed from 10 different trees of each race.

FOREST COVER CHANGES IN STRIP MINE PLANTATIONS [1]

William C. Ashby,[2] Malchus B. Baker, Jr.,[3] and John B. Casteel[3]

Usually in plantations, during a period of several years, the number of trees gradually declines, total tree growth increases, and additional species invade. However, strip mine plantations studied in southern Illinois, which had these trends for 25 years, had marked departures from them following a severe winter and a drought year.

These studies were on the site of the Fidelity Mine of the United Electric Coal Company, 4 miles west of Du Quoin, Perry County, Ill. This area was mined in 1935, and in 1938 and 1939 it was planted to black locust or shortleaf pine. Diameters to the nearest 0.1 inch and basal areas of the overstory species were determined in the early springs of 1963 and 1964.

In 1947 the U.S. Forest Service underplanted hardwoods (table 1) on two adjacent 1/2-acre plots in each overstory area (Mather et al. 1947). The underplanted hardwoods were examined in the winter of 1962-63 for survival, basal area, and tree form. The number and basal areas of a sample of both species were determined early in 1964.

Mortality in previous years had been higher for the black locust than for the shortlea pine (table 2). Accelerated mortality of both overstory species from 1963 to 1964 affected all size classes, was greatest among the smaller trees, and led to a nearly normal size distribution curve among the survivors (fig. 1). Although the locust overstory was ragged, presumably because of sunscald injuries and subsequent infestation by the locust borer, few trees had fallen. However, it was difficult to walk through the pine plots in 1964 because

TABLE 1.--Survival and basal area per acre of underplanted hardwoods, 1963

Species	Black locust		Shortleaf pine	
	Survival	Basal area	Survival	Basal area
	Percent	*Square feet*	*Percent*	*Square feet*
Black walnut (*Juglans nigra*):				
Seedlings	68.7	7.6	78.7	1.2
Seed	46.5	3.1	67.0	1.0
Tuliptree (*Liriodendron tulipifera*)	44.9	4.9	62.7	1.0
Silver maple (*Acer saccharinum*)	55.7	4.4	61.8	.2
Sweet gum (*Liquidambar styraciflua*)	14.3	.2	76.8	1.7
Osage-orange (*Maclura pomifera*)	57.0	1.2	70.8	.4
Ash (*Fraxinus lanceolata* or *F. americana*)	21.9	.0	85.4	.1
Total	--	21.4	--	5.6

[1]This investigation utilized the plantings of a cooperative study between the Central States Forest Experiment Station, Forest Service, USDA; the United Electric Coal Company; and the Illinois Coal Strippers Association. We wish to thank Paul N. Seastrom and personnel of the Central States Station for their helpfulness in these studies.

[2] Associate professor, Department of Botany, Southern Illinois University, Carbondale, Ill.

[3] When the research reported in this paper was undertaken, Baker and Casteel were National Science Foundation undergraduate research participants. Bakes is now in the graduate forestry program, University of Minnesota, St. Paul, Minn.

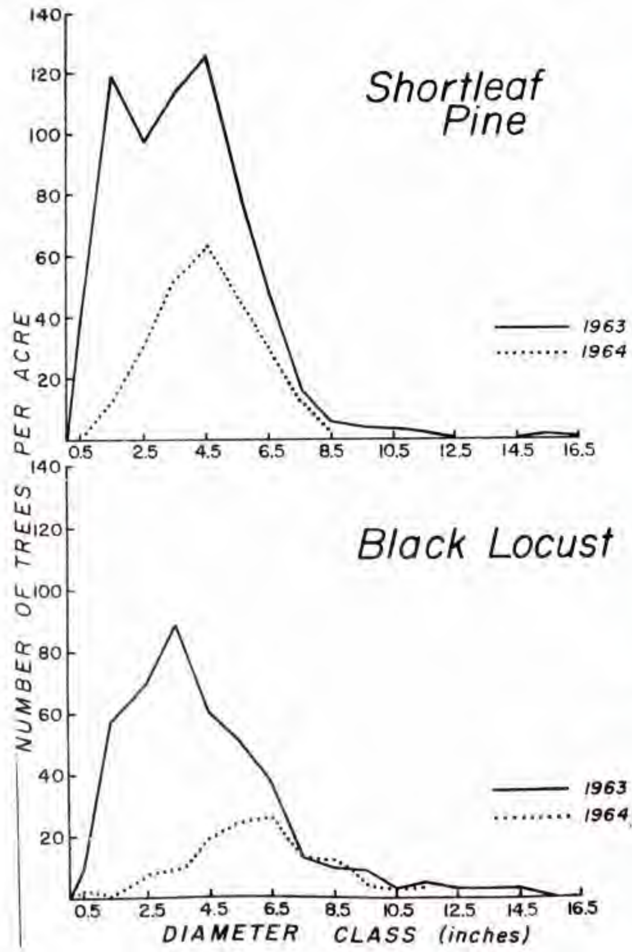

Figure 1.--Number of black locust and shortleaf pine trees per diameter class, 1963 and 1964.

Figure 2.--A shortleaf pine area is shown. The plot underplanted with hardwoods (note dead pines with scaling bark and fallen pines) and intact pine border area can be seen. Row of walnut is in foreground.

of the down trees (fig. 2). Adjacent areas, not underplanted, did not have fallen trees and appeared much as they had in 1962.

Survival percentages (table 1) for the underplanted hardwoods corresponded to trends of former years (2-4, 6). In the black locust area which had higher nitrogen levels (5), the number of trees was less, and the trees were larger. Sweet gum was the only underplanted species which had larger trees in the pine plots, perhaps partly because of sunscald damage observed frequently on sweet gum in the locust plots. The sweet gum, silver maple, and tuliptree in the black locust area had previous severe bark damage, often near groundhog dens. Although dens were not found in the pine areas, bark damage was present.

The major decline in plantation tree numbers was partly responsible for a more than 50-percent decline in the basal area for both species between early 1963 and early 1964 (table 2). Total basal area decreased much less drastically, from approximately 80 to 60 square feet for the locust, and 70 to 40 square feet for the pine plots. This was because of the proportionate contributions of the underplanted and volunteer species. Both were appreciably greater under the locust than under the pine (tables 1 and 3).

Form varied among the underplanted species, Influences of overstory were slight. The black walnut, sweet gum, and tuliptree generally had "good" form, whereas ash, Osage-orange, and silver maple exhibited "poor" form. The main leaders of scattered black walnut on both the locust and the pine plots were killed. This condition seemed to be most frequent in the shortleaf pine area where the crown canopy was open.

TABLE 2.--Survival and basal area per acre of black locust and shortlear pine underplanted with hardwoods

black locust (Robinia pseudoacacia)			Shortleaf pine (Pinus echinata)		
Year	Trees per acre	Basal area	Year	Trees per acre	Basal area
1938.....	[1] 2,700	--	1939	[1] 1,200	--
1947.....	[1,2] 1,170	--	1947	[1,3] 690	--
1963.....	406	54.6	1963	650	63.2
1964.....	113	23.2	1964	242	29.5

[1] These values are taken from the unpublished report of Mather et al, 1947.
[2] The trees averaged about 22 feet in height and were badly riddled by locust borer (Deitschmann 1956).
[3] The trees averaged less than 6 feet tall and showed heavy tip-moth infestation. The plantation was more open (Deitschmann 1956).

TABLE 3,--Number and basal area of volunteer species per acre, all size classes, spring 1964

Species	Black locust overstory		Shortleaf pine overstory	
	Number	Basal area	Number	Basal area
				Sq. ft.
Boxelder (Acer negundo)	125	4.8	70	0.8
Cottonwood (Populus deltoides)	--	--	4	4.5
Sycamore (Platanus occidentalis)	5	2.9	8	3.4
American elm (Ulmus americana)	91	3.1	106	1.8
Black cherry (Prunus serotina)	10	2.2	3	.0
Hackberry (Celtis occidentalis)	45	2.1	--	--
Miscellaneous species [1] ..	26	1.1	6	.3
Total	302	16.2	197	10.8

[1] On the locust plots were mulberry (Morus rubra), willow (Salix nigra), tuliptree (Liriodendron tulipifera), redbud (Cercis canadensis), white oak (Quercus alba), winged elm (U. alata), slippery elm (U. rubra), ash (Fraxinus lanceolata or F. americana), and shingle oak (Q. imbricaria); on the pine plots were willow, winged elm, crab apple (Malus sp.), and red oak (Q. rubra).

Many volunteer tree species were also on the plots in 1962-64. Only a few were large and conspicuously in the canopy. Data from a full tally of all size classes is shown in table 3 and figure 3. Of the 14 species with individuals 0.1 inch d.b.h. or greater, cottonwood was found as a few large individuals (to 19 inches d.b.h.) in the pine only. Volunteer redcedar, not tallied, from 6 to 22 feet in height, was chiefly on open south slopes in the shortleaf pine areas. Others were scattered throughout the study areas. Both species failed when underplanted, the

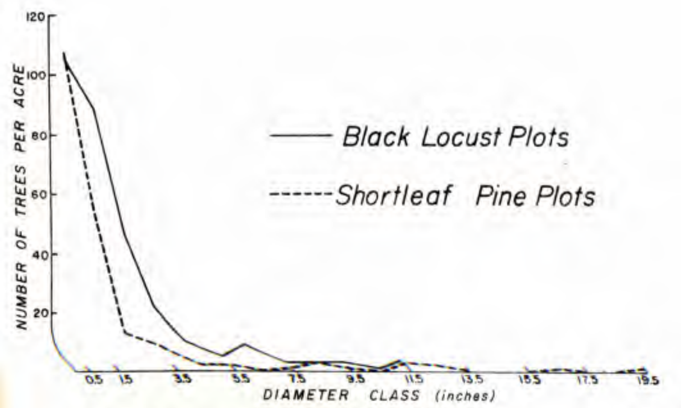

Figure 3.--Number of volunteer trees per diameter class under the two overstories, spring 1964.

cottonwood in both plantations and the cedar in the locust only.

Discussion

Three processes in forest cover change were evident from the present studies. One was the continuing decline in plantation tree numbers, both of the original overstory and the underplanted hardwoods. A second was the increasing importance of the underplanted hardwoods, and of the volunteer species, in basal area. The locust was characterized by more typically mesic forest species, and the pine by species found in old fields and similar relatively open sites (Ashby 1964). The third was the greatly accentuated mortality of the original overstory plantation trees during 1963-64. This mortality first became evident during the winter of 1962-63, which was among the most severe during the past 100 years. At Carbondale, 20 miles south of the study area, a low of -16 F. was recorded on January 28. Rainfall at Carbondale for 1963 was the lowest on record, 27,6 inches, compared to the 53-year mean of 44.9 inches. Possible effects from these two climatic extremes were not separated. The initial widespread dying of the pine, which preceded the summer drought, may have been caused by physiological drought damage during the winter on trees weakened by competition for nutrients with the hardwoods.

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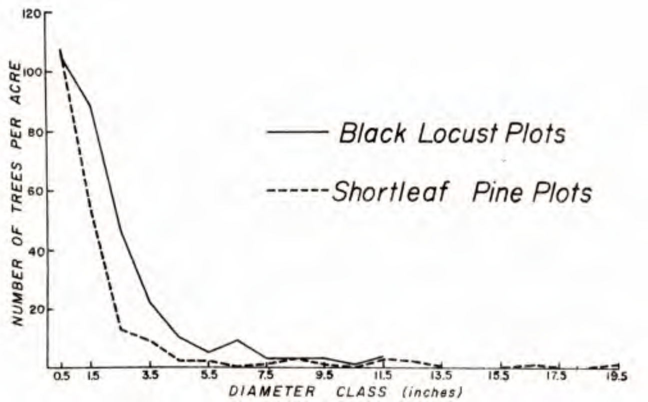

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A TRIAL OF PALES WEEVIL RESISTANCE

Frank S. Santamour, Jr., and Arnold D. Rhodes [1]

The pales weevil (Hylobius pales (Herbst)) is a serious pest of young pine trees in natural reproduction and in plantations in the Northeast, Adult weevils, on becoming active in the spring, are attracted to areas from which pine was recently harvested. Eggs are laid in the bark of pine stumps and logs, and the new brood emerges about September. Damage is caused both by the weevils that have been attracted into an area and by the new brood feeding on the bark of the seedlings. Girdling of the branches or the main stem often results, killing the affected part. In large seedlings, this may be only part of the plant; in small seedlings, it is commonly the entire plant, Various losses have been reported; however, the first-year mortality of 73 percent among newly planted seedlings observed by Friend and Chamberlin (1942) indicates that great damage may occur.

Eastern white pine (Pinus strobus L.) appears to be the favored host where it occurs throughout the insect's range. However, feeding and intensive damage have been noted on the four major southern pines (Beal and McClintock 1943; Sentell 1949). In addition, Finnegan (1959) reported adult feeding on plants of nine coniferous genera (including Pinus) and two hardwood genera in Ontario.

Because of the wide range of host plants, the existence of resistant pine species or individuals seems remote. However, of the subgenus Haploxylon, only Pinus stro bus and P. cembra have been cited as hosts; nothing has been reported on the susceptibility of other white pine species.

The standard recommendation for minimizing weevil damage under natural conditions has been to delay extensive cutting until a good seed year in order to encourage heavy initial stocking on the area. Heavy damage to planted stock has been avoided by delaying the planting of cutover pine land until the third season after cutting.

The present study was undertaken primarily to determine the relative susceptibility of various white pine species, hybrids, and provenances. Determination of differences might result in the interplanting of superior types in natural stands for genetic improvement conversion, as proposed by Schreiner (1958).

Site, Materials, and Rating Methods

Two outplanting areas about 2 miles apart were selected on land of the Amherst Water Department in Pelham, Mass. These areas, designated as Block I and Block II, were openings of approximately 0.1 acre created by selective harvesting of eastern white pine in the spring of 1961. Slope and aspect were similar for the two blocks. However, Block I was in an essentially pure pine stand, and Block II was in a stand where hardwoods were predominant, Block I was also more heavily shaded than Block II.

Logging slash was moved to the periphery of the openings but not additionally treated. At]east five pine stumps were in each opening, and two were within each block planted.

Seedlings of 18 seed lots were used in this test; 7 of them represented various geographic sources of eastern white pine, and 11 were progenies derived from open pollination of exotic white pines or from controlled hybridization of exotic species. All the parent trees of the hybrids and exotics were planted specimens growing near Philadelphia, Pa., except in four of the hybrid combinations where Pinus strobus pollen from Georgia trees was used.

The planting stock of the Pinus strobus provenance seed lots was 3-1, but all the rest were 3-0. Seedlings were planted with a grub hoe on May 19, 1961, at a spacing of 2 feet between trees in rows 3 feet apart. Each seed lot was represented by a two-tree plot in each of two replicates on each of the two blocks; thus, eight trees of each seed lot were tested. Seed lots were completely randomized within

[1] Respectively, geneticist, Morris Arboretum, University of Pennsylvania, Philadelphia, Pa.; and head, Department of Forestry and Wildlife Management, University of Massachusetts, Amherst, Mass. During this study Dr. Santamour as on the staff of the Northeastern Forest Experiment Station, Forest Service, USDA, Durham, N.H.

replicates, and the replicates within blocks were adjacent to one another.

The plantings were first evaluated in August 1961. The trees were rated according to five damage classes: None, light, moderate, severe, and very severe. Light and moderate damage was regarded as not fatal, severe damage as possibly fatal, and very severe damage as almost certainly fatal. Damage also was recorded by five sites on the tree: Old growth on branches, new growth on branches, leader, 1-year growth on main stem, and elsewhere on the main stem. Independent evaluations made by both authors closely agreed.

A numerical damage rating for each tree was computed by assigning a damage-class value of 1 (no damage) to 5 (very severe), and multiplying this figure by the number of damage sites. Thus, the maximum rating for a tree was 25.

Another inspection in November 1961 showed no additional significant damage. Damage in 1962 was generally lighter than that in 1961 but followed the same pattern. No new damage was recorded in 1963. This sequence of decline in weevil attack closely paralleled that observed by Friend and Chamberlin (1942). Since the main surge of damage in our plantings had occurred by August 1961, the ratings of that date were used to compare seed lots.

No intensive attempt was made to determine the composition of the insect population. However, the presence of pales weevil was established, and the type of damage indicated that it was the predominant causative agent.

The experimental design used in this study was partly dependent on the plant material available, but was further predicated on the expectation that high mortality would occur, and that the data for subsequnet analysis would be survival percentages. However, mortality was less than expected, and the rating scheme noted above was devised to extract the maximum information from the experiment. Some of the basic prerequisites for use of the analysis of variance may not have been satisfied by the resultant data. But, since the data did not lend themselves to any other type of analysis, the analysis of variance was utilized as the best method of attaching some meaning to the observations. The significance of differences within arrays was determined by Tukey's range test (Snedecor 1956).

Results and Discussion

Tree mortality that resulted from insect attack was low in these plantings; only 16 of 144 trees were killed. However, the pattern of mortality closely followed the damage ratings: Only four trees had been rated as very severely damaged, and all died. Seven of 21 severely damaged trees, and 5 of 48 of those moderately damaged were the others that were killed.

Wild seedlings adjacent to or within the planting area were much more susceptible, Proximity of the seedlings to pine stumps was not a factor; in fact, many seedlings near the stumps were damaged less severely than others some distance away.

Highly significant differences in damage were found between blocks. Twenty-four trees in Block I were not damaged, but only six trees in Block II escaped attack. Damage rat. ings (tables 1 and 2) in Block II averaged more than double those in Block I. It is not known whether these differences between blocks re. fleeted differences in site conditions or in insect abundance.

Because of the differences between blocks, however, the analysis of differences within blocks was more meaningful. Differences among the hybrid seed lots within both blocks were nonsignificant. This lack of significance mainly resulted from random variation under the low-damage level in Block I, and greater uniformity of damage in Block II (table 1).

Provenance seed lots (table 2) also showed no significant differences in Block I, where high damage in one seed lot in one replicate was responsible for a major part of the total I variance. Under the heavy insect attack in Block II, the random variation was reduced and highly significant differences among seed lots were found. Both the Quebec and Georgia provenances showed significantly less damage than all the other seed lots. It is unlikely that seedling size was a factor here since Quebec seedlings were the smallest and Georgia seed lings were the largest among 21 provenancesat 3 years of age in the nursery (Santamour 1960).

None of the exotic or hybrid white pines used in this study was significantly less sus ceptible to pales weevil damage than eastern white pine. Because of the significant

TABLE 1.--Pales weevil damage in exotic and hybrid white pine progenies

Seed lot No., Pinus	Parentage[1]	Trees killed	Damage rating, total by seedlots		
			Block I	Block II	Total
883.......	Pinus griffithii X P. griffithii..	0	12	28	40
891.......	P. peuce X P. strobus (Ga.).......	1	8	33	41
892.......	P. peuce X open pollination.......	0	19	31	50
857.......	P. flexilis X P. griffithii.......	1	15	42	57
882.......	P. griffithii X P. strobus (Ga.)..	0	28	32	60
896.......	P. monticola X P. strobus (Ga.)...	1	28	36	64
869.......	P. monticola X P. griffithii......	3	31	42	73
876.......	P. ayacahuite X P. strobus (Ga.)..	3	16	58	74
1150-1....	P. flexilis X open pollination....	0	22	57	79
875.......	P. ayacahuite X P. strobus........	1	16	72	88
877.......	P. ayacahuite X P. griffithii.....	2	47	54	101

[1] In hybrid combinations, the species used as the female parent is given first.

TABLE 2.--Pales weevil damage in provenances of eastern white pine

Seed lot designation	State or Province	Trees killed	Damage rating, summed by seed lots		
			Block I	Block II	Total
22 QU..........	Quebec...............	0	5	8	13
1 GA...........	Georgia..............	0	12	10	22
13 MA..........	Massachusetts........	1	14	39	53
8 NY...........	New York.............	0	5	49	54
16 OH..........	Ohio.................	1	8	49	57
3 TE...........	Tennessee............	1	8	53	61
18 WI..........	Wisconsin............	1	35	38	73

differences here observed among the provenances, of this species, the best possibility for selection of white pines resistant to pales weevil for any particular area would appear to be in the testing of various provenances of Pinus strobus. The groundwork for such testing has already been laid by the many widely distributed provenance trials of eastern white pine that the Northeastern Forest Experiment Station and installations of other agencies have recently established. These trials will indicate relative growth and adaptability of provenances in different parts of the species' range. The better performing provenances in a given locality could well be used in trials of pales weevil resistance.

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LOW SEEDBED DENSITIES CAN IMPROVE EARLY HEIGHT GROWTH OF PLANTED SLASH AND LOBLOLLY PINE SEEDLINGS[2] [2]

R. D. Shipman [3]

Abstract. Reduction in nursery bed density for slash and loblolly pine seedlings can result in significantly improved growth of field plantings. With systematic control of seedbed density, both the morphological and physiological properties of southern pine seedlings can be altered. During the second growing season, loblolly and slash pine seedlings taken from low bed densities grew 5.1 and 3.3 inches taller, on the average, than did seedlings produced at high bed densities. Both species after four growing seasons indicated that this growth differential between seedlings of low- and high-density beds had continued in favor of those grown at the lower densities.

Several investigators (1, 2, 5, 6, 7, 8, 10) have shown that the number of seedlings grown per square foot of nursery bed influences survival and early growth of planted southern pine. Most of the reports point out that an increase or decrease in the density of seedbeds produces stock which differs in both its morphological and physiological grade characteristics. For example, Wakeley (10) indicated some of the inconsistencies inherent in the sole use of morphological grades to assess the field performance of planted seedlings. He states, "The effects of nonvisible characteristics within seedlings may be as important as the effects of size and external form." More recently, Iyer and Wilde (3) have conducted studies on the analysis and ranking of nursery stock samples aimed at providing an index of the summary effects produced by a complex I of external and internal factors.

In general, most density studies show that as density is increased the quality (usually size) of the seedlings will decrease. Since bed

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density is a practical and controllable element of nursery production, the goal of optimum seedbed densities is to produce quality seedlings--trees that will satisfy both the biologic and economic requirements of nurseryman and planter. "Quality" seedlings may or may not be associated with size.

The studies reported in this paper were undertaken to determine the effects of varied nursery bed densities on certain external and internal characteristics of slash pine (*Pinus elliottii* Engelm.) and loblolly pine (*Pinus taeda* L.) seedlings. In addition, seedlings taken from the same beds were outplanted on several South Carolina sites. The objectives were to determine what relationships might exist between a given bed density and its corresponding field survival and early height growth.

Materials and Methods

Unstratified slash pine and stratified loblolly pine seeds whose origin was Georgia and South Carolina, respectively, were sown in beds at the Piedmont Nursery near Pickens, S.C., during the period April 23-May 13, 1958. The desired densities for testing both species were 20, 30, 40, 50, and 60 seedlings per square foot. Routine bed preparation, fertilization, and watering were carried out on the experimental beds according to conventional nursery practices. Density checks taken in July and again in September indicated that the actual densities deviated only slightly from the desired ones.

In the laboratory, a representative number of sample seedlings obtained from the above-described seedbeds were analyzed for certain morphological and physiological features as described by Wilde and Voigt (11). Using these techniques, the following measurements were taken on individual seedlings of slash and loblolly pines. Morphological characteristics were: Color of stock, top height, stem diameter, root length, and top-root ratio. Physiological characteristics were: Transpirational water loss from crowns, total absorbing capacity of roots, and specific gravity of stems. The coefficient of variability for heights was also computed. Mean values obtained from measurements on each of the above factors were subjected to analysis of variance using the techniques described by Le Clerg et al. (4).

For the field plantings, 1-year-old seedlings of slash and loblolly pines were lifted with shovels from the same nursery beds as those used for the laboratory samples. Trees were planted in randomized 100-tree plots at a 6- by 6-foot spacing on three South Carolina sites. A total of 9,000 seedlings were planted at monthly intervals beginning on December 23, 1958, and ending March 13, 1959. Approximately 1 month after the plantings were established at each location, initial seedling heights were measured. Each species was analyzed separately according to covariance techniques allowing for differences in initial height. Statistical comparisons of first-year survival according to species and density were also made.

Nursery Results

The following discussion is confined to a summary of those seedling characteristics developed in the nursery which appear to exert most influence upon growth of the field plantings. Of the seedling variables enumerated in table 1, only those which are statistically significant for both species are discussed.

Top-height.--For slash pine, stem lengths produced at bed densities of 20 and 28 were significantly greater than at densities of 41 and 60 per square foot. Also, a density of 28 produced significantly taller stems than a density of 50. Seedlings of loblolly pine grown at 61 and 47 per square foot were significantly greater in height than at densities of 20, 25, and 40. The reasons for this inverse top-height relationship with slash pine are not clear. According to the results, there is some suggestion that density effects on height growth may not become apparent until after the first growing season in the field.

Root length.--Significant differences in primary root length between the various bed densities were evident for both species. In general, lower bed densities produced seedlings having the greatest root length. Also, the total adsorbing capacity of the roots was found to be positively related to seedlings of

TABLE 1.--Summary Effects of Seedbed Density on Slash (S) and Loblolly (L) Pine Seedlings

Characteristics of nursery stock	Number seedlings per square foot (density)										F-value[4]	
	S	L	S	L	S	L	S	L	S	L	S	L
	20[1]	20[2]	28	25	41	40	50	47	60	61	NS	NS
Morphological												
Color[3]												
Top height, cm.......... (inches)	33.4 (13.1)	17.2 (6.8)	35.6 (14.0)	18.1 (7.1)	30.1 (11.8)	20.9 (8.2)	32.2 (12.7)	22.1 (8.7)	29.5 (11.6)	23.2 (9.1)	**	**
Root length, cm..........	29.8	23.1	36.4	23.0	28.9	20.8	31.1	19.8	27.6	18.0	**	**
Stem diameter, mm........	6.8	3.7	4.9	3.6	4.0	3.6	4.4	3.7	4.1	3.4	**	NS
Top-root ratio (ovendry gms)..........	4.7	3.1	5.6	3.0	6.4	2.9	5.6	3.8	4.9	3.6	NS	**
Specific gravity (stem)..	.54	.54	.59	.57	.53	.65	.55	.58	.58	.67	NS	**
Coefficient of variability (height, percent)......	13.2	23.8	8.1	20.1	7.4	17.8	8.5	18.1	8.8	17.3		
Physiological												
Transpirational water loss, gms.............	1.1	.24	1.3	.28	1.4	.32	.81	.24	.61	.26	**	**
Total adsorbing capacity roots, ml.....	.63	.22	.53	.30	.32	.23	.47	.19	.31	.17	**	**

1 Basis: 11 sample seedlings per bed density.
2 Basis: 48 sample seedlings per bed density.
3 Color index description based upon hue, value, and chroma are omitted.
4 **--Significant at 1 percent level of probability.
NS - No significant difference between means.

low density, which is an indirect measure of total root size and extent.

Transpirational water loss.--Water losses from loblolly pine seedlings grown at 40 per square foot were significantly greater than those of seedlings grown at densities of 61, 47, and 20. For slash pine, transpirational water loss from seedlings produced at a bed density of 41 significantly exceeded the water losses from those grown at 60, 50, and 20 per square foot densities. The forced removal of water from seedling crowns under controlled time and temperature conditions was assumed to be a measurable index of the potential transpirational capacity of a given density. Lower density seedlings under these conditions transpired most.

Total adsorbing capacity of roots.--This measure, also known as the "titration value," is an indirect measure of root surface area and is assumed to be indicative of the potential for nutrient and water adsorption by root systems. The data obtained from these trials showed highly significant differences between densities of both species. A trend toward greater root adsorption surface from seedlings of both species grown at lower bed densities is indicated. Loblolly seedlings grown at densities of 20, 25, or 40 per square foot exhibited a significantly greater potential capacity for adsorption than did those grown at higher densities of 47 and 61 per square foot. For slash pine, adsorption capacities of seedlings grown at densities of 20, 28, and 50 per square foot significantly exceeded adsorption capacities of seedlings from beds of 41 and 60 per square foot densities.

Outplanting Results

Survival.--Regardless of planting date, locality, or species, field survival was not significantly improved by a reduction in seedbed density. Precipitation records show that rainfall during the growing season of 1959 was far above the long-term average at all three planting locations (9) (table 2).

The results indicated that with adequate moisture, survival was not affected by seedbed density within the range investigated. These findings are similar to those of

TABLE 2.--Rainfall and Departure from mean in 1959

Location	1959 Annual precipitation	Departure from long-term means
	Inches	*Inches*
I Columbia, S.C..	66.00	+19.85
II Aiken, S.C.....	60.52	+18.02
III Clemson, S.C...	64.67	+13.45

Shoulders (8), who found that in average years in Louisiana there were no survival differences associated with stand density. However, he observed that in moderately dry years, seedlings taken from beds of low densities survived best at the end of the first growing season.

Field growth.--The summary effects of seedbed density were "carried over" into field plantings and influenced the growth of slash pine the first year and of both species the second year after field planting. Slash pine seedlings grown at a density of 20 per square foot averaged 3.22 inches greater first-year height growth in the field than did those raised at a seedbed density of 60 seedlings per square foot. The least significant mean difference in field height growth between any two densities was 1.47 inches at the 5 percent level of probability. A comparison of the values for mean height growth indicates that a seedbed density of 20 per square foot resulted in significantly greater first-year growth than did the higher densities of 50 and 60, and seedlings grown at 41 per square foot grew significantly more than those grown at 60 per square foot. A general trend in increased field height growth with a decrease in original nursery bed density is apparent. The other variables of field planting date and location did not affect first- or second-year growth significantly. Loblolly pine after one growing season in the field showed no significant height growth differences in any seedbed category, although the same trend of greater field growth by seedlings from low-density beds is indicated.

At the termination of the second year's growth, the influence of bed density was even more pronounced. At this stage of development, there were significant differences

TABLE 3.--Average Survival and Height Growth of Planted Slash (S) and Loblolly (L) Pines in Relation to Nursery Bed Density[1]

	Number seedlings per square foot (density)									
	S	L	S	L	S	L	S	L	S	L
	20	20	28	25	41	40	50	47	60	61
First-year survival--percent.....	[2] 97.4	[3] 96.8	96.4	96.6	97.7	96.0	96.5	97.5	97.1	94.9
First-year height growth--inches......	[4] 8.71	9.23	6.86	8.73	7.00	7.77	6.29	7.94	5.49	6.41
Second-year height growth--inches......	[5] 19.69	[6] 22.92	18.18	21.17	17.81	18.83	16.93	19.63	16.40	17.78

[1] Basis: 300 trees planted at three monthly intervals per location and density.
[2,3] No significant difference between density means.
[4] Least significant difference between means is 1.47 inches at the 0.05 percent level of probability.
[5,6] Least significant difference between means is 1.77 and 3.10 inches for slash pines and loblolly, respectively, at the 0.05 percent level.

between the various densities for both species tested. The average differences in second-year field growth between seedlings grown at the lowest and highest seedbed densities was 5.14 inches for loblolly pine and 3.29 inches for slash pine. In the case of loblolly pine, seedbed densities of 20 and 25 resulted in significantly better field growth than the highest density of 61; furthermore, seedlings from the lowest density of 20 were significantly superior in growth to those raised at bed densities of 40 and 47 per square foot. Slash pine growth during the second season in the field was related to density in much the same manner. For example, slash pine raised at bed densities of 20 and 41 per square foot showed significantly higher growth than those from the maximum density of 60. Also, seedlings from the lowest slash pine density of 20 exhibited significantly superior height growth over those from densities of 41 and 50. A comparison of growth between the two species showed the average height increase for loblolly pine, including all densities, locations, and planting dates, to be 2.26 inches greater than that of slash pine during the second growing season in the field (table 3).

Although no measurements have been taken since the second year in the field, observation indicates that the increased height growth of seedlings originating from low-density beds has been maintained, and in some cases accelerated, after four growing seasons. Slash pine trees shown in figure 1 are illustrative of the wide margin in growth observed between seedlings from low-density (20 per square foot)and high-density (60 per square foot) beds 4 years after field planting.

Discussion

Although not all possible morphological and physiological attributes of seedling stock were investigated, it has been shown that certain finite and fairly well-defined individual seedling characteristics can be associated withthe spacing or density under which the seedlings were grown in the nursery. A direct causal relationship between the increased growth of field plantings and individual seedling features was not possible. However, the summary effects of these seedling characteristics were shown to be correlated with differences in bed density.

It is recognized that the simple numerical rankings of a set of complex seedling features is insufficient to show direct nursery and field growth relationships. These data, however, do suggest certain overall average differences and similarities revealed by seedlings grown within a prescribed range of densities for a particular nursery in a single year. The average loblolly and slash pine seedling grown at low bed densities might be characterized as having morphological and physiological features associated with improved field growth.

Since the basic concept of nursery stock grades is to select seedlings that will improve field survival and growth after planting, it is plausible that nursery stock grades might be defined and categorized more rigidly if seedbed density were taken into account. Even though variation within a given bed density will always be present, the average number of high-grade seedlings for a single optimum density was greater than for other densities under conditions of this test.

It is believed that continued investigations aimed at relating field survival and growth to seedling characteristics developed under given bed densities will help to more precisely standardize and define seedling grades. This is one way to narrow the gap between current quantity production of nursery stock and future quality production.

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