PELLETING CONIFER SEEDS FOR CONTROL OF DAMPING-OFF

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The control of damping-off is one of the_. troublesome problems confronting the superintendent of a forest-tree nursery. Various methods have been used, depending on local nursery conditions. A fast and inexpensive method of damping-off control is needed, and pelleting of seed with a fungicide may be the solution at some nurseries. Pelleting is intended to coat the seed prior to sowing with a fungicide which will sterilize the soil in the immediate vicinity of the seed when it is planted, to sterilize the soil through which the germinating seed passes, and to protect the seedling after emergence by reason of the small quantity of fungicides which would be released from the seed coat to sterilize the stem until the seedling passed the critical stage or as long as the seed coat remained attached to the seedling.

Some experimental work with pelleting seed has been done by John G. Berbee, Plant Pathology Department, University of Wisconsin., With some associates, he tested 28 fungicides over a period o13 years and found one which was quite effective for use in this manner. He also found that methyl cellulose was satisfactory for use as the binder needed to hold the fungicide to the seed. 1/

To determine whether pelleting would control damping-off tests were made in the spring of 1955 at the Union Tree Nursery operated by the Illinois Department of Conservation, Division of Forestry. Stratified shortleaf, loblolly, and Scotch pine seed were used. The seeds were pelleted immediately after they were removed from stratification and partially dried.

Two different fungicides--Captan 50W, and tetramethylthiuram disulfide (hereafter indicated as TMTD) which is sold under the trade names of Arasan SF-X, 75% Thiram, and Tuex--were tested. These two fungicides are very different chemically, but both are effective in controlling various fungus diseases. The fungicides were tested separately for comparison.

1 / The Prevention of Damping-off of Coniferous Seedlings. Univ. Wis. For. Res. Notes No, 14:. 2pp October 1954.

To make the fungicides adhere to the seed a solution of one part by measure of methyl cellulose powder in 15 parts by measure of water was used. Since methyl cellulose dissolves slowly, the solution was made several days in advance of its use.

The Dybvig seed cleaner was adapted for pelleting use by reducing the speed of the machine so that seed motion in the cleaner was gently-rolling. A small portion. of seed lying against the vanes of the agitator failed to go through the pelleting process. Most of these seeds did receive some coating of fungicide when the seed was placed on drying screens. This difficulty could be overcome by improving the design of the agitator and hopper. About 10 pounds of seed could be treated in about 5 minutes in this machine, but 7 to 8 pounds seemed to be the most satisfactory amount for best treatment.

The treating process consisted of placing seed in the hopper of the seed cleaner, starting the agitator, adding enough methyl cellulose to thoroughly moisten all the *seed,* and then adding enough powdered fungicide to almost dry up the methyl cellulose. The thickness of the fungicide coating was controlled by the quantity of methyl cellulose solution used; the more methyl cellulose used to wet the seed, the more fungicide used, and the thicker the coating. The motion of the agitator kept most of the seed from forming in a wad unless excessive amounts of cellulose and fungicide were used. As soon as the seeds were coated with the fungicide, the material was removed and placed on a drying screen. Stirring the seed a few times while on the drying screen broke up any small wads that occurred. Under normal conditions the drying of freshly coated seed took about 10 minutes. By volume measure, about 4 parts of fungicide were required to 1 part of methyl cellulose solution. If unstratified dry seed are used, slightly more methyl cellulose would probably be needed. The quantity of cellulose and fungicide to use for various seeds can best be determined through experience.

No injury to seed or seedlings was observed in any of the tests. The pelleting process did not damage the stratified seed; germination test rates were almost identical for treated and untreated seed. Treated and check beds were sown on April 27 and 28. The pelleted seed were sown just before the untreated and within 2 hours after pelleting. The pelleted seeds were larger than the untreated seeds and passed through the seeding machine less freely than the untreated seed. As a result, 13 to 47 percent less seed was sowed in the treated seedbeds than the untreated seedbeds, an important point to remember when considering the final results.

Personnel was not available to make repeated examinations of seedbeds during the critical period to measure the effects of the treatments. However, they were evident to even the casual observer. Counts of damping-off losses were made 21 days after sowing in the central row of various 8-row, 480 feet beds. The data are as follows:

	Seedlings damped-off[1/] (number)
Shortleaf pine, sand stratified, 50-percent germination:	
Captan 50W	43
TMTD	63
Check	305
Loblolly pine, sand stratified, 48-percent germination:	
Captan 50W	10
TMTD	10
Check	195
Loblolly pine, moss stratified, 69-percent germination:	
Captan 50W	5
TMTD	25
Check	310
Scotch pine, sand stratified, 96-percent germination:	
Captan 50W	110
TMTD	88
Check	370

1/ In contrasting these figures with each other the following facts should be borne in mind.

(1) These figures do not show how much, if any, pre-emergence damping-off occurred.

(2) Additional seedlings damped-off after the others were made, mostly in the untreated beds.

(3) Fewer seeds were planted in the treated beds.

Counts on August 1 showed that despite the reduced rate of sowing for treated seed, the number of live trees per linear foot in the treated beds equaled or exceeded the number in the untreated beds.

During the germinating period no molds grew directly above the drilled rows, which indicates that a narrow band of soil was effectly sterilized. No difference was noted in rate of germination between the treated and untreated beds. Moss stratified seed germinated slightly ahead of sand stratified seed. There was no difference in the rate of growth of seedlings in the treated and untreated seed areas.

Bird damage in untreated beds was considerably more than in the treated beds. In fact, no bird damage was observed on any of the treated beds, but this might not have been true if the birds had had no untreated seed to feed on.

The possibility of incorporating a soluble fertilizer in the pelleting process had to be abandoned as the addition of soluable fertilizers to the methyl cellulose solution caused it to lose its adhesive quality. The incorporation of insecticides was not attempted but would be a possibility for control of grubs, cut worms, root weeviles, and wire worms.

This method of damping-off control will be used more extensively at Union State Tree Nursery. An attempt will be made to determine whether Captan 50W or TMTD is more effective although observations so far indicate very little difference in effectiveness between these two fungicides. Perhaps tests should be made to determine if a mixture of these two fungicides would increase the effectiveness of this method of control.

Since this method of controlling damping-off is less hazardous to use, less subject to error, and in most cases cheaper than other methods, any nurseryman producing conifer seedlings should give this method a trial.

CONTROL OF DAMPING-OFF AT BOSCOBEL STATE NURSERY IN WISCONSIN

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At the Boscobel State Nursery, started in 1951, our original conifer seeding was kept at a minimum, as we anticipated poor growth until the nursery area could be inoculated with the important root-producing mycorrhizal fungi. The seed was fall sown, without seed treatment. The species were of white and Norway pine and white and Norway spruce. The spring germination of all species was fair; however, early damping-off soon took its toll of better than 50 percent of the germinated seedlings. Those that came through were then attacked by late damping-off, in June and early July. So few plants were left by late summer that it did not pay to maintain the area.

The following year, in cooperation with the University of Wisconsin, tests were made in attempts to control damping-off. Two damping-off fungi were isolated. Early damping-off, caused by a species of *Pythium,* attacks during the cool and damp weather of early spring; late damping-off, caused by a species of *Rhizoctonia,* attacks seedlings during hot and dry weather, usually during late June and early July. Symptoms of damping-off are as follows: Early damping-off-Slight lesions appear on the stem at the ground line; the roots turn brown to black; and the plants fall over but usually remain green for several days. Late damping-off-The stems become straw colored; the roots are white when first attacked but later turn. brown and die; the stems turn brown but remain standing; and the needles turn brown but do not fall off.

The second year's seeding schedule consisted of several tests of seed pelleting and check plots. DuPont Arasan 50 percent (Tetramethylthiuram disulfide), the organic seed disinfectant and protectant, used with methyl cellulose as a sticker, was used to pellent the fall-sown conifer seed. Proportions of 1 pound of Arasan to 2 pounds of seed, as well as 1 to 4, and 1 to 8, were used. The tests proved that the 1 to 4 trial showed maximum control with the least amount of fungicide.

The sticker held the Arasan on the seed coat throughout the winter, and there was still evidence of some of the Arasan on the seed after the seed coat was forced from the small seedling and had fallen to the ground. While this seed coat remained on the small emerged plant, rain and overhead irrigation washed a small amount of the Arasan material from the seed coat down the stem and on the ground around the plant, resulting in control for damping-off.

As an insurance measure to control this early damping-off, a spray of Tersan 75 percent (the form of the Tetramethylthiuram disulfide chemical that goes into solution) was applied to the seed beds during mid April, about 2 to 3 weeks prior to germination. This early Tersan spray also controlled some of the early weeds for 4 to 6 weeks.

A second application of the Tersan spray was made after emergence of the seedlings, and this spray controlled late damping-off. Occasionally it was necessary to apply a third spray of Tersan to control late damping-off. No ill effects have been noticed as a result of using this seed treatment or spray material.

The Tersan is used at the rate of 1/2 gram of the 75 percent powder per square foot of seedbed area. We used approximately 3 pounds of Tersan to 12 gallons of water to spray a 42-inch wide row 550 feet long. A Silver Prince Myers sprayer was used for this operation, with three fan-shaped spray nozzles on the end of a boom adjusted to have minimum of lap. It covered the bed and half of each path. The screens in each nozzle were removed to prevent plugging of the material in the nozzle ends.

As already mentioned, our soil lacked the mycorrhizal fungi so important in the nursery for growing good healthy seedlings. Inoculation of the Boscobel nursery soils has been carried on primarily by the use of 2-year-old seedling stock from the Griffith nursery transplanted here and distributed as 2-2 stock and by spreading over our nursery area, soil and cull waste obtained from the Griffith State Nursery culling and sorting shed during the shipping season. Forest leaf mold was also used but was difficult to obtain in the great amounts needed. Seedling growth of conifers on these inoculated areas showed more color, growth, and disease resistance than the seedlings grown on the previously seeded areas not inoculated.

These same tests were run with about the same amount of success at the Griffith State Nursery.

TREATMENT OF FOREST-TREE SEED WITH CHEMICAL PROTECTANTS

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Tree seeds, like seeds of other plants, also have many potential enemies, both fungi and bacteria which inhabit the soil. These destructive agencies commonly destroy an appreciable portion of the planted seed. Successful measures to combat these losses would save considerable quantities of high-priced seed.

Each year additional chemical seed protectants appear on the market and the number of species that can be successfully treated has increased. Such treatment accomplishes two results. It kills fungus spores carried on the seed and establishes a zone of protection around the seed as it germinates, minimizing attack by soil-borne organisms.

Treatment of seed prior to planting has shown particular merit for seeds that have a high germinative capacity but have been weakened by long storage or by other causes. Such treatment also assumes added importance for seeds sown in soil harboring high populations of pathogenic fungi. It has been demonstrated, as the result of widespread tests on vegetable and crop seeds, that certain fungicides are best suited to seeds of particular species. Seeds of different species differ in their susceptibility to injury by various fungicides.

During 1951 and 1952 a small experiment was .initiated to determine the effectiveness of one of the many seed fungicides on forest-tree seeds. Seeds of three species of softwoods were dusted with Arasan and planted during the fall (1951) and spring (1952) planting seasons. Results were as follows:

1 / The field work on this project was carried out by Nurserymen H. E. Staley. and Carl Snyder and Senior Forester John E. Ewers. The author planned the project.

	Seedlings per square foot		Increase in survival of treated seed
	Treated (number)	Untreated (number)	(percent)
Hemlock	344	240	43
Northern spruce	336	228	47
Red pine	140	120	17

These results were encouraging. All species treated showed a marked increase in germination as compared with untreated seedlings. For Norway spruce the increase was 47 percent.

In the spring of 1953 additional plots in two forest-tree nurseries were established and treated with two commercial preparations, Arasan 2/ and Spergon. 3/ Seeds of several species were dusted with these two seed protectants, according to the manufacturer's recommendations for vegetable seeds of similar size. Results are presented in Table 1.

Table 1.--Effect of seed fungicide treatment on forest-tree seed

Location and species	Seedlings per sq. ft. treated with Arasan 1/		Check	Increase or decrease in survival	Seedlings per sq. ft. treated with Spergon 1/		Check	Increase or decrease in survival
	Plot 1	Plot 2			Plot 1	Plot 2		
	No.	No.	No.	%	No.	No.	No.	%
Clearfield Nursery:								
White pine	34	48	43	+5.1	46	58	35	+33.0
Chestnut	16	15	25	-18.4	16	12	13	-26.3
Mont Alto Nursery:								
White pine	42	54	47	+1.9	60	55	60	+7.5
Red pine	50	57	67	-15.7	60	81	60	+ 11.0
Nor. spruce	186	154	146	+8.6	198	192	167	+24.6

1/ Rate: For chestnut seed, 1/3 teaspoon per pound of seed; for other species, 1 teaspoon per pound of seed.

The 1953 treatments failed to duplicate the outstanding increases in seedling survival experienced in the single trial with Arasan in 1952. In the later trials, however, double the amount of Arasan (1 teaspoon per pound) was used in treating the same species. Injury due to excessive amount of protectant may have been the cause.

These two small-scale tests conducted during 1952 and 1953 indicate that additional research is warranted to evaluate the possible advantages of treating forest-tree seed with protectants. Two questions must be answered: What fungicide is best suited for each individual species of tree seed, and how much should be applied for consistently favorable results.

To accomplish this, future research should test the most promising seed protectants with various amounts for the various species of forest-tree seeds.

2/ 50 percent tetramethylthiruramdisulphide.. E. I. DuPontde Nemours & Co.

3 / 90 percent tetrachloro-para-benzoouinone. United States Rubber Co.

METHYL BROMIDE GAS CONTROLS WEEDS, NEMATODES, AND ROOT ROTS IN SEEDBEDS 1

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In 1947 at the Saratoga Tree Nursery one of the blocks previously used far transplants was converted into seedbeds. Very poor survival and growth of seedlings in parts of this block were noted. Seed of another species was sown in the block in 1950 and the same pattern of poor survival and growth was observed. A study of air photos and management maps revealed that some 4-0 or 5-0 white pine seedlings had been plowed under during World War II in the areas where the seedlings were not showing good growth. All of the observations pointed to a soils problem, either nutritional or biological.

In 1952 soil analyses and fungus studies were made, and the area was treated experimentally with methyl bromide gas. During the years 1952 through 1954, 128 seedbeds (48 square feet each) were treated with methyl bromide gas on this and other areas at the Saratoga and Lowville Tree Nurseries. Five different species of conifers (Scotch pine, red pine, Norway spruce, white spruce, and Japanese larch) were seeded in these areas.

The first year methyl bromide gas was used, before sowing, four seedbeds were treated at 1 pound per 48 square feet. The same amount of seed was sown in the treated and untreated areas, and the germination in these beds was about equal. The untreated had been sown and maintained just as the gassed beds. At the end of the first year an inventory was taken of the seedlings in the treated beds as well as in the untreated beds adjacent to them. The first-year survival figures are shown in Table 1.

Table 1.--Effect of seedbed treatment with methyl bromide gas on first-year survival of seedlings.

Species	Seedling survival		Production increase
	Treated beds	Untreated beds	
	Number	Number	Percent
White spruce	10,992	2,328	372
Norway spruce	4,584	2,352	95
Scotch pine	4,320	236	1,730
Red pine	2,064	792	161

1/ Tests were made at the direction of E. J. Eliason, Assistant Superintendent of Forest Tree Nurseries, N. Y. State Conservation Department.

First year survival in the beds treated with methyl bromide gas was from 95 to 1, 730 percent better than that in the untreated beds. Also, the trees in the treated beds were greener and had better roots and stems than those in the untreated beds.

In 1953 tests with methyl bromide gas were increased; 104 seedbed.; were treated, and control beds were laid out adjacent to them. Methyl bromide gas was applied at the rate of 2 and 4 pounds per 100 square feet. Seedbeds tested included those in areas with normal seedling growth as well as those in areas where growth was poor. Results were as follows:

1. Application of methyl bromide gas at the rate of 4 pounds per 100 square feet resulted in lower germination and first-year survival. However, application of methyl bromide gas at the rate of 2 pounds per 100 square feet had little if any effect on seed germination but greatly increased first- and second-year seedling survival.

2. Treatment with methyl bromide gas was extremely effective on areas with a sparse stand of seedlings with poor growth. However, seedbeds with normal density and normal seedling growth showed little or no benefit from treatment with methyl bromide gas. Treatment of such seedbeds would not be economically feasible. Treating seedbeds with methyl bromide gas costs about $600 per acre.

3. Methyl bromide treatment resulted in very good weed control for 2 or 3 weeks after seedling germination.

4. Spring treatments with methyl bromide gas were more effective than fall treatments.

Some problems in the use of methyl bromide gas were encountered in the 1953 tests. Therefore, additional tests were made the following year. In the spring of 1954, 20 seedbeds were treated before they were sowed. Results were as follows:

1. No injury was sustained by conifer seeds sowed 3 days after the seedbeds were treated with methyl bromide gas.

2. For good seed germination the soil should be in good tilth. However, the tilth of the soil was not exceptionally important in relation to penetration of the gas.

3. Methyl bromide gas, applied at the rate of 2 pounds per 100 square feet, killed all of the white grubs and prevented further invasion by grubs.

4. On areas where there was no soil biological problem, use of methyl bromide gas resulted in an increase of 14 to 17 percent in seedling production during the first growing season. Larger increases resulted in areas where there was a soil biological problem (table 1).

Late in 1954, Professor Stegeman of the N. Y. State College of Forestry found that nematodes were present in vast numbers in the area on which white pine 4-0 or 5-0 seedlings were plowed under during World War II. Soil and fungous analyses had previously been made on these areas and no nutrient deficiencies or unusual fungous activity had been found. Therefore, the poor seedling growth and survival on these particular areas were attributed to nematode damage. Methyl bromide gas proved to be excellent as a control for the nematodes in these seedbeds. In other areas where root rot fungi were causing poor growth and survival, treatment with the gas was very beneficial but not as spectacular as in the areas infested with nematodes.

After three years of testing with methyl bromide gas on normal and problem areas the inventories taken at the end of the first growing season and at the end of the second growing season were analyzed to determine the effect of the gas treatment on survival of the seedlings. Average losses in treated beds for the period were just about half what they were in the untreated beds. Table 2 shows first- and second-year survival in an area infested with nematode.

Table 2.--First- and second-year seedling survival, following methyl bromide gas treatments of seedbeds in an area heavily infested with nematodes.

Species	Untreated Beds			Treated Beds		
	1-0 seedlings per bed	2-0 seedlings per bed	Loss	1-0 seedlings per bed	2-0 seedlings per bed	Loss
	Number	Number	Percent	Number	Number	Percent
White spruce	2,328	221	90.5	10,992	8,668	21.1
Norway spruce	2,352	987	58.0	4,584	2,439	46.8
Scotch pine	236	80	66.1	4,320	2,620	39.4
Red pine	792	463	41.5	2,064	1,713	17.0
Average			64.0			31.1

There is one drawback to the wide-scale use of methyl bromide gas at the N. Y. State nurseries at the present time. In most of the beds that have been treated with the gas in the past 3 years, spots of stunted and off - color seedlings from a few inches to a foot or more in diameter have appeared. The seedlings usually have a chlorotic color during the growing season, and in the fall they turn purple. The stunting effect continues on through the second and third years, although as the beds fill in during these years the stunting is not so noticeable as it is during the first growing season. A representative of one of the manufacturers of methyl bromide gas inspected these stunted trees but was unable to explain the reason for the stunting. It is possible that the gas is tying up some of the elements in the soil or that the rates of application are too high. Therefore, attempts will be made to eliminate the spots that are already in the seedbeds by adding fertilizers such as superphosphate, ammonium sulfate, and/or muriate of potash. More beds are being treated in 1955, with different rates of gas. Perhaps lower rates of application or the addition of fertilizers will give some clues as to the cause of the stunting and discoloration of the seedlings

In future tests some seedbeds will be treated before white spruce seed is sown. This will be done in an attempt to eliminate a serious root rot problem that has occurred in the white spruce seedbeds during the first and second years.

In 1955, more seedlings from seedbeds treated with methyl bromide gas will be field planted along with seedlings from untreated beds, to test the field survival of these 2- and 3-year-old seedlings. Last year about 100 2-year-old seedlings from the beds treated with the gas were field planted along with controls, and at this time, there are no apparent differences in survival between the treated and untreated seedlings.

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PRELIMINARY TESTS WITH SURFACTANTS FAIL TO SHOW INCREASE IN EITHER GROWTH OR SURVIVAL OF SCOTCH PINE SEEDLINGS

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It has been theorized that the addition of a small amount of surfactant, a wetting agent, to the nutrient medium reduces the surface tension of the water and results in increased penetration, spreading, and dispersion of the nutrients. It also might be expected to lower the energy requirements involved in absorption and translocation by the plant, resulting in plant growth stimulation.

In recent years a number of agricultural workers have investigated the possibilities of using surface active agents to give increased yields of forage, field, and vegetable crops. Results at the University of Wisconsin [1] indicated greatly increased production of vegetable and field crops the year of application as well as the year following application.

A 1954 report from the University of Illinois [2] indicated that the addition of the surfactant, in most cases, did not result in increased yields of dry matter. It did indicate, however, that less water is evaporated from soil treated with a surfactant and that root growth of small seedlings seemed to be stimulated in surfactant-treated soils. The author. found no published reports of effect of surfactants upon forest trees.

To determine if these results are applicable to forest-tree seedlings, two preliminary tests were made. The objectives of these tests were as follows: (1) To determine whether a surfactant added to a nursery bed at the time of seeding would increase the first-year height and/or diameter growth of Scotch pine seedlings. (2) To determine whether a surfactant side dressing could be used to prolong the spring planting season by increasing the survival of forest-tree seedlings planted toward the end of the normal spring planting season. Theoretically, the surfactant would compensate for the lack of available moisture during extremely dry summers by reducing evaporation.

1 / Berger, K. C., and L. G. Nelson. Yields of Several Crops as Influenced by Soil Applications of a Surface Active Agent. Agronomy Abstracts. 1954.

2/ Spurrier, E. C., and J. A. Jackobs. The Effect of Surfactants Upon Plant Growth. Agronomy Abstracts. 1954.

A test consisting of two parts was set up. In the first part of the test a 100 percent active non-ionic type surfactant, ethylene -oxide -thioether condensate, was applied in a water solution to 4 x 4 feet completely randomized plots of a seeded nursery bed. The soil consisted of a silt loam topsoil over a well-drained gravelly silt loam subsoil. The surfactant was applied at concentrations of 0, 10, 50, 200, and 400 pounds per acre. Three replications were used. The test beds thereafter were handled in the normal nursery operation, including overhead irrigation at the equivalent rate of not less than 1 inch of rainfall per week.

In the second part of the test, eight blocks consisting of two rows often Scotch pine seedlings (1-0) were planted in the field. In each block one row was randomly treated with a 60 percent active surfactant, sodiumalkyl-aryl-sulfonate. Application of the readily soluble surfactant was made in powder form at the rate of 5. 5 grams (2 level tablespoons) per tree, placed in bands 3 inches in radius around each seedling. This rate of application was approximately equivalent to 8 pounds of active surfactant per acre. The planting was made on two old fields consisting of approximately 6 inches of silt loam topsoil over intermediately to poorly drained claypan subsoils. The vegetative composition on both areas consisted of a moderate cover of perennial weeds and grasses. Planting was made April 26, which is rather late for southern Illinois conditions. The trees were side dressed with the surfactant at the time of planting.

No observable differences in height or diameter growth were noted among the treated plots of Scotch pine in the nursery.

The results of the field planting are shown in the table below. The mean number of live seedlings was approximately the same for the treated and untreated plots.
It is concluded that, under the conditions and rates of application used in this test, the two surfactants did not result in either increased first year growth of nursery seedlings of Scotch pine, or better first year survival of field-planted 1-0 Scotch pine

Block No.	Live trees (10 per plot) after 1 growing season: Treated (number)	Untreated (number)
1	8	9
2	9	8
3	0	1
4	4	0
5	3	4
6	5	5
7	3	4
8	2	5
Total Live Trees	34	36
Mean per Plot	4.3	4.5

seedlings.

CONTROL OF STRAWBERRY ROOT WEEVIL IN THE NEW YORK STATE NURSERIES

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In the early summer of 1950, about a dozen spots (approximately 1 foot in diameter) of dead trees were found in beds of 2-year-old white spruce and Norway spruce seedlings at Lowville Nursery. Most of these spots were on the south side of the seedbeds, and death of the seedlings was tentatively attributed to sunscald. No spots like these were seen during the 1951 growing season. In the fall of 1951 all of the stock at Lowville appeared to be healthy.

In the spring of 1952, just as the frost was leaving the ground and the shipping season was about to get under way, the needles of a large portion of the 3-year-old white spruce seedlings began to turn brown and/or grayish-green in spots from 1 to 48 square feet in area. Upon examination it was found that the fine roots were gone. As the seedlings were pulled from the ground the bark sloughed off the roots. Also, radiating out from these spots were areas of trees with green, healthy looking tops, but the roots were completely destroyed. About 1-1/2 million trees had to be destroyed as they were not fit to send out for field planting. At that time the cause of the condition was not known or even suspected.

In the fall of 1952, specialists at Cornell University and the State College of Forestry suggested that the causal agent might be strawberry root weevil. During the winter of 1952-53, on the basis of greenhouse tests at the Saratoga Nursery, the larvae of strawberry root weevil were determined to be the cause of the losses. To work out control measures studies were made of the life cycle and feeding habits of the weevil. This information is given at the end of this article.

Again in the spring of 1953 it was observed that larval feeding during the late fall and early winter had caused the loss of about 2 million 2- and 3-year-old seedlings, most of them at the Lowville Nursery, but some at the Saratoga Nursery. Most of the seedlings killed were white spruce but other species, including red pine, Norway spruce, Douglas-fir, and balsam fir, were also attacked.

1/ Investigations were made at the direction of Mr. E. J. Eliason, Assistant Superintendent of Tree Nurseries, NYS Conservation Dep't. Mr. Hill is Horticulturist, Bur. of Nurseries, NYS Cons. Dep't.

The objective of the control measures in the spring of 1953 was to completely eliminate the weevil-from both nurseries, in the shortest possible time. Therefore, there was little time for experimental work, and control on a wholesale basis was initiated immediately. , Soil samples taken at this 'time revealed that the majority of the weevil larvae were in the top 6 to 8 inches of soil. The first control method used was rototilling after .one of several different types of chemicals had been applied to limited areas while the weevil was in the larval stage. The chemicals used were lindane, paradichlorobenzene, dieldrin, and chlordane. This method of control destroyed some of the larvae, but it did not reduce the population to any great extent. Whether the slight reduction in larvae was caused by the rototilling, the chemicals, or a combination of the two is not known. This method was again used when the weevils were in the pupal stage, but it had no noticeable effect on the pupae population.

During the second week in June an entomologist from the Shell Chemical Corporation visited the Lowville Nursery and suggested that a dieldrin spray be applied at 1 /2 pound (50 percent wettable powder) per acre in about 25 gallons of water as soon as the majority of the adult weevils emerged from the soil. A power sprayer was used to apply the dieldrin water solution and the Lowville Nursery was literally covered with dead and dying adult weevils. At this time, a very few adult black vine weevils were discovered at the Lowville Nursery. The larvae and adults of this insect are similar to the strawberry root weevil, but are about twice the size. The adults and larvae of the black vine weevil are about 1 /4 inch in length, and the adult is black. The same control measure is applicable to the two species of insects. To control both species of weevils during the summer of 1953 all the seedbeds, cover cropped areas, and the land surrounding the nurseries were sprayed twice with dieldrin at the rate given above.

In the summer of 1954, only a few larvae were found in the soil. In fact, where a shovelful of soil would have yielded 50 to 100 larvae in 1952, only about 15 larvae could be found on an acre in 1954. However, at the rear of the Lowville Nursery an eruption of adult weevils occurred in some NS 3-0 stock. This may have been the result of a skip in the dieldrin spraying the previous summer or inadequate spray for the extremely high population in that area. During the summer of 1954, both nurseries were again completely sprayed with dieldrin at the rate of 1 /4 pound (50 percent wettable powder) per acre in 25 gallons of water when the adult weevils emerged.

Dieldrin will be sprayed at the 1 /4 pound per acre rate on. all nursery property at Lowville and Saratoga when the adult weevils are expected to emerge, until there are no signs of the two species of weevils. It is believed that 100 percent control of these insects was achieved by the fall of 1954.

The extremely rapid buildup in the weevil population during the year 1951 might be attributed partly to a high soil moisture content throughout the growing season, a warm summer, .and moderate temperatures until late in the fall. Where the weevils originally came from is a mystery because examination of the fields surrounding the nurseries showed them to be completely clear of adults and larvae.

The following information on life cycle, feeding habits, and damage of the strawberry root weevil (*Brachyrhinus ovatus*) may be helpful to others who may need to control this weevil. The life cycle of the black vine weevil (*Brachyrhinus sulcatus*) is similar to that of the strawberry root weevil.

Description of weevil stages. The adult weevil is 5 to 6 mm. long; its color is light brown to black, depending upon maturity; and it is wingless and has a, modified snout. The larva is 3 to 5 mm. long, its body is white to creamy white in color, its head is brown. The pupa is 4 to 6 mm. long and is white to light brown, depending upon maturity.

Life cycle of the strawberry root weevil (Brachyrhinus ovatus). In July the adult weevil lays 15 to 30 eggs in soil crevices and under loose debris on the ground. Each egg is about 0. 5 mm. in diameter, is white when first laid, and turns brown after a day or 2. The eggs hatch into larvae within 2 or 3 weeks. The larvae feed on roots of seedlings until the ground freezes, and they resume feeding in early spring. Overwintering larvae start to pupate about the middle of May. The pupal stage lasts about 10 days to 2 weeks; after this stage the adults remain in the cell for about a week until their bodies are well hardened. The first adults emerge from the soil about June 1, and the majority of the adults have emerged by the second or third week in June The adults then feed on the needles of the seedlings about 3 or 4 weeks before they are capable of oviposition (laying eggs). Thus there is a 2- or 3- week period, after the majority of the adults have emerged, for spraying to control the weevil. The life cycle may vary slightly with weather conditions.

Description of weevil feeding. The adults feed on needles of seedlings during the night. They cut spruce needles in two just above the center. On the other species they cut out pieces of the needles along the sides. The larvae feed on the roots of seedlings of all species. In the New York State nurseries they were especially damaging on white spruce; they consumed all of the fine roots and stripped the bark from the larger roots, sometimes girdling them.

Weevil damage and early identification. The larvae feed extensively on the roots until the ground freezes around them. Usually no damage can be seen on the seedlings until spring, too late to do anything about the stock that is old enough for shipping. In early spring, as soon as the frost is out of the ground, spots of seedlings with brown and grayish green needles appear throughout the beds. The seedlings can be pulled from the ground very easily because all of the fine roots are gone and part of the bark on the larger roots has sloughed off. Examination of the top 8 inches of soil supporting the discolored seedlings is necessary to determine whether or not larvae are present. The larvae are difficult to see, but they can be separated out by sifting the soil. If there is a heavy infestation when the seedlings are removed, the presence of larvae will give the ground the appearance of just having been covered with rock salt.

MICRO-ORGANISMS IN NURSERY SEEDBED SOILS

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One phase of the forest-tree seedling research program at the Alabama Station is a study of some of the soil micro-organisms. The preliminary work was primarily concerned with identification of fungi associated with damping-off and with nematodes associated with root rot. Sawdust and cover crops are extensively used as sources of soil organic matter; therefore the study was expanded to include them.

Rotations being studied at the Auburn Nursery include the following: (1) Sawdust, mineral fertilizers, and continuous seedling production; (2) cover crops, with and without sawdust, and mineral fertilizers; and (3) intermittent seedling production. Some rotations receive a soil chemical treatment prior to seedling production; other rotations do not.

Important questions that may influence a soil management program include the following: (1) What species of organisms are associated with the breakdown of different types of organic matter? (2) When are these organisms most active ? (3) What is the relationship between these organisms and availability of nutrients, especially nitrogen? (4) Which of these organisms attack the roots and stems of forest tree seedlings ? (5) Under what conditions may a nurseryman expect a heavy seedling loss due to action of soil micro-organisms ? Answers to these questions may greatly influence nursery management practices.

Many kinds of organisms, including bacteria, actinomycetes, fungi, and nematodes, are responsible for the disintegration of cellulose and related compounds in the soil. However, bacteria and actinomycetes are not known to be causes of important diseases of tree seedlings. Therefore, in 1953, the study was limited to soil fungi. Soil samples collected from seedbeds receiving different treatments were cultured on a medium of potato dextrose agar. As colonies of fungi developed, they were examined under the microscope and classified by genera. The colonies in each genus were counted and calculated as a percentage of the total fungus population that developed. The fungi found are listed in table 1. In table 2 they are grouped according to their probable relationship to plants, as follows: (1) Cellulose destroyers, (2) antagonists,

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(3) pathogens, and (4) sporodics.

Addition of cellulose to the soil results in extensive development of fungi that possess very strong cellulose-decomposing power. The' first five genera in table 1, namely, Chaetomium_, Thielavia, Aspergillus, Penicillium, and Trichoderma, are potent cellulose destroyers.

An antagonist may be defined as an organism that inhibits the growth of other nearby organisms. A single organism may be classified into two or more groups. For example, Aspergillus, Penicillium and Trichoderma must be classified as antagonists as well as cellulose destroyers The influence of organic materials in controlling the development of disease-producing fungi in the soil is due to the effect of antagonistic organisms favored by some forms of organic matter. These play an inportant role in suppressing the growth of plant parasites.

The last four genera listed in table 1, Curvularia, Pythium, Phytophthora, and Fusarium, are root pathogens. These genera include many of the root rot and damping-off organisms.

The fungi classified represent only a fraction of the total fungus population, and they are largely spore formers. This means a disproportionate representation, percentage wise, for these spore formers. However, tentative conclusions have been made, as follows: (1) Many of the active fungi in seedbeds were beneficial rather than harmful. (2) Incidence of cellulose-decomposing and antagonistic fungi increased sharply with rising temperatures. (3) The increase of antagonists with rising temperatures is accompanied by a sharp decrease of root pathogens. (4) The cellulose-destroying community remained in a definite balance. Disappearing genera were replaced by genera of the same physiological type. Penicillium apparently replaced Trichoderma and, in turn, Aspergillus replaced Penicillium and Thielavia. (5) The pathogens did not maintain a balance, but rather were replaced by genera that were both cellulose destroying and antagonistic.

Table 1.--Fungi isolated from sawdust-mulched pine nursery seedbeds, Auburn, Ala., in 1953.

Fungi isolated (genus)	Percentage of total isolations				
	May 13	June 6	June 29	July 25	Aug. 25
Chaetomium	12	11	2	0	0
Thielavia	9	12	37	4	3
Aspergillus	0	17	18	26	55
Penicillium	0	0	28	61	27
Trichoderma	38	33	14	8	2
Curvularia	0	0	0	0	10
Pythium or Phytophthora 1/	19	20	0	0	0
Fusarium	22	7	0	0	0

1/ Most investigators are unable to distinguish Pythium from Phytophthora in culture. Some of these colonies had the appearance of Phytophthora cinnamomi. If the latter organism was obtained by these methods, it was purely accidental.

Table 2.--Type classification of fungi isolated from sawdust-mulched pine nursery seedbeds at Auburn, Ala., in 1953

Fungus type	Percentage of total isolations 1/				
	May 13	June 6	June 29	July 25	Aug. 25
Cellulose destroyers	21	40	85	91	85
Antagonists	38	40	60	95	82
Pathogens	41	27	0	0	0
Sporodics	0	0	1	1	13

1/ Since some genera in table 1 are both cellulose destroyers and antagonists, percentages here usually total more than 100.

THE USE OF SAWDUST AS A MULCH ON RED, WHITE, AND JACK PINE SEEDBEDS

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The practice in most northern nurseries of the Forest Service is to sow most of the seed in the fall, especially red and white pine and the spruces. Fall seeding has resulted in better germination and bigger seedlings than spring sowing. However, the fall-sown beds apparently need to be mulched to prevent the seed from being uncovered by the wind during the periods they are not covered with snow. The material most used for this mulching has been straw, marsh hay, or in some cases burlap, which must be removed in the spring as soon as germination starts. The removal of the mulch involves considerable labor and, unless the mulch is removed before germination starts, some of the seedlings are destroyed in removing the mulch even if it is removed very carefully.

To eliminate mulch or find a material that could be left on the beds, a series of experiments were started in 1948. Seedbeds of red pine were left unmulched for comparison of germination with mulched seedbeds. Results in 1948 were as follows:

	Unmulched	Mulched
Average number of seedlings germinated per square foot:		
Plot 1	49.8	51.0
Plot 2	40.1	46.2

Mulching did result in a better stand but perhaps not enough better to justify the cost of mulching. For the next 4 years tests were made with seedbeds mulched with straw and sawdust. Results were as follows:

	Sawdust Mulch	Straw Mulch
Average number of seedlings germinated per square foot:		
Jack pine from Upper Michigan	53.2	41.6
Jack pine from Lower Michigan	44.8	33.8
Red pine from Chippewa	49.5	36.9

In these tests better germination resulted from the seedbeds mulched with sawdust than from those mulched with straw.

In the fall of 1953 about 80 percent of the fall-sown red pine beds were mulched with sawdust, and the remaining beds were mulched with straw. The straw mulch was removed as soon as the seed started to sprout in the spring. Germination counting plots (2 square feet in size were established in about 10 percent of the beds, and germination counts were made every week throughout the germination period.

Germination was a little slower in the beds mulched with sawdust, but by the second week total germination was about equal in the beds mulched with straw and those mulched with sawdust. The losses from damping off and other causes were about the same under both mulches. Results of these tests are as follows

	Sawdust Mulch	Straw Mulch
Germination, average number per square foot:		
Fall 1953	8.2	9.8
June 1, 1954	51.0	42.0
July 15, 1954 1/	44.2	39.6

1/ One percent count of all beds.

It was difficult to apply and keep a uniform layer of sawdust on the beds. A sand spreader of the type used to spread sand on highways was the best spreading machine used. To obtain uniform coverage it was necessary for the men shoveling the sawdust into the spreader to regulate their rate of feeding into the spreader. A manure spreader was tested, but it proved unsatisfactory because it distributed the sawdust into little piles, which had to be spread by hand. Rolling the beds after the sawdust was applied resulted in less blowing away of sawdust and less washing away of the sawdust during rains. A Payer of sawdust 1/4 inch thick was spread over the beds.

Sawdust as a mulch for pine seedbeds in the North appears to be more satisfactory than straw. Where there is a ready available supply of sawdust, it is cheaper to apply than straw and the total cost is much less than straw, which must be removed when germination starts. The sawdust mulch provided a more uniform moisture condition during the germination period. Germination was delayed a few days in the beds mulched with sawdust, and this might prevent injury from a heavy frost that so often occurs just as the seedlings are starting to emerge. Higher germination and a higher final stand per square foot were obtained in the beds mulched with sawdust than those mulched with straw. Seedlings could come through a 1-inch layer of sawdust, but they were slower in emerging and a few less emerged. A 1/4-inch layer was very satisfactory. The sand spreader used for spreading the sawdust does not do as uniform a job as is desired, and a better spreader is needed.

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POLYETHYLENE FILM FOR SEEDBED MULCH

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Obtaining good germination of redcedar seed was a vexing :problem in Oklahoma C-M 4 nurseries before the technique of covering newly sown seedbeds with polyethylene sheets was developed. With polyethylene film for seedbed mulch, germination has been satisfactory. Preliminary trials with film mulching were started in 1946. The results were so favorable that for the past 6 years all cedar seedbeds have been mulched with this material.

Polyethylene has become available and relatively inexpensive in the last few years. One common use is as wrapping material for fresh vegetables in a store. Polyethylene is waterproof, it stretches slightly and has some elasticity, and it tears with difficulty but cuts easily.

The current supply was purchased from E. I. Dupont de Nemours and Company at Wilmington, Delaware. The film was supplied in rolls, 53 inches wide and approximately 1000 yards long. Cost was approximately 10 cents per linear yard. Thickness was 200 gauge, yielding 15, 000 square inches to the pound.

Sowing technique is simple. Clean, dry, untreated seed is sown on conventional seedbeds. A light covering (1/8 to 1/4 inch thick) of sawdust is spread over the beds after sowing. After the beds have been watered thoroughly the polyethylene film is laid over the beds. Burlap is laid over the polyethylene and both are pegged to the soil with 5 inch soil staples made from no. 9 wire.

The beds are then sided with 1 x 6 inch boards. This gives some wind protection to the burlap and polyethylene and provides support for the lath shade which is laid over the beds when germination has been completed. The purpose of the burlap is primarily to hold the polyethylene in place. Other covering such as straw, hay, -and cottonburrs have been used successfully, but these were considerably more awkward.

The seedbeds are sown about December 10. Germination usually begins about March 1, and is completed by March 10 or 15. The burlap and polyethene are removed from the beds at this time. Lath picket snow fencing is then laid over the beds; the fencing is supported by the 1 x 6 inch side boards. The burlap is then laid over the lath shade and remains over the lath for an additional 10 days. This gives the new seedlings a chance to straighten up and completely open their cotyledons before being exposed to the sun and wind and also provides some additional insurance against unseasonable freeze damage that might occur after germination. This protection was sufficient to protect the seedlings at temperatures as low as 12^0 F. during the hard freeze occurring on March 21, 1955, about 10 days after the seed had emerged.

The principle advantage of polyethylene mulching appears to be that the seed is held in a uniformly moist medium throughout the after-ripening period. The moisture rises to the top of the soil, and the undersurface of the polyethylene collects moisture as a pane of glass does. The seed is completely protected in a moist medium with enough air to prevent any stagnation. The soil under the polyethylene does not become hard and crusty. No irrigation is necessary while the seedbeds are covered in this manner. The polyethylene can be rolled up and used a second and third time before it deteriorates.

Similar mulching techniques have been used very successfully with early spring sown Austrian pine, ponderosa pine, sycamore, lilac, multiflora rose, and several other bed-sown species. A trial sowing of shortleaf pine sown in late May suffered heavy loss from solar radiation heat under polyethylene. However, this was obviously too late in the season and no supplemental covering of burlap or straw was used to shade out the sun.

Stratified redcedar, sown in March, showed good results. If germination can be completed before hot weather sets in there appears to be no adverse effects from solar radiation.

STORAGE OF AFTERRIPENED SEED OF EASTERN REDCEDAR

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Seed of eastern redcedar is extremely variable in its response to stratification. Some seeds complete the afterripening process in 2 or 3 weeks and others in the same lot may require 3 months of stratification.[1] When such seed is sowed, losses are liable to result from damage to radicles of germinated seed and from seed not ready to germinate.

At the forest nursery at Stillwater, Okla. , tests were conducted to determine whether germination of afterripened eastern redcedar seed could be arrested without impairing viability. Seed samples included in the tests were from several localities and of several ages, as follows: Lot No. N-47, 1947 crop from Nebraska; Lot No. N-48, 1948 crop from Nebraska; and Lot No. OK-49, collected in 1949 in the vicinity of Stillwater, Okla. The seeds were stratified for 84 days (average period needed to afterripen seeds in all lots), beginning October 6, much earlier than usual. After 84 days of stratification, peat moss was removed from the seeds. Some of the seeds were dried for 1 hour, to remove the surface moisture, and then stored at freezing temperatures of + 20° F. Others were placed in water immediately after stratification and then stored at + 20° F. As a deck for this experiment, some seeds were stratified for 84 days but were not subjected to freezing. Results of these tests were as follows:

	Germination (Percent)
Lot No. N-47:	
Dried and stored at + 20° F. for 28 days	4
Dried and stored at + 20° F. for 113 days	1
Check	9
Lot No. N-48:	
Stored in ice block at + 20° F. for 28 days	23
Stored in ice block at + 20° F. for 65 days	25
Stored in ice block at + 20° F. for 100 days	34
Check	29

1/ Afanasiev, M., and Cress, M. Producing Seedlings of Eastern Red Cedar (*Juniperus virginiana* L.) Okla. Agr. Expt. Sta. Bul. B-256, 21 pp. 1942.

	Germination (Percent)
Lot No. OK-49:	
Stored in ice block at + 20° F. for 28 days	**1/ 78**
Stored in ice block at + 20° F. for 65 days	**75**
Check	**66**

1/ Includes germination of 18 percent during stratification, prior to freezing.

Following this test, seed samples containing the highest percent of viable seed from Lot No. OK-49 were stored at various temperatures, after a stratification period of 97 days. Many of the seeds had begun to germinate. Seeds stratified for 97 days but not frozen were used as a check. Results of this test were as follows:

	Germination (Percent)
Stored in ice block at −12° F. for 30 days.	**0**
Dried for 1 hour & stored at −20° F. for 30 days	**3**
Dried for 1 hour & stored at + 4° F. for 30 days.	**3**
Stored in ice block at + 20° F. for 30 days	**19**
Check	**74**

From the results obtained in these tests it appears that storage of After-ripened redcedar seed in ice at + *20°* F. for as long as 3 months does not impair the viability of the seed if germination does not occur in storage. Seeds with radicles protruding through the endosperm showed injury in the form of darkened tips and failed to resume growth after storage at +20 ° F. Storage at + 4° F. and lower killed, most of the seed.

To obtain additional information on the effects of cold storage (at +15° to 20°F.) on germination of redcedar seed following stratification for various periods, another test was made the following year. Seed from Lot No. OK-49 was tested. Stratification began on July 29. Results *were as* follows:

	Germination in storage (Percent)	Germination 3 weeks following setting (Percent)
Stratification for 77 days, followed by--		
Cold storage for 12 days	0	65
Cold storage for 24 days	0	68
Cold storage for 49 days	0	67
Cold storage for 91 days	0	73
No cold storage	0	65
Stratification for 94 days, followed by--		
No cold storage	2	60
Stratification for 126 days, followed by--		
No cold storage	29	58
Stratification for 168 days, followed by--		
No cold storage	79	82

From the results obtained in these tests it is concluded that afterripening and germination can be arrested by storing afterripened (but ungerminated) seed at + 15° to + 20° F. However, germinating seed is injured by subfreezing temperature and does not resume growth later.