SOIL ANALYSIS IN SERVICE OF NURSERY PRACTICE [1]

S. A. Wilde and H. H. Krause [2]

This paper appraises the relative significance of the results obtained by analysis of various properties of nursery soils, and stresses the limitations of certain analytical data. Soil analysis may serve as a useful tool of soil fertility maintenance and the production of vigorous nursery stock only if unjustified assumptions and misinterpretations are excluded. The value of systematic soil analyses is illustrated by a concrete example presenting a record of changes in the fertility status of a nursery soil during a 7-year period of stock production.

Although soil analysis was brought to life in the cellars of medieval alchemists, it stubbornly refuses to attain maturity and in many of its aspects still remains a "problem child." Reasonably dependable analytical data may be expected only in the determination of some soil characteristics, such as texture, bulk density, some other physical properties, contents of total carbon, nitrogen, and soluble salts, exchange capacity, and the supply of replaceable bases. On the other hand, when an attempt is made to disclose nutrients available to plants, soil analysis at times enters the realm of gross approximations. In such analyses, vitally important for plant production, one frequently encounters unjustified assumptions and misinterpretations. To gain the full benefit provided by analytical data, the manager of a nursery soil must be fully aware of the data's limitations. A review of the relative significance of the numerical expressions of different soil fertility factors is here discussed.

The determination of soil texture of the root-bearing zone and substratum provides one of the most important informations on the productive potential of nursery soils. The content of the fine soil materials, that is silt and clay particles, is responsible for the retention of water and soluble salts. In turn, the fine soil fraction determines in large measure the rate of artificial watering, as well as the kind, the rate, and the manner of applying fertilizers. From the standpoint of nursery practice, simple methods of textural analyses are sufficiently accurate and reliable.

About the same methods may be repeated in the determination of soil organic matter. In many respects organic matter supplements the effect of mineral colloids and, in addition, usually serves as a storehouse of all essential nutrients--nitrogen, phosphorus, bases, and trace elements. The recently developed rapid methods of organic matter determination provide data of unquestionable practical importance.

The effect of mineral colloids and organic matter is conveniently summarized by the data of the adsorbing or exchange capacity of the soil. Again, for the purposes of fertility maintenance of nursery soils, there is no reason to question the reliability of the exchange values provided by modern methods of soil analysis.

As recent investigations have shown, the pH values of soil result from the activity rather than from the concentration of hydrogen ions. Moreover, pH values are only distantly related to the total acidity or total alkalinity of soils. These latter properties are of much greater importance than the pH values in many aspects of soil fertility, such as availability of nutrients, activity of soil microorganisms, incidence of fungus diseases, and the choice of applied fertilizers. The ecological significance of the pH value varies considerably depending upon conditions of climate, content of mineral and organic colloids, and the origin of the soil. An adjustment of soil reaction cannot be made on the basis of pH value alone, for the amount of lime needed to bring a soil from, let us say, pH 4.5 to pH 7 may vary from 2 to 8 tons, depending on the texture and the exchange capacity of the surface soil layer. Just as great a variation in the amount of sulfur or

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aluminum sulfate may be encountered in acidification of a soil from pH 8.0 to pH 5.0. Therefore, in management of nursery soils it is often necessary to determine the total acidity and the content of carbonates besides the pH values (Wilde, 1954).

The determination of the total nitrogen content should be included among other essential and dependable methods of soil analysis (A.O.A.C., 1950). However, such determinations supply information on the total supply of nitrogen, but not on the content of this element available to plants. Some nursery soils, given a heavy application of peat, may show as much as 0.2 percent or about 4,000 pounds per acre of the total nitrogen. Yet, seedlings on such soils often experience an acute nitrogen starvation, for the entire content of this element is in the form of high molecular compounds unavailable to plants. -

In recent years attempts are being made to devise a method for the determination of hydrolysable nitrogen fraction that should be available to plants. However, analyses of this kind, as well as periodic determinations of ammonia and nitrate nitrogen, reveal only approximate potentialities. In a way they resemble electrocardiograms that require an interpretation by a specialist, who may or may not establish a correct diagnosis. Ordinarily, the nursery soil manager must be satisfied with the empirical appraisal of the microbiological activity of the soil and corresponding estimate of the fraction of the total nitrogen that is released in available form. In nursery soils with uninhibited activity of ammonifying and nitrate-forming microorganisms, the annual release of available nitrogen fluctuates between 1 and 2 percent of the total nitrogen. Under conditions of conservative irrigation, the nitrogen requirement of even exacting nursery stock is usually met if the soil analyzes 0.2 percent of the total nitrogen providing annually between 40 and 50 pounds of this element per acre in available form. Otherwise, the nitrogen deficiency must be estimated on the basis of the color of nursery stock, which serves as a very sensitive gage of the supply of nitrogen released in the form of nitrates, ammonia, and amino acids.

The situation is more complicated with the determination of the supply of available phosphorus. It is partly because the deficiency of this element is not readily revealed by the foilage of seedlings. Moreover, the results of analyses for available phosphorus, like those for many other essential nutrients, have only one-sided significance. If the extraction of soil samples is accomplished with the use of a reasonably mild solution, such as 0.002 N sulfuric acid (Truog, 1930), then the presence of about 50 pounds per acre of extractable phosphorus eliminates the possibility of phosphate starvation of nursery stock of most exacting species. With less exacting trees, the adequate phosphate nutrition is assured even if the content of extractable phosphorus is only 10 pounds per acre. On the other hand, analyses showing traces of available phosphorus may or may not be trustworthy. This is because weak solutions fail to extract much of the phosphorus incorporated in organic matter, phosphate minerals, and iron or aluminum compounds. A considerable fraction of this less soluble phosphorus, however, is available to seedlings whose root systems are endowed with mycorrhizal fungi. To a certain extent, the determination of available phosphorus may be facilitated by the use of stronger extracting solutions. Nevertheless, procedures of this kind require participation of an expert, for potent reagents may extract phosphorus that is not available to plants.

Within certain limits, what is said about phosphorus is true of other nutrients that may be deficient in nursery soils, particularly potassium, magnesium, and calcium. The experience of the last quarter of a century has shown beyond a doubt that a reasonably high content of exchangeable bases, as determined by the use of normal ammonium acetate (Chapman and Kelly, 1930; Volk and Truog, 1934), or similar weak extracting solutions, assures adequate nutrition of nursery stock. Contrariwise, the low content of bases, especially potassium, as determined by analysis, does not always identify their deficiency. This is largely because of the enormous nutrient-extracting ability of mycorrhizal fungi and the effect of root sloughings producing chelating compounds that complex iron and release bases from unweathered minerals. In recent time, therefore, the claims are made that the use of more drastic methods for extraction of available bases, such as boiling of soil samples with 1 N nitric acid, yields more reliable information (Leaf, 1957). However, there are no sufficiently prolonged observations on nursery soils to make a definite statement on the merits of this procedure.

Another important detail in soil analysis is that no general agreement exists as to the nature and strength of extracting solutions. This is true not only for different countries and States, but even different investigators. Therefore, a statement that a nursery soil has 50 pounds per acre or 25 p.p.m. of available phosphorus in some places indicates plentiful supply of this element and in others an acute deficiency.

Because unification of analytical procedures cannot be expected, it is advisable to relate the results of analyses obtained by different methods to soils supporting stands of different productivity ratings (Wilde, 1938; Wilde and Patzer, 1940; Youngberg and Austin, 1954). For purposes of nursery soil management, particular attention should be given to soils that support a vigorous natural reproduction of species in question, for such soils present prototypes of nursery beds. For example, using methods of soil analysis accepted by the Wisconsin Soils Department, sandy soils of glacial outwash and river terraces supporting healthy reproduction of red pine are characterized by the following statistical averages: Reaction, pH 5.3; total N, 0.12 percent; available P_2O_5, 25 parts per million; available K_2O, 75 parts per million; exchange Ca, 3.0 m.e. per 100 grams; exchange Mg, 0.9 m.e. per 100 grams. The use of other analytical methods may provide a somewhat different set of numerical expressions of soil fertility. Nonetheless, as long as the composition of the nursery soil is maintained at a comparable level with that of natural seedbeds, the seedlings will not undergo malnutrition or an unbalanced nutrient ratio. In other words, as long as forested soils are used as primary standards, the results of soil analyses will preserve their relative significance. The experience in many nurseries demonstrates the value of this approach.

Considering all mentioned precautions and amendments, soil analysis serves as an extremely useful tool in maintenance of nursery soil fertility and production of nursery stock. The value of soil analysis is illustrated by the following concrete example featuring the "life history" of the Monico Industrial Nursery of the Consolidated Water Power and Paper Co.

This nursery was established in 1950 on a level 20-acre area of glacial outwash, located near Rhinelander, Wis. The soil was previously used for raising farm crops and as a grazing ground. Consequently, it was depleted in organic matter and several essential nutrients. Upon initial analysis, the soil was given an application of peat, hardwood-hemlock leaf mold, and commercial fertilizers including ammonium sulfate, ammonium nitrate, superphosphate, and potassium sulfate. The area was then assigned to the production of white and black spruce with some red pine and a few ornamentals.

In the course of the following 8 years, the nursery soil was subjected annually to complete analysis. Depending on conditions, two to three samples were collected from each acre block. The pH value of the soil was determined by the use of a glass electrode, texture by Cenco hydrometer, organic matter colorimetrically by oxidation with dichromate, total nitrogen by the Kjeldahl method, phosphorus by the Truog method, exchange capacity and the contents of exchangeable potassium, calcium, and magnesium by leaching with neutral N ammonium acetate and by the use of the Beckman model DU flame spectrophotometer. Occasionally, these analyses were supplemented by the determination of nitrate and ammonium nitrogen by the phenol-disulfonic acid and nesslerisation methods, respectively, and specific conductance by the use of a resistance bridge with a cathode magic eye (Wilde and Voigt, 1959).

The application of fertilizing materials was coordinated with the results of current soil analyses, particular attention being paid to losses of nutrients by leaching during wet years. The gradual change in soil fertility status is illustrated by the average results of analyses for the entire area (table 1).

The improvement in the level of different soil fertility factors and in the ratio of available nutrients was paralleled by the improvement in the quality and survival coefficient of produced nursery stock. Besides these achievements, the fully productive state of the nursery soil was attained with minimum expenditure on natural and commercial fertilizers. According to the records of the nursery superintendent, the expenditures

TABLE 1.--Changes in the state of fertility factors in a nursery soil during the period 1950-58, Monico Industrial Nursery, Consolidated Water Power and Paper Co.

Year of analysis	Reaction pH	Organic matter	Exch. capacity	Total N	Avail. P_2O_5	Avail. K_2O	Exch. Ca	Exch. Mg.
		Percent	*M.e. per 100 g.*	*Percent*	*Pounds per acre*	*Pounds per acre*	*M.e. per 100 g.*	*M.e. per 100 g.*
1950............	5.3	1.3	2.8	0.030	183	107	1.12	0.30
1951............	5.7	1.5	3.0	0.037	133	137	1.30	0.35
1952............	5.4	1.6	4.0	0.039	151	80	2.02	0.58
1953............	5.5	2.0	4.5	0.050	159	112	2.41	0.60
1954............	5.6	2.1	4.4	0.055	184	152	2.38	0.72
1955............	5.5	2.1	4.5	0.052	256	161	2.44	0.59
1956............	5.7	2.4	5.3	0.060	208	157	3.32	0.68
1957............	5.6	2.3	5.8	0.058	149	126	3.59	0.66
1958............	5.0	2.9	5.9	0.074	180	147	3.51	0.73

on soil improvement constituted 7 percent of the total annual cost of producing 4-year-old white and black spruce transplants.

The use of biocides was restricted to occasional light applications of chlordane (10 pounds per acre), made to prevent the building up of white grub population. The negligible losses of seedlings from parasitic organisms or toxic chemicals were an encouraging detail of the established method of nursery soil management.

Although the files of the authors include records of systematic soil analyses for much longer periods and larger nurseries, none of them provide as clear cut a picture of the gradual improvement of soil fertility under planned management as was observed in the Monico Nursery.

The analytical work was performed by the authors, and the following members of the University of Wisconsin Soils Department: R. Wittenkamp, A. L. Leaf, Th. Keller, C. B. Davey, D. L. Mader, Mrs. V. A. Vasaitis, and F. P. Haberland.

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MANUAL APPLICATION OF METHYL BROMIDE--SOIL FUMIGANT

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Methyl bromide is a soil fumigant applied under a gasproof cover for treatment of seedbeds prior to seeding. Use of the chemical controls disease, insects, nematodes, and weeds, and stimulates growth. It is economical, effective, relatively easy to use, and can be spread either by hand or machine.

Wide areas can be covered in a single application of the fumigant by means of polyethylene covers. These range in size from 1,600 to 8,000 square feet, and may be conveniently reused from bed to bed or from one plot to another.

Methyl bromide gas comes in cylinders or in 1-pound cans. For small areas, the 1-pound can is cheaper despite higher initial cost. The gas is marketed under such trade names as Dowfume MC-2, Unico, and Pestmaster.

The equipment needed for manual gassing includes a 4 mil polyethylene film, a metering gage or scale to weigh out the gas, and evaporation cans to place under the film or a vaporizing unit to take the place of cans. The nurseryman will determine the width of the plastic sheet for his seedbed. It has been found, for example, that a 60-inch width is best for 4-foot beds, especially if the plastic is to be reused.

As a preliminary, prepare seedbed soil in the usual way. Set the gas in the sun or in a warm room so that it may heat to 60-80 degrees F. Postpone gassing if the morning is excessively wet or cold. A good time to gas is from 10:00-11:00 a. m. when the seedbeds are warm. Higher temperatures increase the destructive effectiveness of the fumigant on weeds and organisms. Also, remember that the beds should have good soil moisture for several days before they are treated.

Four men should be adequate to cover one-fifth of an acre during a morning's work. A 3-man crew can lay and flip over the plastic cover; 1 skilled man will be needed to inject the gas.

At every 15 to 30 feet, sink evaporation pans into the soil to within an inch of the top. Used quart oil cans, fruit juice cans, or antifreeze cans may serve as injection points. In each can, set firmly a plastic tube connected to the gas container. Determine the amount of fumigant for each station by using a meter gage or a platform scale mounted on a pickup truck. A strip 10 feet wide with an injection point every 25 feet would require enough fumigant for 250 square feet, or 1 pound per 100 square feet. Each station would then need 2.5 pounds of methyl bromide.

Spread the plastic film over the area, placing the sides and ends in a furrow or trench and sealing them with soil. Deduct the amount of gas to be used at a station from the total weight of the gas container, and set the balance at this reading. Let the fumigant flow into the cans beneath the film until the scale balances. Then close the valve, disconnect the hose, move to the next station, and reset the scale.

Gas is conducted through a 1/4-inch plastic tube with a special adapter on one end that will fit the valve on the gas cylinder, and a 1/4-inch compression nut on the other end to fit a similar compression nut on the tube in the evaporation can.

Soil temperature for this method of gassing should be 50^0 F. or more. For gassing in soil temperatures as low as 45^0 F., use a vaporizing unit. This insures more uniform distribution and control. It also eliminates the use of cans and tubes under the plastic cover. The vaporizing unit can be installed on the pickup along with the scales and the gas cylinder. A plastic tubing with necessary fitting connects the cylinder to the vaporizer. By means of a 3/4-inch plastic hose connected to the cylinder and placed under the cover at a determined spacing (e.g., 25 feet), the gas is injected into the soil and the point of entry under the cover is sealed.

For effective gassing, include paths, pipelines, ditches, and end areas. Allow the cover to remain in place for at least 24 hours. In using the cover on a large area, only one edge of it need be reset after that period. The other edge is left firmly sealed in the soil when the cover is flipped over to treat an adjacent seedbed.

The rate of gas application will depend on the species and the severity of disease and weed problems. Weeds vary somewhat as to ease of kill, and plant species vary in their reactions to different soils gassed with the same strength. For example, at Vallonia a 2/3-pound treatment results in satisfactory weed control. It also controls shortleaf pine disease satisfactorily. It tends to overstimulate growth (unbalances top-root ratio) of shortleaf pine, does not upset top-root ratio of Virginia pine, and does not control disease in white pine, nor does it overstimulate or upset the top-root ratio of white pine. This means that constant testing or experience is needed to maintain good balance and an economical rate of application.

The growth-stimulation factor of methyl bromide, the most significant of the sterilization chemicals tested to date, varies from soil to soil. The average dose for easily produced and easily stimulated species, such as shortleaf pine, is one-half pound per 100 square feet. The maximum suggested dose for difficult-to-grow or hard-to-stimulate species, such as white pine, is 1 to 1-1/4 pounds per 100 square feet.

The average total cost of fumigating an acre with methyl bromide is $234.

As a safety precaution, wear goggles, face shield, and loose clothing when using methyl bromide. To avoid trapping or confining the gas, do not wear gloves. Remove clothing made wet by the liquid gas. Wipe off or aerate gas on the skin. Burns look severe; they turn white and swell but are not serious except in the eyes. If eyes are affected, rinse with water and rush to the doctor. Do not cover burns before they are aerated.

A RAPID METHOD OF FUMIGATING NURSERY SOILS WITH METHYL BROMIDE

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For fumigating soils in larger nurseries, efficient and complete machine gassing is more practical, economical, and timesaving than hand gassing.

Machinery has been developed that lays a polyethylene film on seedbeds and, as it is being laid, injects methyl bromide under the film in the form of a vapor (fig. 1). Using this method, it was possible to treat a 4- by 525-foot seedbed in one-half of a man-hour. This compared with about 10 man-hours on a similar plot, using methods employed in hand gassing.

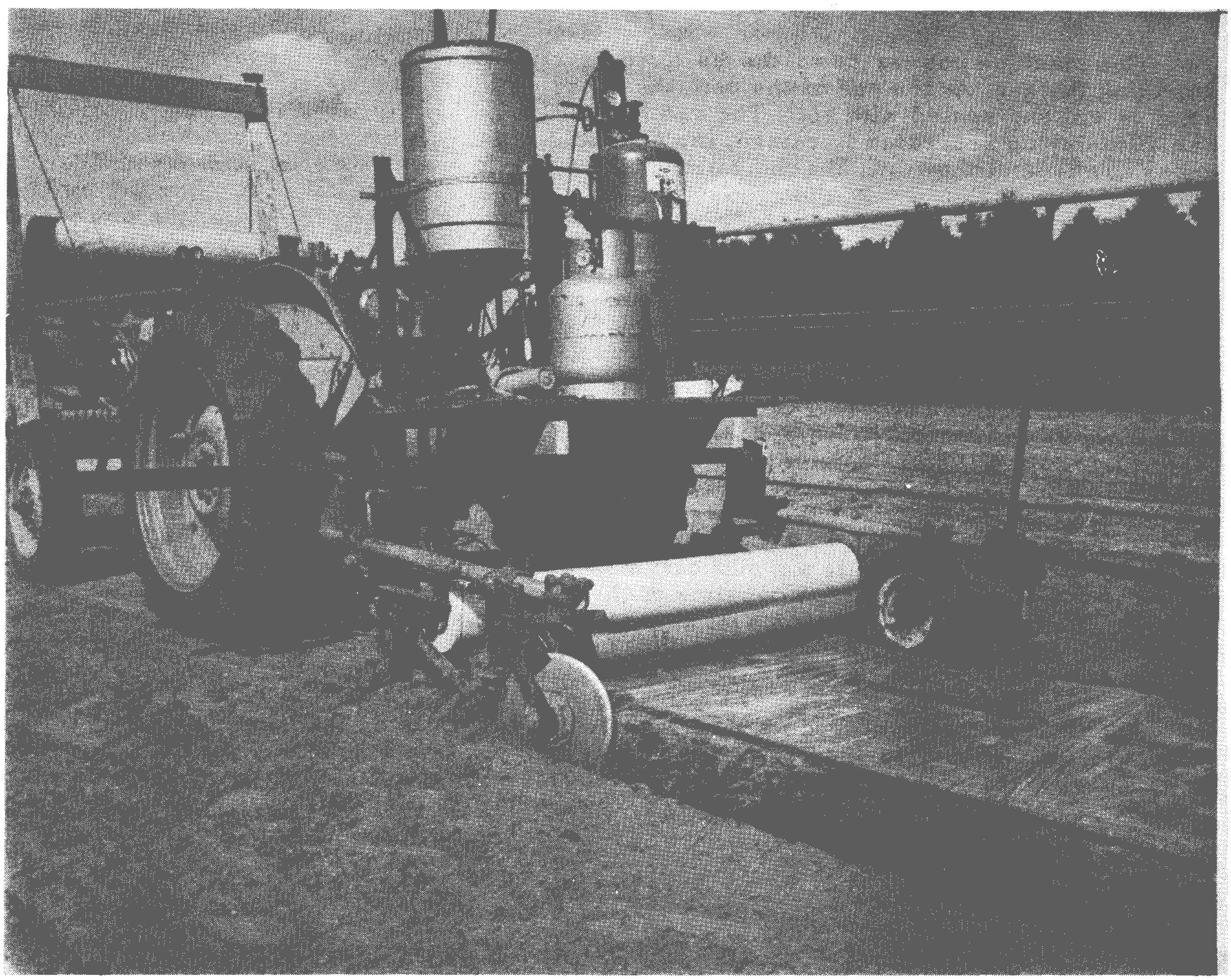

Figure 1.--A film-laying machine used to cover and fumigate seedbeds.

When the plastic cover was laid by hand, a 4 mil polyethylene film was needed to withstand the handling and permit its reuse. With a film-laying machine, a 2 mil polyethylene film weighing and costing half as much is equally effective. The film can be used several times if handled carefully.

The machine is made up mostly of standard cultivator and planter parts. It is available commercially, or may be made in a local shop from plans that can be furnished.

The important components of the machine are the film-laying apparatus, which can be raised from or lowered to the ground, a cylinder of methyl bromide gas, a vaporizer, a gas burner, and a branched 1/2-inch plastic pipe system that extends under the film or cover about 10 feet. All parts are mounted on a tractor or attached to it.

The film passes under a roller, which places the film flat on the soil and prevents the wind from blowing it. Disks attached to the front of the machine open a trench on each side of the bed. Rubber-tired wheels press the edges of the film into the trench, and the rear disks or scrapers roll soil in on the edges, thereby sealing them.

The machine advances into the bed until the plastic gas tubes attached to the vaporizing unit are under the film. Then the tractor is stopped so that the end of the film can be sealed with soil, and the rest of the laid film inspected to make sure that it, too, is sealed. This done, the tractor operator turns on the fumigant, discharging the necessary amount of gas into the soil.

The machine moves down the seedbed at a predetermined rate, laying the film and injecting the gas. At the end of the bed, the operator turns the gas off while the end of the film is cut and sealed with soil. The gas is then turned on for about a second. After that, the film-laying apparatus is raised, the operator drives the tractor forward until the gas tubes are free of the film, and the remainder of the film on the soil is sealed.

The fumigant runs through the vaporizing unit before it is injected into the soil. This unit consists of copper tubing coiled and placed in a 30-gallon, water-filled steel drum. A gas burner heats the water. A pressure-reducing regulator insures the injection of a constant flow of the fumigant regardless of pressure. The regulator found best for this purpose has a calibrated dial that regulates the delivery of water. It does the job without freezing up under constant use, and automatically adjusts itself for pressure change.

The use of the vaporizer permits fumigation when the soil temperature is as low as 45 degrees. Its use may require less fumigant per acre; also, the soil may need fewer hours of cover. This, however, is for the individual nursery to determine. The usual period for the soil to remain covered is 24 hours.

A machine called the "Poly-triever" has been developed to pick up and reroll the polyethylene soil cover. It is a modification of the apparatus that rolled up burlap used to mulch seedbeds. The machine consists of three rollers mounted on a tractor. Two of the rollers force the soil used to seal the cover to the side, and also keep the cover fully stretched so that it will rewind easily. Between the two rollers, cylindrical brushes, driven by a small gasoline motor, remove the soil and water from the film.

The third roller, powered by an air-cooled motor, rolls up the film. The edges of the film must be guided to insure an even roll. Working this machine, 3 men could roll up the film on a 525-foot bed in 10 to 15 minutes. Many refinements will doubtlessly develop on the Poly-triever as its use grows, improving both the efficiency and ease of the operation.

METHYL BROMIDE DISPERSER

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The February 1958 issue of Tree Planters' Notes shows how methyl bromide (CH_3Br) is being used by the Forestry Department of Rutgers University as a forest nursery soil fumigant. The Ryland Croshaw Nursery uses another method of dispersing this chemical. The methyl bromide is contained in a 1-pound pressurized can equipped with a puncturing device and a 1/4-inch-diameter plastic tube (fig. 1). The tube is inserted in a 1-gallon jug, and the chemical from the can under considerable pressure is easily dispersed beneath an airtight plastic or rubberized seedbed cover. Use of the jug prevents spillage and helps to hold up the seedbed cover.

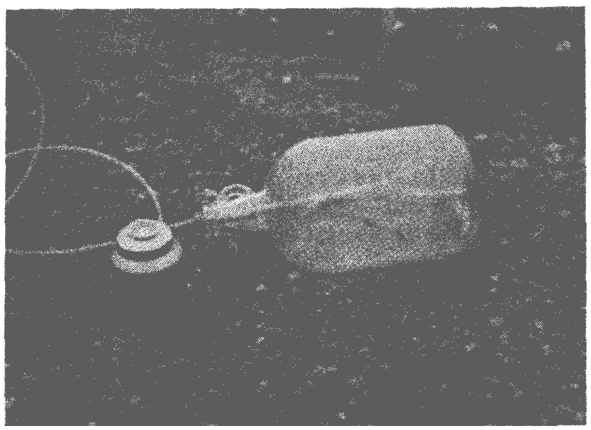

Figure 1.--Methyl bromide disperser assembled and ready for use.

CAUTION: In handling the chemical listed, follow directions and heed precautions given by the manufacturer.

THE EFFECT OF SOIL FUMIGATION ON THE GROWTH AND YIELD OF LOBLOLLY PINE SEEDLINGS IN THE NURSERY

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The production of pine seedlings is expensive and exacting. The gross cost of nursery stock may be several thousand dollars per acre; few, if any, crops are more soil depleting or require more careful soil management practices. These factors, together with increased demands for more and better seedlings, are of much concern to those charged with the responsibility of seedling production and nursery management. In general, a unit of nursery soil tends to produce a constant weight of seedling tissue in the form of either many small seedlings or fewer large ones; therefore, any practice that will insure a maximum production of plantable seedlings is of considerable importance.

The purpose of this study was to test the general hypothesis that more plantable loblolly pine seedlings of better quality could be grown on a given unit of nursery soil through soil fumigation for the control of plant parasitic nematodes. Nematodes are microscopic eelworms, many of which feed on the roots of plants. They may be the underlying cause of puzzling ailments in certain nurseries.

Nematologists have established the fact that parasitic nematodes are associated with the roots of all the major southern pines. They have found seven different genera of parasitic nematodes that can attack the roots of loblolly (Pinus taeda), slash (P. elliottii), longleaf (P. palustris), and shortleaf (P. echinata) pine seedlings. A recent survey showed that among several species of parasitic nematodes Xiphinema americanum and Helicotylenchus spp. occurred most commonly in a number of forest soils in Louisiana. Available information indicates that X. americanum may be of considerable economic importance in southeastern United States, probably as a parasite of trees and shrubs. A species of Helicotylenchus has been established as a parasite of boxwood.

Materials and Methods

To ascertain the effects of soil fumigation for the control of nematodes and the effects of nematodes on the growth and development of loblolly pine seedlings, an experiment was established at the North Louisiana Hill Farm Experiment Station, Homer, La., during 1956.

The site selected for the nursery was a portion of an abandoned old field containing scattered pole-sized loblolly and shortleal pine. The soil type was Lakeland fine sand. An analysis of the soil indicated that nematodes (primarily Xiphinema americanum and Helicotylenchus app.) were present in high numbers.

The experiment included various types of nematocide treatments, with a split-plot design for seedling density superimposed upon each treatment. Seedlings were grown at two densities, 30 and 60 per square foot, on plots treated 2 weeks prior to planting with the following soil fumigants-[2] "D-D"' at 25 gallons per acre; "Nemagon"[4] at 7.5 gallons per acre; "Dowfume W-85"[5] at 7.5 gallons per acre; "Dowfume MC-2"[6] at 2 pounds per 100 square feet; and check (no fumigants). The treatments were established on plots 4 feet square in a 5 by 5 latin-square design.

The initial application of fertilizer was made on March 8, 1956, at the rate of 600 pounds per acre of 8-8-8 broadcast and mixed into the soil. An additional application of 300 pounds per acre of 8-8-8 was made on the surface between rows on June 25, 1956.

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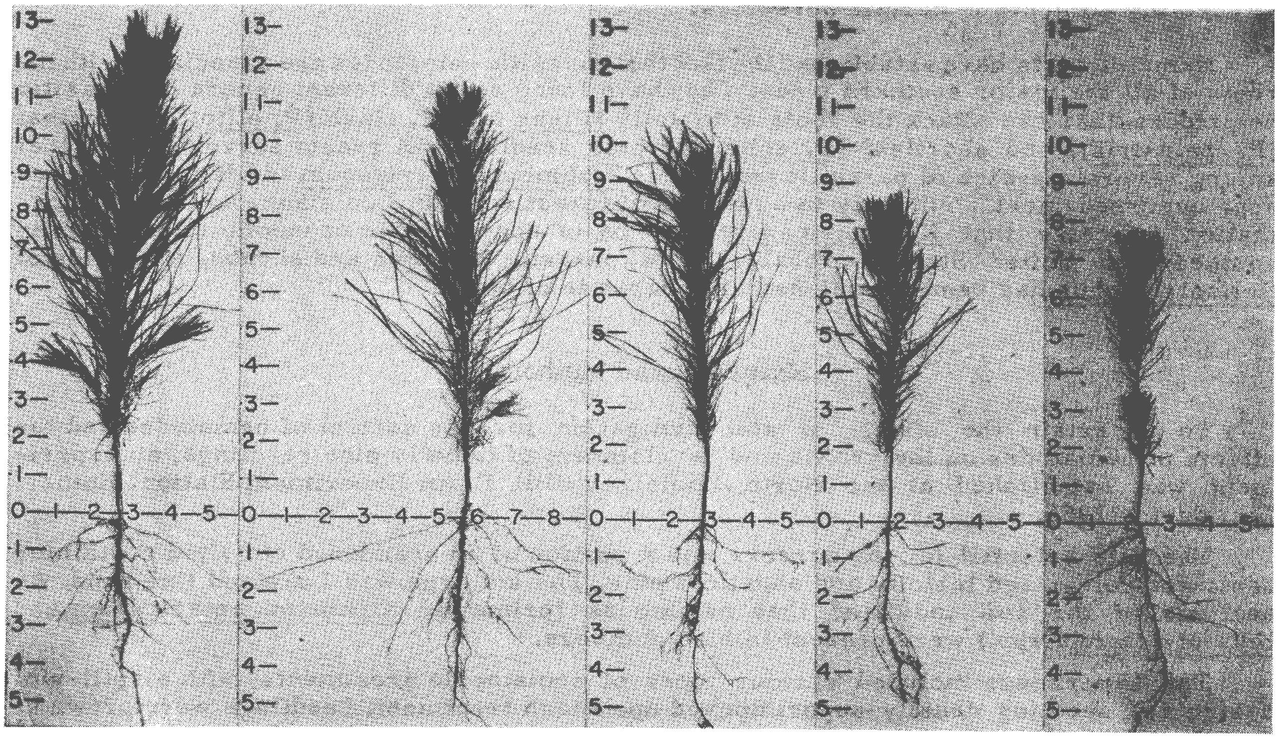
2 Mention of any chemical company or product does not imply endorsement by the U.S. Department of Agriculture.
3 1,3-dichloropropene-1,2-dichloropropane (50-50) mixture supplied by Shell Chemical Corp.
4 1,2-dibro-3-chloropropane (97 percent) supplied by Shell Chemical Corp.
5 1,2-dibromoethane (83 percent) supplied by Dow Chemical Co.
6 Methyl bromide (98 percent), chloropicrin (2 percent) supplied by Dow Chemical Co.

Soil samples were collected in April, June, July, and September and processed for extraction of nematodes by standard laboratory methods. The nematodes present were recorded as to identity and number in each treatment on each sampling date.

The seedlings were lifted from a depth of 12 inches and graded according to Wakeley's[7] morphological grades during the week of February 3, 1957. The data collected from each treatment-density class were analyzed statistically.

Results

The increased vigor and growth of seedlings (fig. 1) in the fumigated plots were correlated directly with reduced populations of parasitic nematodes. The first sampling for parasitic nematodes 2 weeks after fumigation showed that they were virtually eliminated from the treated plots. All fumigants were highly effective, and there were no differences in initial nematode control. Numbers of the ectoparasitic nematodes <u>Xiphinema</u> <u>americanum</u> and <u>Helicotylenchus</u> spp. were suppressed in all fumigated plots throughout most of the growing season. The results suggested that parasitic nematodes were the cause of severe growth reduction of loblolly pine seedlings in the untreated plots.



MC-2 D-D NEMAGON W-85 CHECK

Figure 1.--Representative samples of loblolly pine seedlings 130 days old grown in plots treated with various nematocides. (Background numbers represent inches.)

Table 1 shows the effect of soil fumigation on the production and quality of loblolly pine seedlings grown at the different densities. "Plantable" seedlings include Grades 1 and 2; Grade 3 seedlings are considered "cull."

Soil fumigation increased the yield of plantable seedlings at both densities. At the lower density, the increase was from 24 to 28 seedlings per square foot, an increase of 17 percent over the nonfumigated yield. At the higher density, the increase was from 31 to 43 seedlings per square foot, an increase of 39 percent over the nonfumigated yield. This increase in plantable seedlings due to fumigation was statistically highly significant.

[7] Wakeley, Philip C. Planting the southern pines. U.S. Dept. Agr., Agr. Monog. 18. 233 pp.. illus. 1954.

Table 1.--Effect of soil fumigation on production and quality of loblolly pine seedlings grown at two densities

Density and treatment	Grade 1 seedlings per sq. ft.		Grade 2 seedlings per sq. ft.		Grade 3 seedlings per sq. ft.		Plantable seedlings per sq. ft.	
Density--30 per sq. ft.:	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
MC-2..................	18	57	11	35	2	8	29	92
D-D...................	17	54	12	38	2	8	29	92
Nemagon...............	16	51	12	39	3	10	28	90
W-85..................	14	44	14	43	4	13	28	87
Check.................	9	31	15	46	7	23	24	77
Density--60 per sq. ft.:								
MC-2..................	15	25	32	53	13	22	47	78
D-D...................	11	19	33	55	16	26	44	74
Nemagon...............	8	13	33	55	19	32	41	68
W-85..................	8	13	33	55	19	32	41	68
Check.................	2	4	29	48	29	48	31	52

Table 2.--Effect of soil fumigation on the size of loblolly pine seedlings

Seedbed density and treatment	Grade 1		Grade 2		Grade 3	
	Stem height	Stem diameter at root collar	Stem height	Stem diameter at root collar	Stem height	Stem diameter at root collar
Density--30 per sq. ft.:	*Inches*	*32 ds of an inch*	*Inches*	*32 ds of an inch*	*Inches*	*32 ds of an inch*
MC-2.........	17.4	8.0	13.7	5.0	10.6	3.0
D-D..........	16.9	7.6	12.9	5.0	10.7	3.0
Nemagon......	15.9	7.8	12.3	5.0	9.9	3.0
W-85.........	14.3	6.8	11.4	4.8	9.6	3.0
Check........	12.4	6.6	9.8	4.2	7.9	3.0
Density--60 per sq. ft.:						
MC-2.........	18.4	7.8	14.0	5.0	11.3	3.0
D-D..........	16.1	7.0	13.3	5.0	10.7	3.0
Nemagon......	16.2	7.2	12.8	4.6	10.2	3.0
W-85.........	15.3	6.8	12.6	5.0	10.1	3.0
Check........	13.2	6.6	10.6	4.0	8.8	3.0

The maximum production of plantable seedlings was attained by fumigating and increasing seedbed density to 60 per square foot. This combination almost doubled the production per square foot of nursery space. Although the cull percentage was increased even with fumigation, as a result of increased density, the loss resulting from wasted seed was minor compared with all the other economic factors involved in nursery management.

Table 2 summarizes the effect of soil fumigation on height and diameter growth of all seedling grades. Since the seedlings were lifted-at the same depth and some of the roots of the larger plants were destroyed, analyses of growth data were restricted to stem height and stem diameter.

Soil fumigation resulted in significantly greater height and diameter growth of Grade 1 and 2 seedlings. Increased density had no detrimental effects on the height and diameter growth of the seedlings within these grades.

Information obtained as to lateral root development (table 3) further shows the response of loblolly pine seedlings to fumigation. The data show that the lateral root development of seedlings grown on the fumigated soil was much more extensive. Within each grade, more lateral roots with greater total lengths were obtained at both densities.

Table 3.--Effect of soil fumigation on the lateral root development [1] of loblolly pine seedlings

Seedbed density and treatment	Grade 1		Grade 2		Grade 3	
	Lateral roots per seedling	Total length	Lateral roots per seedling	Total length	Lateral roots per seedling	Total length
Density--30 per sq. ft.:	*Number*	*Inches*	*Number*	*Inches*	*Number*	*Inches*
MC-2.........	25	89	18	46	13	20
D-D..........	21	82	16	41	12	21
Nemagon......	17	79	15	49	9	23
W-85.........	16	74	14	57	12	29
Check........	17	67	12	35	11	22
Density--60 per sq. ft.:						
MC-2.........	24	79	20	50	14	26
D-D..........	23	77	20	45	12	26
Nemagon......	17	55	17	51	12	27
W-85.........	23	81	17	50	14	26
Check........	16	61	14	42	9	18

[1] Ninety-nine percent of the lateral roots measured originated within 8 inches of the root collar.

Summary

The results of this study indicate that the practice of soil fumigation for nematode control offers considerable promise for increasing the production and improving the quality of loblolly pine seedlings in nurseries infested with certain parasitic nematodes.

This experiment, designed to measure the effects of soil fumigation on the growth and development of loblolly pine seedlings, showed the following:

1. The production of plantable seedlings was almost doubled by fumigating the soil and increasing seedbed density from 30 to 60 per square foot.

2. Fumigation of the soil resulted in the production of seedlings with better morphological characteristics within each grade, irrespective of the density.

3. Increased density had no detrimental effects on the morphological characteristics of the plantable seedlings produced.

4. The yield of plantable seedlings was greater on fumigated soil, regardless of density.

5. Soil fumigation was highly effective in reducing populations of parasitic nematodes during the period of active pine seedling growth.

RED PINE NURSERY STOCK FUMIGATION IN MICHIGAN CONSERVATION DEPARTMENT NURSERIES

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The European pine shoot moth has become one of the most serious plantation pests of red pine in Michigan. It was introduced into the United States in 1913 and first recorded in Michigan in 1930. Since that time it has been reported in most of the counties in Lower Michigan and in 5 of the 15 counties in the Upper Peninsula. These 5 are Houghton, Schoolcraft, Mackinac, Luce, and Chippewa. Distribution of the shoot moth into and throughout the State has been mainly a result of infested nursery stock. The shoot moth larva overwinters in a bud and can therefore be in the stock during fall and spring shipping seasons.

A threefold action program of hand roguing, fumigation, and spraying was started to control the shoot moth in three Conservation Department nurseries following its discovery in the seedling and transplant beds in the fall of 1957. The infestation was found shortly before the fall shipping season, and fumigation following hand roguing appeared to be the immediate answer to prevent shipping infested trees. A search of the literature and personal communications revealed no commercial scale fumigation of red pine nursery stock. However, Dr. H. A. U. Monro, Science Service Laboratory, Canadian Department of Agriculture, had been conducting research on the effect of methyl bromide fumigation on the shoot moth and on red pine and permitted the use of his unpublished data. The Conservation Department gratefully acknowledges the recommendations and assistance given them by Dr. Monro.

Beginning in early September 1957, all beds 2 years of age and older were carefully checked and the infested trees hand rogued. Most of the infested trees can be found and removed by this method; however, some maybe missed. This was demonstrated by having the same crew rogue the same beds three times. Each time infested trees were found. Hand roguing the 2-2 transplants costs approximately $0.50 per thousand trees examined at a labor cost of $1.86 per hour. This cost varies greatly with the intensity and thoroughness with which the operation is done. Since hand roguing could not be relied on to remove all the infected trees, a fumigation program was set up in the nurseries.

The third phase of the action program is spraying the beds with DDT during the summer to kill the hatching larvae. It is hoped that the spraying in the future will provide complete control and eliminate the need for fumigation and hand roguing.

However, further studies on the techniques and effects of the fumigation will be made so that this information will be available when needed if spraying control is not complete or some other pest is encountered.

<u>FUMIGATION PROGRAM-- All</u> stock from beds inwhich shootmoth larvae were found was fumigated prior to shipping from the nursery. Normal lifting, sorting, and packing procedures were followed, producing open-end bales with the pine tops exposed. After the bales were ready for shipping, they were placed in the fumigation chamber (fig. 1) and exposed to methyl bromide gas. Little extra expense was added to the cost of the trees other than for the additional handling of the bales in loading and unloading the chamber.

A total of 8,542,944 red pine were fumigated during the fall of 1957 and spring of 1958 before leaving the nurseries. This was broken down by age groups as follows: 1,575,000 2-0 seedlings, 5,092,000 3-0 seedlings, and 1,875,944 2-2 transplants.

Fumigant--Methyl bromide is a colorless, odorless liquid boiling at 38.5°F. It is toxic to humans, nonflammable, and as a gas is 3.3 times as heavy as air. When used for most fumigation, chloropicrin is added to methyl bromide as a warning agent. However, chloropicrin is highly phytotoxic to pine and the methyl bromide must be used without the chloropicrin when treating live pine trees. Absence of the warning agent makes the use of methyl bromide more hazardous to humans, and additional safety precautions must be taken. Anyone working with methyl bromide should become familiar with its action and use adequate caution.

The action on insects may be slow, and control results cannot be evaluated for at least 48 hours after treatment.

Chamber- -Detailed plans and list of materials for a fumigation chamber of 600 cubic feet capacity, for use in treating pine nursery stock, are available from the Forestry Division, Michigan Department of Conservation, Lansing 26, Mich.

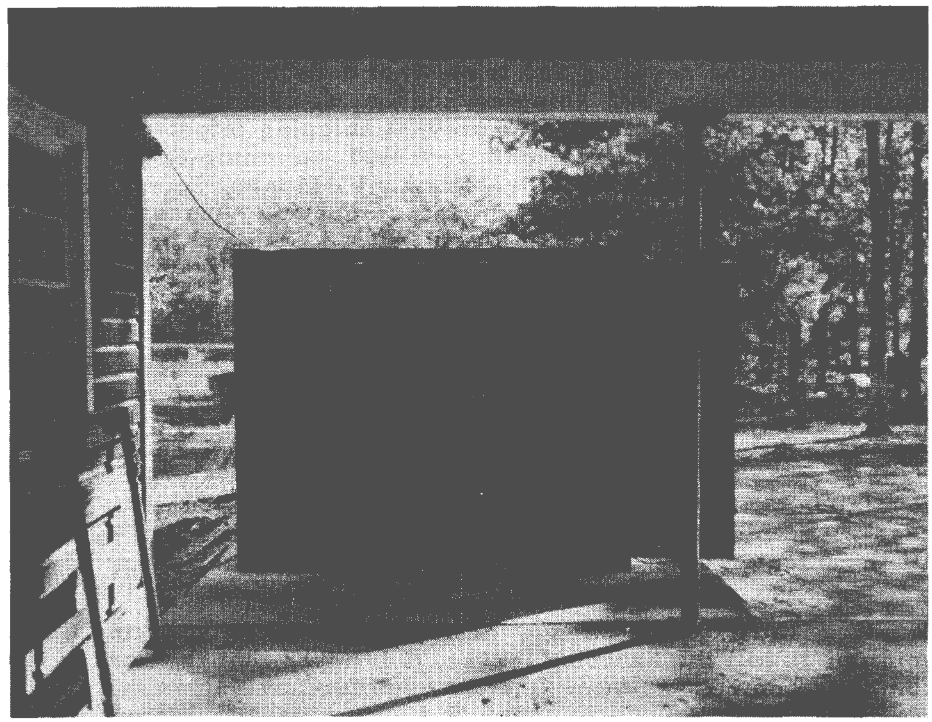

Figure 1.--Front view of chamber used for fumigation of pine nursery stock at Higgins Lake Nursery showing method of loading.

Location: The chamber was located on the loading platform outside the main buildings so that there was a minimum distance to move the trees (fig. 2). After treating, the trees were removed from the chamber, and left on the loading platform for additional aeration prior to truck pickup. An exhaust fan was used to pull fresh air through the chamber after treatment and blow the gas away from the buildings.

Capacity: The following number of trees would approximately fill the chamber:

150,000 2-0 seedlings, or
60,000 3-0 seedlings, or
20,000 2-2 transplants.

These amounts will vary with the size of the nursery stock and the manner in which it is packed.

Loading:--Two rows of bales are placed on 2 by 4 boards in the chamber so that there is some free air space underneath, along the sides, and down the middle. Two separators of 2 by 4 boards are placed on top of each row, and additional layers are added using separators between each layer. Three to five layers, depending on the size of the bales, are used when the chamber is filled to capacity.

An air space around the piles on all sides is essential for good circulation of the gas. The stock is placed no closer than 18 inches from the ends and ceiling of the chamber.

Gas Circulation:--An 18-inch fan is used in the chamber to assure good gas dispersal and is located at the center of the back of the chamber at floor level, with the fan directed along the floor toward the front of the chamber.

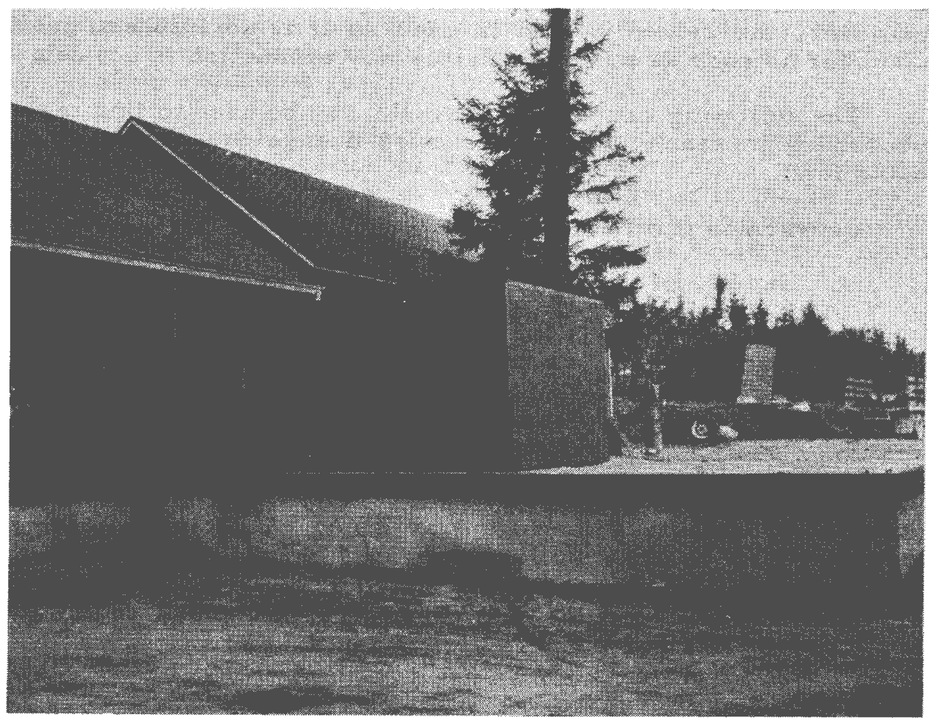

Figure 2.--Rear-side view of chamber showing location on loading dock.

The fan is turned on at the start of the gas introduction and is left on for the first 15 minutes of the fumigation period. Longer circulation is unnecessary and tends to force the methyl bromide out of the chamber if small leaks are present.

Either a reversible fan or a second 18-inch fan is used to clear the chamber of gas after fumigation. Gas is expelled through a small door at the rear of the chamber. The chamber is allowed to clear for 30 minutes before men enter and remove the bundles .

Gas Introduction:--Methyl bromide can be bought in 1-pound cans and larger cylinders. The 1-pound cans are the most conveniently handled when small amounts are used. Special applicators outside the chamber are used to puncture the sealed cans allowing the methyl bromide to enter the chamber through a plastic tube. The discharging of the gas into the chamber is hastened by immersing the cans and coil of tubing in warm water. Inside, the methyl bromide is caught in a shallow evaporating pan placed near the top of a chamber. A heat lamp placed 6 to 8 inches below the evaporating pan helps to vaporize the methyl bromide, particularly when the air temperature is in the 40's.

Dosage: The following dosage rates for a 2-hour exposure period were used as recommended by Dr. H. A. U. Monro:

Temperature:	**Dosage (methyl bromide) per 1,000 cu. ft.** *(Pounds)*
40	6
50	5
60	4

Within limits, a smaller amount of gas can be used if the exposure time is lengthened. However, the 2-hour period is used as it is desirable to get the trees in and out of the chamber as soon as possible. In this way production is not delayed.

The following conversion formula can be used to find the amount of methyl bromide necessary to reach the recommended dosage for chambers containing other than 1,000 cubic feet.

Conversion formula:

$$\text{Number of pounds needed} = \frac{\text{Recommended dosage in lbs.} \times \text{chamber capacity in cu. ft.}}{1{,}000}$$

Example--Number of pounds of methyl bromide necessary to reach the desired concentration of 5 pounds per 1,000 cu. ft. in a 600 cu. ft. chamber.

$$\text{Number of pounds needed} = \frac{5 \times 600}{1{,}000} = 3$$

Methyl bromide costs about $0.70 a pound in 1-pound pressure cans. At 60°F., the approximate cost for the fumigant for treating 2-0 seedlings is 1-1/3 cents per 1,000 trees and 4 cents per 1,000 2-2 transplants.

RESULTS

Effect on Insects--According to the research findings of Dr. Monro (personal communication), a dosage of 4 pounds of methyl bromide per 1,000 cubic feet is necessary to kill the shoot moth larvae at 60°F., with higher concentrations required at lower temperatures. Complete mortality was attained when the temperature was 60° or more.

At lower temperatures some shoot moth survival occurred. Presumably this was due to loss of gas by absorption in the walls and to slow or incomplete vaporization of the methyl bromide. These causes have been corrected by painting the inside of the chamber with a resin base paint and heating the evaporating pan for more rapid vaporization.

Effect on Trees--Many of the treated trees were checked after one growing season in the field. No serious effects could be noted. In addition, during April and May, 1958, sample bundles of 50 trees were exposed for 1, 2, and 3 treatment periods of 1-½ to 2 hours and then field planted, along with untreated trees. While the trees subjected to 2 and 3 periods were aired between treatments and would not be as severely affected as if the treatment had been continuous for the total time, nevertheless, some information was obtained. All sample trees were checked inlate August for percent of survival and amount of 1958 terminal growth. The samples do not lend themselves to statistical analysis because of lack of replications, and insufficient variation of treatment temperatures, length of treatment period, and dates of fumigation. However, we believe that the following observations are valid:

1. Jack pine, red pine, and white spruce rank in increasing susceptibility to methyl bromide in the order listed. Jack pine and white spruce were included in the experiment to obtain data useful if fumigation of these species for an insect is necessary in the future.

2. Mortality of red pine was about the same whether receiving one period of recommended treatment or no treatment. Increasing the number of treatment periods caused higher tree mortality. Jack pine and white spruce showed the same reaction.

3. Terminal growth of the living trees averaged almost the same for all treatments and untreated stock. On some trees where new growth had started before fumigation, the growing buds appeared to be injured. However, side buds often took over and grew about the same as the uninjured terminals. There may be growth or mortality differences that will show up after 2 or more years. However, the slight differences in growth present after 1 year may equalize out after additional years.

<u>CONCLUSION--Hand</u> roguing cannot be relied on to eliminate all shoot moth infested trees from the nursery beds. Fumigation of red pine nursery stock with methyl bromide offers an inexpensive, simple method of preventing the spread of the European pine shoot moth on nursery stock. As far as could be determined, little or no fumigation of bundled red pine nursery stock had been done on a commercial scale prior to the treatments by the Michigan Conservation Department.

Examination of fumigated trees planted in the field did not reveal any serious effects from the treatment recommended to kill the shoot moth after one growing season.

Costs for the methyl bromide were less than 4 cents per thousand trees.

It is expected that a thorough spray program during the summer will eliminate the shoot moth from the beds, thereby doing away with the necessity for fumigation and hand roguing. However, fumigation provides a useful and economical control method, and studies will be continued to determine more conclusively its effects on the insects and trees.

NURSERY-INFECTED SEEDLINGS DEVELOP FUSIFORM RUST CANKERS AFTER OUTPLANTING

Felix J. Czabator [1] and Hans Enghardt [2]

Nursery-infected seedlings that appear to be free of fusiform rust at planting may be the cause of unexplained mortality in young pine plantations. Such concealed infection, added to cull for rust in nurseries and natural infection in plantations, makes fusiform rust the most serious disease of pine seedlings in the South today.

Outbreaks of fusiform rust at nurseries in Louisiana and Mississippi during the past 2 years were responsible for a high percentage of cull, one nursery losing 35 percent of its slash pine production in 1957. This high incidence of infection in nurseries, which had followed recommended control practices, drew attention again to the rust problem. Investigating this outbreak led to the finding that many of the apparently disease-free seedlings shipped from the nurseries were infected with fusiform rust.

In September 1958, after excessive losses had been reported in an 80-acre slash pine plantation, an examination revealed that mortality was due primarily to fusiform rust infection, with cankers at or below the ground line, depending on the depth of planting. A very high percentage of the surviving seedlings had cankers at the ground line. The location of these cankers is considered to be positive evidence of nursery infection. Approximately 90 percent of the seedlings in this plantation were nursery-infected. A nearby planting of loblolly pine, from the same nursery, had 40 to 60 percent nursery-infected seedlings. Another plantation of 1957-58 slash pine from the same nursery, but lifted and graded about 1 month later, had 37.5 percent nursery-infected seedlings when examined 1 year after planting.

Samples of these seedlings were sectioned and examined microscopically.' All examinations confirmed the presence of rust mycelium in seedlings with basal swellings.

The grading crew at the nursery was well trained, and spot checks showed that only a low percentage of seedlings with visible infections were being passed. It appears that much of the nursery infection was latent, that is, not sufficiently developed to be detectable by routine grading.

Further experience indicated that latent infection may also escape more exacting standards of grading. An experimental planting of loblolly pine, which had been carefully graded by an experienced regeneration specialist, was examined 10 months after planting. This plantation also had appreciable numbers of seedlings with ground-line galls. These seedlings had come from three nurseries in the same State. At nursery A, the beds in which the stock was produced had 55 percent of the seedlings visibly infected; at nursery B, 30 percent of the seedlings in the experimental beds had been culled because of visible rust galls. A precise tally for the experimental beds at nursery C was not available, but the nurserywide cull for rust had been under 5 percent.

When the origin of the planting stock is considered, the percentage of latent infection was approximately proportional to the percentage of cull at the nursery (table 1).

In a study aimed at evaluating nursery grading standards, three classes of slash pine seedlings were selected as disease-free at nursery D, in another State. The percentage of visible infection was quite high at this nursery. The seedling classes were as follows:

(1) Seedlings examined and passed by nursery graders.
(2) Seedlings re-examined by research personnel after being passed by nursery graders.
(3) Seedlings having basal branches, but no visible signs of fusiform rust.

1 Southern Forest Experiment Station, Forest Service, U.S. Dept, of Agr., New Orleans, La.
2 Louisiana Forestry Commission, assigned to the Alexandria Research Center. Southern Forest Experiment Station.
3 Microscopic examinations by Dr. F. F. Jewell. Southern Institute of Forest Genetics, Gulfport, Miss.

Table 1.--Proportion of latent nursery infection and visible cull on 1957 loblolly pine by nursery sources

Source of seedlings	Fusiform rust developing after planting	Cull for rust at nursery
	Percent	*Percent*
Nursery A[1]	19.6	55
Nursery B	15.4	30
Nursery C	1.5	([2])

[1]This nursery supplied seedlings for the 80-acre plantation discussed above.
[2]Low, but not known precisely.

Ten months after planting, all three classes of seedlings had ground-line galls (table 2). In addition, there were varying percentages of mortality in these classes, although no determination as to cause of early mortality had been made.

The higher percentage of infection on the regraded seedlings compared to routine nursery-graded seedlings is consistent with the latent nature of the infection. Normally, it would be expected that seedlings carefully examined by several people would have less infection than those subjected to a single rapid examination by nursery graders. However, in latent infection, there are no distinct signs to indicate which seedling should be culled, and it is a matter of chance whether an infected seedling is culled or not. If it is assumed that the mortality (table 2) was due primarily to latent fusiform rust, it appears that the amount of latent infection was the same whether the seedlings were graded once, or regraded.

Infection of seedlings with basal branches was substantially higher than that for either class of unbranched seedlings. Although Henry[4] has reported that seedlings with basal branches, lifted and planted in 1937, did not develop cankers, visible infection in nurseries was quite low in 1937.[5] In the present study, a high percentage of latent infection is postulated, and a considerable amount of infection may have been concealed by the branches.

Table 2.--Mortality and fusiform rust infection on slash pine, by grading class

Class	Rust	Mortality	Total
	Percent	*Percent*	*Percent*
Regular nursery grading	2.7	16.2	18.9
Regraded	7.0	12.0	19.0
Basal branches	29.5	8.0	37.5

It is probable that latent infection is the result of differences in rate of development of the galls on seedlings in the nursery. Some seedlings may develop a visible gall in 4 to 6 months after infection; on other seedlings galls may require 8 to 10 months to become visible. Sleeth [6] believed that galls developed at a slower rate on unthrifty and undersized stock. The common experience of nurserymen finding more rust during lifting than their inventory showed may be the result of this variation in rate of gall development. It is highly probable that more latent infection is present in seedlings lifted in December than

4 Henry, Berch W. Basal branches no symptom of fusiform rust on slash pine seedlings. U.S. Forest Serv„ Tree Planters' Notes 24, p. 16.1956.
5 Siggers, Paul V. Weather and outbreaks of the fusiform rust of southern pines. Jour. Forestry 47: 802-806. 1949.
6 Sleeth. Bailey. Mortality of slash pine seedlings infected by Cronartiurn fusiforme. U.S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 35. 1940.

in those lifted 2 months later. The galls continue to develop during this time, and the infected seedlings are culled out. In at least three nurseries, the percentage of cull for fusiform rust at the end of the lifting season (February 1959) was 3 to 5 times that in December 1958.

It appears certain that culling out seedlings with obvious cankers at the nursery does not assure rust-free stock. Early in the lifting season, at least one-third of the infection may be latent, and the seedlings will not show the classical symptom of the disease-the pronounced swelling on the stem. Basal branching in itself apparently is not evidence of rust infection, but graders should scrutinize seedlings with such branching in heavy rust years. Further studies are needed to improve detection techniques during grading, and to determine if the proportion of latent infection is the same each year.

Latent infection of nursery stock is not a new phenomenon. Sleeth [6,7] recognized this condition in 1940, and reported from 4 to 19 percent latent infection on uncankered seedlings planted in 1939. Wakeley[8] also called attention to the fact that nursery-infected seedlings may fail to develop cankers by lifting time. Latent infection probably has been overlooked because the tendency toward deep planting usually conceals galls developing after outplanting, and on large plantings dead seedlings rarely are pulled up to determine the cause of mortality. Nurserymen and planters should be aware of latent infection, which may account for poor survival in severe rust years, even when rainfall is ample.

During normal years, latent infection probably is not serious. When visible nursery infection is about 2 to 3 percent of the crop, the concealed infection may be no more than 1/2 to 1 percent. In high-hazard years, when the visible cull in the nursery may be 50 percent or more, an additional latent infection of 20 to 25 percent of the total crop may be expected. This means that approximately 75 percent of the nursery production is worthless, and that the cost of producing 1,000 plantable seedlings has jumped from $4 to about $16. Considered in this light, a 100 percent increase in cost of fusiform rust control in the nursery is entirely justified.

As inspection during grading may not assure rust-free seedlings, the nurseryman should rely mainly on preventing infection in the seedbed. Current knowledge indicates that careful spraying with ferbam, ziram, or zineb will reduce infection to a tolerable level. Ferbam should be used at the rate of 2 pounds in 75 gallons of water per acre; a spreader-sticker should be included, and the solution applied at a pressure of at least 300 pounds per square inch through No. 2 nozzles[9].

Timing and frequency are of the utmost importance. Spraying should begin as soon as the seed begins to germinate, and should be repeated at least twice a week until germination is complete. After that, the spray should be applied at 5- to 7-day intervals until mid-June. Spraying should be more frequent if rain washes off the fungicide, and additional sprays should be applied during critical periods: that is, whenever prolonged periods of high humidity coincide with temperatures between 60° and 80° F.[10]

This intensified program may result in 8 to 10 more sprayings than a conventional schedule of 12 to 15 sprays per season. The slight increase in cost, however, is likely to be offset by a reduction in the number of culled seedlings.

Unless better commercial rust-detection methods can be developed, it may not be advisable to ship seedlings from beds with more than 50 percent visible infection. Such a procedure would avoid the expense of lifting, grading, and shipping stock that will only be a burden to the planter.

CAUTION: In handling the chemicals listed, follow directions and heed precautions given by the manufacturer.

6Sleeth. Bailey. Mortality of slash pine seedlings infected by Cronartium fusiforme. U.S. Forest Serv. South. Forest Expt. Sta. South. Forestry Notes 35. 1940.

7Sleeth, Bailey. Fusiform rust control in forest-tree nurseries. Phytopath. 33:33-44., illus. 1943.

8 Wakeley, Philip C. Planting the southern pines. U.S. Dept. Agr., Agr. Monog. 18. 233 pp.. illus. 1954.

9Foster. A. A., and Henry, Berch W. Nursery control of fusiform rust demands careful spraying. U.S. Forest Serv. Tree Planters' Notes t4, pp. 13-15. 1956.

10Verrall, A. F. Fusiform rust of southern pines. U.S. Dept. Agr. Forest Pest Leaflet 26. 4 pp., illus. 1958.

CYPREX: A SUPERIOR CONTROL FOR SHOTHOLE DISEASE OF CHOKECHERRY[1]

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University of Nebraska, Department of Plant Pathology, Lincoln, Nebr.

Introduction

The shothole disease of chokecherry seedlings has seriously threatened nursery stock in past years. Chokecherry was used extensively in shelterbelt plantings of 1936 to 1942, and on the basis of its performance is considered to be an adaptable, desirable plant for providing a low, dense component of windbreaks. In Nebraska the chokecherry is increasing in importance as a source of wildlife food, and serves a minor role in ornamental plantings. Under conditions favorable to disease development, outbreaks of the shothole disease, caused by the ascomycetous fungus, Coccomyces lutescens, have severely reduced the marketability of nursery seedlings, in some places resulting in total loss of first-year plantings.

Infected leaves first show chlorotic lesions, which later become necrotic and fall out leaving the leaf with a typical shothole appearance (fig. 1). Under more severe infections the typical shothole aspect does not appear; rather, the coalescence of closely spaced lesions produces a general blighting of the leaf and subsequent defoliation.

Figure l.--Typical shothole symptoms on first-year chokecherry seedlings.

In the spring and summer of 1958 a spray program was designed to test the effectiveness of several fungicides in controlling this disease.

Methods

First-year chokecherry seedlings, seeded in the fall of 1957 at the Plumfield Nurseries in Fremont, Nebr., were sprayed with eight fungicides. The fungicides and

[1] Published with the approval of the Director as paper No. 944. Journal Series. Nebraska Agricultural Experiment Station.
[2] Graduate assistant and Extension Plant Pathologist, respectively.

dosages used are given in table 1. Four replications were drawn from a randomized block for each treatment. The first spraying was conducted May 11, 1958, 2 weeks after the seedlings had emerged. The last spraying was conducted September 3. A total of nine sprayings with the prescribed fungicides were made, following at approximately 2-week intervals between May 11 and September 3. The first three sprayings were applied with a Hudson knapsack sprayer at 20-25 pounds per square inch (p.s.i.). The remaining sprays were applied using a Century pressure sprayer at 200-250 p.s.i. to provide complete coverage of the increasing foliar surface.

Table 1.--Fungicides screened for control of chokecherry shothole disease

Fungicide	Manufacturer	Active ingredient	Form	Dose per 100 gallons
Cyprex..........	American Cyanimide Co.	Dodecylguanidine acetate 70 percent	Wettable powder	1 pound.
Maneb (Manzate)..	DuPont Co.	Maneb (Manganese ethylene bix-dithio carbamate) 70 percent	do	2 pounds.
Actispray (Actidione)....	Upjohn Co.	Actidione (B-(2-(3.5-dimethyl)-2-hydroxyethyl)-glutarimide) 7.7 percent	Tablet	2 parts per million.
Zineb (Parzate)..	DuPont Co.	Zineb (Zinc ethylenebis-dithiocarbamate) 65 percent	Wettable powder	2 pounds.
Captan (Orthocide 50)...........	California Spray Chemical Corp.	Captan (N-trichloromethyl-mercapto-4-cyclohexene-1, 2-dicarboximide) 50 percent	do	4 pounds.
Dyrene..........	Chemagro Corp.	2,4-Dichloro-6-(0-chloro-aniline)-triazine 50 percent	do	2 pounds.
Puratized agricultural spray.	Gallowhur Chemical Corp.	Phenyl mercury triethanol-ammonium lactate 7.5 percent	Liquid	1 pint.
Bordeaux mixture.	Locally prepared	$CuSO_4$ and lime	Powders	5 pounds, 7 pounds.

At times throughout the duration of the spraying, readings were taken on the various aspects of the disease. Five readings each were taken on incidence and severity, four on defoliation, and one on plant vigor. Scales were prepared for each disease aspect to be considered, and are as follows:

Incidence

0--No infection or trace.
1--Only a few older leaves spotted.
2--All older leaves spotted.
3--All but newest leaves spotted.
4--All leaves spotted.

Severity

0--No spotting or trace.
1--Light spotting.
2--Moderate spotting, no blighting.
3--Heavy spotting, some blighting.
4--Extensive blighting.

Defoliation

0--No defoliation.
1--Light defoliation.
2--Moderate defoliation.
3--Heavy defoliation, lower stems bare.
4--Complete defoliation.

Vigor

1--Above 18 inches in height.
2--12-18 inches in height.
3--6-12 inches in height.
4--Below 6 inches in height.

Readings were taken in each replicate plot, and the readings of the four replicates for each treatment were averaged to arrive at a single index rating for each fungicide.

Results

Readings for the treatments and the control are presented in table 2. Concerning "incidence," "severity," and "defoliation," for which several readings were taken, only the first and last readings are presented. The single reading for "vigor" is also presented. In addition to the disease ratings, the rank of each treatment denoting the order of its effectiveness in comparison to that of the other treatments is also given.

Table 2.--Index ratings and comparative rankings of spray treatments[1]

Treatment	Incidence				Severity				Defoliation				Vigor Sept. 8		Overall rating Sept. 8[2]
	June 30		Sept. 8		June 30		Sept. 8		June 30		Sept. 8				
Cyprex	1.00	1	2.40	1	0.93	1	1.08	1	0.25	1	0.00	1	1.25	1	4.73
Zineb	2.43	2	3.58	2	2.25	3	3.35	2	0.68	2	2.25	2	2.15	2	11.33
Actispray	2.68	4	3.85	4	2.18	2	3.35	4	0.83	4	3.10	5	2.58	3	12.88
Maneb	2.83	6	4.00	5	2.60	5	3.25	2	1.33	5	2.75	3	3.08	5	13.08
Puratized agricultural spray	2.43	2	3.83	3	2.50	4	3.65	5	0.75	3	2.85	4	2.75	4	13.08
Dyrene	2.75	5	4.00	5	2.83	6	4.00	8	1.75	6	4.00	8	3.65	7	15.65
Captan	3.00	7	4.00	5	3.08	7	3.65	5	2.58	7	3.75	6	3.50	6	14.90
Bordeaux	3.40	8	4.00	5	3.33	8	3.75	7	3.08	8	3.85	7	3.68	8	15.28
Check	3.40	8	4.00	5	3.48	9	4.00	8	3.83	9	4.00	8	4.00	9	16.00

[1] Lowest index indicates best disease control. First figure for each date is index rating, second figure is comparative rank.

[2] Overall disease rating (last column) equals sum of September 8 readings.

Cyprex was by far the most effective of the fungicides tested. Throughout the spraying period Cyprex-treated seedlings showed a minimum of disease in all aspects concerned. By mid-September they averaged nearly 18 inches in height and had lost no leaves because of disease, whereas the checks were less than 6 inches in height and were completely defoliated (see fig. 2).

Figure 2.--The tall plants with heavy foliage are Cyprex-treated chokecherries. The check plants in the foreground are do foliated and small.

Zineb (Parzate), maneb (Manzate), puratized agricultural spray, and actispray (Actidione) may be placed in a group giving moderate control, while Dyrene, captan (Orthocide) and bordeaux mixture may be classified as giving little or no control. Control plants were a total loss with no commercial value.

CAUTION: In handling the chemicals listed, follow directions and heed precautions given by the manufacturer.
Mention of any chemical company or product does not imply endorsement by the U.S. Department of Agriculture.