Comments

Tree Planters' Notes
is published quarterly by the State and Private Forestry Staff, Forest Service, U.S. Department of Agriculture, Washington, DC 20250. The Secretary of Agriculture has determined that the publication of this periodical is necessary in the transaction of public business required by law of this Department.

Cover: Lifting pine seedlings at Forest Servive's W. W. Ashe Nursery (Brooklyn, MS.)

Tree Planters' Notes Expands and Modernizes

Welcome To New Editorial Board Members

We are proud to announce that the following individuals have agreed to serve on our editorial board: Dr. James P. Barnett (USDA Forest Service), Dr. Steven Grossnickle (British Columbia Research Inc., BCRI), Dr. John Mexal (New Mexico State University, NMSU), and Dr. Kenneth Munson (International Paper Co., IP). Expanding the board will enable us to better serve our readers by providing more access to authors "in the field." We will also benefit from their considerable years of experience in reforestation.

Jim Barnett has been with the Southern Forest Experiment Station, in Pineville, Louisiana, for 33 years and has authored over 200 articles. He has contributed much to our understanding of southern pine regeneration and has developed guidelines for growing seedlings in containers.

Steve Grossnickle works for a private research firm in Vancouver, Canada, and has been a leader in the field of stock quality assessment. He is currently also an associate editor for the ***Canadian Journal of Forest Research.***

John Mexal has been professor of horticulture at New Mexico State University for the past 11 years. He is also the director of the Center for Forestation of the Americas, which is a training center and clearinghouse for reforestation and restoration activities, focusing on Central America (but also including North and South America).

Finally, Ken Munson is the manager for forest productivity, nurseries, and orchards for International Paper, headquartered in Dallas, Texas. Ken has worked for IP for the last 10 years in progressively responsible positions and has worked extensively in the Pacific Northwest as well as the South.

These folks will be indispensable to ***TPN*** as we continue to publish articles that can make a difference in reforestation success and as we expand into international areas. We extend a hearty welcome to them.

Computer Age Hits Home

The age of the computer has finally arrived at ***TPN***. This is the first issue that we are publishing using "the machine." Authors were instructed to submit both hard copy manuscripts and a PC disk version. We then submitted the edited disk to the design and printing contractors.

This change should speed up our publication time considerably, as we eliminate the "galley proof" stage, although authors will still be able to review final proofs of their manuscripts. No doubt you have noticed that our printing schedule has been tardy. Our apologies, but we have a very limited staff to put out the journal and our other assignments have a way of crowding in. In addition, our shift to peer believe that it has been well worth the trouble. More and better manuscripts arrive in the mail, and the referee process has resulted in significant improvements in those articles sent through this review process. We still are getting articles in print in less than 10 months from their submission date. Check out our new article submission procedures on the inside back cover of this issue.

As always, we welcome your comments. So give us a call or FAX us. Thanks!

Rob Mangold
Editor-in-Chief
Cooperative Forestry
USDA Forest Service
Washington, DC

Rebecca Nisley
Managing Editor
USDA Forest Service
Hamden, CT

Note: Our concept of this editorial space is that it should be a place to publish opinions and ideas relating to the reforestation profession. We invite you to submit ideas for commentaries. The views expressed here are solely those of the author(s) and do not necessarily reflect those of the *Tree Planters' Notes* editorial staff, the Forest Service, or the U.S. Department of Agriculture.

Tree Planter's Notes, Volume 45, No. 2 (1994)

Alternatives to Methyl Bromide: Assessment of Research Needs and Priorities for Forestry, Nursery, and Ornamental Crops

Robert Linderman, Wayne Dixon, Stephen Fraedrich, and
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This report summarizes the findings of a session at the USDA workshop "Alternatives to Methyl Bromide" held in Arlington, Virginia, in June 1993. The report is published in full in the 1993 USDA publication, Alternatives to Methyl Bromide: Assessment of Research Needs and Priorities. Tree Planters' Notes 45(2):43-47; 1994.

The specific objectives of the USDA workshop "Alternatives to Methyl Bromide" were to

- Evaluate the existing and potential alternatives to methyl bromide uses as a postharvest commodity and quarantine treatment and as a soil fumigant to control agricultural pests.
- Identify research needs and priorities to develop effective alternative pest management strategies that do not rely on the use of methyl bromide.

The workshop was attended by over 250 individuals, many of whom were pest management specialists and scientists from various industries, universities, and State and Federal agencies. The workshop was divided into nine sessions. One of these sessions (session VIII) was devoted to the impact of the loss of methyl bromide on nursery production of forest tree seedlings and ornamental trees and shrubs. The evaluation process for each discussion group included the identification of the pests that would become a problem without methyl bromide, assessment of the scope of the problem (that is, national or regional), and a determination of the existing and potential alternative pest management practices available. As a final step, the group prioritized the research needs of the commodity group it represented. The nursery session was chaired by Robert Linderman, Wayne Dixon, Stephen Fraedrich, and Richard S. Smith, Jr., and comprised the following participants: Larry Abrahamson, William Carey, Everett Hansen, Harvey Holt, Robert James, Jennifer Juzwik, Robin Rose, and David Schisler.

The production of forestry and ornamental crops includes a wide diversity of plant species. The plants themselves are the product, and they are grown in many different types of production systems, from bareroot in ground beds and fields to production in containers and greenhouses. These plants are produced in every part of the United States and shipped from their site of production to their site of use. Shipping, handling, storage, and outplanting become considerations in dealing with disease and insect problems. The geographical sites of production may have great differences in climate, soil, and pest problems. Production systems are also influenced by a variety of manager and market demands.

Methyl bromide has been widely used to control soilborne root diseases, nematodes, insects, and weeds. The primary use of methyl bromide has been to treat ground beds. However, it has also been used to treat container mixes and containers to eradicate soilborne plant pests known to limit production and quality.

Commodities, Pest Problems, and Scope

The wide diversity of forestry and ornamental commodities produced in nurseries and greenhouses includes trees for reforestation, Christmas tree farms, and landscape and ornamental purposes, as well as fruit trees and small fruits.

The soilborne pests of these commodities include pathogens, nematodes, insects, and weeds. The scope of these problems is national or regional. Additional problems are expected to arise and the scope of current problems will increase if methyl bromide is not available for use in producing these commodities.

Pathogens. Soilbome fungal pathogens include *Fusarium, Pythium, Phytophthora, Rhizoctonia, Cylindrocladium,* and *Verticillium,* which are national problems. Regional problems are caused by *Macrophomina* in the South and West, and *Phoma* in the West.

Soilborne bacterial pathogens include *Agrobacterium* and *Erwinia,* which are national problems, and other deleterious bacteria, which are a regional problem in the West.

Nematodes. Plant parasitic nematodes are a national problem and include a large number of species. Different species may be important in each region. Estimated annual yield loss throughout the world due to damage by plant parasitic nematodes on ornamental plants is 11.1%. *Meloidogyne* species are a major problem in container-grown ornamentals.

Insects. Cutworms, white grubs, and root weevils are national problems. Regional insect problems include lesser cornstalk borer, pine sawflies, fire ants, mole crickets, and ground pearls in the South; sod and pine webworms in the North and South; cranberry girdler and black vine weevil in the North and West; root aphids, strawberry weevils, and western flower thrips in the West; and fungus gnats in the South and West.

Weeds. Spurges, nutsedges, grasses, chickweeds, hardwood trees, pigweed, clover, thistle, mustards, geraniums, and mosses and liverworts are national weed problems. Regional weed problems include bird's foot trefoil in the West, and sicklepod and carpet weed in the South.

Control of Soilborne Pests in Nurseries

Integrated pest management systems for control of soilborne pests are used in forest tree nurseries and ornamental nurseries. Methyl bromide has been an important and primary component of these systems. The regulatory withdrawal of methyl bromide (and possibly of other pesticides) will necessitate an increasing reliance on more complex integrated pest management systems in the future. These systems will incorporate existing and potential cultural, physical, biological, and chemical control practices. Outlined in the text that follows are needs that must be addressed for development of short-term and long-term integrated pest management programs in order to maintain nursery productivity. A summary of existing and potential alternative pest control practices that can be incorporated into these integrated pest management programs is provided in the subsequent sections.

Short-term (2 to 6 years) integrated pest management systems. It is imperative that integrated pest management programs be developed for the short term to ensure that the removal of methyl bromide causes minimal disruption of nursery and greenhouse operations that produce forest-tree seedlings and ornamental crops. These integrated pest management programs would emphasize the integration of existing cultural, physical, biological, and chemical control practices. Included in these programs would be the use of other existing soil fumigants, as well as other pesticides where appropriate. Investigations are needed on the timing of applications, determining rates, and how best to apply and utilize other existing pesticides (including alternative soil fumigants). An emphasis should be placed on minimizing pesticide use by maximizing understanding of when, how, and at what rates to use pesticides.

Long-term (more than 6 years) integrated pest management systems. Issues regarding environmental quality and concerns over public health and safety are only likely to become progressively greater with time. Therefore, the use of many currently existing soil fumigants and other pesticides may be questioned in the future. Crop production managers will be forced to rely increasingly on nonchemical control strategies. It is therefore imperative that long-term research efforts be initiated in the development of biologically based, environmentally sound integrated pest management programs. These programs should emphasize the integration of existing and potential cultural, physical, and biological cultural control practices. Integration of environmentally safe chemical control practices that target specific organisms should be emphasized. Host resistance should be utilized where appropriate and economically feasible. Methods to detect pest population levels and accurately forecast their impact are essential and need to be developed.

Existing Alternatives to Methyl Bromide

Other chemicals. Some fumigants such as Basamid® and metham sodium are available for use in the production of forest-tree seedlings and ornamental crops. In addition, fungicides (for chemical drenches, root dips, and seed treatments), herbicides (including mineral spirits), and insecticides are available to control some soilborne diseases, insects, and weeds. However, none of these alternative chemicals appear to be as effective as methyl bromide. Also, these chemicals may be potential environmental contaminants, may pose health and safety concerns, and may require more time, labor, and space allocations. The future use of at least some of these chemicals is likely to be limited by regulatory challenges and uncertain legal longevity.

Cultural practices and systems. Management of some soilborne plant pests of forestry, nursery, and ornamental crops may be achieved to a limited extent by crop rotations, fallowing, water management, soil amendments, cover crops, intercropping, mulches, and sowing. These cultural practices are currently available, are environmentally compatible, conserve beneficial soilborne organisms, and are subject to no or minimum regulation. However, they are not uniformly applicable nationally, require more land, are labor intensive, require a greater knowledge base, are potentially more variable qualitatively, may be more site and problem specific, may cause damage to soil properties, and require increased energy consumption and equipment maintenance.

Physical methods. Physical methods that may be used to a limited extent for managing some soilborne plant pests of forestry, nursery, and ornamental crops include soil solarization, heat pasteurization using steam, flaming for weeds posteremergence, cultivation of weeds, mechanical weeding, hand weeding, mulching, composting, trapping, and erecting physical barriers. These methods are generally readily available, broad spectrum, environmentally benign, subject to minimal regulation, and some at least have a short turn-around time. Soil uniformity and altered microbial ecology may be adversely affected by some of these methods. Primary disadvantages of these methods include tarp disposal problems, increased energy costs, reduced efficacy, and smaller/narrower windows of opportunity.

Biological control. Biological control systems can be used to a very limited extent for the control of some soilborne pests in the production of forest-tree seedlings and ornamentals. These systems are based on the use of bioactive composts, soil amendments, beneficial organisms (predators, parasitoids, parasites, competitors, and antagonists), pheromones, bioherbicides, and bioinsecticides. A narrow pest specificity may be a problem with some of these methods. Other disadvantages include: a lack of uniform quality, unknown compatibility with other treatments, a need for repeated applications in some cases, transportation of compost, reduced efficacy and increased variability of pest control, potential toxicity from high salts and heavy metals in composts, as well as a limited knowledge base from which to work. A major positive attribute of biological control practices is that they are generally considered to be environmentally acceptable.

Potential Alternatives to Methyl Bromide

Other chemicals. Anhydrous ammonia, reregistered pesticides, pesticides with expanded use labels, new combinations of existing and available chemical pesticides, and naturally occurring pesticides are potential alternatives to methyl bromide for controlling soilborne pests of forestry, nursery, and ornamental crops. However, many of these approaches have not yet been developed sufficiently for widespread use. Other limitations include possible adverse environmental impacts, longer posttreatment waiting periods, regulatory challenges, and uncertain legal longevity.

Cultural practices. In addition to further developments and refinements to increase efficacy of cultural practices described above under "Existing Alternatives,"potential pest control practices also include: improved irrigation systems; better sowing technology; new cultivation technology; survey and detection systems; refinements in compost technology; and integration of practices to maximize pest control.

Physical methods. Soil solarization; composting; irradiation; electronic heating (microwave); insect trapping; use of physical barriers such as mulches, matting, and soil stabilizers; and greenhouse heating are broad-spectrum, environmentally benign approaches. Many of these technologies are available; however, they have not been sufficiently developed for widespread use to manage soilborne pests of forestry, nursery, and ornamental crops. Some of them provide a short turn-around time. These approaches are subject to minimal regulation. Problems associated with these approaches include tarp longevity and disposal, greater energy costs, reduced efficacy, smaller/narrower window of opportunity, negative public perception of irradiated products, and worker safety issues involving use of irradiation and microwave equipment. Composting and new cultivation technology are needed.

Biological control. Biological control systems for soilborne pest management for forestry, nursery, and ornamental crops are based on introduction, augmentation, and conservation of biocontrol agents; enhancement of resident microbes; microbial combinations; insect behavior modification chemicals; and allelopathy. These systems are generally environmentally sound, but may be of limited use due to narrow pest specificity. Other limitations include unknown compatibility with other treatments, need for repeated applications, reduced efficacy and increased variability of pest control, and the currently limited knowledge base. Improved production, formulation, and delivery technologies for microbial antagonists need to be developed. Microbial antagonist combinations need to be evaluated. Biological control strategies need to be integrated with cultural and chemical approaches.

Genetics and biotechnology. Genetics and biotechnology are potential approaches to developing pestresistant hosts through gene transfer or induced pest resistance. These approaches were considered to be largely impractical as a means of pest control in the production of forest and ornamental crops, because of the wide diversity of plant species grown and the large number of pest problems encountered.

Detection systems. Biotechnological approaches may be used to identify specific organisms and to distinguish pathogenic organisms from nonpathogenic and beneficial microorganisms. Such systems are highly desirable for use in any integrated pest management program. Potential negative aspects are the high cost of biotechnologically derived products.

Host resistance. Plant breeding and biotechnology are potential approaches to developing pest-resistant hosts through gene transfer or induced plant resistance. Widespread development and use of pest-resistant hosts were generally considered to be impractical as a replacement to methyl bromide for forest-tree nurseries and ornamental crops. The primary reasons were the large diversity of plant species grown and the large number of pest problems encountered in the production of forestry and ornamental crops. Generally, host resistance is an environmentally benign approach to pest management. Biotechnology approaches to developing pest-resistant hosts could result in lower production costs, less cultural management, and increased energy efficiency. Moreover, host resistance to pests is compatible with other pest management systems or treatments. In most cases, pest resistance is limited to a specific pest. Major limitations include impracticality due to crop diversity, expensive development and final products, long development time, uncertain public acceptance of biotechnology-derived plants and plant products, limited knowledge of sources of pest-resistance genes and technology to identify, isolate, transfer, and manipulate genes, and overly optimistic expectations.

Research Needs and Priorities

High-priority, short-term needs and priorities.

- Develop integrated pest management systems that make maximum use of existing chemical, cultural, physical, and biological control practices.
- Develop new chemicals and chemical application technology. The emphasis in the short term should include timing of application, determining rates, and how best to apply and utilize other existing pesticides (including alternative soil fumigants). An emphasis should also be placed on minimizing pesticide use by maximizing understanding of when, how, and at what rates to use pesticides.
- Develop new culture/crop production systems. Improve the efficacy of currently available cultural control systems. Test locally effective methods for their effectiveness on a broader basis.

High-priority, long-term needs and priorities.

- Develop new culture/crop production systems and integrate appropriate existing cultural practices. Conduct research that develops a fundamental knowledge on cultural control practices and use this knowledge to develop new and improved systems.
- Develop biologically based, environmentally sound integrated pest management systems that place increasing emphasis on the integration and use of cultural, physical, and biological control practices. Integration of pest-resistant hosts into these systems should be emphasized only where applicable and economically feasible. Emphasis should be placed on the use of safer chemicals that affect specifically the target organisms.
- Develop physical pest management treatments and integrate into crop production systems. Increase research on soil solarization, pasteurization, and heat treatment methodologies. Develop methods to detect pest population levels and accurately forecast their impact.

Medium-priority, short-term needs and priorities.

- Develop physical pest management systems
- Develop biological pest control management systems, including the development of basic knowledge and a fundamental understanding of biological pest control.

Medium-priority, long-term needs and priorities.

- Develop biological pest control practices, including development of basic knowledge and a fundamental understanding of biological pest control.

Overwintering Black Spruce Container Stock Under a Styrofoam® SM Insulating Blanket

Robert E. Whaley and Lisa J. Buse

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In northwestern Ontario, large numbers of container seedlings are overwintered either outdoors or in frozen storage. Seedlings stored outdoors are subject to severe conditions overwinter and are prone to considerable damage, whereas freezer storage is expensive and has its own associated risks. To examine an alternative method for overwintering black spruce (Picea mariana *(Mill.) B.S.P.) container stock, we tested different configurations of a rigid Styrofoam® SM insulating blanket. Third-year outplanting results showed no differences in growth or survival performance between controlled frozen and Styrofoam® SM stored stock.* Tree Planters' Notes 45(2):47-52; 1994

Currently, about 159.2 million seedlings are produced for forest renewal in Ontario. Of these, about 55 million container and 44 million bareroot seedlings are overwintered outdoors. These seedlings can suffer considerable damage during outdoor overwinter storage, principally from root damage due to rapid freezing and shoot desiccation. Other problems include mechanical damage, such as the flattening of seedlings from the weight of snow and ice, and snow mold. All these problems are due to, or accentuated by, insufficient or fluctuating snow cover on outdoor stored stock and/or improper conditioning of the seedlings. Therefore, the emphasis in overwintering nursery stock is on protecting seedlings from desiccation and protecting seedling roots from critically low and/or rapid changes in temperature (McNiel and Duncan 1983).

Outdoor overwintered container stock suffered heavy losses in the Thunder Bay area in the years leading up to and including 1987 (OMNR 1987). These losses prompted the examination of alternative overwintering techniques, such as indoor frozen storage facilities, snow making, and insulating blankets. This report examines the feasibility of outdoor overwintering black spruce *(Picea mariana* (Mill.) B.S.P.) seedlings grown in Styroblocks under Styrofoam® SM insulating blankets.

Insulating blankets have been in use throughout North America since the mid-1970's for protecting overwintered horticultural plants (Green and Fuchigami 1985). Their use in forestry for protecting container seedlings is a recent practice. Several different configurations of insulating blankets have been tried, such as placing polyethylene film over plants packed in straw or covering seedlings with a sandwich of straw between layers of either clear or translucent polyethylene film (Green and Fuchigami 1985). Other insulating materials used have included rigid Styrofoam® and manufactured "Microfoam " sheets that can be up to 19 mm thick (Gouin 1977).

The procedure for protecting container seedlings consists of either erecting a frame over seedling trays to support the blanket or aligning rigid trays on their sides and surrounding them with an insulating blanket, thereby sealing in the stored stock. The weight of winter snow and/or other material such as wooden strips holds the blanket down and keeps it from whipping in the wind.

To evaluate the use of a Styrofoam® SM insulating blanket for protecting overwintered container stock, we began tests at Hodwitz Enterprises Ltd. in Thunder Bay, Ontario, in 1990. The objectives of our tests were to:

1. Examine the feasibility of overwintering Styroblock seedlings under Styrofoam® SM insulating blankets.
2. Determine the cost of and procedures for overwintering stock using insulating blankets.

Materials and Methods

A demonstration project was established at Hodwitz Enterprises Ltd., Thunder Bay, Ontario, to investigate the ability of rigid Styrofoam® SM insulating blankets to protect seedlings from rapid and extreme changes in temperature, drying winds, and desiccating sun. The containers examined were Styroblock 130's and 165's, which measure about 47 by 35.1 by 13 cm (18 by 14 by 5 in) and hold 130 and 165 seedlings, respectively.

Test Configuration – Year 1. For the first overwintering period of this test (1990-91), 50 trays of Hodwitz Enterprises' black spruce Styroblock 165 seedlings were placed under an insulating blanket. This equated to approximately 8,200 seedlings.

The treatment trays were placed on their sides in pairs, with seedling tops together— the tray tops were about 25 cm (10 in) apart— and tray bottoms touching, in both single- and double-layer configurations (figure 1B). The "blanket" consisted of covering the trays with 5.1-cm-thick (2-in-thick) R10 Styrofoam® SM on the top and sides. The treatment seedlings remained covered from mid-November to mid-April. The control trays were stored as normal outdoor overwinter stock-uncovered and unprotected by cardboard boxes (figure 1A).

Temperature probes were inserted into selected root plugs while the trays of seedlings were being placed under the insulating blanket. A total of 12 temperature probes were used to monitor both air (4) and in-plug temperatures of the single-layer (2), double-layer top (2) and double-layer bottom trays (2). Two probes were also placed in control trays, inside the container medium. An automatic recording device logged temperatures from the probes hourly during the entire storage period. Probes in the control, single-layer, and

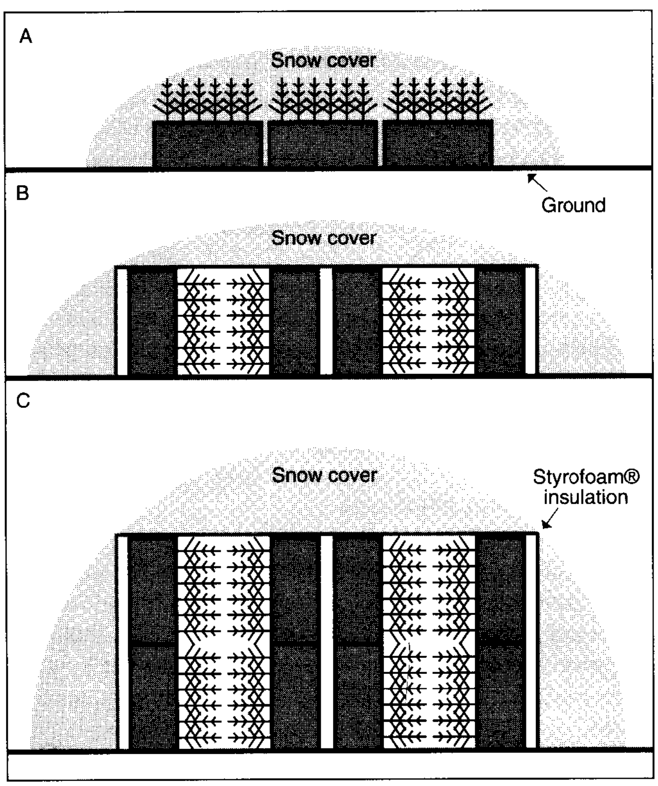

Figure 1—*Diagrammatic representation of overwinter storage treatments for black spruce in Styroblock 165's stored normally* **(A)**, *one layer* **(B)**, *and two layers deep* **(C)** *under the Styrofoam® SM blanket.*

double-layer bottom trays were approximately 10 cm (4 in) above ground level, whereas probes in the double-layer top trays were approximately 45 cm (18 in) above ground level.

Six trays of the same Hodwitz stock were also placed into controlled frozen storage at the former Thunder Bay Forest Nursery (TBFN), Thunder Bay, Ontario. These trays were first placed in plastic bags inside cardboard storage boxes and then overwintered in cold storage at -2 °C (28.4 °F). This stock remained in cold storage from mid-November to mid-April.

Test Configuration — Year 2. In 1991-92, the stacking configuration was changed. Although the controls remained the same, the Styroblock 165 trays under the blanket were stacked with seedling tops closer together-the tray tops were about 10 to 15 cm (4 to 6 in) apart-but with their bottoms touching and three rows high. The "single-layer" treatment was discontinued. Instead, trays of seedlings were sealed in plastic bags inside standard nursery cardboard boxes and placed in a standard shade area for overwintering. These boxes had no overwinter protection other than that provided by normal snowfall throughout the winter.

Between 3,000 and 4,000 Styroblock trays of black spruce seedlings were placed under the blanket in the second year. The trays consisted of both Styroblock 130's and 165's, with a total of about 500,000 seedlings being stored.

The Styrofoam structure was also improved (figure 2). Sand and gravel were laid down as a base to facilitate proper drainage, along with a layer of Weedmat® to prevent the growth of weeds during the summer months and to provide a better stacking and walking surface.

Temperature probes (a total of 12) were once again placed in selected root plugs of control seedlings (1), those sealed in cardboard boxes (1) and in the top (2), middle (2), and bottom (2) layer trays under the Styrofoam blanket. In addition, 4 probes were used to monitor outdoor and underblanket ambient air temperatures. An automatic recording device logged temperatures from the probes from late-November until seedlings were removed from storage on May 1, 1992. Temperature probes for the control, cardboard box, and bottom layer underblanket were approximately 10 cm (4 in) above ground level, while probes in the middle and top underblanket trays were approximately 45 and 80 cm (18 and 31.5 in) above ground level, respectively.

No seedlings were placed into controlled frozen storage during this second year of the test.

Figure 2—*Operational setup of Hodwitz Enterprises Styrofoam® SM cold frame for the overwinter storage of container stock.*

Seedling testing and outplanting. Bud flushing tests were conducted by the Ontario Ministry of Natural Resources' North Central Region container production monitoring staff between February and April of each year of the study. Sample seedlings were removed from under the Styrofoam blanket and from the outdoor storage area, thawed, potted into a peatvermiculite mixture, placed in a greenhouse, and monitored for bud swell and flushing.

An outplanting trial was implemented in the spring of 1991 using stock from each of the two 1990-91 insulating blanket treatments. Eighty seedlings from each of the insulating blanket and frozen storage treatments were outplanted in the spring of 1991 in the Thunder Bay Nursery outplant trial site near Raith, Ontario. Seedlings from each treatment were planted in four replicates of 20 seedlings each at 2-m (6.5-ft) spacing. The seedlings were measured in the fall of both 1991 and 1993 for total height, height increment (CAI), and root collar diameter (RCD). None of the control seedlings were outplanted. The balance of the (1991) experimentally stored seedlings were operationally planted by Canadian Pacific Forest Products (now Avenor), Thunder Bay, Ontario.

No seedlings from the 1991-92 overwintering study were experimentally outplanted in the spring of 1992. This is unfortunate, as apparently these seedlings overwintered better than those from the first year of the test. All of the overwintered seedlings were planted by Canadian Pacific Forest Products as part of their normal reforestation program.

Results

Overwintering-1990-91. Temperature monitoring showed that stock under the insulating blanket maintained fairly constant and warmer temperatures than control stock (figure 3). Minimum temperatures fluctuated less than 1 /C (33.8 /F) under the blanket in late fall, while the control fluctuated (sometimes daily) by 3 /C (37.4 /F) before sufficient snow had fallen to help in the insulation process. The seedlings were place into storage in mid- to late November and weather records show that 14 cm (5.5 in) of snow fell on December 12th and another 10 cm (4 in) on December 20th. Temperatures inside the structure then hovered at 0 /C (32 /F) throughout the balance of the winter months, while the control continued to vary by up to 5 /C. Ambient temperatures for the overwintering period ranged from 0 to -35.5 /C (32 to -31 /F) (figure 3). Snowfall for the storage period can be seen in table 1.

Flushing tests conducted throughout the winter months showed that seedlings from all treatments were normal and healthy. After thawing for 6 to 13 days, the potted seedlings took from 4 to 9 days to reach full bud swell. All seedlings were fully flushed in another 4 to 5 days.

The stock monitoring staff noted that all seedlings were healthy except for those underblanket seedlings in tray plugs closest to the ground. These were prone to considerable damage, believed to be the result of warmer temperatures and higher humidity at ground level. This problem was also experienced at Jellien Nursery in Armstrong, Ontario, where a similar test was conducted with jack pine *(Pinus banksiana* Lamb.) (Neill 1991, personal communication). There are no temperature records for the Armstrong trial.

Overwintering-1991-92. Minimum temperatures recorded in the second season of this trial were considerably different from the first year. In the first year, the temperature in the control fluctuated throughout the winter, while in the second year the control remained more stable (as ambient temperatures were more moderate and snow cover more consistent) until early March, when lack of snow cover and plunging ambient temperatures allowed temperatures in the root plugs to drop considerably and rapidly. Underblanket root

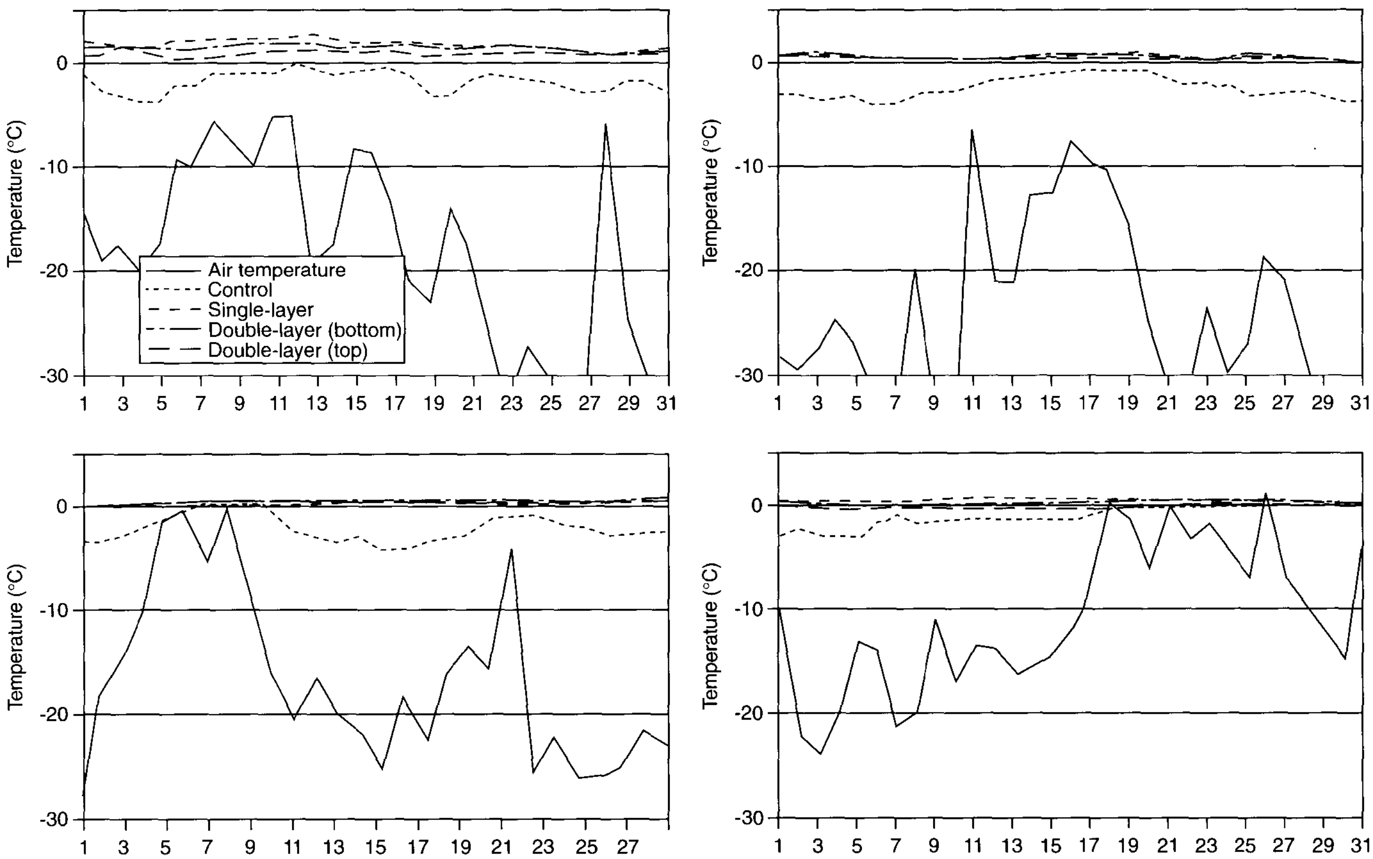

Figure 3—*Temperature fluctuations for outdoor stored Styroblock seedlings, compared to those under a Styrofoam® SM insulating blanket through the winter of 1990–91.*

Table 1-*Monthly snowfall (cm) amounts for Thunder Bay, Ontario, during the winters of 1990-91 and 1991-92 and the 30-year average for comparison*

	1990-91		1991-92		30-year average	
Month	cm	in	cm	in	cm	in
December	50.4	19.7	53.6	20.9	46.2	18.0
January	44.0	17.2	24.8	9.7	48.4	18.9
February	15.6	6.1	28.4	11.1	30.7	12.0
March	23.6	9.2	2.4	0.9	34.2	13.3
Totals	133.6	52.1	109.2	42.6	159.5	62.2

plug temperatures fluctuated between -1 and -5 °C (30.2 and 23 °F) during this second winter (figure 4) while ambient temperatures ranged from 0 to -29 °C (32 to -20.2 °F).

One flushing test involving the stored stock was conducted during the winter of 1991-92. Seedlings were removed from both the Styrofoam and outdoor storage areas, thawed, potted, and placed in a green house. The underblanket stock all had good color with no damage, while some of the outdoor stock had dead terminal buds and desiccated tops.

Outplanting results. Third-year outplanting results from the black spruce seedlings overwintered under the Styrofoam® SM blanket and the same stock overwintered in conventional cold storage at the TBFN were nearly identical (figure 5). Even though the under blanket seedlings outplanted in this test came from the first overwintering period (which had less than ideal storage temperatures, see Discussion), outplant performance of all measured parameters (height, CAI, RCD, and survival) showed no differences from that of the frozen stored stock.

Discussion

During the first year of the trial, temperatures under the blanket were observed to hover around -0 /C (32 /F). This is too warm for seedling storage (Hocking and Nyland 1971, Zalasky 1986, Odlum 1992) and can

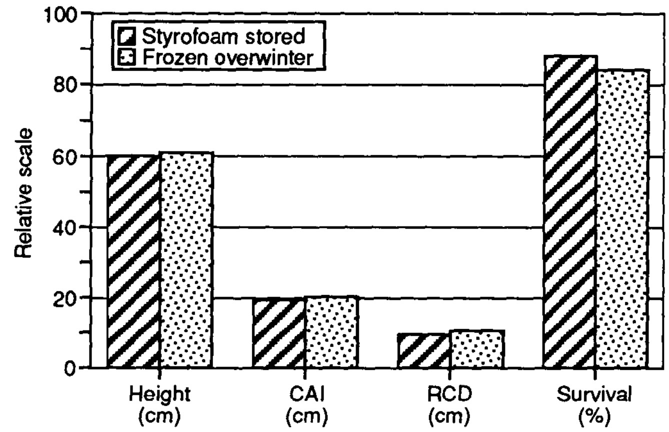

Figure 5—*Third-year outplanting results for black spruce seedlings grown in Styroblock 165's at Hodwitz Enterprises and overwintered under a Styrofoam® SM insulation blanket and in a conventional cold storage unit at the former Thunder Bay Forest Nursery. CAI = height increment, RCD = root collar diameter.*

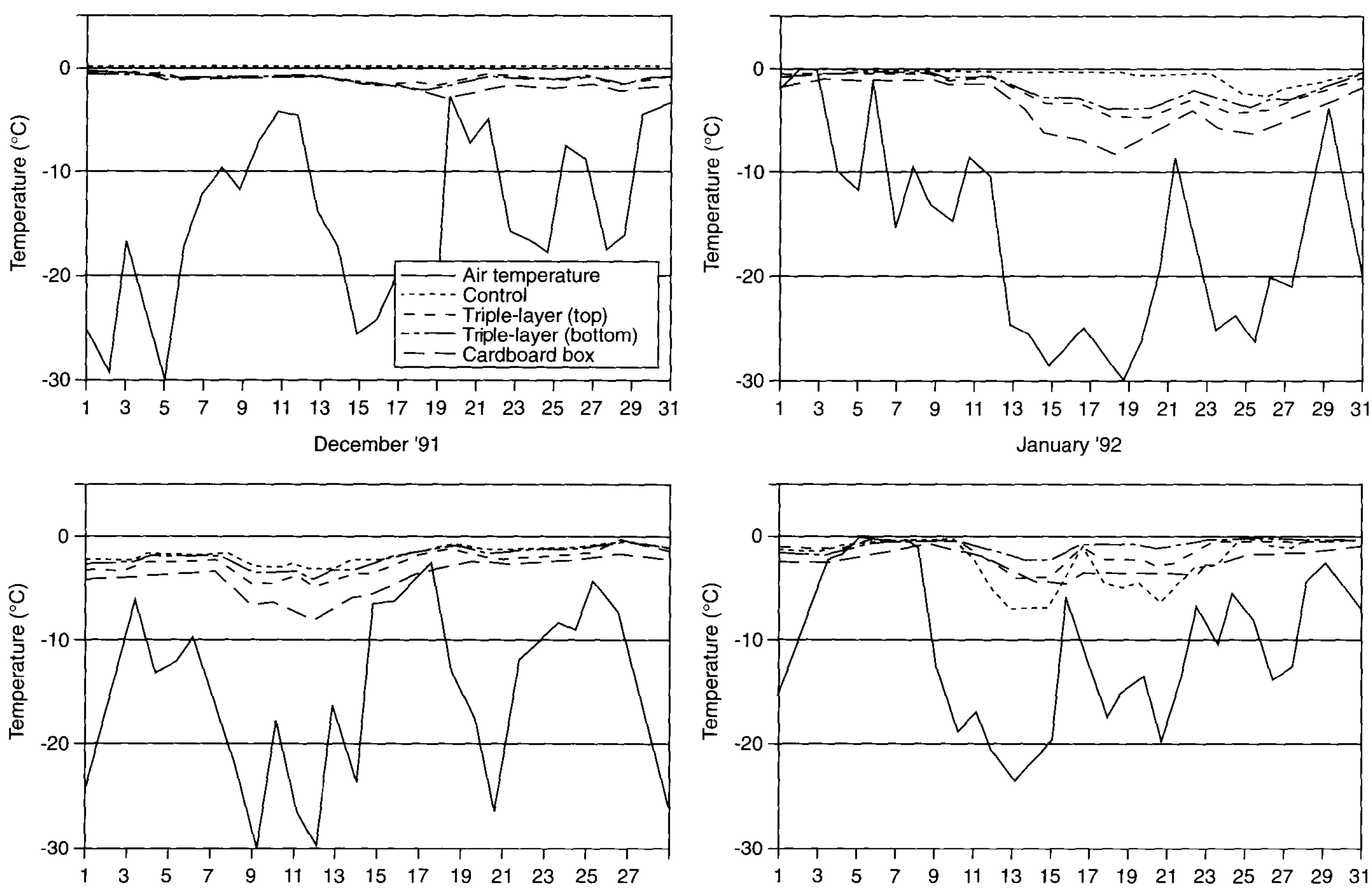

Figure 4—*Temperature fluctuations for outdoor stored Styroblock seedlings, compared to those under a Styrofoam® SM insulating blanket through the winter of 1991–92.*

promote mold growth. It resulted in excessive damage to seedlings touching the ground, where both temperature and humidity were higher.

Changing the structure of the storage area under the blanket in the second year, by stacking the trays three high (figure 2), changed the overwintering storage temperatures and provided a better balance between cold outside air temperatures and ground heat. The storage temperatures, although somewhat variable, ranged from -1 to -5 /C (30.2 to 23 /F). This range is closer to ideal for overwintering stock, and the stock came out of storage in the spring of 1992 looking extremely healthy (Duckett 1992, personal communication).

The reduced desiccation, reduced temperature fluctuation, and reduced seedling mortality observed in this test with the use of the Styrofoam structure mirror results of a similar trial in Alberta (Matwiend).

Constructing the final overwintering storage unit cost about Can$8,000.00, with minimal maintenance costs (Hodwitz 1992, personal communication). If storage unit construction costs are depreciated over 5 years, then overwinter storage costs are about Can$6.30 per thousand. This compares to 1991 capital and operating expenses of Can$26.50 per thousand for freezer storage (Aidelbaum 1993).

Over the winter of 1992-93, Hodwitz Enterprises stored about 1.2 to 1.3 million seedlings in the unit. Loading the unit took 10 nursery workers 3 days. Unloading took a similar amount of time.

The unit should remain sealed throughout the winter, but timing of the unloading of the unit in the spring is critical. Temperature probes should be placed inside the Styrofoam blanket unit (during the loading process in the fall) to monitor underblanket temperatures in the spring. As soon as underblanket temperatures rise and remain above freezing, the unit must be opened and unloaded to prevent the seedlings from overheating.

Conclusions

Outplanting performance did not differ between the underblanket and the frozen storage treatments. However, with potential cost savings of about Can$20.00 per thousand over freezer storage, the storing of Styroblock seedlings under a Styrofoam® SM blanket seems to be a practical and economical alternative to freezer storage. Outdoor storage of seedlings, which costs practically nothing, will continue to be used by nurseries. But this savings in overwinter storage must be weighed against the potential losses that can occur (i.e., annual losses of outdoor overwintered container stock can range between 1 and 3 million in northern Ontario, depending upon weather and seedling preconditioning (Duckett 1992, personal communication)). However, when selecting a system for overwinter storage of seedlings, numerous factors must be taken into account. These include elements of stock handling such as extraction, packaging, grading, transportation, field storage, and timing of flushing/ planting.

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Influence of Mechanical Incorporation Method on Dazomet Distribution in Conifer Nursery Soil

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Four mechanical incorporation methods were evaluated for their ability to distribute dazomet (Basamid®), a granular soil fumigant, in soil during a spring nursery field trial. Dazomet distribution downward in soil was determined by radish seed bioassay and soil analysis for fungal pathogens. Discing and other treatments adequately moved dazomet down to 15 cm (6 in), and marginally deeper. The disc, Roterra®, and combination disc and cultipak treatments gave complete control of Pythium *and* Fusarium ***species down to 10 cm (4 in), and partial control down to 20 cm (8 in). The cultipak by itself provided inferior mixing, resulting in the least amount of pathogen control.*** Tree Planters' Notes 45(2):53-57; 1994.

The gaseous fumigants methyl bromide and chloropicrin have been widely used in conifer nurseries because they give consistent control of fungi and weed seed. Although these compounds have performed well operationally, in the mid-1980's a number of people began to evaluate the performance of alternative fumigants because of environmental and worker safety concerns with methyl bromide (Campbell and Kelpsas 1988, Landis and Campbell 1991, McElroy 1985, McElroy 1986, Tanaka and others 1986). Now, the performance of these alternatives has been made even more crucial by the 1993 decision by the U.S. Environmental Protection Agency (EPA) to ban the use and production of methyl bromide in the United States by 2001.

Dazomet (Basamid® Granular) has received attention as an alternative fumigant because it is labeled for forest nurseries and is used extensively in Europe. Unlike methyl bromide, the fine granular compound is spread on the soil surface and incorporated with conventional tillage equipment. The resulting granule breakdown releases the gas methyl isothiocyanate, the primary fumigating agent.

Because tillage equipment differs between nurseries, we wondered about the suitability of different mechanical incorporation implements for mixing dazomet in the soil. European data exist for some types of equipment (BASF 1984), but there are few or no regional data for commonly used forest nursery implements. A fumigation trial was installed at the USDA Forest Service's J. Herbert Stone Nursery (Central Point, Oregon) in the spring of 1987 to address dazomet incorporation. Two objectives were established:

1. To determine the influence of different incorporation implements on dazomet distribution in the soil.
2. To determine the effects of each incorporation treatment on pathogen control.

Methods

Incorporation treatments. In early April, four incorporation treatments were selected to mix dazomet into nursery soil, representing a wide range of currently available mechanical implements (figure 1). The choice of implements was based on their potential for good incorporation and their availability. The incorporation treatments are summarized as follows:

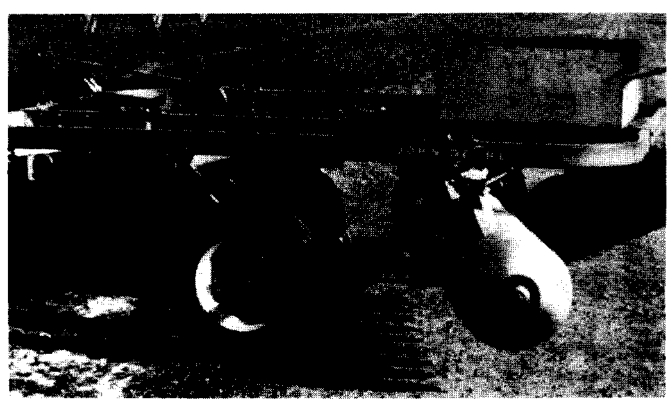
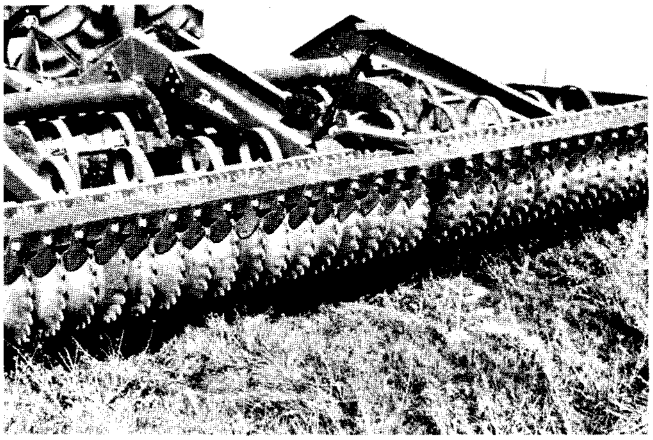


Figure 1—*Implements used to incorporate dazomet: disc (**above**),* [Figure continued on next page.]



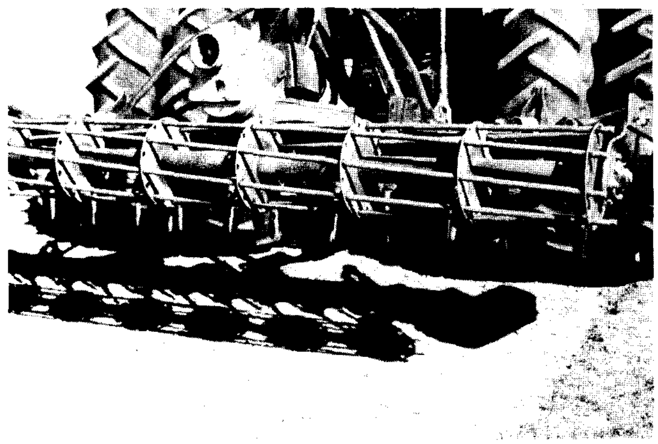


Figure 1 (continued)—*Implements used to incorporate dazomet: cultipak* **(left)**, *Roterra®* **(right)**.

Implement	Description	Maximum incorporation depth*
Disc	Double-gang disc 18-in (46-cm diameter)	9 in (23 cm)
Brillion cultipak	Harrow/roller (spring tines followed by serrated rollers)	6 in (15 cm)
Disc & cultipak	Treatment #1 followed by #2	9 in (23 cm)
Lely Roterra®	Power harrow (vertical rotating tines)	6 in (15 cm)

* Incorporation depth based on tine length or disc radius.

Field soil was preconditioned by cultivation to reduce clod size. In addition, the soil received irrigation and natural rainfall before treatment to enhance fungal development and to ensure adequate moisture for granule breakdown. Treatment plots 12.2 by 24.4 m (40 by 80 ft) in size were established in one portion of one field and replicated twice. An application of dazomet at the rate of 392.3 kg/ha (350 lb/acre) was broadcast over the entire treatment area with a droptype granule spreader and was followed immediately by the four incorporation treatments. To evaluate the effect of water sealing, half of each plot was irrigated with 6 mm (.25 in) of water after incorporation, and the other half was left unirrigated (unsealed).

Within each treatment plot, six sample points (three in each irrigation half) were established for soil collection. To determine dazomet movement downward in the soil profile, soil was stratified and collected from three sampling depths10, 15, and 20 cm (4, 6, and 8 in)-at each point.

Assay methods. Dazomet's presence was evaluated using two assay methods. The first consisted of a bioassay using radish seeds, similar to one described by Semer (1987). One pint of soil was collected from each depth immediately after pesticide incorporation and placed in canning jars. Untreated soil from an adjacent field was used as a control. About 20 to 24 seeds were sown in each jar, tightly capped, and placed indoors, in ambient light and temperature, at the nursery. Two weeks after sowing, the germinants were counted. Little or no germination of seeds indicated the presence of dazomet at biologically active concentrations (figure 2).

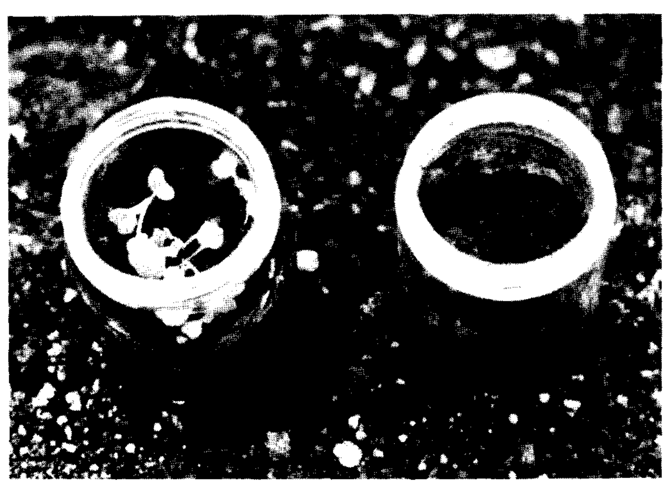


Figure 2—*Bioassay for the presence of dazomet in untreated* **(left)** *and treated* **(right)** *soil.*

The second method for determining dazomet distribution consisted of soil pathogen analysis. Soil from each point was evaluated for population levels of the fungi *Pythium* and *Fusarium* before treatment in 0-to 20-cm (0- to 7.9-in) composite samples, and 4 weeks after incorporation at three depths at each sample point. Pathogen sampling methodology followed that used previously by Campbell and Kelpsas (1988).

No statistical analysis was carried out on pathogen and radish germination data due to the high variation in results within treatments, the small sample sizes, and the small number of replications. Preliminary calculations of confidence intervals on the radish germination data were extremely large due to the above factors. (Note: this trial was initially set up as a "quick and dirty" look at how well the various implements performed, with only one replication and the radish seed assay planned. It was later amended to include two replications and to assay for pathogens as well as radish germination. Treatments were not randomized within treatment blocks.)

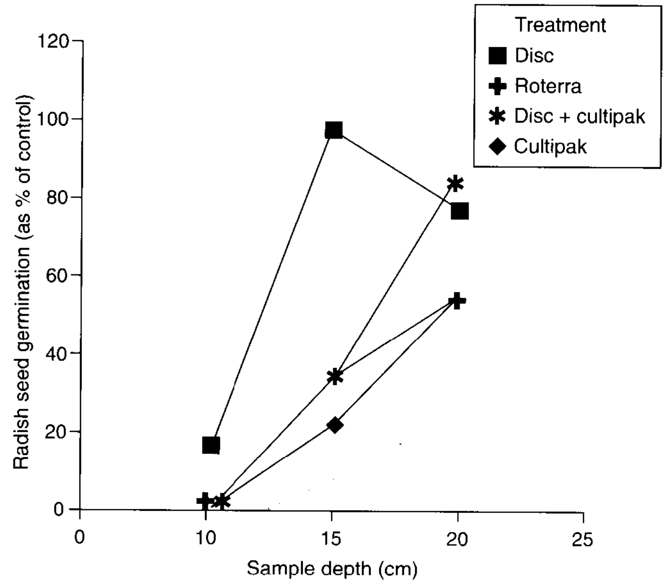


Figure 3—*Radish seed germination in dazomet-treated soil taken at three depths: 10, 15, and 20 cm (4, 6, and 8 in).*

Results and Discussion

Seed bioassay. Little or no radish seed germination in the 10-cm (4-in) soil samples indicated that all incorporation treatments were effective in mixing dazomet down to that depth (figure 3). Similarly, at the 15-cm (6-in) depth, the disc, disc plus cultipak, and Roterra treatments moved the material adequately to prevent or slow germination of radish seeds. The cultipak treatment was inferior to the other methods at this depth, probably because the soil was not mixed well with the narrow single teeth on the implement. All incorporation methods were less effective in moving dazomet to the 20 cm (8 in) depth, but enough material reached this level to provide some fumigation effect, based on inhibition of germinant development.

Soil pathogens. Soil analyses for the pathogenic fungi *Fusarium* and *Pythium* (table 1) revealed pretreatment levels for both genera that were variable and generally low — *Fusarium* levels are often over 1,000 propagules per gram (PPG) and *Pythium* over 100 PPG. The differences between nonirrigated and irrigated areas were variable and showed no apparent differences. As a result, the irrigated and nonirrigated samples for each incorporation treatment were pooled and the means reported here.

All treatments except the cultipak method eliminated *Fusarium* and *Pythium* populations from pretreatment levels at the 10-cm (4-in) depth. The higher incidence of *Fusarium* at 15 and 20 cm (6 and 7.9 in), especially with the cultipak method, and of *Pythium* at 20 cm (7.9 in) by the Roterra, indicates that all the implements did not provide uniform mixing lower in the soil profile.

The percentage of all soil samples containing any level of *Fusarium* or *Pythium* was distinctly reduced by dazomet when compared to the pretreatment sample percentages (figures 4 and 5). The cultipak treatment stands out as the method that provided the poorest pathogen control. This observation is consistent with the radish bioassay results and pathogen analysis noted earlier.

All four incorporation methods may provide enough mixing to impact *Pythium* populations down to the 15-cm (6-in) zone. For *Fusarium,* the disc and Roterra appear to give adequate control down to 20 cm (7.9 in). The actual level of control needed for either *Fusarium* or *Pythium* is specific to each nursery and depends, among other things, on the mix of pathogenic and nonpathogenic organisms present in the soil, seedling species, seedling growth rate, soil temperature, and soil moisture.

Conclusions

All four mechanical methods were effective in mixing dazomet into shallow soil depths down to 10 cm (4 in). The cultipak and Roterra, both with 6-inch (15-cm) tines, did not mix as well as the disc at deeper depths. We would not recommend that they be used alone for dazomet incorporation.

Table 1 -*Mean fungal populations (propagules per gram) at various sampling depths*

Sample depth	Disc	Cultipak	Disc + cultipak	Roterra
Fusarium				
Pretreatment				
0-20 cm	134	129	140	100
Posttreament				
10 cm	0	55	0	0
15 cm	0	103	36	6
20 cm	6	106	48	50
Pythium				
Pretreatment				
0-20 cm	8	45	5	10
Posttreatment				
10 cm	0	0	0	0
15 cm	4	3	0	0
20 cm	0	1	0	25

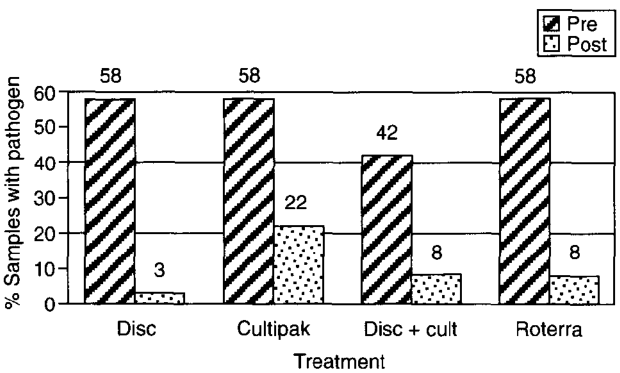


Figure 4—*Percentage of soil samples for each treatment containing any level of* Fusarium *before (PRE) and after (POST) dazomet application.*

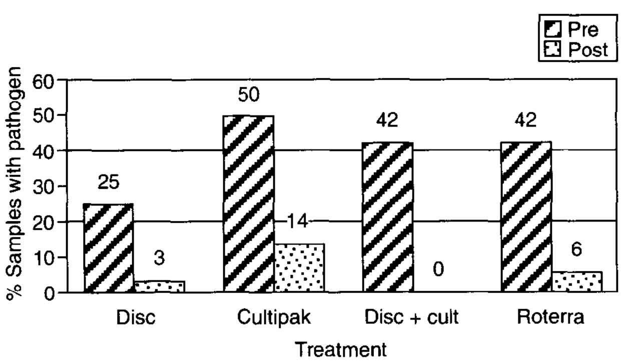


Figure 5—*Percentage of soil samples for each treatment containing any level of* Pythium *before (PRE) and after (POST) dazomet application.*

Target depths for dazomet treatment depend on specific nursery conditions; however, determining your target depth can be made several ways: aim for the same depth that methyl bromide is applied — 20 cm (7.9 in) or greater; use the typical seedling rooting depth during the period of greatest disease susceptibility; or simply use the depth that seems to provide good control based on several years of experimental or operational use.

Several northwest nurseries now use dazomet operationally. The J. Herbert Stone Nursery incorporates dazomet with an 18-inch disc, followed by a cultipak and roller. The Coeur d'Alene Nursery in Idaho uses a Roterra with 12-in (30.5 -cm) tines (twice as long as the tine used in this trial), with a roller attachment. Both nurseries find that dazomet mixing and subsequent pest control are adequate with these implements.

Although irrigation sealing under these study conditions presented no clear advantage over unsealed soil, it still may be useful in maximizing dazomet performance. This may be especially important in the fall when drier and warmer soils favor rapid fumigant release.

The results of this study, as well as successful experiences in a number of nurseries, indicate that forest nurseries can effectively apply and incorporate dazomet with a number of tillage implements. The performance of the disc treatments in this trial suggests that this common implement can be used successfully to distribute dazomet to soil depths necessary for seedling development.

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Comparing Methods of Artificially Regenerating Loblolly and Slash Pines: Container Planting, Bareroot Planting, and Spot Seeding

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In central Louisiana, loblolly (Pinus taeda *L.) and slash* (P. elliottii *Engelm. var.* elliottii) *pines were artificially regenerated by three methods: (1) planting 14-week-old container stock, (2) planting 1+0 bareroot stock, and (3) spot seeding. A common seed source was used for each species for all regeneration methods. Spot seeding was done by sowing 10 repellent-treated seeds per spot on the same 2.44- by 2.44-m (8- by 8 ft) spacing used for planting. Each seeded spot was thinned to one seedling after establishment was certain. After 15 growing seasons, loblolly and slash pines in the container and bareroot plantings had outproduced the spotseeded trees. Loblolly pines on the container, bareroot, and seeded plots yielded 146.2, 163.9, and 96.7 m^3/ha, respectively. Slash pines on the container, bareroot, and seeded plots yielded 190.1, 178.8, and 149.4 m^3/ha, respectively. The seeded trees were younger from seed than the bareroot stock, and this is reflected in stand volume. Although container stock was only 14 weeks old at planting, growth was comparable to that of the bareroot seedlings. Results show that seeding can be a low-cost regeneration alternative if some reduction in volume is acceptable.*
Tree Planters' Notes 45(2):63-67; 1994.

Bareroot seedlings are the preferred planting stock in the South because they are relatively inexpensive to produce and are generally reliable. However, container planting and direct seeding are alternative regeneration techniques with several advantages over bareroot planting (Brissette and others 1991, Derr and Mann 1971). Container stock of uniform size can be quickly produced. Production flexibility allows container seedlings to be planted throughout an extended planting season, provided soil moisture and climatic conditions remain favorable. Container seedlings perform well on adverse sites and allow faster planting rates than bareroot seedlings. Direct seeding costs are usually lower than planting costs. Seeding is less labor intensive, and large tracts can be seeded quickly, freeing workers for other duties.

Container planting and direct seeding also have disadvantages (Brissette and others 1991, Derr and Mann 1971). Trees produced in containers will likely cost more than bareroot stock grown in existing nurseries. Container seedlings are bulky to transport and must be handled differently from bareroot seedlings. Because container seedlings may be smaller initially, severe herbaceous competition may reduce their early development. Seeds and newly germinated seedlings are more vulnerable to predators and adverse weather conditions than planted seedlings. Thus, direct seeding is less dependable than planting, and trees are not established in rows unless additional care and expense are taken in seed placement.

Because each of these three methods of artificial regeneration has advantages and disadvantages, the field performance of loblolly *(Pinus taeda* L.) and slash *(P. elliottii* Engelm. var. *elliottii)* pines was evaluated for the three methods: (1) container planting, (2) bareroot planting, and (3) direct seeding at predetermined spots (spot seeding). Spot seeding was used to better control future stand density and spacing so more direct individual tree growth comparisons with the two planting methods would be possible.

Methods

Study area. The site is a gently sloping (1 to 30%) Beauregard silt loam (Plinthaquic Paleudult, fine-silty, siliceous, thermic) in central Louisiana. The Beauregard silt loam is normally a productive soil for pine management with site indices of 85 to 90 at 50 years (Haywood and Toliver 1989, Kerr and others 1980). The main limitations on tree growth are low natural fertility and a perched water table. Average yearly (57.5 in or 146 cm) and winter/spring seasonal (30.2 in or 77 cm) precipitation during the 15-year study were similar to the 42-year average precipitation amounts recorded nearby.

The pine stand was clearcut in 1973, and residual trees and logging debris were single-chopped with a rolling drum chopper. Competing vegetation was restrained by at least one controlled burn before 1978, and the area was again burned in the winter of 1978 before plot installation. By this time, debris and stumps had deteriorated. The plant cover was predominately bluestem *(Andropogon* spp. and *Schizachyrium* spp.) and panicum *(Panicum* spp. and *Dichanthelium* spp.*)* grasses, forbs, and scattered small hardwoods.

The area was treated with an ant poison to reduce losses to Texas leaf-cutting *(Atta texana* Buckl.) and fire *(Solenopsis* spp.*)* ants. The plots were rotary mowed to reduce grass and brush competitors after the 2nd, 9th, 12th, and 14th growing seasons.

Planting stock. All seeds were obtained from a local source in central Louisiana and stratified for 30 days before use. The container seedlings were grown at Pineville, Louisiana, in Keyes' Tree Starts® and Styroblocks® for 14 weeks before outplanting. Both Tree Starts and Styroblocks had a volume of 65 cm^3 (4.0 in^3). The Tree Starts were a molded mixture of organic and inorganic materials. A peat-vermiculite mixture was used as the growth medium in the Styroblocks. Two kinds of containers were used because there was an insufficient supply. However, seedlings from both containers were of equal quality and size.

Container seedlings were fertilized with 20-19-18 nitrogen/phosphorus/potassium at 150 ppm nitrogen through a watering system each time they were watered during the last 10 weeks of the 14-week growing period. The greenhouse environment was kept at 24 ± 5 /C (75.2 ± 9 /F) with a 16-hr photoperiod.

The 1+0 bareroot seedlings were sown in 1977 at the Louisiana Department of Agriculture and Forestry's Columbia Nursery according to standard nursery practices. Characterization of the container and bareroot stock before planting showed that the container seedlings were consistently smaller than the bareroot stock. The direct-seeded seeds were treated with standard bird and rodent repellents (Derr and Mann 1971).

Plot establishment. For both loblolly and slash pine, plots for each regeneration method were installed in a randomized complete block design with 4 blocks serving as replicates, for a total of 12 plots per species (three stock types by four blocks). Plots were 13 rows of 13 trees (or spots) each spaced at 2.44 by 2.44 m (0.10-ha gross plot).

Outplanting and seeding. The 1+0 bareroot seedlings were hand planted at a 2.44- by 2.44-m (8- by 8-ft) spacing in February 1978. Seeding was also done in February on the same 2.44- by 2.44-m spacing by sowing 10 repellent-treated seeds per hand-raked 30 cm (11.8 in) -diameter spot. Seeds were placed on the soil and lightly pressed into the surface, but left uncovered. Thus, the seeded trees were actually 1 year younger than the bareroot trees. The 14-week-old container seedlings were planted in holes made by a punch at the same spacing in April 1978. Container planting was delayed because the seedlings had not developed sufficiently to plant until April.

Dead seedlings in both plantings were replaced with transplants in early June to ensure that plot stocking was comparable. The bareroot replacements had been kept in 1 liter (1.1-qt) pots; the container replacements were held within the greenhouse. Each seeded spot was thinned to one seedling after establishment was certain.

Control of stocking allowed individual tree and plot volume growth comparisons to be made on a more biologically sound basis, which was the same reason we controlled stocking and spacing on the seeded plots. Regardless, Haywood and Tiarks (1990) found that analyses of pine growth and yield data sets that did or did not include inplanted trees resulted in the same statistical conclusions. Mortality that occurred after replanting and thinning of seeded plots was due to a lack of seedling vigor, predators, or the elements. Therefore, the reported survival at age 15 years reflected the long-term survival potential of each stocking type.

Measurements and data analysis. On 8 trees for each of 8 rows within the central area of each plot (0.04 ha or 0.1 acre), total height measurements were taken after the 1st through 5th, 10th, and 15th growing seasons. After 10 growing seasons, tree stems were examined for fusiform rust galls, which are caused by *Cronartium quercuum* (Berk.) Miyabe ex. Shirai f. sp. *fusiforme* Burdsall & Snow. After the 15th growing season, diameter-at-breast-height (dbh) and survival measurements were taken. Outside-bark volumes were calculated using Baldwin and Feduccia's formula for loblolly pine (1987) and Lohrey's formula for slash pine (1985).

For each pine species, height, dbh, volume per tree, survival, stand volume, and fusiform rust data were analyzed by analysis of variance. Mean comparisons were made with preplanned orthogonal comparisons (probability> F-value = 0.05): container plus bareroot planting versus spot seeding and container planting versus bareroot planting.

Results and Discussion

After 5 years, container and bareroot loblolly pine seedlings were an average of 1 m taller than the seeded seedlings (figure 1). The difference in average loblolly pine height between the two plantings and the seeded plots increased to 1.5 m (4.9 ft) by age 15. From the 5th through the 15th growing seasons, container and bareroot slash pines were an average of 1 m (3.3 ft) taller than the seeded slash pines. Campbell (1985) had similar results; he found that 20-year-old loblolly and slash pines that had been broadcast sown into a grass rough were 2 and 1 m (6.6 and 3.3 ft) shorter than planted loblolly and slash pines, respectively. The height differences between the container and bareroot plantings were not significant for either species (table 1). These results confirm earlier ones showing that superior performance of container over bareroot stock occurs only under stressful conditions (Barnett and McGilvray 1993).

For loblolly pine, the container and bareroot plantings had significantly greater dbh than the seeded plots (table 1). However, for slash pine, the difference in dbh between the average for the container and bareroot plantings and the seeded plots was not significantly different (probability > Fvalue = 0.06).

For both pine species, the container and bareroot plantings had significantly greater outside-bark volume per tree than the seeded plots (table 1). After 15 years, volume per loblolly pine averaged 104, 99, and 85 dm^3, and volume per slash pine averaged 144,

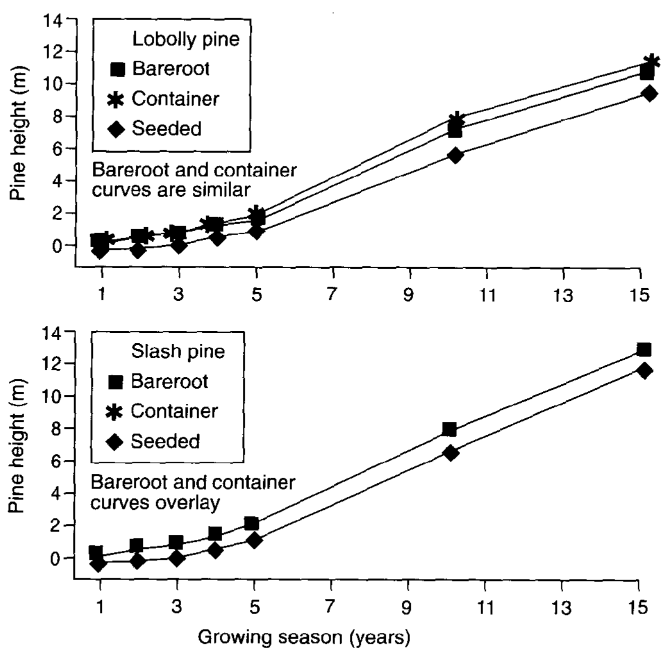

Figure 1—*Average height of loblolly* **(top)** *and slash* **(bottom)** *pine from the 1st through the 15th growing seasons.*

155, and 126 dm^3 on the container, bareroot, and seeded plots, respectively. Because Campbell (1985) broadcast seeds, his range in volume-per-tree differences after 15 growing seasons was greater than for this experiment.

It is difficult to separate the influence of survival on individual tree growth and yield per unit area. However, all three variables— percentage survival, volume per tree, and volume per hectare— can be useful in evaluating treatment effects, especially for long-term field studies.

As with volume per tree, long-term loblolly pine survival was significantly greater for the container (94%) and bareroot (88%) plantings than for the seeded (68%) plots after 15 years (table 1). Therefore, the 15-year-old loblolly pine also had significantly greater yields for the container (164 m^3 /ha) and bareroot (146 m^3/ha) plantings than for the seeded (97 m^3 /ha) plots. Campbell's 15-year-old loblolly pine studies yielded 248 and 174 m^3/ha on the planted and broadcast-sown treatments, respectively (1985).

For this experiment, average long-term slash pine survival values on the container (79%) and bareroot (68%) plantings were not significantly different from those on the seeded (70%) plots after 15 years (table 1). However, because of the differences in individual tree size, the 15-year-old container and bareroot plantings yielded somewhat more volume than the seeded plots: 190, 179, and 149 m^3/ha, respectively (probability > F-value = 0.07). Campbell's 15-year-old slash pine yielded 151 and 162 m^3/ha on the planted and broadcast-sown treatments, respectively (1985).

Slash pine was the most productive species on all treatments at this Paleudult silt loam site, although the study design would not allow us to prove this outcome statistically. Regardless, loblolly has been shown to be more productive than slash pine on other Paleudult soils (Haywood and others 1990).

After 10 growing seasons, 7% of the loblolly and 13% of the slash pine trees had stem infections caused by fusiform rust (data not shown). These levels of infection by age 10 are generally low for central Louisiana (Cain 1978, Derr and Mann 1970). There were no regeneration-method differences for either species.

Conclusions

Evidently, either container or bareroot planting stock can be used with little or no effect on mid- to late-rotation yields for either loblolly or slash pine.

Table 1 -*Characteristics and statistical information on loblolly and slash pine 15 years after outplanting*

Species and regeneration method	Height (m)	Dbh (cm)	Vol/tree (dm^3)	Survival (%)	Stand vol (m^3/ha)
Loblolly pine					
Container	11.4	14.5	103.5	94	163.9
Bareroot	11.1	14.0	99.3	88	146.2
Seeded	9.8	13.5	84.9	68	96.7
Means	10.8	14.0	95.9	83	135.6
Slash pine					
Container	13.2	15.9	144.0	79	190.1
Bareroot	13.2	16.3	155.4	68	178.8
Seeded	12.2	15.2	126.0	70	149.4
Means	12.9	15.8	141.8	72	172.8

Species and regeneration method	Probabilities > F-value				
	Height	Dbh	Vol/tree	Survival	Stand vol (m3/ha)
Loblolly pine					
Seeded vs. container + bareroot	0.0060	0.0465	0.0438	0.0057	0.0007
Container vs. bareroot	0.4557	0.1990	0.5980	0.3669	0.1420
Error mean square	0.3285	0.2477	112.55	82.316	218.46
Slash pine					
Seeded vs. container + bareroot	0.0096	0.0555	0.0197	0.6814	0.0650
Container vs. bareroot	0.8366	0.3580	0.1910	0.2484	0.5528
Error mean square	1.3616	0.3335	121.48	126.11	643.74

Therefore, planting stock choices can be based on more immediate factors such as establishment costs, planting date, and site and climatic conditions likely to be encountered during the first growing season (Brissette and others 1991).

As expected, spot seeding was less effective than either planting method (Campbell 1985). However, the seeded trees were younger than planted bareroot stock. The container stock was about the same age as the seeded trees, but the initial greenhouse period allowed the container stock to develop rapidly and perform equally to bareroot material. Results showed that direct seeding can be a viable regeneration alternative, especially when regeneration costs are a limiting factor. Still, a definite decrease in individual tree size and, possibly, per hectare yields should be expected with direct seeding.

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Nursery-to-Field Carryover and Post-Outplanting Impact of *Macrophomina phaseolina* on Loblolly Pine on a Cutover Forest Site in North Central Florida

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The charcoal root rot fungus— Macrophomina phaseolina *(Tassi) Goid.— was carried over from nursery seedbeds to a field planting site on asymptomatic, apparently healthy loblolly pine* (Pinus taeda *L.*) *seedlings. Seedlings on which the pathogen was carried to the field exhibited reduced survival over two growing seasons. The implications of this nursery-to-field carryover are discussed.* Tree Planters' Notes 45(2):68-71; 1994

Charcoal root rot, caused by *Macrophomina phaseolina* (Tassi) Goid., has been and still is considered a problem in many southern forest tree nurseries (Barnard and Gilly 1986, Fraedrich and Smith 1994, Hodges 1962, Rowan 1971, Seymour 1969, Seymour and Cordell 1979, Smith and others 1989). Although once previously reported as a problem in 2-to 7-year-old slash pine *(Pinus elliottii* Engelm.) plantations on reforested sandhills in western Florida (Smalley and Scheer 1963), *M. phaseolina* traditionally has been considered a "forestry problem" primarily in seedling nurseries. Recently, however, Barnard and others (1995) reported *M. phaseolina* to be commonly associated with and a probable contributor to first-year mortality of slash pine seedlings planted on recently converted agricultural croplands.

The concern with any "nursery disease" is the potential for the causal agent itself (i.e., the pathogen) to be carried into the field on healthy-appearing nursery stock, with subsequent disease development after outplanting. This potential has been evaluated for some forest tree pathosystems (Barnard 1984, Barnard and others 1985, Hansen and others 1980, Saunders and others 1992, Smith 1967), but information is lacking with regard to this potential in many others. An outbreak of charcoal root rot at the Florida Division of Forestry's Andrews Nursery in August 1987, provided an opportunity to evaluate nursery-to-field carryover of *Macrophomina phaseolina* and its effect on survival of outplanted loblolly pines (*P. taeda* L.). This paper summarizes the results of this evaluation.

Materials and Methods

A preliminary assessment of the occurrence of *M. phaseolina* on both dead and "healthy" (i.e., asymptomatic, potentially saleable) loblolly pine seedlings was performed on September 30, 1987. Twenty-five side-by-side pairs of live and dead seedlings were removed from disease--impacted seedbeds with a shovel (figure 1) and carried in an ice chest to the laboratory for evaluation. In the laboratory, a single 1-cm root collar segment and four randomly selected 1-cm primary lateral root segments were excised from each sample seedling. These segments were then soaked for 3 minutes in 0.5% sodium hypochlorite, rinsed in sterile deionized water, plated onto acidified (3.3 ml of 50% lactic acid/liter) potato dextrose agar, and incubated at ambient laboratory conditions. Plates were periodically examined over a period of 7 to 10 days for developing colonies of *M. phaseolina.*

In January 1988, seedbeds in which charcoal root rot occurred were divided into two groups: disease-free seedbeds (i.e., seedbeds or areas within seedbeds with no noticeable seedling symptoms or mortality) and disease-impacted seedbeds (seedbeds or areas within seedbeds having abundant seedling mortality). At that time, 50 surviving and apparently healthy seedlings were lifted at random from seedbeds representative of each of the two treatments and evaluated as described above for the presence of *M. phaseolina.* At the same time, 250 surviving and apparently healthy seedlings from each treatment were transported to the field and machine planted at a 6 X 10 ft (about 2 X 3 m) spacing on a cutover pine plantation site in north central Florida in alternating 50-tree row plots (5 replications). Comparative sizes of seedlings between the two treatments were assessed at lifting/ outplanting by measuring root collar diameters to the nearest millimeter on 50 randomly selected seedlings from each of the two treatments.

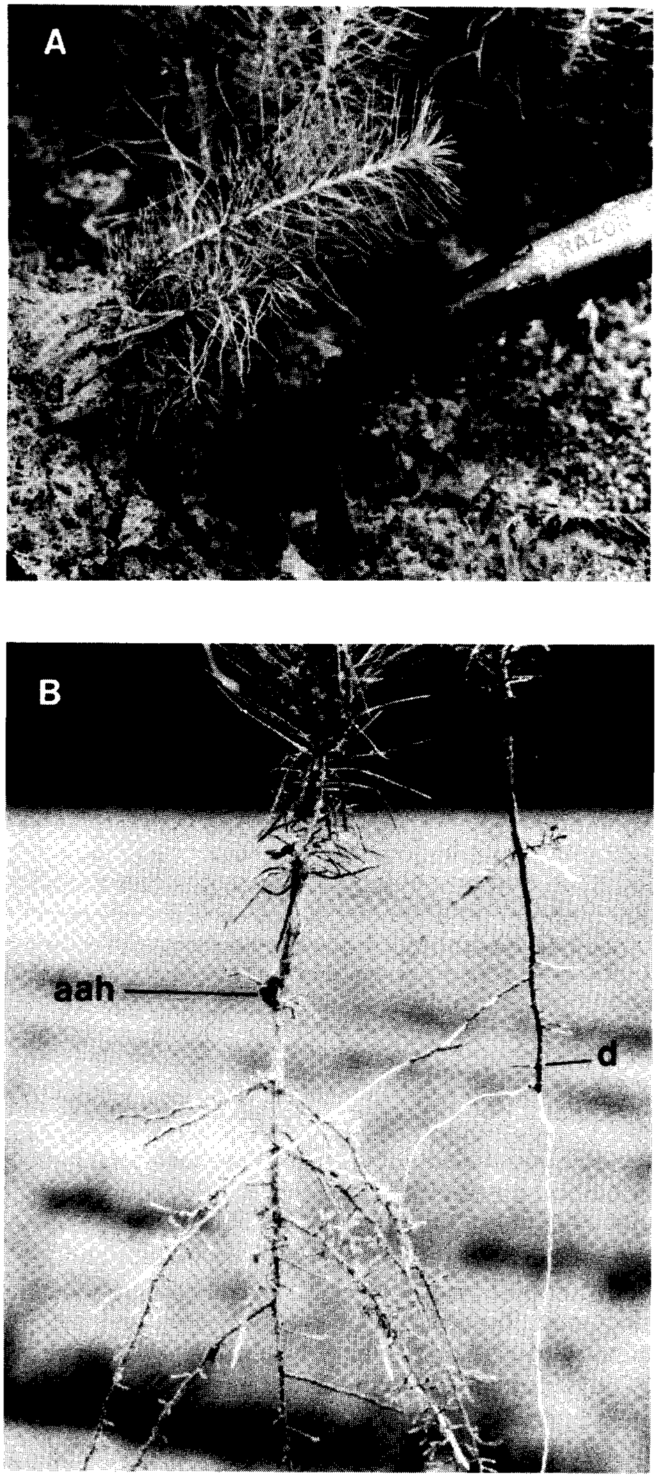

Figure 1A—*Side-by-side sampling of dead* **(d)** *and asymptomatic, apparently healthy* **(aah)** *loblolly pine seedlings in a charcoal root rot-impacted seedbed.* **B**—*Roots of dead* **(d)** *and asymptomatic, apparently healthy* **(aah)** *seedlings.*

The field site was visited in September 1988 and 1989 after one and two growing seasons respectively. On each visit, the percentage of surviving seedlings was determined, and all dead or dying seedlings were carefully dug, transported to the laboratory, and evaluated for the presence of *M. phaseolina.* This evaluation consisted of both visible inspection for the presence of subcortical microsclerotia (Barnard and others 1994, Barnard and Gilly 1986, Smith and others 1989) and culturing for the pathogen as described above. Year-end survival data were subjected to analysis of variance (ANOVA) and differences between treatment means within each measurement year were evaluated for significance at P# 0.05.

Results

In September 1987, *M. phaseolina* was readily recovered from asymptomatic, apparently healthy seedlings adjacent to dead seedlings in disease-impacted seedbeds (table 1). *M. phaseolina* was also recovered in January 1988 from surviving, asymptomatic seedlings taken from disease-affected seedbeds. The percentage of seedlings yielding the pathogen in the January 1988 collection, however, was considerably lower than that in the September 1987 collection. *M. phaseolina* was not recovered from any of the sample seedlings removed from disease-free seedbeds.

At the time of lifting and outplanting in January 1988, the surviving, asymptomatic seedlings from disease--affected seedbeds were slightly larger in stem diameter than seedlings from disease-free seedbeds. Figure 2 shows the distribution of seedling stems within 1-mm diameter classes from each of the two treatments.

Seedlings from disease-free seedbeds exhibited significantly (P # 0.05) better survival than those from disease-affected seedbeds over the course of the 2 years of field monitoring (table 2). In neither of the two treatments, however, was survival particularly poor. The association of *M. phaseolina* with dead and dying seedlings was clearly treatment-related (table 3). The pathogen was detected on approximately 75% of the dead and dying seedlings from disease-affected seedbeds, but only on 5% of those from disease-free seedbeds.

Table 1– *Recovery of* Macrophomina phaseolina *from roots of loblolly pine seedlings removed from charcoal root rot-impacted seedbeds in a Florida forest nursery*

				M. phaseolina isolations			
		No. of	No. of	Trees		Roots	
Date	Treatment*	trees sampled	roots plated	No	%	No.	%
09/30/87	Live	25	125	10	40	10	8
	Dead	25	125	19	76	42	34
01/28/88	3	50	250	0	0	0	0
	33	50	250	9	18	10	4

*Live = healthy seedlings adjacent to dead seedlings; Dead = dead seedlings (see figure 1); 3= healthy seedlings from unaffected portions of seedbeds; 33= "healthy" seedlings removed from portions of seedbeds with abundant seedling mortality.

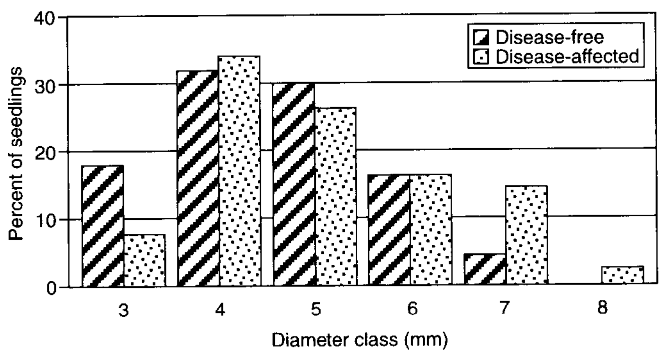

Figure 2—*Frequency distribution of stem diameters for loblolly pine seedlings taken from disease-free and disease-affected nursery seedbeds.*

Table 2 – *Survival of outplanted loblolly pines removed from* Macrophomina phaseolina-*infested seedbeds after 1 and 2 growing seasons in the field*

	% Survival			
	Sept. 2, 1988		Sept. 21, 1989	
Rep. no.	Trt I*	Trt II*	Trt I*	Trt II*
1	97.9	89.8	89.6	87.8
2	98.0	93.9	94.0	85.7
3	100.0	88.5	91.7	82.7
4	100.0	92.2	90.0	88.0
5	100.0	97.9	94.0	89.6
Mean‡	99.2a	92.5b	91.9a	86.8b

*Trt 3 = healthy seedlings from unaffected portions of seedbeds; Trt 33= "healthy" seedlings removed from portions of seedbeds with abundant seedling mortality.

‡Means across computed sampling dates that are followed by different letters differ significantly at P # 0.05.

Discussion

The data reported in this paper demonstrate that *Macrophomina phaseolina* can indeed be carried from the nursery to the field on asymptomatic, apparently healthy seedlings (table 1). In addition, such nursery-to-field carryover can result in reduced survival of outplanted seedlings (table 2). However, these facts must be interpreted within the framework of operational forestry practices, varying weather conditions, differences among field outplanting sites, etc. For example, although differences in survival between seedlings from the two treatments were statistically significant (table 2), it is questionable whether such differences are managerially consequential. It is also probable that in a drier planting year, survival would have been poorer and differences in survival between treatments would have been greater; 1988 was a good planting year with respect to rainfall and soil moisture, and the impact of *M. phaseolina* as a pathogen is typically greater when host plants are under drought or moisture stress (Barnard and Gilly 1986, Barnard and others 1994, Hodges 1962, Palti 1981). At the same time, it can be argued that on sites with abundant indigenous *M. phaseolina*e.g., converted agricultural croplands (Barnard and others 1995), the impact of nursery-to-field carryover of *M. phaseolina* would be inconsequential due to the abundance of inoculum already on site. Typical of cutover forest sites (Barnard, unpublished data), the outplanting site employed in the present study had relatively low levels of *M. phaseolina* (about 0.8 colony-forming units/g of soil compared to about 6 to 13 colony-forming units/g of soil on converted agricultural croplands; Barnard and others 1995) before establishment of the test planting. Finally, consideration must be given to the fact that in

Table 3 — *Numbers of dead loblolly pine seedlings evaluated and percentage recovery of* Macrophomina phaseolina *after 1 and 2 growing seasons in the field (seedlings outplanted from* M. phaseolina-*infested nursery seedbeds)*

Date samples collected	No. dead trees		% Trees positive for *M. phaseolina*	
	Trt I*	Trt II*	Trt I*	Trt II*
09/02/88	2	18	0	66.7
09/21 /89	18	15	5.6	80.0
Overall	20	33	5.0	73.0

*Treatments: defined at lifting from nursery seedbeds (see tables 1 and 2). I= healthy seedlings outplanted from unaffected portions of seedbeds. II = "healthy" seedlings outplanted from portions of seedbeds with abundant seedling mortality.

the present study, every effort was made to purposely obtain seedlings contaminated with *M. phaseolina.* In an operational nursery management situation, such seedlings would likely (and should) be avoided (i.e., skipped during lifting), thus minimizing the "threat" of nursery-to-field carryover of the pathogen.

Acknowledgments

The author expresses his appreciation to Sarah Walker, Steve Gilly, Ernie Ash, and Dale Rye for their technical assistance and to the JSC Container Corp. of America for providing the outplanting site for this study.

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Wind Effect on Windbreak Establishment in Northern Australia

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Wind effects on the early growth of three species– Callistemon salignus, Eucalyptus microcorys, *and* Melaleuca armillaris *– planted to form windbreaks were examined in a field study on the Atherton Tablelands in north Queensland, Australia. Trees of these species were grown with and without wind protection using* Zea mays *(maize). Wind direction and speed were measured daily at intervals of 2 hours throughout the experiment. Tree angle to ground, height, and crown size were measured at age 5 months, when the maize was being harvested. Trees of each species leaned over as a result of wind. Tree height and crown growth were significantly reduced by wind. Using tall annual crops to protect windbreak trees during establishment is a useful technique.* Tree Planters' Notes 45(2):72-75; 1994.

It has long been recognized that wind causes physical and destructive damage to crops (Bates 1917, Caborn 1957, Bird et al. 1984). Kort (1988) noted that wind causes adjacent leaves to rub against each other, creating various kinds of damage. Strong wind may cause lodging of mature crops (Marshall 1967). Plant physiological processes are also influenced by winds, which cause changes in plant surface temperature and light interception by altering leaf angle (Grace 1988).

Many studies have shown that windbreaks can provide protection from wind and benefit crop growth (Marshall 1967, Kort 1988, Sun and Dickinson 1994). The benefits of windbreaks on livestock are also well documented (Reid and Bird 1990). Because of these benefits, windbreaks have become an important strategy for agriculture management in many areas of the world (Sturrock 1988).

Apart from windbreak design and assessment of the windbreak effect on crops using existing windbreaks, planting and establishment of windbreaks has also attracted some attention. Most of the establishment studies dealt with species selection, site preparation, weed control, and water requirements during the establishment period (Sheikh 1988). However, few studies have been carried out to examine the effect of wind on the establishment of the windbreak itself. Wind that can damage crops may also affect the growth of young trees and thus affect the establishment of windbreaks. It is important to know to what extent this effect would influence the growth of young trees and to develop techniques to improve windbreak establishment in windy areas. The work reported here was undertaken to further our understanding of techniques for establishing windbreaks that are subjected to wind.

Materials and Methods

Callistemon salignus, Eucalyptus microcorys, and *Melaleuca armillaris* were the windbreak tree species. Details of their seed sources are given in table 1. Maize *(Zea mays)* protected these trees with wind protection during their early growth.

The study site was in the middle of an 860- by 760-m (2,824by 2,493-ft) paddock, 2 km (1.2 miles) from Atherton, a town on the Atherton Tablelands in north Queensland (lat. 17/10' S., long. 145/28' E., alt. 710 m or 2,329 ft). The euchrozem soil is used to grow crops of maize, peanuts, and potatoes on a rotation system. The land is flat and exposed fully to winds. According to a long-term weather record from a local weather station, the prevailing wind in this area comes from the southeast and is frequently strong throughout the year.

Maize was planted on an 800- by 220-m (2,624 by 721 ft) rectangular site within the paddock on December 15, 1991. On both the south and north sides of the maize paddock, two windbreaks running east to west (figure 1) were planted on January 9, 1992. Because the prevailing wind was from the southeast, the northside windbreak would be protected by maize while the southside windbreak would not. It would be most ideal to set the maize site and windbreaks perpendicular to the direction of the prevailing wind (Oboho and Nwoboshi 1991), in this case, to the southeast. However, we were limited by the shape of the available study paddock.

Both windbreaks were made up of two rows of trees, one row of *C. salignus* and *M. armillaris* on the windward side and one row of *E. microcorys* on the leeward side (figure 1). The distance between these

Table 1– *Australian tree species used in this shelterbelt establishment study*

Species	Seed source	Lat.	Long.	Altitude (m)	Ann. rainfall (mm)
Callistemon salignus	Pomona	22°20'	152°54'	500	1,500
Eucalyptus microcorys	Connondale	26°47'	152°30'	500	1,000
Melaleuca armillaris	Beerburrum	26°56'	152°57'	32	1,500

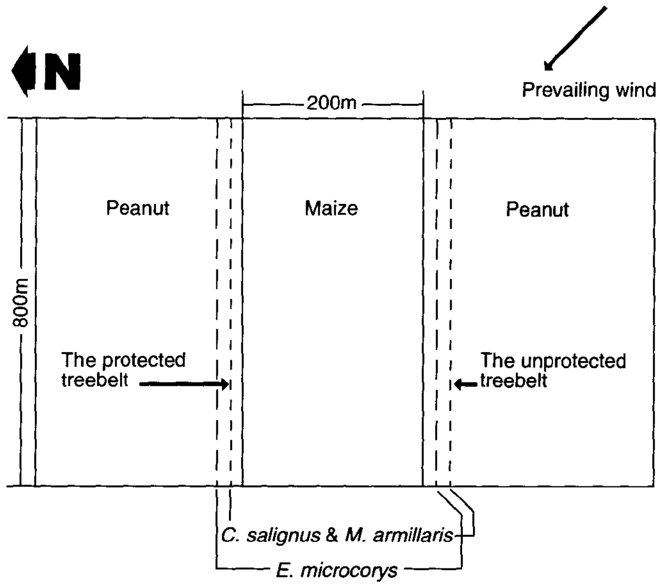

Figure 1—*Layout of the experiment.*

two rows was 2 m (6.5 ft). For each windbreak, 6-week-old seedlings of *C. salignus and M. armillaris* were hand-planted in sequences of 5 trees each, with a 2-m intrarow spacing; seedlings of *E. microcorys* were planted 4 m (13.1 ft) apart. There were 200 trees for each species in each windbreak. The soil was deeply ripped prior to tree planting.

An automatic weather station was located about 2.5 km (1.5 miles) from the study site. Because the study site and weather station were relatively close, with no undulating topography between them, wind direction and speed measured by the station were considered similar to those at the study site. Wind direction and speed were recorded daily at intervals of 2 hours throughout the experiment.

Maize height was observed and recorded during the experiment. Tree height, angle to ground, and tree crown size were measured at age 5 months, when the maize crop was being harvested. In both the protected and unprotected windbreaks, these measurements were taken from 40 randomly selected trees of each species. These randomized trees were chosen in the section starting at 50 m (164 ft) from the eastern boundary and ending at 50 m from the western boundary to exclude any possible edge effects. For each selected tree, two perpendicular cross diameters of tree crown were measured and the product of these two values was used as crown size (m^2). Tree angle to ground was measured using a protractor at 30 cm (1 ft) from the base. An angle of 0/ indicates a completely prostrate tree, whereas an angle of 90/ indicates a straight-standing tree.

The data were subjected to regression analysis (Zar 1984). For each species, tree angle to ground, height, and crown size were also calculated as a ratio by dividing the mean value measured in the unprotected windbreak by that measured in the protected windbreak. The ratio was used to assess quantitatively the protection effect of maize on young tree growth.

Results

Of the 150 days of the experiment, there were 116 days during which wind came from the southeast. Of these 116 days, there were 58 days when the wind reached maximum speeds greater than 20 km/hr, 49 days when it reached speeds from 10 to 20 km/hr, and 9 days when it was less than 10 km/hr.

The maize was 60 cm (23.6 in) tall when trees were planted and grew to 1.4 m (55.5 in) within 2 weeks. The maize attained its maximum height of 2.2 m (86.6 in) at 4 weeks after the trees were planted.

For each species, the mean angle to ground of the protected trees was greater than 80/ while that of the unprotected trees was less than 45/ (figure 2A), and the difference between the protected and unprotected trees was large. All trees leaned towards the northwest. At the end of the experiment, trees in the unprotected areas were straightened and tied to a stake that was inserted vertically beside the tree. This was undertaken to ensure that a good windbreak would be established.

The mean heights of *C. salignus, E. microcorys, and M. armillaris* when planted were 52 ± 1.7 cm (20.5 ± .67 in) (SE), 46 ± 2.2 cm (18.1 ± .87 in) (SE), and 51 ± 1.4 cm

(20.1 ± .55 in) (SE), respectively. At 5 months, the mean heights of the unprotected trees for each species were less than those of the protected trees (figure 2B). *E. microcorys* trees were taller than *C. salignus and M. armillaris* in both the protected and unprotected situations.

The protected trees of each species had a greater tree crown than the unprotected trees (figure 2C). For both the protected and unprotected trees, *E. microcorys* had a greater crown than *C. salignus and M. armillaris.*

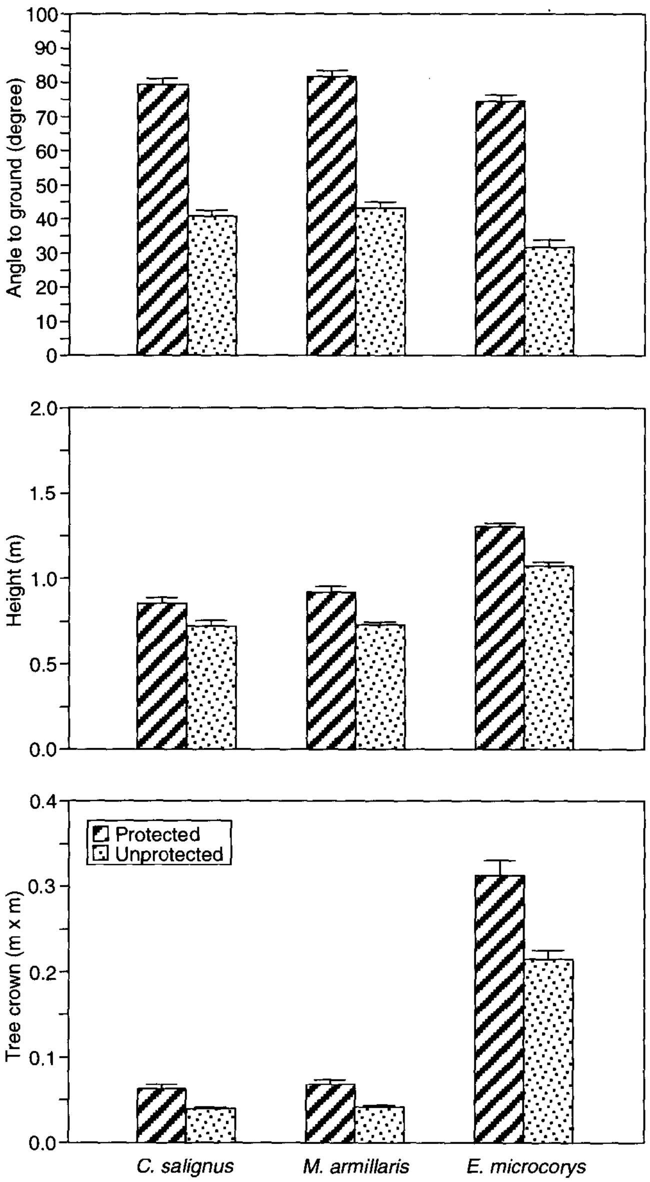

Figure 2—*Mean of tree angle to ground (A), height (B), and crown size (C) of each species in both the protected and unprotected windbreaks.*

No clear signs of physical damage to tree leaves were found.

For each species, the angle to ground of the unprotected trees decreased as plant height increased (figure 3). This negative correlation was statistically significant ($P < 0.001$). There was not a clear correlation for the protected trees ($P < 0.1$). No correlation was found between tree crown and angle to ground for each of the three species for both the protected and unprotected trees, except for *E. microcorys* in the unprotected situation.

Discussion

Because trees in this study leaned markedly in the direction of the prevailing wind, there was little doubt that tree inclination was caused by wind. Protected trees also showed some inclination, probably because they were not effectively protected during the first 2 weeks after planting, when the maize was not yet tall enough to provide effective protection. Wind also affected young tree growth in this experiment, as evidenced by the differences in plant height and tree crown growth between the protected and unprotected trees.

That the wind caused a reduction in plant growth suggests that the establishment of windbreaks in unsheltered areas is likely to be slowed down by wind effect. Because wind resulted in trees leaning towards the ground, the quality of the established windbreaks may be reduced if they are subjected to strong wind during establishment. It is interesting to note that for each species, the angle-to-ground ratio of unprotected trees to protected trees was much greater than the plant height and crown size ratios of the unprotected trees to the protected trees. This suggests that wind may cause a greater negative impact on the quality of the windbreak establishment than on the quantitative growth of trees, at least for the species studied.

Maize provided an important protection to young tree growth from wind effect. The faster growth of the sheltered trees in this experiment may be attributed to a more favorable microclimate provided by shelterbelts, as suggested by Grace (1988). Unlike the physical damage caused by wind on crop leaves (as reported by Kort 1988), the physiological stress caused by wind may be the most destructive for quantitative growth of trees, as suggested by the results for the young trees in this study.

For the same species, wind effect on tree leaning appears to vary with plant height. Taller plants are likely to lean more than shorter trees when subjected

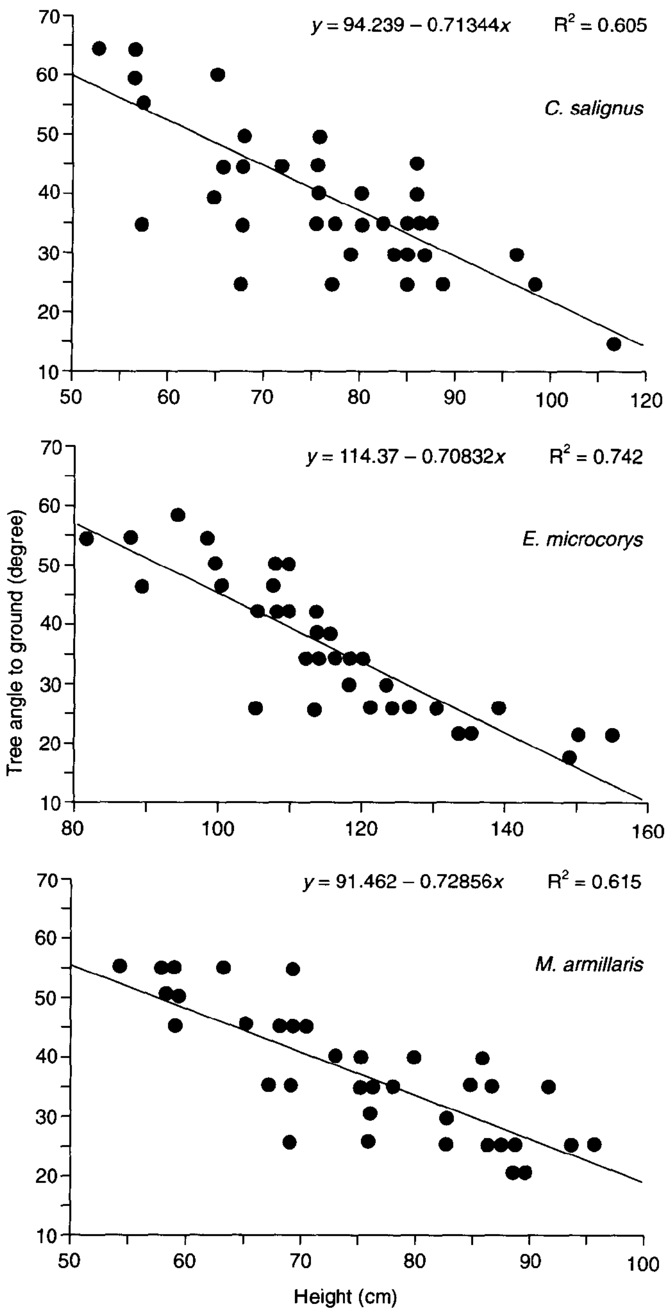

Figure 3—*Correlation of tree angle-to-ground to plant height of Callistemon salignus, Eucalyptus microcorys, and Melaleuca armillaris.*

to wind impact. This suggests that for the same tree species, fast growth may disfavor tree resistance to physical impact of wind. This contradicts the wish of farmers, who normally hope that trees will grow fast in their early stage, thus resulting in the quick formation of windbreaks and thereby reducing labor for maintenance, such as weed control. This controversy may be solved if trees are sheltered when young. Tree crown size of *E. microcorys* appears to be a factor affecting tree leaning when subjected to wind impact. This may be because trees with a greater crown had a bigger leaf surface to receive wind impact and a heavier weight on the tree top. Compared with *E. microcorys*, the tree crowns of *C. salignus* and *M. armillaris* were much smaller. This may explain why their crown size did not affect leaning. It is suggested that plant morphology may play an important role in resisting wind impact, and this idea deserves further studies.

Conclusion

Because windbreaks are generally planted on windy farm lands as shelterbelts, the young seedlings used for these windbreaks will often also be affected by wind. Using tall annual crops to protect windbreaks during their establishment appears to be a useful technique. These established windbreaks will in turn provide protection for crops from wind damage. This reflects a mutually beneficial effect between windbreaks and crop growth in agroforestry systems.

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Sowing of Pelletized Seed: A Technique To Simplify Eucalypt Raising in Tropical Nurseries

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The sowing of pelletized eucalyptus seeds in containers, adapting growing techniques developed in Italy, could simplify nursery operations in tropical areas. This system is more advantageous than the traditional nursery technique of broadcasting in the seedbed, then pricking out and transplanting small seedlings into pots-because it is less laborious, permits mechanical sowing, and prevents damage caused by transplanting machines and root deformations (U- or J-roots) caused by manual transplanting.
Tree Planters' Notes 45(2):58-62; 1994.

Tropical forestry plantations have been estimated at 25 million ha (61.73 million acres), with a rate of planting of about a million hectares per year. In some 90% of these plantations, fast-growing species are planted, and, among these, trees of genus *Eucalyptus* play a preponderant role (Bonner 1992).

Without any doubt, everything concerned with plantations of indigenous species deserves greater attention and study, but the fact cannot be overlooked that the great diffusion of eucalypts outside of their natural habitat has been, and still is, the result of numerous, decisive advantages that count a great deal when it comes to selecting the species for a plantation. It is up to the planter to decide which species are the most suitable ones for each environment, just as research has the possibility of contributing objective elements of judgment to ensure that such selection will be correct.

In the present context, no claim is made to analyze whether the preference for exotic trees is a positive fact or otherwise. What is proposed is a simplification of eucalypt-growing for nurseries.

Characteristics of Eucalyptus Seed and Traditional Raising Systems in Italian Nurseries

What is commonly referred to as "eucalyptus seed" is a mixture of fertile seeds, sterile structures, unfertilized ovules, and impurities of various types, the last three components being what is known as "chaff." The various fractions are not generally separated out. Using current equipment for separation is not easy, because the size and specific gravity of fertile seeds and chaff are frequently similar. For this reason, this last component, in nursery practice, acts as inert matter that helps to distribute the fertile seeds evenly when uncleaned seeds are broadcast in seedbeds or trays.

The small size and irregular shape of fertile seeds, and the presence of chaff intimately mixed with them, make it difficult to handle the former. Generally speaking, it is practically impossible to take the fertile seeds one at a time, although in some species their volume is relatively large (*Eucalyptus globulus, E. gomphocephala, E. occidentalis,* etc.). Because of these characteristics, growing eucalypts in Italy traditionally takes place in two stages: first the seeds are broadcast in cold frames in the open air or in heated seedbeds, and then the young seedlings are pricked out and transplanted into containers, where they remain for a few months for further growth.

Transplanting, either manual or mechanized, is an effective technique provided the necessary precautions are adopted. It is of fundamental importance for the plantlets lifted from the seedbed to be of adequate size and to be in the proper physiological state to ensure a high survival rate after being transplanted into containers. The most satisfactory results are generally obtained by transplanting very small plantlets, but this requires exclusively manual operations and presents handling problems because the plantlets are very small and delicate. With manual transplanting the plantlet has to be perfectly placed in the container in order to avoid severe root deformations.

In Italy, transplanting machines are fairly widespread; however, their use may cause "strangling" in the root collar area when the pincers holding the plantlets are not perfectly regulated (figure 1). It is also very important that weather conditions are appropriate during transplanting because intense heat or strong winds can lead to seedling mortality due to excessive transpiration.

On the other hand, sowing uncleaned seed, which in general contains a high proportion of chaff, directly in containers does not permit a correct dosage of fertile seeds. There is a tendency to place a large number of

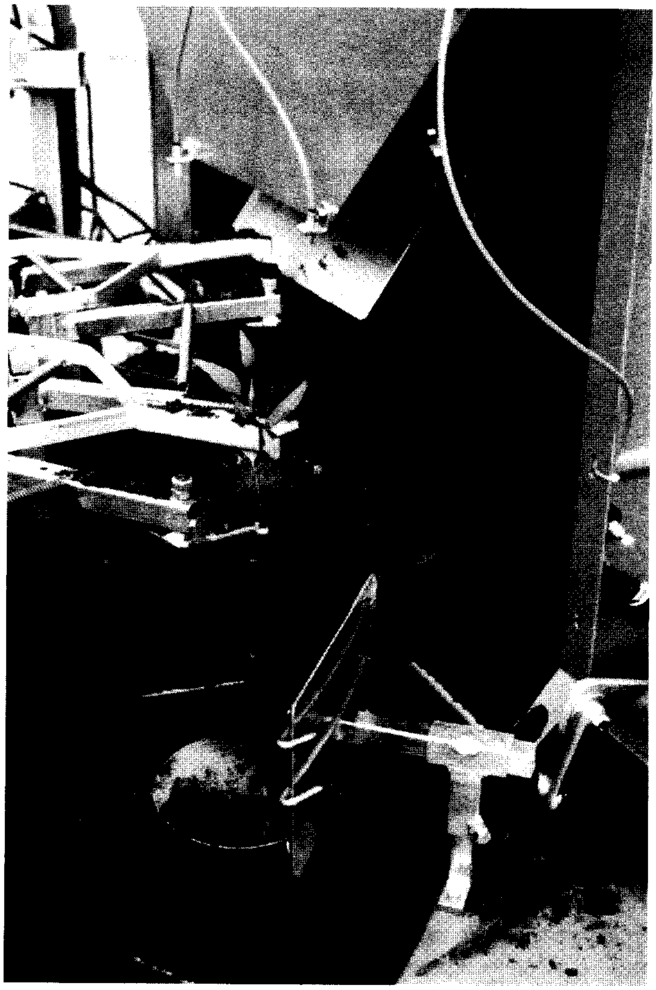

Figure 1—*Potting and transplanting machine (see pincers holding a seedling).*

seeds in each container, with a considerable increase in waste of seeds because of the thinning of excess seedlings that is subsequently necessary.

Considering that nurseries usually have a large number of activities to carry out, generally concentrated in limited periods of time, the need may arise for anticipating or postponing sowing and/or transplantation, so that these operations have to be performed at unfavorable moments with plantlets of not very adequate development.

Use of Pelletized Seed for Direct Sowing in Containers

Considering the meticulous nature of the techniques involved at the various stages of the traditional seedling raising system just described (seedbed stage + transplanting in pots), the need arose in the Centro di Sperimentazione Agricola e Forestale (Società Agricola e Forestale/Ente Nazionale Cellulosa e Carta) to develop a technique that would enable work times to be reduced and survival rates in the nursery to be improved. The direct sowing of pure fertile seeds in containers could succeed in simplifying the raising process, but for this the chaff had to be wholly removed and the volume of the seed had to be increased artificially to provide easy handling. After various attempts, both aims were achieved by a Swedish firm (Hilleshbög), which pelletized the seeds. After processing, small spherical pellets were obtained, 3 mm in diameter, consisting of inert matter that disintegrated upon contact with water or moist soil. Each pellet contained one seed (figure 2).

Pellets of *E. globulus* ssp. *bicostata, E.* x *trabutti,* and *E. viminalis,* with a germinative capacity of 75, 84, and 79%, respectively, were used in Società Agricola e Forestale (SAF) nurseries situated in Italian regions with torrid summers (Campania, Calabria, Sicily, and Sardinia), to assess the practical difficulties of the new growing system. These preliminary experiments showed the need to investigate the sowing dates and materials for covering the pellets. Thus, in 1984-85, trials were carried out in SAF nurseries in Rome and at a location close to Salerno (Campania), which, in fact, provided useful information for defining the most adequate operational methods at the different raising stages. The trials carried out (Piotto 1987a) and the results obtained are described briefly below.

After sowing 2 pellets in each container (plastic bags with a volume of 760 cm^3 or 45.6 in^3), light, frequent waterings were made with fixed overhead sprinklers in order to assist the disintegration of the pellets. The containers were provided with shade until the sixth leaf appeared on the plantlets and also during the hottest part of the summer.

On the basis of a split-split-plot experimental design with six replications, an analysis was made of the influence of five sowing times (May 14 and 30, June 13 and 27, and September 3) and of three types of covering material (mixture of 50% soil and 50% peat, gelatine, and perlite) on the emergence percentage and on the development achieved by the plants at the end of the raising period.

When perlite was used to cover the pellets, the highest number of seedlings were produced (figure 3). Gelatine, on the contrary, led to a very limited number of emergences, whereas the soil-peat mixture gave intermediate results. From the standpoint of survival and development of the material obtained, sowing at

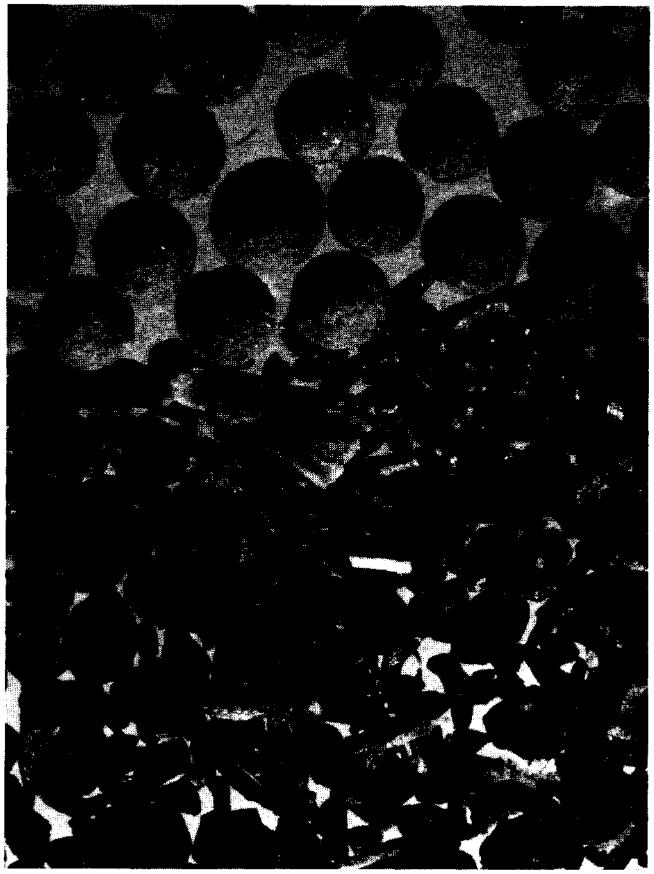

Figure 2—*Pelletized and nonpelletized* Eucalyptus viminalis *seed (notice the chaff in the latter).*

Figure 3—*Eucalypt seedling emergence in containers covered with perlite.*

the end of June proved most advantageous in Rome and at the end of May in Salerno, especially when perlite was used to cover the pellets. For the best combination of factors studied, the percentage of empty containers at the end of the emergence period varied between 3 and 10%, according to the species and the nursery.

Further research was necessary to understand the problem of the disintegration of the thicker pellets (3.25 to 3.75 mm), which had been prepared to contain larger seeds (*E. gomphocephala).* During the standard germination tests to determine the germinative capacity, it had been observed that these pellets offered some degree of resistance to disintegration, and this raised doubts as to their nursery performance. The germination of pelletized seed and that of decoated seed were then compared by removing the inert material forming the pellet, both in a laboratory-controlled environment and in an open-air nursery (Piotto 1987b).

At the end of 1 week, the percentage of pelletized seed that had germinated in the cabinet-type germinators (at conditions of alternate cyles of 16 hours at 20 /C and 8 hours at 30 /C, without light) amounted to 35%, while the level reached by the decoated seed was 74% (figure 4). In the nursery, at the end of 7 days, the emergence of both was about the same: 42 and 47%, respectively. After 1 month, the emergence in the nursery was 80% for pelletized seed and 76% for the decoated seed, which means that their performances were very similar. In the laboratory, on the other hand, the initial differences continued,

Figure 4—Germination of pelletized seeds of Eucalyptus gomphocephala **(top)** *and of decoated seeds* **(bottom)** *after 1 week in cabinet germinators.*

although in less accentuated form: the pelletized seed germinated less (69%) than the decoated seed (84%). The conclusion was thus reached that pelletized seed sown in open-air nurseries did not find coating a limiting factor, even when this was of relatively large size, because its breakdown was appreciably facilitated by the mechanical action of the irrigation water, something that did not occur in the laboratory, where the environment is normally moist but static. Subsequent trials have shown that the results obtained in the experiment described are always reliable when a high-quality coating technology is applied, that is to say, only if the preparation of the pellet and the materials used to make it ensure its rapid disintegration in contact with water. If, on the contrary, the coating material is not sufficiently crumbly, it gives rise to delays in emergence. It is therefore essential to deal with commercial companies with extensive experience in seed processing that are capable of preparing a product having the requisites imposed by conditions in open-air nurseries. Many years have elapsed since the first pelletization (1983), and pellets prepared by various companies Hilleshög Asgrow, and Royal Sluis) have been available for several years. No connection has been found between the date that the pellet was prepared and the field germinability of the enclosed seed, at least within certain time limits. That is to say, no aging of the material has been noted able to severely limit germination. Fortunately, the initial qualitative characteristics of the pellet as regards coating material remain. There are, however, other aspects of nursery growing that are far more decisive for the success of plant production, namely:

- Choosing a sowing date to ensure the maximum emergence of plantlets and adequate development of plants at the end of their period in the nursery.
- Sowing at the proper depth (3 to 5 mm).

- Using a light and friable covering material (e.g., perlite) that creates no obstacles to germination of the tiny eucalyptus plantlets.
- Placing a nonwoven cloth over the containers for a few (3 to 6) days after sowing to prevent the wind from blowing the perlite or other light covering material away.
- Watering with overhead sprinklers that produce very small droplets, because these must not cause the seeds to move or the covering material to be shifted; the first waterings should be abundant to hasten the breakup of the pellets and to maintain a good level of moisture in the superficial part of the potting mix until the radicle penetrates the growing medium.
- Shading, above all in the initial stage, and always when required by strong insolation.

Some of our results were valid only for the specific site where the trials were carried out (sowing dates, for example). However, in general, the subsequent application of the technique of direct sowing of pellets for the commercial production of some millions of eucalyptus seedlings in areas of Italy with very hot summers has demonstrated the feasibility of the proposed method for growing on a vast scale over the course of several years. The direct sowing of pelletized seed therefore proves to be an efficient alternative to the traditional system of seedbed sowing with subsequent transplanting into containers in that it offers the following advantages (Piotto and Rossi Marcelli 1993):

- It is less laborious.
- It avoids the damage usually caused by transplanting machines when the plantlet is grasped by the collar during transplanting operations.
- It avoids the typical root deformations that are fairly frequently observed after manual transplanting (J- or U-shaped roots).
- It makes mechanized precision sowing possible because pellets are uniform in size and shape.

The author has first-hand experience of tropical nurseries within the framework of an international watershed management project in Honduras (Bauer 1980), and this experience makes her feel fully in agreement with those who claim that there is no abrupt difference between plantation management in temperate areas and in tropical ones (Ladrach 1992). In any case, the basic principles discussed here can be adapted to situations in tropical nurseries. The use of pelletized eucalyptus seed, adapting the idea developed in Italy, could be an example.

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