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Abstract

This proceedings is a compilation of 23 articles on various aspects of forest nursery management in western North America. In addition to general nursery technical reports, special sections are devoted to fumigation in forest nurseries and articles pertaining to Great Plains nurseries. A summary of past meetings and content of Proceedings for the years 1960-1988 is included.

Note

As part of the planning for this symposium, we decided to process and deliver these proceedings to the potential user as quickly as possible. To do this, we asked each author to assume full responsibility for submitting reviewed manuscripts in photoready format within tight deadlines. Thus, the manuscripts did not receive conventional Forest Service editorial processing, and consequently, you may find some typographical errors and slight differences in format. We feel quick publication of the proceedings is an essential part of the symposium concept and far outweighs these relatively minor distractions. The views expressed in each paper are those of the author and not necessarily those of the sponsoring organizations or the USDA-Forest Service. Trade names are used for the information and convenience of the reader, and do not imply endorsement or preferential treatment by the sponsoring organizations or the USDA-Forest Service.

On the cover: Soil fumigation with methyl bromide/chloropicrin using the continuous tarp method (photo from Cordell 1989 — in this Proceedings)

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Retired Colorado State Nursery manager Marvin D. Strachan was honored for his 30 years of service to the Intermountain Forest Nursery Association. The award was presented by Lee W. Hinds, past manager of Lincoln-Oakes Nurseries and long-time member of the Association. Marv was one of the organizers of the first meeting in 1960, when he was manager of the Big Sioux Conifer Nursery in Watertown, SD.

Contents


JOSEPH H. STOECKELER
ARBORETUM

Intermountain Nursery Association: An Historical Account of 30 Years' Progress — 1960-1989[1]

Marvin D. Strachan[2]

Abstract.--This paper reports on the 30-year history of the Intermountain Nursery Association. The persons active in organizing the Association as well as those active and responsible for important progress through the years are noted. The difference in discussion topics between 30 years ago and now are also noted. The importance and progress in technology transfer is pointed out. A condensed review of all previous meetings has been prepared and is included as an appendage to the 1989 proceedings.

It is a pleasure and an honor for me to speak to you today pertaining to the historical aspects of the Intermountain Nursery Association. There are less than 250 forest nurseries producing tree planting stock for conservation/reforestation use in the United States and I have found that nurserymen are some of the most sincere and dedicated people I have known. You are my kind of people.

The Intermountain Nursery Association originated in 1960, at a time when most of the state and federal nurseries in the region were either new or had experienced major expansion as a result of the USDA Soil Bank programs. Agricultural leaders throughout the nation felt that trees planted on agricultural Soil Bank acres would permanently take cropland acres out of production and relieve national agricultural surpluses. A corresponding shortage of adaptable tree planting stock was recognized and the various states were encouraged to establish nurseries to produce the tree planting stock necessary to plant the cropland acres taken out of production. Federal USDA funds were made available for nursery establishment and expansion.

The nurseries so affected were developed very rapidly. Suitable nursery sites had to be located, soils and water had to be tested for optimum seedling production capabilities, irrigation water supply developed, and funds obligated for facilities, equipment, and all supplies necessary to produce and distribute seedling trees during the fiscal year fund allocation.

Most of the new nurseries were developed or expanded on lands previously occupied by agricultural crops and far removed from forest soil conditions. Problems developed early on with soil conditions, climate, soil/species adaptation, lack of technique and technology and adequate production funding. Most of the new nurserymen, with limited nursery experience, were looking to the Lake States, West Coast, and Southeast regions for technology transfer to assist in their local problems. Formation of the Intermountain Nurserymen's Association was a welcome experience to these nurserymen.

Leadership in the initial stages was provided by encouragement from the Intermountain State Foresters and through the efforts of Marv Strachan and Wally Wheeler, Division of State & Private Forestry, USFS, Denver, in calling the nurserymen in the region together for organizational purposes. The Association started with a small number of nurseries represented but grew annually with the addition of nurseries in North Dakota, the prairie provinces of Canada, the reforestation nurseries in Montana and Idaho and representatives from Kansas, Oklahoma, Texas, New Mexico, Arizona and Nevada. Research and Administrative representa-

[1]Paper presented at the Intermountain Nursery Association annual meeting, Bismarck, ND, August 14-18, 1989.

[2]Marvin D. Strachan is retired Nursery Manager, Colorado State Forest Service, Fort Collins, CO and a former Nursery Manager and founder of the Big Sioux Nursery, Watertown, SD.

tives from the various state and federal agencies enhanced a much broader perspective of nursery operations.

An even broader scope of nursery production, equipment use, seedling handling and nursery management was attained through the efforts of Homer "Red" Ward, Washington State Department of Natural Resources. His encouragement and invitations for the Intermountain Nurserymen to meet jointly with the Western Forest Nursery Council began in 1964 and continued in 1967, 1968, and 1969. The first joint meeting was held at the Coeur d'Alene nursery in 1970. The joint merger of the two nursery organizations was proposed several times but in each case the merger was rejected by vote of the organizations. Each organization wished to maintain separate nursery associations but would meet jointly whenever possible. The Intermountain Nursery Association meets every other year during even dated years. The Intermountain Nurserymen meet jointly with the Western Forest Nursery Council during the even dated years.

Further assistance to the Intermountain Nursery Association was provided in 1978 with the selection of Steve McDonald, USFS, as a Westwide Nursery Specialist. Tom Landis followed in this position in 1981. The nursery specialist not only enhanced nursery technology transfer between nurseries in the region and provided liaison within the nursery industry but also assisted in annual meeting program development, compilation of papers and funding for printing of the proceedings of the Intermountain Nursery Association annual meetings beginning in 1980.

During the 1985 annual meeting, the membership voted to change the name of the Intermountain Nurserymen's Association to the present name of INTERMOUNTAIN NURSERY ASSOCIATION.

A review of the past proceedings provide many memorable thoughts of the many experiences and progress of the association. Not only has the nursery association provided the opportunity for nurserymen to visit and learn from nurseries in most states in the western half of the country but also have provided for special events. Some of these special events have been:

(1) The North American Containerized Forest Tree Symposium held in Denver, Colorado in 1974. This symposium brought together many nurserymen, foresters and scientists throughout the United States, Canada and many foreign countries to learn of the state-of-the-art in containerized seedling production.

(2) The tour of containerized nurseries in Oregon in 1978 for Intermountain Nurserymen sponsored and hosted by the USFS through efforts of Steve McDonald and Frank Ter Bush. This happened at a time when several of the Intermountain nurseries were very new in containerized production or were contemplating entering into this mode of production.

(3) The North American Forest Tree Nursery Soil Management Workshop in Syracuse, New York in 1980. This workshop brought together nurserymen from throughout the United States and Canada to learn more of nursery soil management. Such special events have been of great value to the nurserymen and were made possible through your association.

One of the most important things that has happened within the Intermountain Nursery Association during the past 30 years is the advance in technology. This evidence is dramatic when examining the proceedings for the past three years. Such topics as:

(1) Computer vision for grading seedlings

(2) Field performance of mini-plug transplants

(3) Root growth potential as an indicator of outplanting performance

(4) Superabsorbent hydrogels and their beneficial long-term opportunities

(5) Nursery crop management computer system

(6) Cumulative trauma disorders in forest nursery workers

(7) Monitoring cold hardiness of tree seedlings by infrared thermography

(8) Bedhouse seedling production

(9) Irrigation according to PMS and tensiometer instruments.

These things were never heard of, or not used, 30 years ago. However, the more things change, the more they stay the same as evidenced by topics in the past three years' proceedings. Some problems seem to be continuous items for discussion since the beginning of time as follows:

(1) Nursery practices/seedling sizes/field performance

(2) Effect of nursery culture on morphological and physiological development of seedlings

(3) Impact of lifting date and storage on field performance

(4) A stock quality assessment procedure for characterizing nursery grown seedlings

(5) Effects of nursery density on pine seedlings

(6) Fall lifting--its effects on dormancy intensity of ponderosa pine seedlings

(7) Weed control--alternatives to herbicides

(8) Some effects of cold storage on seedling physiology

(9) Fumigation effect on soil-borne pathogens, mycorrhizae, and growth of seedlings

(10) Soil compaction--effects on seedling growth

(11) Herbicides for conifers--what's new?

(12) When to measure seedling quality in bareroot nurseries

(13) Soil mapping and testing

(14) Organic matter--how much is enough?

(15) Should private nurseries produce seedlings for federal/state reforestation programs?

One topic that seems to tell most of the story was found in the proceedings of the 28th meeting in 1988. The topic was entitled "Fixing the Edsel: Can Bareroot Stock Quality be Improved?" It seems that as long as we have forest nurserymen they will press for more technology and better application to grow a better tree.

Thank you ladies and gentlemen for inviting me here today to review the past 30 years of progress in the Intermountain Nursery Association.

Importance of Species and Seed Source Selection in Great Plains Nurseries[1]

Richard A. Cunningham[2]

Abstract.--Increased tree planting, resulting from federal programs and tree planting promotions, has increased the transfer of planting stock among Great Plains states. These transfers increase the probability that poorly-adapted planting stock may be planted. Nursery managers and tree planters are cautioned to use only seed source-identified planting stock. Local seed sources are recommended unless appropriate provenance tests support the use of specific non-local seed sources.

INTRODUCTION

Tree planting in the Great Plains, and in the United States as a whole, has greatly increased in the past five years (USDA 1988). This trend has been driven by several factors. Tree planting has been promoted by The Conservation Reserve Program (CRP), the Centennial tree planting programs in North Dakota and South Dakota, Soil Conservation Districts, the American Forestry Association's Global Releaf program, and the National Arbor Day Foundation. The increased tree planting emphasis developed quickly in the last two years and has left little lead time for nurseries to gear up their production to meet the increased demand for planting stock. Nursery managers are well aware that increased seedling production requires increased seed procurement several years in advance of need for the planting stock. The rapid increase in the demand for planting stock has outstripped the capacity of many nurseries to produce it and shortages of some species have occurred.

In order to avoid shortages, tree planters and nursery managers may attempt to procure stock from non-traditional sources such as public nurseries in other states, or from private nurseries in the same, or other states. Purchasing planting stock from non-traditional sources increases the probability that poorly-adapted seedlings will be planted. This can be the result of several factors:

1) private nursery staff may be uninformed about importance of seed source:
2) out-of-state nurseries may not have appropriate seed sources:
3) tree planting contractors may accept non-adapted stock just to get something to plant;
4) seedlings may be repackaged and lose identity;
5) some planting stock may pass through several vendor's hands with a resulting loss of information at each transaction.

THE PROBLEM

Whenever seed or seedlings are moved to a region where they have not been tested, an element of risk is involved because their performance potential is unknown. They may perform very well, or very poorly. Poor adaptation may result in poor survival, slow growth, damage or losses from insects, diseases, drought and cold. Unfortunately, these impacts may take several years to become evident. In addition, it may be difficult to separate the causes of these impacts. Poor performance may be the result of any combination of the following factors:

1) poor physiological condition of nursery stock;
2) poor planting techniques;
3) poor maintenance practices; or
4) genetically non-adapted or poorly-adapted seed sources.

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[1]Paper presented at the Intermountain Forest Nursery Association Annual Meeting. [Bismarck, N.D., August 14-18, 1989].

[2]Richard A. Cunningham is a Research Geneticist, USDA-Agricultural Research Service, Mandan, N.D.

There are several examples of the use of poorly-adapted seed sources in the Great Plains. Siberian elm was planted extensively throughout the Great Plains during the 1920's and 1930's. Several different seed sources had been planted but no trials comparing seed sources had been established. Early autumn freezes that occurred in 1938 and 1942 and the extremely cold winter of 1942 were followed by widespread die-back and mortality of Siberian elm throughout the Great Plains (George 1944, Webb 1948, Maxon 1951). Siberian elm trees grown from unknown seed sources or southern seed sources suffered losses 75-90 percent greater than northern seed sources from the Harbin area of China or farther north.

Many provenance tests have been established in the Great Plains and nearly all of them contain dramatic examples of non-adapted, or poorly-adapted seed sources. The ponderosa pine provenance study established by the Rocky Mountain Forest and Range Experiment Station in 1968 included test sites throughout the Great Plains. The results after 15 years of growth in those tests have been reported by Van Haverbeke (1986). Table 1 shows results from the plantations at Watertown, South Dakota and Hastings, Nebraska. The north-central Nebraska race performed the best at both sites. The percentage loss in survival and total height of five other races is compared to the north-central Nebraska seed source. These results could be interpreted as demonstrating that if one of the five other races were planted at either Watertown or Hastings, their performance would be inferior to that available by planting the north-central Nebraska race. The percentage loss values estimate how inferior those races would be.

Clonal tests of vegetatively propagated species also provide good examples of poorly-adapted clones. Table 2 compares the performance of six Populus clones five years after planting in central North Dakota. The hybrid clone Populus Xeuramericana (14271) performed best in terms of total height, lack of crown die-back and fewer terminal shoots. If any of the other clones are planted in central North Dakota, they can be expected to be inferior to clone #14271 to the extent shown in the percent loss columns.

Table 1. Relative performance of ponderosa pine races at two locations in the Great Plains.

Watertown, South Dakota

RACE	SURV (%)	Loss[1] (%)	HT (ft)	Loss[1] (%)
Southern	18	81	5.5	65
Northwest	38	60	8.7	45
Central Rocky Mtn.	70	26	10.2	35
Foothills-Black Hills	75	20	12.0	24
N. High Plains	92	3	13.9	12
N.C. Nebraska	95	0	15.8	0

Hastings, Nebraska

RACE	SURV (%)	Loss[1] (%)	HT (ft)	Loss[1] (%)
Northwest	56	44	9.8	42
Central Rocky Mtn.	99	1	10.3	39
Southern	85	15	10.9	36
Foothills-Black Hills	99	1	11.9	30
N. High Plains	98	2	13.1	22
N.C. Nebraska	100	0	16.9	0

[1] Percent loss compared to north-central Nebraska race.

SOLUTIONS

There are several strategies that can be utilized to reduce the use of poorly adapted seed sources. They range from simple and low cost to complex and costly. The most elementary of these strategies is to always use seed sources of known origin. Knowledge of seed source origin is critical for documenting performance, either bad or good. Performance records can then be linked to individual seed sources, and will serve as valuable bases for deciding whether to use that seed source again in the future.

Knowledge of the geographic location of the trees from which the seed was harvested gives you some information about the potential adaptation of those trees to your planting site. If the trees are native to the area, they are likely well adapted in terms of survival. If the trees are planted and their origin is unknown, their performance may provide an acceptable demonstration of their adaptation, particularly if they are at least one-half the normal rotation age for that species and intended use. If seed sources of known origin are not available, it is better to postpone planting for a year rather than risk the problems of planting ill-adapted stock. Remember, a landowner has to live with his, or your, choice of planting stock for the life of the plantation. If he chooses not to live with poorly performing planting stock, then he must bear the expense of removing them and starting over again.

Table 2. Relative performance of *Populus* clones at Mandan, North Dakota.

CLONE	MORT[1]	LOSS[2]	TERM[3]	LOSS	HT	LOSS
	- - %	- -	(no)	(%)	(ft)	(%)
NE-259	74.0	74	4.2	162	11.7	29
Nor'Easter (NE-237)	34.5	34	3.6	125	14.6	14
Northwest Poplar	2.0	2	1.4	+12	12.7	23
Siouxland	2.5	3	4.6	188	15.5	7
Imperial Poplar	3.0	3	3.5	119	15.7	6
Euramericana (14271)	0	0	1.6	0	16.7	0

[1]MORT = percentage of the crown that is dead.

[2]Percentage loss compared to Euramericana (14271) clone.

[3]TERM = the number of terminal shoots in the top one-third of crown.

Fortunately many state forestry agencies have recognized the importance of using planting stock grown from well-adapted seed sources. One state, Arkansas, has even gone so far as to adopt a policy that prohibits the planting of Atlantic coastal seed sources of loblolly pine in Arkansas if the plantings are to be cost-shared by that agency. Acceptable, local seed sources are identified on a map of Arkansas. This policy was prompted by the poor survival and growth of Atlantic coastal sources in some plantations that had been planted by forest industries 20 years previously.

The second strategy to use in a sound seed procurement program is to use local seed sources whenever possible, unless you have reliable information documenting specific non-local seed sources that may perform better than your local seed sources. Populations of native species will have become adapted to the local environment through the process of natural selection. They should survive well and perform satisfactorily. If the results of provenance tests have identified superior non-local seed sources, then they should be used if available. However, don't try to "stretch" the area of adaptation too far. If your planting site differs significantly from the site upon which the provenance test was conducted, the results may not apply to your site. Seed zoning systems can provide guidelines useful in determining whether a particular seed source can be considered "local" for a particular planting site (Cunningham, 1975). Seed may not be available from local seed sources as a result of poor seed years. It is a good practice to build up an inventory of seed in "good" seed years, to help carry you through the "bad" seed years.

Another strategy to consider in seed procurement is the use of seed from seed increase blocks or seed production areas. These areas can provide reliable sources of large quantities of seed that have the potential for genetic superiority. Seed production areas can be relatively inexpensive to establish and can be managed for increased seed production. Phenotypic selection can be followed by roguing to eliminate undesirable trees. Good performance through at least one-half the rotation age usually is a reliable predictor of performance at maturity. Planting stock grown from the seed harvested in seed production areas can be monitored to provide performance records and document seed sources of known performance potential.

One of the most intensive, and costly seed procurement strategies, is the use of seed from seed orchards. Seed orchards are normally developed only for high priority species. They are expensive to establish and maintain and usually require many years before they produce useful quantities of seed. The advantage they offer is the high level of genetic superiority their progeny should possess, particularly if the trees in the orchard have been progeny tested and the orchard has been subsequently rogued of poor performing clones. Even untested seed orchards generally have a high potential for genetic superiority and are usually superior to other available seed sources.

Genetically superior clones of vegetatively propagated species can be quickly integrated into the production programs of most nurseries. Cuttings from superior clones can be established in stooling blocks that will provide thousands of cuttings for rooting in production beds. Superior Populus clones have been propagated this way for years. Generally, clones are propagated and distributed separately, but there is increasing interest in distributing clonal mixes of several compatible clones. The idea is that several clones will provide some buffering capacity against pest outbreaks and help prevent complete plantation mortality.

Finally, officially named and released cultivars should be used when they are available and appropriate for the intended use. Cultivars are the culmination of a tree breeder's efforts to improve a particular species. Cultivars are tested over a variety of sites for several years to insure that they perform above average for that species and are worthy of release. They may be propagated from seed or vegetative parts. The area of adaptation is usually specified and its recommendations should be followed. Once again, don't try to "stretch" the area of adaptation. Lists of cultivars that have been released for use in conservation plantings have been published (Cunningham 1988).

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The Status and Future of USDA Forestry Research in the Great Plains[1]

W. J. Retveld, Stephen E. McDonald, Charles W. Fudge, and Gary L. Hergenrader[2]

Abstract.-- The number of USDA field units active engaged in tree-related research in the Great Plains has declined from nine to two in recent years, and funding is flat. Despite this decline in overall effort, the USDA Forest Service Unit in Lincoln, Nebraska is developing a novel research program of research on improvement of tree stress and pest resistance. In addition, a research and development initiative is being developed that will emphasize agroforestry systems that integrate tree windbreaks with conservation farming practices.

INTRODUCTION AND HISTORY

Before discussing the future involvement of the U.S. Department of Agriculture in Great Plains forestry research, it would be appropriate to briefly review its past involvement. Historically, the Forest Service and the Agricultural Research Service have played important and productive roles in researching and solving problems related to Great Plains forestry. The Soil Conservation Service has contributed significantly through the formulation of tree establishment and management guidelines, and the establishment of regional Plant Materials Centers. Great Plains land grant universities have made important contributions in conducting forestry research, establishing demonstration studies, and disseminating research results through their extension divisions. Several bibliographies and state-of-the art reviews have been compiled on Great Plains forestry and windbreak technologies (Alcorn and Dodd 1984; Brandle, Hintz, and Sturrock 1988; Campbell and Pratt 1974; Cunningham 1982; Loucks 1983; Read 1961).

USDA research installations devoted primarily to Plains forestry and related subjects in the Great Plains have been located at Bottineau, Mandan, and Denbigh, ND; Sidney, MT; Cheyenne, WY; Akron, CO; Lincoln, NE; Manhattan, KS; and Woodward, OK.

THE PRESENT

In contrast to the past, the number of Agricultural Research stations and Forest Service field units currently engaged in tree related research in the Great Plains has declined to two (Mandan, ND and Lincoln, NE, respectively) in recent years. Agricultural Research Stations adjacent to the Great Plains, which may have researched tree problems in the past, now emphasize research on grasses, agronomic crops, fruit trees, soil erosion, and other subject areas indirectly related to Plains forestry. Examples are the Northern Plains Soil and Water Conservation Laboratory at Sidney, MT, and the Wind Erosion Laboratory at Manhattan, KS. The Forest Service Shelterbelt Laboratory at Bottineau, ND, and the Wildlife Project at Lubbock, TX, were closed in 1982.

The research project: "Genetic Improvement of Trees for Soil and Water Conservation" at Mandan, ND, is the sole ARS project directly engaged in tree research in the Great Plains. This project has 1.3 scientist years assigned to tree-related research. Forest Service research relating directly to Great Plains forestry is centered solely at Lincoln, NE, and is staffed by five scientists. Thus there are presently only 6.3 USDA scientist years being devoted directly to forestry research in the Great Plains--a region containing one-fourth of the land area of the contiguous United States.

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[1]Paper presented at the Intermountain Nurserymen's Conference (August 15, 1989; Bismarck, ND).

[2]W.J. Rietveld is Project Leader, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Lincoln, NE; Stephen E. McDonald is Assistant Director, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO; Charles W. Fudge is Director of Timber, Forest Pest, and Cooperative Forestry Management, USDA Forest Service, Region 2, Lakewood, CO; and Gary L. Hergenrader is Nebraska State Forester, Professor, and Head of Department of Forestry, Fisheries, and Wildlife, University of Nebraska, Lincoln.

THE FUTURE

Despite the decline in USDA Plains forestry research, the possibilities for future scientific contributions to Plains forestry seem bright. A solid foundation of research knowledge has been laid. Procedures have been developed for procuring sound seed; raising quality nursery stock; growing containerized tree seedlings; designing, establishing and managing windbreaks and other plantings; controlling disease pathogens and insect pests; developing genetically improved strains of tree seed; and determining physiological, ecological and soils relationships to tree performance.

Now, Plains forestry research is entering a new and exciting era, with new tools available for research at the molecular, process, and whole plant levels. The probability for productive research is high indeed, with the availability of new computer technology and sophisticated research instrumentation, and a cadre of young, well-trained scientists in a variety of forestry-related disciplines.
Cunningham (1984) cited packaging of clonal mixtures of hardwood species; research in tree survival, cold hardiness, and drought hardiness; adaptability to problem soils; and selection and breeding for faster growth and more desirable form characteristics as future tree improvement research possibilities. Cunningham further pointed to biotechnology playing a significant role in the future of Plains forestry.

Concurrent with the new era of research at the process and molecular levels, there will be a need to continue and complete previously begun long-term studies of a more applied nature. Cunningham (1984), for example, cited the need to continue traditional tree improvement research consisting of provenance testing of newly introduced species, followed by selection, clonal and full-sib progeny testing, and seed orchard establishment. Continuing research in soils, genetics, entomology, pathology, and windbreak establishment, management, and renovation should not be abandoned, but rather, should supplement and complement more basic research in these allied fields.

The prognosis for increases in USDA funding for Plains forestry research appears bleak for the foreseeable future. In FY 1988, the Rocky Mountain Station had the smallest percentage budget increase of all Forest Service Experiment Stations in the U.S.; and the Station's budget has been the smallest of all Station budgets for some years. The Station was larger in terms of people and funding 10 years ago than at present. Conversely, the Station has produced more research publications per scientist during the past three years than any other Forest Service Research Station in the United States. In fact, the Rocky Mountain Station produced more research publications last year than during any other year in its 50-plus year history. We conclude that the Rocky Mountain Station, of which the Lincoln field unit is a part, is productive, but not as competitive as we need to be.

SOME FOOD FOR THOUGHT

With 75 years[3] of Great Plains forestry research experience behind us, it is appropriate that we take time to reassess our situation. Following are several key points affecting and characterizing the direction of Great Plains forestry research:

1. The Great Plains is predominantly a semiarid food-producing region. There are few forests in the Great Plains. Most trees planted in the Great Plains are in cities, or in farmstead and field windbreaks where they must serve a specific purpose.

2. The Great Plains is characterized by environmental extremes and periodic droughts, and is threatened by predicted global climate changes. The trees we plant must have adequate stress and pest resistance to withstand present and future environments.

3. Great Plains agriculture is experiencing some stress of its own from: a) low farm income and high subsidies, b) growing public concern with agri-chemical pollution and food contamination, c) periodic droughts and water shortages, d) topsoil loss, e) surface and groundwater contamination, and f) lack of sustainability of present high-input farming systems. A crisis situation is building, but it's not readily apparent to everyone, as was the dust bowl.

4. The Great Plains holds 71.5 percent of U.S. cropland where wind erosion is greater than the soil loss tolerance of 5 tons/acre/year (USDA 1987), yet only 3.5 percent of this land is protected by windbreaks. The present 1 million acres of windbreaks produce $700 million/year[4] in benefits (Rietveld 1989, unpublished data). Two-thirds of these windbreaks are aging and in need of renovation (Fewin and Helwig 1988). Unless cost-effective renovation techniques are developed and promoted, we expect the present net loss of windbreaks (0.4 percent /year) to escalate.

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[3]Agricultural Research Service shelterbelt research in Mandan, ND began in 1914; Forest Service windbreak research in Lincoln, NE began in 1953.

[4]Rietveld, 1989; estimated from available data. A subsequent publication will present details of estimating the value of windbreak benefits and an economic analysis of agroforestry in the Great Plains.

5. The Conservation Reserve Program (CRP) is a lost opportunity for Great Plains forestry (Deneke and Bratton, in press). As of the seventh signup, only 20,500 acres (0.13 percent) of the 16 million acres enrolled in CRP in the 10 Great Plains states were planted to trees; 90 percent of the remaining acres were planted to grasses. Unfortunately, when the program expires in 10 years, most of these highly erodible lands can, and probably will, be plowed again.

6. Great Plains forestry lacks a clearly defined role in the national scene because of the lack of timber production and lack of understanding of the value of agroforestry. Consequently, federal funding for Great Plains tree-related research is declining.

7. The Great Plains region is representative of millions of acres of semiarid lands westwide and worldwide where tree planting for crop, animal, and road protection; soil and water conservation; water quality; biological diversity; recreation and wildlife benefits; environmental quality; and socio-economic benefits are more important and more valuable than timber production.

Considering these key factors, two main implications stand out: (1) there are enormous potential benefits from tree planting in the Great Plains, and (2) Great Plains forestry is languishing because of its low priority. Although we, as foresters, recognize that trees should be an integral part of the Great Plains ecosystem, we must also recognize that trees, like any other crop, must be economically justifiable in a predominantly agricultural community. Promoting tree planting from the standpoint that "trees are nice" will have moderate success, mostly in establishing urban and farmstead trees, but the real need is in establishing field windbreaks. In the fields, trees most definitely must: (1) have a definite purpose, (2) be suited to the task, and (3) be economically justifiable, or they simply won't be planted or won't be kept.

Our research, technology transfer, and education efforts in the Great Plains must go beyond "trees are nice" and "plant trees for protection". We must broaden our scope and develop and deliver complete, integrated, and fully tested agroforestry systems. Agroforestry, as applied to the semiarid Great Plains, is defined as: a sustainable land management system that synergistically integrates the wind erosion and crop protection of tree windbreaks with the water erosion protection of conservation farming practices, thereby fully protecting the soil resource, stabilizing and optimizing productivity, and providing additional amenities. Thus, in the Great Plains, the primary agroforestry benefits are from soil and crop protection; other benefits are secondary in comparative value, yet highly significant.

To accomplish such an undertaking, we need to develop partnerships with agricultural scientists. From a forestry research standpoint, an immediate need is to focus on developing trees especially suited for field windbreaks, and to develop appropriate agroforestry windbreak technologies. This is discussed further in the following sections.

In our present role as Great Plains foresters, we obviously have a lot to offer, but as evidenced by CRP, a lot of people are not listening. Why? We need to take a hard look at our identity, priority, acceptance, and future role in the Great Plains agricultural community. If we are to realize the fruits of our new research potential, we must become more politically astute and proactive in promoting the importance and value of Great Plains agroforestry and collectively competing for the available research dollars. And we must do it as intensively as we have cooperated in the past to solve important and difficult research problems.

PROGRAM REDIRECTION

Over its 36-year history, the Lincoln, NE field unit of the Rocky Mountain Station has produced a valuable foundation of research information on tree improvement, windbreak establishment and management, and pest biology and management. Technology transfer in the Great Plains will be enhanced with USFS State and Private Forestry establishing two new Forest Pest Management positions at Rapid City, SD and transferring its Great Plains Forestry Specialist to Lincoln. These factors, along with personnel changes at Lincoln, make program re-direction possible.

The new research emphasis at Lincoln will be to "Improve stress and pest resistance of Great Plains tree species." We feel that more emphasis needs to be placed on research that focuses on our basic understanding of the interactions of tree physiology and genetics, environmental stresses, and pest populations in order to achieve more ecologically sound, biologically acceptable, long-term solutions to Great Plains forestry problems. Our general hypothesis is: lack of adaptation and environmental stresses lower tree vigor, which predisposes them to pest attack. These pests cause further stresses, which result in tree decline and premature death. Our new interdisciplinary research will emphasize molecular genetics, stress physiology, pathology, and entomology. Specific objectives are to: (1) screen for intraspecific differences in tree stress and pest resistance, (2) understand tree vigor/pest/natural enemies/environment interactions, (3) develop tree adaptability models for the Great Plains, (4) understand mechanisms of tree stress and pest resistance, and (5) develop stress and pest resistant trees.

This research effort, under existing funding levels, is now possible because of the wealth of provenance tests established in the Great Plains that will provide a diversity of genetic materials, and the solid foundation of basic biological information on Great Plains species. Despite the emphasis on new science and technology, our focus will be highly applied. Our approach will be process-oriented so we understand the key interrelationships, but we will strictly adhere to the goal of producing more stress- and pest-resistant trees. We anticipate that this strategy will not only focus on the root causes of Great Plains forestry problems, but will also vastly improve our competitiveness for research dollars.

A GREAT PLAINS AGROFORESTRY INITIATIVE

We believe the real key to the success of Great Plains forestry is developing, packaging, delivering, and suppporting complete, integrated, and sustainable agroforestry systems. Such an effort cannot be accomplished under current research funding levels. Thus, we have developed an initiative to establish a center for semiarid agroforestry research, development, and technical assistance at Lincoln, NE. The 20-year research, development, and demonstration program would develop economically and environmentally sound sustainable agroforestry systems, attain public acceptance of windbreak technologies and conservation farming practices, and improve the quality of life in semiarid environments. Our goal is to convert at least 12 million of the 48.2 million acres of highly wind-erodible lands in the Great Plains to agroforestry during the 20-year program.

The components of the agroforestry program include: (1) Forest Service research on improving tree resistance to stress and pests, as previously described; (2) Forest Service, Soil Conservation Service, and Agricultural Research Service interagency cooperative research and development on windbreak technologies, tree improvement, biological control of tree insect pests, economic evaluation, and social science; (3) supporting extramural research on related subjects by Great Plains universities; (4) agroforestry demonstration areas in Great Plains States in cooperation with state forestry agencies and agricultural experiment stations; (5) technical assistance on tree pest management by USDA Forest Service State and Private Forestry personnel co-located at the Center, working in cooperation with State forestry agencies, Agricultural Extension Agents, and Soil Conservation Service; (6) agroforestry technical assistance by the Soil Conservation Service, State forestry agencies, and Agricultural Extension Service; and (7) international exchange of agroforestry information by USDA international liaison personnel co-located at the Center.

Specific goals to be accomplished by the agroforestry center and its cooperators are: 1) develop sustainable agroforestry systems that will minimize topsoil loss and water contamination while maintaining crop productivity and farm income; 2) adapt, demonstrate, document, and model the effectiveness of agroforestry under different farming systems and soil/climate conditions; 3) develop genetically superior trees for windbreaks that will have improved stress and pest resistance and a longer effective lifespan; 4) increase farmer and public acceptance of sustainable agroforestry systems; and 5) increase biodiversity, wildlife habitat, recreation opportunities, and environmental quality.

An ecomonic analysis of various program alternatives revealed that the 20-year program, in combination with existing cost-sharing programs, could convert 12 million acres of highly wind-erodible land to agroforestry with an average benefit:cost ratio of 170 and net present value (4 percent) of $10.88 billion. In combination with new cost-share and land rent incentives (e.g., 75 percent tree planting cost-share plus rent on land occupied by windbreaks during the tree establishment period), 24 million acres could be converted to agroforestry, with an average benefit:cost of 86 and net present value (4 percent) of $21.68 billion.

We have developed a prospectus for the Great Plains Agroforestry Center, and are in the process of contacting cooperators to enlist their support. We have been working closely with Senators James J. Exon (D-NE) and Robert Kerry (D-NE), and are developing strategies to include the Great Plains agroforestry program in legislation before the Congressional session beginning in Sept. 1989. If our efforts are successful, the establishment of the Great Plains Agroforestry Center and umbrella of cooperative programs would be a strong boost for everyone concerned with Great Plains forestry, and would clearly define the future direction of forestry in the Great Plains.

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Soil Fumigation in Bareroot Tree Nurseries[1]

Thomas D. Landis and Sally J. Campbell[2]

Abstract.--This paper gives a general overview of fumigation in bareroot tree nurseries in the United States. Application methods, biological activity, behavior in the environment, risks, to human health, and economics are discussed. Information is presented for the more commonly used fumigants: methyl bromide, chloropicrin, dazomet, metam-sodium, and vorlex.

INTRODUCTION

Chemical fumigants have been used in forest nurseries since the early 1900's when formalin, an aqueous solution of formaldehyde gas, was recommended for control of fungal damping-off (Tillotson 1917). Other chemical fumigants were tested in forest tree nurseries in the late 1940's. Methyl bromide was initially used for weed control, but was also found to control damping-off fungi (Niner 1951), white grubs, and nematodes (Clifford 1951). Ethylene dibromide was found to be both effective and economical in controlling root rot at a southern nursery, costing less than $50 per acre ($123 per hectare) (Henry 1951). Methyl bromide fumigation was considerably more expensive at over $600 per acre ($1482 per hectare) (Clifford 1951).

In the years since those early trials, chemical fumigation of seedbeds has become an accepted pest control practice in forest tree nurseries. A survey of nursery soil fumigation practices in 1981 reported that over 90 percent of southern and western nurseries used fumigants to control a broad spectrum of nursery pests but was primarily used for weed and disease control. Around 90 percent of all soil fumigation was done with methyl bromide and methyl bromide/chloropicrin, with Telone, Vorlex, and Vapam used occasionally (Ruehle 1986). A more recent survey of Federal nurseries in Washington and Oregon revealed that fumigants still account for 93 percent of annual pesticide use, with methyl bromide/chloropicrin and dazomet the most popular chemicals (table 1).

Soil fumigation is an interesting topic for several different reasons. It is one of the most expensive cultural operations in a nursery, presently costing around $1,000 per acre ($2470 per hectare) or more. Because of this high cost, chemical fumigation can only be economically justified on the most valuable agricultural crops such as seed tobacco, strawberries, and ornamentals. Soil fumigation is also effective - it works. As previously mentioned, fumigation is the most effective pest control practice used in forest nurseries today, and nursery managers consider pre-sowing fumigation to be a normal part of the cultural sequence. But soil fumigation has become controversial in recent years because of concern about the safety of these biocides, both at the nursery and in the surrounding area. Other concerns include disposal of fumigation tarps, possible groundwater pollution, and adverse effects on beneficial soil microorganisms. These issues have forced nursery managers to take another look at the soil fumigants that they are currently using and reevaluate other pest management options.

PHYSICAL AND CHEMICAL PROPERTIES OF COMMON NURSERY FUMIGANTS

Four chemicals have commonly been used for soil fumigation in forest nurseries in the United States and Canada in recent years (table 2).

Methyl bromide/chloropicrin (MBC) is available in two common formulations: one containing 2 percent chloropicrin (MBC-2), and another containing 33 percent chloropicrin (MBC-33). The chloropicrin in MBC-33 is an active fumigant, whereas that in MBC-2 is only added as a tracer to the methyl bromide, which has no detectable odor. MBC is available from several different manufacturers under a number of different trade names (table 2). MBC is applied as a pressurized liquid that changes into a gas when injected into the soil. This pervasive fumigant is always covered with a one or two mil [0.001 to 0.002 in. (0.025 to 0.051 mm)] thick plastic tarp, which is impermeable to the fumigant gases.

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Table 1 - Average annual pesticide use in Federal forest nurseries in Oregon and Washington

Pesticide	Pounds of Active Ingredient	Percent[1] of Total
Fumigants		
MB-C	33,250	66
Dazomet	13,461	27
SUBTOTAL	46,711	93
Herbicides		
Bifenox	1,425	3
DCPA	420	1
Dicamba	25	<1
Diphenamid	585	1
Glyphosate	44	<1
Oxyfluorfen	320	1
SUBTOTAL	2,819	6
Fungicides		
Benomyl	102	<1
Captan	60	<1
Chlorothalonil	414	1
DCNA	60	<1
Metalaxyl	58	<1
SUBTOTAL	694	<1
Insecticides		
Acephate	3	<1
Carbaryl	3	<1
Chloropyrifos	50	<1
Fenvalerate	15	<1
Malathion	6	<1
SUBTOTAL	77	<1
TOTAL	50,491	100

[1] = < means less than listed value

Source: USDA Forest Service (1989)

Two tarping techniques have been used for covering injected fumigants. Continuous tarping is a operation in which each strip of plastic tarp is glued to the previous one, resulting in the entire field being covered with a solid sheet (fig. 1). Another alternative technique is strip fumigation where the fumigant is applied under separate sections of tarp that are covered on both sides with soil (fig. 2). After the prescribed treatment period has passed, the untreated strips of soil must be fumigated to provide complete coverage. Under either system, the tarp must remain intact during the entire fumigant exposure period. If the integrity of the fumigation tarp is broken before the end of the treatment period (fig. 3), then these areas must then be retreated.

Dazomet, also known as Basimid Granular[R], is a unique formulation for a fumigant because it is applied as a very fine granule that converts into a gas when it encounters water in the soil. These

Figure 1 - Continuous tarp fumigation consists of glued, overlapping sheets of fumigation tarp which form a solid cover.

Figure 2 - Strip fumigation consists of treating separate strips of the field, and then returning to fumigate the untreated sections.

Figure 3 - Wind can break the glue seal between adjacent strips of fumigation tarp before the exposure period is completed, requiring the area to be retreated.

Table 2 - Physical and chemical properties of common soil fumigants and their application in forest nurseries

Chemical Name	Trade Name(s)	Active Ingredients/ (Breakdown products)	Formulation/Activity	Application Methods
Methyl bromide + chloropicrin	Brom-O-Gas[R] MBC-33[R] Meta-Brom 98[R] Namco Pathofume B[R] Pic-Brom 33[R] Terr-O-Gas 67[R]	Two formulations: 98% methyl bromide + 2% chloropicrin and 67% methyl bromide + 33% chloropicrin	Liquified gas, bottled under pressure. Volatilizes at ambient pressure and temperature	Injected into the soil, and covered with plastic tarp
Dazomet	Basamid-Granular[R]	Tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione (Methyl isothiocyanate)* (Formaldehyde) (Hydrogen sulfide) (Monomethylamine)	Fine crystalline solid Volatilizes after contacting soil moisture	Incorporated into the soil, and sealed with roller and/or water
Metam-sodium	Vapam[R] Metam[R] Soil-Prep[R] Nemasol[R]	Sodium N-methyldithio-carbamate (Methyl isothiocyanate)	Liquid. Volatilizes after application to soil.	Injected into irrigation system, or into soil
Vorlex	Vorlex[R]	80% Dichloropropene/ dichloropropane 20% Methyl isothiocyanate	Liquid. Volatilizes after application to soil	Injected into soil; may or may not be tarped

* = () indicates the breakdown product and active fumigant gas

Source: modified from Thomson (1988)

"micro-granules" are normally applied through drop-type spreaders (fig. 4), immediately incorporated into the soil (fig. 5), and physically contained with a roller or water-sealed with sprinkler irrigation. The fumigant activity results from the interaction of a mixture of different gases, the most common being methyl isothiocyanate - MITC (table 2).

Metam-sodium (Vapam[R]) is a liquid fumigant that also converts to MITC gas in the soil (table 2). It can be either injected into the irrigation system and applied through sprinklers, or directly injected into the soil. Although this fumigant can be water-sealed like dazomet, the label recommends that it can be covered with plastic tarp "for better results."

Vorlex is a liquid fumigant that volatilizes into a mixture of different fumigant gases: dichloropropane/dichloropropene, and MITC (table 2). This fumigant is soil-injected, and may or may not be covered with a plastic tarp (fig. 2).

Figure 4 - The fumigant dazomet is a fine "microgranule", which is applied with drop-type fertilizer spreaders.

Figure 5 - After application, the dazomet granules are incoporated into the soil and sealed with a roller or water seal.

BIOLOGICAL ACTIVITY OF MAJOR FUMIGANTS

Although fumigants are commonly thought to be biocides that kill all organisms, there are differences in effectiveness between the different chemicals. The common nursery fumigants are not equally effective against the four major groups of nursery pests: fungi, insects, nematodes, and weeds (table 3). The concept of a "target pest" is important when choosing a control method. Fumigation should never be used as an all-purpose pest control treatment; instead, target pests should be identified and all control options analyzed before a fumigant is used.

Fungi

All fumigants do a reasonably good job on the common soil pathogenic fungi, especially at the higher application rates (James 1989). The MBC-33 formulation is the only one that can control the more resistant fungal pathogens such as Cylindrocladium spp. and Macrophomina phaseolina [(Maub.)Ashby] that form resistant resting stages called sclerotia. Luckily, these persistent pathogens are not found in nurseries in cooler environments. Cordell and Wortendyke (1972) provide a good review of the older literature on the relative effectiveness of the methyl bromide formulations compared to other fumigants.

Based on many early trials, MBC-33 became the standard fumigant for forest nurseries in the United States. Dazomet, however, is becoming increasing popular as an alternative to methyl bromide fumigation in recent years. McElroy (1986) tested MBC-33, dazomet, metam-sodium, and vorlex at several Pacific Northwest nurseries and found that all gave good control of Fusarium spp. and Pythium spp., the principal soil pathogens in that area. Tanaka and others (1986) also did fumigation trials at two nurseries in this region, comparing dazomet to MBC-33 at two application rates [the standard 360 lb/ac (404 kg/ha), and a 2X rate]. They also monitored soil populations of Pythium and Fusarium and found that dazomet was nearly as effective as the standard rate of MBC-33, and that the 2X rate of MBC-33 was not justified. Campbell and Kelpsas (1988) report that fall fumigation with MBC-33 was more effective than dazomet or metam sodium in

Table 3 - Relative pest control effectiveness of common nursery fumigants

	Fungi	Insects	Nematodes	Weeds
MBC-33*	Yes	Yes	Yes	*Most*
MBC-2	*Most*	Yes	Yes	*Most*
Dazomet	*Most*	Yes	Yes	*Most*
Metam-Sodium	*Most*	Yes	Yes	*Most*
Vorlex	*Most*	Yes	Yes	*Most*

*Methyl bromide/chloropicrin comes in two major formulations: 67%:33% and 98%:2%

reducing soil populations of Pythium and Fusarium through the spring sowing period. James (1989) reported that, while dazomet and MBC-33 both lower populations of pathogenic fungi, MBC-33 provides a longer period of control.

The relationship of soil pathogen population levels to seedling disease and growth is unclear, however. Tanaka and others (1986) found that MBC-33 gave better control of Fusarium root rot infections and produced significantly larger Douglas-fir [Pseudotsuga menziesii (Mirb.)Franco] seedlings than dazomet. On the contrary, Campbell and Kelpsas (1988) found that dazomet produced significantly larger ponderosa pine (Pinus ponderosa Laws.) seedlings than MBC-33; metam-sodium seedlings were also larger, although the differences were not statistically significant.

Insects and Nematodes

All of the fumigants do a reasonably good job of controlling soil insects and nematodes (table 3). Insect damage is rarely severe enough to justify fumigation on its own, but nematodes have been the main target pests for fumigation in forest nurseries. MBC fumigants provide excellent control of nematodes in forest nurseries (Ruehle 1975), and the MBC-2 formulation is generally recommended. Both MBC-33 and dazomet at the 350 lb/ac (393 kg/ha) rate controlled populations of the root lesion nematode (Pratylenchus penetrans Cobb), although a lesser rate of dazomet (150 lb/ac = 168 kg/ha) had less effect (McElroy 1986). Peterson and Riffle (1986) caution that, while fumigation greatly reduces the nematode populations in soil, it does not completely eradicate them.

Weeds

Weeds are sometimes the primary target pest for fumigation (Grierson 1989), but none of the fumigants control all species of weeds (table 3). MBC-33 is not as effective for controllings weeds as MBC-2 at standard application rates, but is a good herbicide at a 400 lb/ac (449 kg/ha) rate (Ruehle 1986). Methyl bromide also tends to scarify the seed coat of hard-seeded weed species such as many legumes, and actually stimulate germination immediately after fumigation. This may be beneficial in the case of fall fumigation because the recently germinated weeds are soon killed by frost. Vorlex was found to give less weed control than the other fumigants in a Pacific Northwest nursery (McElroy 1986). Since little data has been reported on which weed species are resistant to which fumigants, it would be wise to contact chemical company representatives and other nursery managers before selecting a fumigation chemical.

Microbial Reinvasion of Fumigated Soil

Because "nature abhors a vacuum", fumigated soil will eventually become recolonized by a full complement of endemic microorganisms, both beneficial and pathogenic. Even the most effective soil fumigation can be ruined if the target pest is able to rapidly reinvade the treated soil.

The most common source of reinvading microorganisms is from adjacent untreated soil, but they can also move up from soil strata underneath the fumigated layer. Reinvasion studies with the pathogenic fungus Fusarium oxysporum f. sp. melonis (Snyd. and Hans.) have shown that, although the fungus could not be isolated from fumigated soil after 6 days, by 32 days, the pathogen was isolated consistently from the outer edges of the treated area. There was also evidence that the fungus was reinvading from lower untreated soil layers because, after 10 weeks, there was a distinct population density gradient from below the fumigated layer to the soil surface (Marois and others 1983). Vaartaja (1967) studied the development of several soil microorganisms after fumigation and found that reinvasion by fungi occurred in several ways: rain splash, irrigation water, blowing dust, and soil carried on boots. Another probable source of contamination is nursery tillage equipment that carries soil from untreated to treated fields.

Rapid reinvasion with benefical microorganisms is desirable. Many fungal species that form mycorrhizae produce air-borne spores that can blow into fumigated soils within a few months after fumigation. The fungi that form endomycorrhizae, however, are slower recolonizers because their spores are not carried by air and must be reintroduced on soil particles (Marx and others 1989). Actually, beneficial microorganisms may be the first to reestablish in fumigated soil. Fungi of the genus Trichoderma spp. and bacteria are among the earliest colonizers (Vaartaja 1967), and Trichoderma may be responsible for the positive seedling growth response often observed in fumigated soils (Ingestad and Nilsson 1964).

To slow the rate of reinvasion by soil-borne pathogens, nursery managers should reduce obvious sources of recontamination such as transported soil and surface water runoff. Nursery implements should be cleaned before being used in fumigated soil; some nurseries use portable steam cleaners to both clean and sterilize their equipment. Fumigated fields should be physically isolated by a ditch or other type of drainage system to intercept surface runoff which can carry contaminated soil particles or motile spores of water mold fungi. Because reinvasion will eventually occur, nurseries should schedule fumigation as close to the date of sowing as is practically possible. Obviously, fall-fumigated fields are more liable to recontamination than spring-fumigated ones; in many bareroot nurseries, however, fall fumigation is the only option because spring soil temperatures are too low to allow early fumigation. Reinvasion is usually slower in soils which have had pathogen populations reduced to near zero (e.g. after MBC fumigation), as compared to soils where a low residual population of pathogens remain after treatment (e.g. after dazomet fumigation).

APPLICATION CONSIDERATIONS FOR SOIL FUMIGATION

Relative Safety of Application

The primary consideration when selecting a fumigant should be worker safety. All the common fumigants are hazardous chemicals, but the MBC formulations and vorlex are "restricted use pesticides," which means that they can only be applied by specially trained, certified applicators. Because of their concerns about nursery worker safety, many nursery managers choose to contract their MBC soil fumigation. Dazomet and metam-sodium are relatively less hazardous to apply, and so most nurseries do their own fumigation with these chemicals.

Soil Properties

Soil temperature is critical to the effectiveness of all fumigants because the vapor pressure of any gas is a function of temperature. The temperature will, therefore, determine how quickly the fumigant gases pervade the soil particles and also define their persistence in the soil. In the case of the granular dazomet, temperature controls the speed of conversion of the solid particles to a gas (Neumann and others 1984). Warm soil temperatures, in the presence of moisture, also increase the metabolism of nursery pests and make them more susceptible to the fumigants (Boone 1988).

Although some soil fumigants are reported to be effective at colder temperatures, the lower temperature limit for all fumigants should be 50°F (10°C) at a soil depth of 6 inches (15 cm). Because soil temperatures take too long to warm in the spring, most northern nurseries fall fumigate while soils are still warm. Dazomet should not be applied if soil temperatures are too warm, however; Thomson (1988) recommends an upper limit of 90°F (32°C). Soil temperatures can also affect the fumigation technique; tarping is recommended for vorlex if the temperature exceeds 75°F (24°C)(Thomson 1988).

Fumigation effectiveness is also a function of soil moisture content, which should usually be in the range of 50 to 75 percent of field capacity (Boone 1988). Moist soil promotes good tilth which leads to good fumigant penetration. Again, soil moisture stimulates nursery pests to their most susceptible state (germinating weed seeds, fungi in the mycelial state, and emerging nematodes). For the granular dazomet, a soil moisture content of 60 to 70 percent is necessary for rapid conversion to a gas (Neumann and others 1984). The soil seal that is recommended for dazomet, and possibly other similar fumigants, should be maintained by periodic light irrigations for 3 to 5 days after application (Thomsom 1988). Soil can also be too wet for effective fumigation, however. Overly wet soil can form large clods when tilled and also has a high percentage of pores filled with water, both of which restrict fumigant penetration.

The physical condition of a soil is also important for effective fumigation. Soil should be tilled to a a moderate-sized crumb structure if possible to generate a large proportion of macropores to carry the fumigant gases. The high surface-to-volume ratio of large clods inhibits fumigant penetration, whereas the numerous small particles that are produced in a overworked soil create micropores that slow movement of fumigant gases.

Soil organic matter content should also be considered. Undecomposed organic matter may inactivate the fumigants (Boone 1988). In the case of dazomet, the effective gases may be bound by the organic matter itself or by the ammonia created as the organic matter breaks down (BASF 1984). Green manure or cover crops should be turned under and organic amendments applied long enough before fumigation to allow complete breakdown. Organic matter may also delay dissipation of the fumigant gases; it is recommended that crops not be sown until at least 30 days after fumigating high organic soils with metam-sodium (Thomson 1988).

Exposure and Aeration Periods

The mandatory waiting period between fumigation and sowing the seedling crop consists of two different intervals: the exposure period, in which the fumigant gas is active, and the aeration period, when the gas is allowed to dissipate from the treated area. The aeration period is normally followed by a germination test (table 4). This consists of sowing seeds from a rapidly germinating species, such as radish or lettuce, in a small sample of soil from the fumigated area. A non-fumigated control soil sample should also be taken at the same time for comparison. Both soil samples should be placed in lidded glass jars and watered. At the end of about 5 days, the seedlings should have emerged and be developing normally (fig. 6); poor germination or distorted growth means that some fumigant fumes still persist in the soil.

The recommended number of days for the two fumigation waiting periods depends on soil temperature and weather conditions, but the total period can range from 8 to 50 days for MBC or dazomet (table 4). Dazomet typically requires a longer period under normal nursery fumigation conditions, however; because MBC is immediately converted into a gas, it becomes active more rapidly than the granular dazomet. At a typical soil temperature of 50°F (10°C), the exposure period for dazomet will take 12 days, compared to 3 days for MBC. Wet weather can cause problems with fumigant dissipation, particularly with the granular dazomet. McElroy (1986) reported that 1 inch (2.5 cm) of rain after dazomet fumigation moved the fumigant deeper into the soil; this delayed the escape of the fumigant, resulting in phytotoxicity to the crop seedlings. Similar consequences have been observed with the chloropicrin component of MBC (McElroy, personal communication).

Table 4 - The effect of soil temperature on fumigation waiting periods

	Methyl Bromide/ Chloropicrin	Dazomet
Fumigant Applied and Soil Sealed		
Exposure Period (Gas Activity)	1 to 3 days	4 to 25 days
Tarp Removed or Soil Seal Broken		
Aeration Period (Gas Escapes)	2 to 14 days	2 to 20 days
Test For Residual Fumes		
Germination Testing	5 days	5 days
Sow Crop		
Total Waiting Period	8 to 22 days	11 to 50 days

Source: BASF (1984)

Figure 6 - At the end of the aeration period, a germination test should be performed on the fumigated soil to make certain that it is safe to plant the crop.

ECONOMICS OF SOIL FUMIGATION IN FOREST TREE NURSERIES

Because fumigation is such an expensive cultural practice, it is necessary for nursery managers to provide economic justification. In a successful nursery operation, economic realities mandate that the costs of fumigation be offset by the benefits of the practice.

Fumigation Costs

The cost of fumigation can be prohibitive in smaller nursery operations, where cash flow problems make it difficult to come up with the money for fumigation so early in the crop cycle. Fumigation is also less expensive for larger nurseries because many fumigation contractors have the same set-up charge regardless of the amount of acres to be treated. Nurseries in remote locations are also at an economic disadvantage because contractors must reflect travel costs in their fees. One way to save money on fumigation contracts is to coordinate the timing of fumigation with other nurseries in the general area so that the contractor can visit each operation on an efficient travel circuit.

Soil fumigation costs can vary between chemicals. Campbell and Kelpsas (1988) reported that the per-unit chemical cost of applying MBC-33 was similar to dazomet, while the metam-sodium chemical costs were less. The 1989 soil fumigation costs for the 10 USDA Forest Service nurseries averaged around $1,200/ac ($2,964/ha) for MBC contracts, and around $1,000/ac ($2,470/ha) for nursery-applied dazomet (table 5). These figures reflect chemical and application costs, as well as the cost of tarp removal in the case of MBC.

Table 5 - Statistics on soil fumigation costs for USDA-Forest Service nurseries in 1989.

	Fumigation Costs Per Acre	
	Contract Application	Nursery Application
Methyl bromide/chloropicrin		
Number of nurseries	5	1
Average	$ 1,137	$ 902
Range	$942 to $1280	N/A[1]
Dazomet		
Number of nurseries	0	4
Average	N/A	$1,032
Range	N/A	$938 to $1173

[1] N/A = Not applicable

Benefits from Fumigation

The benefit side of the economic scale can be subjective, and figures are often outdated because the comparisons were only done when fumigation was first implemented. One easy way to determine fumigation benefits is to leave one or more small "check" or untreated areas in the seedbed so that seedling yield information can be compared to fumigated areas. Growth information, such as seedling height, caliper, biomass, and root growth, should be collected at intervals during the growing season because the benefits are sometimes only visible at one time during the rotation. The true test of fumigation benefits, however, is to harvest seedlings from each area and have them graded; this will generate actual "shippable seedling" data that can be converted back into dollars and compared to fumigation costs.

BEHAVIOR OF FUMIGANTS IN THE ENVIRONMENT

Because fumigants are highly toxic pesticides, there is widespread concern that they or their breakdown products may contaminate the water, air, or soil in the nursery or in adjacent areas. The physical properties of fumigants determine how readily they move or persist in the environment after application; environmental factors, such as soil characteristics and amount of rainfall, also influence contamination potential and persistence. Several physical characteristics for MBC and dazomet determine their pollution potential in the environment (table 6).

Water Quality

Both surface and groundwater can become contaminated with pesticides from surface water runoff or leaching through the soil profile. The likelihood that a particular fumigant will contaminate water is dependent on a number of factors, including soil characteristics, pesticide characteristics, the local climate, amount of precipitation and/or irrigation, number of applications of the pesticide, rate at which the pesticide is applied, surface and groundwater hydrology of the site, drainage system at the site, and cultivation practices used at the site to increase infiltration (USDA Forest Service 1989).

The most significant factors affecting water pollution by pesticides are solubility in water and leaching potential (table 6). Pesticides must first dissolve in the soil water before they can leach downward. The situation concerning the solubility of fumigants in water is confusing because the solubility of a gas in water is usually measured under greater atmospheric pressure than that normally encountered in nursery soil (Chemical Fate Testing Guidelines 1983). Even though MBC is given a "moderate" solubility rating in water (table 6), it is estimated that only about 0.1 % of the applied MBC would ever leach from the nursery soil (USDA Forest Service 1989). Even though dazomet has a "high" water solubility rating, the leaching potential for its principal active ingredient (MITC) is negligible due to its rapid degradation in the soil and its high volatility (table 6). In fact, no groundwater contamination by methyl bromide, metam sodium, or MITC has yet been detected in the United States (Parsons and Witt 1988), although traces of MBC were identified in groundwater in Holland (Rattink 1984).

Table 6 - Effect of physical properties of methyl bromide/chloropicrin (MBC) and dazomet on water, soil, and air pollution

Pollution Site	MBC	Dazomet
Water		
Solubility in water[1]	Moderate	High
Leaching potential	Low	Negligible
Soil		
Persistence in soil[2]	Low	Low
Decomposition mode	Biological and chemical	Chemical
Air		
Volatility[3]	High	High

[1] Solubility is rated as High (> 100 ppm), Moderate (1-100 ppm), and Low (< 1 ppm).

[2] Persistence is rated in half-lives: High (> 180 days), Moderate (30-180 days), and Low (< 30 days).

[3] Volatility is rated in vapor pressure units: High (> 1.00 mm Hg), Moderate (0.001 - 1.00 mm Hg), and Low (< 0.001 mm Hg).

Source: USDA-Forest Service (1989)

Groundwater contamination by 1,2-dichloropropane and 1,3-dichloropropene, two components of the fumigant vorlex, has been detected in a number of states (Parsons and Witt 1988). However, it has not been determined that these occurrences were due to vorlex contamination because these two chemicals are found in other fumigants, such as D-D, and are also used for other non-agricultural purposes.

Surface water run-off can occur when rainfall or irrigation exceed the infiltration capacity and water flows over the soil surface or when water moves laterally through the soil profile into a surface water source such as a stream or drainage ditch. Surface water can become polluted either directly with soluble pesticides or when non-soluble pesticides are adsorbed onto soil particles and carried along with surface water flow. The surface water run-off potential for MBC is considered negligible (USDA Forest Service 1989); the situation for dazomet, vorlex, or metam-sodium is unclear but should not be significant.

Soil Quality

Two physical characteristics of fumigants that affect the soil pollution potential are persistence in soil and the type and rate of decomposition. The soil persistence of MBC is rated low (table 6) because MBC is rapidly broken down by both biological and chemical means (USDA Forest Service 1989). MBC and inorganic bromide residues are absorbed by plants and animals; MBC is metabolized and the inorganic residues are relatively non-persistent. There is very little information about the environmental fate of chloropicrin, including its persistence in the soil (USDA Forest Service 1986).

Following incorporation, dazomet is also relatively non-persistent in soil (table 6). This fumigant chemically breaks down into many different products, all of which are lost from the soil within a few days through further degradation and volatilization, which are dependent on soil moisture and temperature. Soil type and pH also influence the effectiveness of the fumigant and its rate of breakdown. Soils with high clay or organic matter content can bind MITC, thus reducing its effective concentration (BASF 1984) and intermediate pH values (around 6.5) maximize degradation. (USDA Forest Service 1987). There is little information on metam-sodium, but, since MITC is the primary breakdown product, its behavior in soil should be similar to that of dazomet.

Persistence of 1,3-dichloropropene (1,3-D, a component of vorlex) in the soil is considerably higher; the half-life of 1,3-D is 14 to 180 days, depending on environmental conditions. 1,3-D disappears through degradation (biological and non-biological hydrolysis), dispersion through the soil, volatilization into the air, and irreversible binding to soil particles. Temperature and soil moisture influence the rate of these processes (USDA Forest Service 1987).

Air Quality

Since fumigants are gases or volatilize after application, there is potential for drift into adjacent areas (table 6). The labels on all four fumigants direct the applicator to seal the soil surface in some fashion (water seal, rolling, or plastic seal) after application. If properly

Table 7 - Toxicity of common nursery fumigants in relation to other chemicals

Toxicity Category	Pesticide Label Signal Words	Pesticides and Other Chemicals	Acute Toxicity[1] Oral LD_{50}	Acute Toxicity[1] Other
I-Severe	Danger-Poison		0-50 mg/kg	
		Chloropicrin	38	Dermal = 100 mg/kg Inhalation = 0.178 to 150 mg/l
		Nicotine	50	
II-Moderate	Warning		50-500 mg/kg	
		DDT	100	
		Caffeine	200	
		Methyl bromide	214	Inhalation = 4.5 mg/l
		Dazomet	363	Dermal = 200 to 10,400 mg/kg Inhalation = 302 to 60,000 mg/l
		Vorlex	538	Dermal = 470 to 961 mg/kg Inhalation = 11 mg/l[3]
III-Slight	Caution		500-5,000 mg/kg	
		Metam-sodium	820	
		Aspirin	1,700	
		Table Salt	3,750	
		Glyphosate	4,320	
IV-Very Slight	Caution		5,000-50,000 mg/kg	
		Oxyfluorfen	5,000	
		Captan	9,000	
		Ethyl alcohol	13,700	

[1] Oral and dermal ratings are measured in lethal doses (LD_{50}), and inhalation ratings in lethal concentrations (LC_{50}) - the amount of pesticide per unit of body weight that is required to kill 50% of the test animals. These values are only examples of some study results - published values may vary considerably.

Sources: USDA Forest Service (1989); USDA Forest Service (1987); Bohmont (1983) Great Lakes Chemical Company (1989); Thomson (1988) applied, damaging aerial concentrations of a fumigant should occur rarely, due to the restrictive seal, rapid degradation of the fumigant, and the large volume of air into which it can disperse if it escapes through the seal. However, if the seal is poor or weather conditions prevent rapid dispersion (for example, an inversion layer), toxic fumigant concentrations may build up and injure adjacent plants, animals, or people. Myers (1989) reports that, following MBC fumigation at a forest nursery, an air inversion caused a local accumulation of MBC gases; they had apparently escaped through the tarp and caused minor health effects to residents living near the nursery. Forest nursery managers have reported fumigant damage to adjacent seedlings for both MBC and dazomet. White pines seem to be particularly susceptible to dazomet fumes (Scholtes 1989), whereas Douglas-fir is sensitive to MBC (Myers 1989).

EFFECTS OF FUMIGANTS ON HUMAN HEALTH

All pesticides are poisons, and fumigants are among the most acutely toxic pesticides used in bareroot forest nurseries. It should be remembered, however, that the actual hazard of any chemical is a function of both toxicity and exposure. If fumigants are applied by trained, certified applicators and according to label instructions, the potential health hazards can be

Table 8 - Potential health hazards of common nursery fumigants

Fumigant	Known Health Hazards
Methyl bromide	Exposure Symptoms - Although it has no odor, methyl bromide causes severe chemical skin burns, swelling of bronchial membranes, and kidney damage. Small amounts will cause nausea and vomiting, and may lead to mental confusion, double vision, tremors, lack of coordination, and slurred speech. Continued exposure leads to coma and death.
	Cancer - Variable information.
	Reproductive/Developmental - Organ weight variation in offspring of rats; fetal and maternal toxicity.
Chloropicrin	Exposure Sumptoms - Chloropicrin has an obnoxious odor and was used as a chemical warfare agent in World War I. It is extremely irritating--causing tearing, swelling of bronchial membranes, gasping, and vomiting. Severe exposure may result in irregular heartbeat and asthma.
	Cancer - Insufficient information.
	Reproductive/Developmental - No information.
Dazomet	Exposure Symptoms - Dazomet is irritating to skin and eyes.
	Cancer - None observed in animal studies.
	Reproductive/Developmental - No information on dazomet, but methyl isothiocyanate causes maternal toxicity and fetal death in animals.
Vorlex	Exposure Symptoms - Highly irritating to eyes, skin, and lungs.
	Cancer - Methyl isothiocyanate is not carcinogenic in animals, but 1,3-dichloropropene appears to be.
	Reproductive/Developmental - No information on vorlex, but xylene, one of the ingredients, causes birth defects in animals.

Sources: USDA Forest Service (1989); USDA Forest Service (1987); Bohmont (1984); Thomson (1988); Great Lakes Chemical Company (1989).

reduced to acceptable levels.

All chemicals, including pesticides, can be ranked according to the dose of the chemical required to kill half of a population of test animals; this dose is known as the LD_{50} (table 7). Although oral exposures are most frequently used to determine LD_{50}, other types of chemical exposure are more relevant for fumigants. With all fumigants, there is a risk of inhalation exposure due to their gaseous nature at the time of application or shortly after. Because dazomet is applied as a fine granule, inhalation of granules could be significant as well. There is a dermal exposure hazard with both MBC if skin comes into contact with the pressurized liquid, and dazomet if granules contact the skin.

The common nursery fumigants vary considerably in their toxicity, ranging from the severe to the slight category (table 7).

MBC is the most toxic fumigant used in forest nurseries because chloropicrin ranks in the severe category and methyl bromide is in the moderate category (table 7). Chloropicrin, also known as "tear gas", is extremely irritating to eyes and skin (table 8). Concentrations as low as 2 ppm can be lethal if inhaled for as little as 1 minute, and concentrations of 0.1 ppm can be injurious over longer periods (Thomson 1988). Pure methyl bromide is relatively less toxic than chloropicrin and is rated in the moderate toxicity category (table 7). This fumigant is particularly dangerous to use because it is colorless and odorless. Chronic exposure to methyl bromide causes severe health hazards (table 8); exposure to 2,000 ppm of methyl bromide for 1 hour may be lethal (Thomson 1988).

In formulations containing a mixture of methyl bromide and chloropicrin, exposure time to excessive amounts is usually very short; this is due to the extremely irritating nature of the chloropicrin which compels the person being exposed to quickly move from the area. Information about the cancer-causing ability of MB and chloropicrin is varied. For chloropicrin, there is no information regarding carcinogenicity. For MB, some carcinogenic effects are reported (Great Lakes 1989) although very recent reports indicate no cancer effects (Sargent 1989).

Dazomet and vorlex share a common active ingredient (MITC), and rank in the moderate toxicity category (table 7). Dazomet does not break down into a gas until it contacts soil moisture; because of this, it is easier to control than an injected gas. The micro-granule formulation of dazomet can be irritating to skin and eyes (Thomson 1988). Although dazomet has not caused cancer in animal studies, other health effects have been observed (table 8).

Metam-sodium also breaks down into MITC, but is slightly less toxic than dazomet or vorlex, which places it in the slight toxicity category (table 7). Metam-sodium can be irritating to skin, eyes, and mucous membranes (Thomson 1988), but the risk of cancer from exposure to MITC is apparently low (table 8).

Quality of Fumigant Exposure Data

The quality of information on the effects of fumigants on human health is marginal or inadequate in some areas (tables 8 and 9). The published

Table 9 - Quality of nursery pesticide database for each toxicity category.

Fumigant	Systemic	Carcinogenic	Reproductive/ Developmental	Mutagenicity	Neurotoxicity	Immunotoxicity
Methyl bromide	Adequate	Sufficient: new studies could change conclusions	Marginal: variable results	Adequate	Adequate	Inadequate
Chloropicrin	Adequate	Marginal: variable results	Inadequate	Marginal: variable results	Inadequate	Inadequate
Dazomet	Sufficient: new studies could change conclusions	Adequate	Sufficient: new studies could change conclusions	Marginal: variable results	Sufficient: new studies could change conclusions	Marginal: variable results

Source: USDA Forest Service (1989).

information can be categorized by six types of toxicity: systemic, carcinogenic, reproductive and developmental, mutagenicity, neurotoxicity, and immunotoxicity (table 9). Very little work is done on humans; human data is usually derived from accidents or from operational exposure. Therefore, most tests have been done on animals, such as rats or rabbits, and much of the available information is difficult to interpret and compare because different units were used and results were variable. Table 9, however, categorizes the general state of data (adequate, sufficient, marginal, or inadequate) from available published animal studies.

Human Health Risks

When determining the danger of a particular pesticide, both the toxicity of the material, as well as the probablity of exposure, are important. The nursery workers at greatest risk for exposure to fumigants are those involved in applying them: tractor drivers, shovelers, and tarp lifters (table 10). Other nursery workers, such as weeders or inventory crew, will have almost negligble risk since they are in the fields after the fumigant has long since dissipated. For the general public, including residences adjacent to the nursery, there is more potential risk of exposure to fumigants than other pesticides due to the gaseous nature of the fumigants allowing them to diffuse and be carried away from the site of application and onto neighboring property.

The probability that detrimental health effects will occur has been estimated, based on Threshold Limit Values (TLV's), for the various workers involved in fumigant application and for the general public (table 10). A TLV is the estimated maximum concentration for an 8-hour workday exposure that will not result in any adverse effects. Workers using MBC-33 are at the highest risk because their estimated doses for chloropicrin exceed the TLV. Workers applying dazomet are at a lower risk because their estimated doses are less than the TLV (table 10). Risks associated with dazomet application should be further reduced by the lag time between application and formation of toxic compounds in the soil. Gases from both MBC and dazomet can drift for some time after application and may cause workers and neighbors to experience some degree of minor irritation. Although there are not documented cases of serious injury to these people, fumigant drift under certain weather conditions have caused concern (Myers 1989).

FUTURE AVAILABILITY OF FUMIGANTS

For the past few years, nursery managers have expressed concern about the possibility that the use of some fumigants, particularly MBC, will be severely restricted or banned. This is a legitimate concern because other fumigants have been banned after they were detected in groundwater in agricultural areas. A soil fumigant (DBCP) is the most widespread pesticide contaminant of groundwater in the United States, and its use was suspended in 1979. Since then, other fumigants have also been detected in groundwater and subsequently removed from the market: D-D, a nematicide, along with EDB, a close chemical relative of MBC (Russell and others 1987). Because of this "guilt by association," groundwater is being tested across the country for MBC, but it has not been detected as of this date (Parsons and Witt 1989). It is considered unlikely that MBC would ever be detected, however, because it rapidly dissociates into inorganic bromide and a methyl-containing substance before reaching

Table 10 - Probability of health hazards for public and workers exposed to common soil fumigants

		Fumigation Applicators[1]		
Fumigant	Public	Driver	Shoveler	Tarp lifter
Methyl bromide	Low	Moderate	Moderate	High
Chloropicrin	Moderate	High	I[2]	I
Dazomet	Low	Moderate	N/A[2]	N/A

[1] Average exposures per workday, based on historical data of workers not wearing protective clothing.

[2] I = Insufficient information; N/A = Not applicable

Source: USDA Forest Service (1989)

groundwater supplies (Bentson and Lavey 1989).

Another concern about the future of soil fumigants is the possible link to cancer. MBC is particularly suspect because it is considered a possible mutagen in humans (USDA Forest Service 1989), and the closely-related EDB has already been shown to be a potent carcinogen in animals (Russell and others 1987). Although further cancer testing is underway for both methyl bromide and chloropicrin, the results are inconclusive so far (USDA Forest Service 1989).

At the present time, however, none of the four currently used fumigants (MBC, dazomet, metam-sodium, or vorlex) are in any danger of losing their pesticide registration in the United States. We specifically inquired about the re-registration status of the MBC fumigants and company representatives and EPA scientists informed us that they will continue to be available to the agricultural community (Andersen 1989).

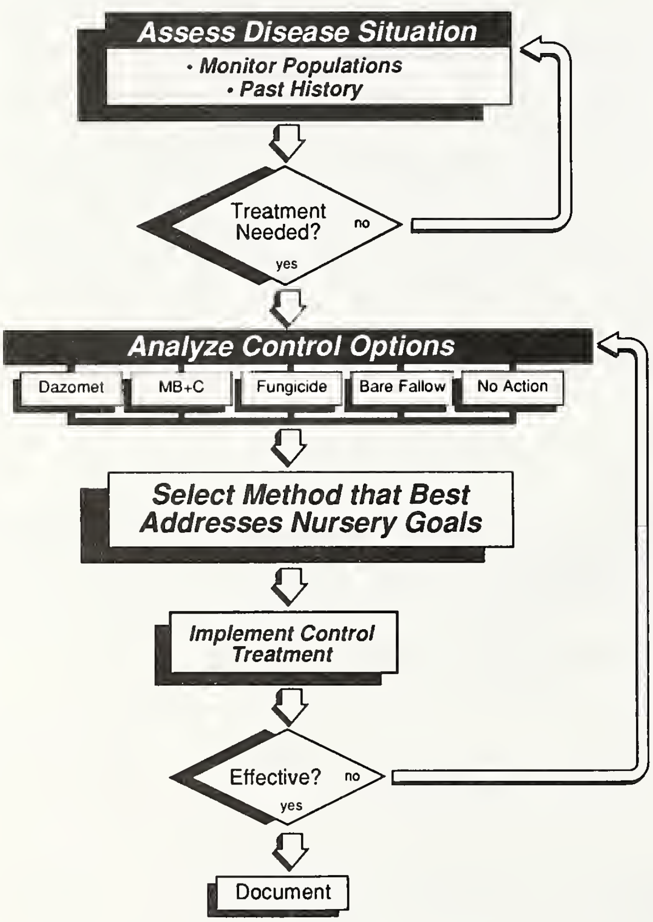

Figure 7 - A flow chart can help nursery managers think through the sequential steps in a integrated pest management (IPM) program. This example shows the sequence of events for managing a soilborne disease problem.

CONCLUSIONS AND RECOMMENDATIONS

Although fumigants are extremely toxic pesticides, they are relatively not persistent in the environment, they have immediate severe health risks, but long-term risks are not much more severe than other pesticides. If properly applied with adequate precautions, they can continue to be a major weapon in the chemical arsenal.

Fumigation and Integrated Pest Management

Soil fumigation, along with other cultural activities and pesticides, should always be viewed in the larger context of an overall nursery pest management plan. Progressive nurseries have begun to define their pest management activities in the context of Integrated Pest Management (IPM). IPM in forest nurseries can be defined as:

> "Integrated nursery pest management is the maintenance of seedling pests at tolerable levels by the planned use of a variety of preventive, suppressive, or regulatory methods (including no action) that are consistent with nursery management goals. It is implicit that the actions taken are the end-result of a decision-making process where pest populations and their impact on hosts are considered and control methods are analyzed for their effectiveness as well as their impact on economics, human health and the environment" (USDA Forest Service 1989).

Use of a fumigant, like any other pest control method, must be analyzed for the entire range of nursery effects:

* control of the target pest
* impact on seedling growth and survival
* cost of application
* effect on the environment
* hazard to worker health and public safety.

Selection of a pest control method to control a specific target pest will depend on the priorities and resources of the nursery. Pesticides are no longer applied based solely on their ability to control a pest or because they are considered to be more cost effective than other methods. Other issues, such as risk to human health, may drive the decision to use or not use a particular pest control method.

The decision-making process for managing soil-borne pests in a forest nursery can be illustrated with a flow chart which shows both the steps and the order in which they are taken (fig. 7). In this flow chart, there are several key steps:

1. Determining whether or not there is a pest problem in need of treatment

2. Deciding which pest control methods are available to reduce or prevent crop damage

3. Analyzing the benefits and drawbacks of each method

4. Selecting the best pest management method in accordance with the goals and priorities of the nursery

5. Implementing pest treatment

6. Evaluating the treatment for effectiveness

Documentation is an important yet often neglected part of an IPM program. Adequate documentation includes figures on pest population trends, type of control treatment (what was used, rates, dates of application, etc.), and treatment effectiveness, but there should also be some documentation of the analysis and rationale used for selecting the treatment to aid in future decisions.

If fumigants are analyzed and applied in a comprehensive IPM context, nursery managers can be assured that they are acting in a logical, environmentally sound manner and will continue to be able to use these effective pesticides.

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Effects of Fumigation on Soil Pathogens[1] and Beneficial Microorganisms

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Abstract.--Soil fumigation with broad-spectrum biocides is a non-selective means of killing soil-borne pathogens in forest seedling nurseries. Beneficial microorganisms (antagonists, competitors, pathogen parasites and mycorrhizal fungi) are also killed by most fumigants. Organisms are killed by direct contact with fumigants. Dormant structures of microorganisms are usually more resistant to fumigant action. Specific fumigants are more effective against certain microorganisms. Fumigant effects on populations of selected pathogens (*Fusarium*, *Pythium*, *Phytophthora*, *Rhizoctonia*, *Macrophomina*, and *Phoma*) and certain antagonistic fungi, bacteria, and mycorrhizal symbionts are discussed.

INTRODUCTION

Using soil fumigation to control soil-borne diseases has recently increased in importance at many forest tree seedling nurseries in the United States. Techniques using broad-spectrum soil fumigants to enhance plant production by reducing impacts of pathogenic fungi were first developed for agricultural crops (Miller and Norris 1970). Operational soil fumigation over a relatively large area was probably first successfully used for strawberry production in California (Wilhelm and others 1974). Techniques and products developed for agriculture have been implemented at many forest tree nurseries. Soil fumigation has usually improved the number and quality of seedlings produced (Klock and Benson 1975; Norris 1983; Norris and Hessburg 1985; Smith and Bega 1966) while reducing weeds and soil insect problems.

Over the years, several chemicals have been tested for use as soil fumigants. However, consistent beneficial effects have only been obtained with a few products and formulations (Munnecke and Van Gundy 1979; Wensley 1953). Combinations of several different fumigants are often more effective than single chemicals (Smith and Bega 1966), as is the case with methyl bromide and cholorpicrin (MBC). MBC is the most commonly used fumigant combination for forest nurseries, and although different formulations have been tested, the most popular and effective solution for controlling soil-borne pathogens is 67 percent methyl bromide and 33 percent chloropicrin. Most fungi are more susceptible to cholorpicrin mixtures than the methyl bromide alone (Ebben and others 1983; Munnecke and Van Gundy 1979). Other fumigants used less frequently include metam-sodium (Vapam®) and dazomet (Basamid®).

All fumigants kill soil microorganisms non-selectively through direct contact (Boone 1988). Susceptibility of microorganisms to fumigants is variable, especially at reduced or "sub-lethal" dosages. However, all microorganisms are susceptible if fumigant concentrations are high enough. Fumigant action is largely affected by soil temperature, i.e., most chemicals are more effective at higher temperatures (Gandy and Chanter 1976).

ECOLOGY OF SOIL MICROORGANISMS

Nursery soil is an extremely conducive habitat for a variety of microorganisms. Their relative numbers may fluctuate widely and are greatly affected by season, cropping history, and types of amendments. Normally, microorganisms interact with each other and compete for substrates. Many pathogenic fungi are rapid initial colonizers of suitable substrates, such as host roots. This provides them a better competitive position since many do not compete well with more free-living, saprophytic soil organisms (Papavizas 1985).

Most soil organisms are either actively colonizing substrates or dormant. Substrates are colonized by a succession of organisms. As indicated above, pathogens often are initial colonizers and are followed by other organisms that are better competitors. Competition by soil microorganisms is often intense; many are capable of producing powerful antibiotics which give them competitive advantages (Papavizas 1985), while some parasitize other organisms. Another competitive advantage is rapid spore germination and growth when new substrates become available.

Many pathogens produce dormant "resting" structures which are stimulated into activity by presence of a suitable host. Roots of most plants exude amino acids which may stimulate germination of spores as well as provide directional gradients for motile spores and growing hyphae of certain pathogenic fungi (Rovira 1970). Most dormant structures are fairly long-lived and resistant, although they respond readily to

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host root exudates and may be susceptible to damage by biocides like soil fumigants.

FUMIGATION EFFECTS

General

Most soil fumigants are non-selective in their action against microorganisms, but rarely are all organisms killed during standard treatments. Organisms tightly bound in soil aggregates and those deeper in the soil below the zone of effective fumigation (greater than 25-30 cm) may escape undamaged (Fuller and others 1980; Kolbezen and others 1974; Marshall 1985). Some investigations (Baines and others 1966; Ebben and others 1983) found that different organisms have different sensitivities to commonly used fumigants. These tests were usually done at lower fumigant concentrations. Most of these investigations showed that microorganisms which produce more resistant dormant structures (such as fungal sclerotia) are more resistant to fumigants.

Once fumigated, soil is conducive to rapid reinvasion by microorganisms (Danielson and Davey 1969; Munnecke and Van Gundy 1979). A "biological vacuum" may occur and any organism initially introduced into fumigated soil often expands rapidly to produce abundant populations because of the lack of competition from other organisms. Fumigation also releases an abundance of nutrients (from death of previous organisms) which may provide an important source of growth substances for invading organisms (Munnecke and Van Gundy 1979). Organisms commonly reinvading fumigated soil produce air-borne propagules, are located deeper in the soil, or reside within adjacent non-treated fields (Danielson and Davey 1969). Important re-invaders may also be introduced on seed, nursery implements, or in water.

Effectiveness of soil fumigation is often monitored by assaying for selected microorganisms before and after fumigation (Johnson and Zak 1977; Marshall 1983). The two most common genera of fungi assayed are *Fusarium* and *Pythium*. Soil dilutions on selective agar media are made and the number of propagules (colony forming units) per unit weight of soil (usually grams) are calculated. These assays are for total populations of these fungi and do not necessarily determine levels of pathogens. There are pathogenic and saprophytic strains of both *Fusarium* and *Pythium*. Therefore, it may be difficult to correlate soil populations of either of these organisms with disease (Bloomberg 1965), although predictions of losses based on soil assays are sometimes made (Hildebrand and Dinkel 1988). Further, most soil assays do not include levels of potential antagonists (such as bacteria, Actinomycetes, *Trichoderma*, etc.). Levels of these competitors may be more important in predicting disease than the levels of *Fusarium* and *Pythium* in the soil (Marshall 1983; Papavizas 1985).

Effects on *Fusarium*

Fusarium spp. are widely diverse fungi which are very important plant pathogens (Nelson and others 1983). Although important pathogens of agricultural crops and forest seedlings in nurseries (Sutherland and others), *Fusarium* spp. are not often pathogens in natural forest stands. In soil, most pathogenic species of *Fusarium* produce dormant structures called chlamydospores. However, species which do not normally produce chlamydospores produce other resistant-type structures in the soil (Hargreaves and Fox 1977). Most chlamydospores, other types of spores (macroconidia) and other resistant structures are fairly long-lived in the soil; their longevity depends on level of microbial antagonism and presence of suitable host substrates. Chlamydospores germinate when stimulated by host root exudates (Rovira 1970). Rapid colonization of host material after spore germination is important for this group of fungi.

Fusarium spp. are generally reduced by soil fumigation (Gillman 1977; Roberts and others 1988). However, they are less sensitive to some fumigants, such as methyl bromide, as some other fungi (Ebben and others 1983; McCarter and others 1978; Munnecke and others 1978; Norris 1986). Dry macrocondia (Weststeijn 1973) and mycelium (Munnecke and others 1978) may be quite resistant to fumigants. Metam-sodium may (Corden and Young 1965) or may not (Ben-Yephet and Frank 1985; Campbell and Kelpsas 1988) be as effective as MBC in reducing *Fusarium* levels. Dazomet reduces *Fusarium* levels in soil, but usually not as effectively as MBC (Campbell and Kelpsas 1988). Surviving propagules may quickly reinvade dazomet treated soil (Hoffman and Williams 1988). Vorlex® (methyl isothiocyanate and chlorinated hydrocarbons) did not significantly reduce numbers of *Fusarium* propagules in two studies (Manning and Vardaro 1977; Sinclair and others 1975). However, in another study (Marois and others 1983), this fumigant eliminated *Fusarium* from the top 20 cm of soil, although the pathogen quickly reinvaded fumigated soil from below.

Except in dazomet treated soil, *Fusarium* spp. may be rather slow recolonizers of fumigated soil (Danielson and Davey 1969; Johnson and Zak 1977). However, if introduced on seed or from adjacent non-fumigated fields, these fungi may increase to levels higher than those found before fumigation (Young 1940).

Effects on *Pythium* and *Phytophthora*

Pythium and *Phytophthora* are two very important plant pathogens. These "water molds" produce motile zoospores which move through soil in water and seek out host roots to infect. As such, they are usually more damaging in poorly drained soils. They can inhabit water supplies and be introduced through irrigation water. Many agricultural crops and forest seedlings in nurseries are attacked by these fungi (Sutherland and others 1989).

Dormant structures of *Pythium* and *Phytophthora* are either asexual (sporangia and chlamydospores) or sexual (oospores). These thick-walled spores can remain viable in soil for extended periods of time and withstand periods of desiccation. When soil moisture is adequate, sporangia will germinate to produce zoospores capable of attacking plant roots. Oospores and chlamydospores germinate to produce a mycelium that may grow toward host roots in response to root exudates (Rovira 1970).

Pythium and *Phytophthora* are more sensitive to most fumigants than several other plant pathogenic fungi (Gillman 1977; Munnecke and others 1978; Norris 1986). Their mycelium is readily killed by fumigants, even at relatively low concentrations (Roberts and others 1988; Smith and Bega 1966). Oospores and chlamydospores are probably the most resistant to fumigant action, but at concentrations usually employed at forest nurseries, they are readily killed as well (Munnecke and others 1978). One problem in controlling these fungi with fumigation is the rapidity with which they reinvade treated soil (Campbell and Kelpsas 1988; Johnson and Zak 1977; Tkacz 1983; Vaartaja 1967). Reinvasion may occur from large populations existing below the zone of fumigation and/or through irrigation water. Experience indicates that they are usually detected in higher numbers than *Fusarium* in recently fumigated soil (Tkacz 1983). Dazomet is more effective in reducing populations of *Pythium* than *Fusarium* (Tanaka and others 1986).

Effects on *Rhizoctonia*

Rhizoctonia solani is an important pathogen of many agricultural crops and causes damping-off of conifer seedlings in nurseries (Sutherland and others 1989). This organism is well adapted to the soil environment. For example, it rapidily colonizes organic material introduced into soil before many other organisms, and it is rather resistant to microbial competitors. *Rhizoctonia* is also capable of producing sexual spores (basidiospores) which may be disseminated long distances in air or water.

Rhizoctonia is usually more sensitive to fumigants than *Fusarium*, but less sensitive than either *Pythium* or *Phytophthora* (Munnecke and others 1978), although responses of *Rhizoctonia* spp. are not often assayed in nursery soils (McCarter and others 1978; Smith and Bega 1966).

Effects on *Macrophomina*

Macrophomina phaseolina causes charcoal root disease of several conifer species in forest seedling nurseries (Smith 1975). The fungus produces abundant sclerotia which may remain viable in the soil for long time periods. The only effective way of reducing these soil propagules is by fumigation, particularly with MBC (Cordell 1982; Rowan 1981; Smith and Bega 1966).

Effects on *Phoma*

Phoma comprises a diverse group of soil-borne fungi that attack a wide range of host plants. Most species are considered relatively weak pathogens, but some *Phoma* spp. can cause serious root and stem rots and tip dieback of bareroot seedlings (James and Hamm 1985). Most species produce several spore stages; dormant structures in soil are either chlamydospores or dictyochlamydospores. On suitable substrates under moist conditions, *Phoma* spp. produce sporophores called pycnidia which ooze spores capable of moving in the soil.

Assays for *Phoma* in fumigated soil are not usually conducted. However, experience with styroblock containers indicates that these fungi may be difficult to kill with standard sterilants (James and Woollen 1989). It is likely that most fumigants, especially MBC at dosages normally employed, effectively kill most propagules of *Phoma* in nursery soil.

Effects on Beneficial Microorganisms

Bacteria

Many diverse groups of bacteria commonly inhabit nursery soil. Several species are antagonistic toward common soil-borne pathogens (Cornwall 1985). Some soil bacteria form dormant spores relatively resistant to environmental degredation. Some species, such as *Bacillus*, may produce spores resistant to fumigants, at least at low chemical concentrations (Altman 1970). Bacteria are also very rapid recolonizers of fumigated soil (Ingestad and Nilsson 1964; Martin 1963; Wensley 1953).

Actinomycetes

This group of primitive fungi are common soil inhabitants and many species are antagonistic toward other soil fungi (Cornwall 1985). Members of this group may remain dormant in the soil for long periods of time; however, most members are readily killed by commonly used fumigants. They will reinvade fumigated soil, but slower than some other types of fungi (Cornwall 1985).

Trichoderma

Trichoderma spp. are common soil-borne fungi that reside in many soil types, including those from forest nurseries (Papavizas 1985). They exist saprophytically on a wide variety of organic substrates, readily competing with or being antagonistic toward many plant pathogenic fungi, including *Fusarium*, *Pythium*, *Phytophthora*, and *Rhizoctonia*. Some species of *Trichoderma* produce powerful chemicals toxic to other fungi; other species are parasitic on certain groups of soil fungi (Papavizas 1985). *Trichoderma* spp. are usually less sensitive to common soil fumigants than many soil-borne pathogens (Gandy and Chanter 1976). These fungi are often the first to be detected at high levels after soil fumigation (Danielson and Davey 1969; Ingestad and Nilsson 1964; Vaartaja 1967; Wensley 1953), often reaching higher population levels than in nonfumigated soil (Marshall 1986; Martin and Pratt 1958; Sinha and others 1979; Vaartaja 1967). *Trichoderma* often is the dominant microorganism in fumigated soil (Bollen 1961; Martin and others 1957; Warcup 1957).

Endomycorrhizal Symbionts

Endomycorrhizal fungi are important in production of many hardwood tree seedlings. They are not disseminated readily because their spores are soilborne. Most endomycorrhizal symbionts are quite sensitive to fumigants and are readily killed at concentrations normally used. These fungi are more sensitive to low doses of methyl bromide than many soil-borne pathogens (Menge 1982), although not all propagules are usually killed, especially those below the zone of effective fumigation (McGraw and Hendrix 1984). Endomycorrhizal fungi are usually very slow to infest fumigated soil because of their subterranean sporulation (Menge 1982). Growth depression of crop plants following fumigation has been at least partially due to reduction of endomycorrhizal inoculum in the soil (Munnecke and others 1978; Wilhelm and others 1974). In cases where endomycorrhizal fungi are necessary for satisfactory production of seedling stock, they must be reintroduced manually following fumigation.

Ectomycorrhizal Symbionts

Ectomycorrhizal fungi, common inhabitants of conifer seedling nurseries, are usually reduced the first year following fumigation, but often return to pre-fumigation levels the second year (Johnson and Zak 1977; Peterson 1970). Although most ectomycorrhizal fungi are susceptible to most fumigants, Rowan (1981) reported that *Thelephora terrestris* is somewhat resistant to MBC because fumigation did not affect soil-borne inoculum of this species. Ectomycorrhial fungi were not significantly reduced in Vorlex® treated soil (Sinclair and others 1975). Although retardation of mycorrhizal formation may occur in fumigated soil, seedling response may still be greater than in non-fumigated soil because of reduced pathogen levels (Hacskaylo and Palmer 1957; Laiho and Mikola 1964). Ectomycorrhizal fungi are readily disseminated by air-borne spores and usually reinfest fumigated soil if there are large conifer trees near nurseries or if adjacent fields harbor inoculum (Cordell 1982).

In cases where inoculum is not readily available, these fungi may have to be reintroduced manually following soil fumigation.

CONCLUSIONS

Communities of soil microorganisms tend to stabilize quantitatively and qualitatively in the absence of biocides that may preferentially inhibit certain species. When susceptible hosts are introduced into soil, certain pathogens may proliferate unless restricted by the action of competitors or antagonists. As indicated earlier, spores of pathogens are stimulated into activity by the presence of host roots. However, if resident populations of antagonists are sufficient, pathogens may not be able to cause disease. Over time, pathogens and competitors/ antagonists tend to come into "balance" and will remain so until that balance is upset. Several factors can upset this balance, including introduction of extensive amounts of susceptible host material, introducing pathogen populations (such as on seed), and treatment of soil with biocides.

Because most fumigants are non-selective in their action, their use results in a soil habitat colonized most by the organisms first reintroduced following treatment. If these initial colonizers are "good" fungi, i.e., those competitive with or antagonistic toward pathogens, any pathogenic fungi inadvertently introduced will not proliferate and little disease will likely result. Conversely, if pathogens are the first to be reintroduced into fumigated soil, such as on seed, they will proliferate and reach higher levels than before fumigation and disease losses could be extensive. One problem with soil fumigation is that once this practice is implemented, it usually has to be repeated before each successive crop because the biological balance of microorganisms in the soil has been disrupted.

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Soil Fumigation at J. Herbert Stone Nursery[1]

John R. Scholtes[2]

Abstract.--A brief discussion of the history, and current fumigation operations and experiences at the J. Herbert Stone Nursery. Also a post script to this presentation.

INTRODUCTION

The J. Herbert Stone Nursery (JHSN) was established Through a joint effort between the USDA Forest Service and Bureau of Land Management. The site was obtained in two purchases in 1976 and 1982. It is administered by the Rogue River National Forest. The nursery is located in Southwestern Oregon near the towns of Central Point and Medford, Oregon. The total area of the Nursery site is 306 acres with approximately 213 acres of seedling production area. Douglas-fir makes up approximately 60% of the production although a total of 18 - 22 species are produced each year.

The climate is described as "mediterranean" having hot-dry summers, a long growing season and wet-mild winters. The established lifting window for the "dormant plant" lifting season is between December 1st and March 1st.

Most of the nursery's clients are made up of several National Forests and Bureau of Land Management Districts within the southwestern quarter of Oregon and the northern portion of California. Some specialty products such as 1-0 Western larch are being produced for clients as far away as Northern Idaho and Western Montana.

Age classes being grown include both 1-0 and 2-0 ship seedlings with a minor but increasing number of 1-1 transplant seedlings being ordered. These different species and age classes are further divided into a complicated array of "cultural groups" in order to custom grow seedlings which meet the different morphological characteristics requested by the clients while still producing plants that are phenologically sound for lifting, handling and transplanting. The "target seedling" concept has been used for several years to establish the range in options which are available to clients have when ordering seedlings.

PAST EXPERIENCES WITH FUMIGATION

Soil fumigation has been a standard part of the nursery production program since the first seed was sown in the spring of 1978. The original fumigant used was a mixture of 67% methyl bromide and 33% chloropicrin (MB-C). This material was applied and covered with plastic tarp in the standard manner. It was always applied by a fumigation contractor. Fumigation was generally done in the fall before sowing. There have been small areas fumigated in the spring when there were seedlings still occupying areas designated for sowing the following spring. In these cases, the seedlings were removed during the winter lifting season and the fumigation was completed as soon as the soil was in acceptable condition that spring.

Fumigation has always been done for the control of soil born pathogenic fungi which are known to cause pre and post germination dampening-off as well as root rot during later plant development. The pre and post fumigation soil tests have consistently shown that MB-C is a highly effective fumigant for the pathological fungi which were considered threatening at this site.

However, there has been an increasing concern over the continued use of MB-C. This concern has developed from several factors. There has been rumors that MB-C may be more stringently regulated or even banned from use. There have also been rumors about tighter controls on the disposal of the tarp and other materials which have been in contact with the chemical. One nursery had an incident involving this material as well as other factors which led to an administrative decision to ban the use of the product at that site. Recent experiences with poor contractor safety and performance at JHSN has also been a major factor in searching for an alternative product.

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[1]Paper presented at Intermountain Forest Nursery Association Annual Meeting. [Bismack, North Dakota, August 14-17, 1989].

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The development of a new formulation of the fumigant dazomet known as Basamid[R] spurred the Nursery Management and the Forest Pest Management people in the Forest Service Regional Office in Portland, Oregon to look into the use of this new product as a nursery fumigant. Several tests have been conducted at JHSN over the past several years.

The first test involved several small plots in a single seedling bed. Different levels of dazomet were incorporated into plots. pre and post fumigation soil analysis was done to evaluate the effectiveness of the material. Seedlings were also grown in these plots and evaluated. The data was very encouraging so the following year, an area of approximately one acre was not fumigated with methyl MB-C. The standard fumigation layout in this field required that fumigation be done perpendicular to the way the seedbeds run. Therefore, the area left untreated ran across an entire field of seedbeds. This area was later treated with dazomet. pre and post fumigation soil samples were taken for both fumigants for laboratory analysis by FPM personnel. The area was sown to several species of seedlings involving many different seedlots. The soil samples proved that, while the dazomet was not quite as thorough as the MB-C, it still performed within the ranges considered to be effective. Informal evaluation of the seedlings growing in the two treatment areas did not detect any differences.

The following year, about half of the ground to be fumigated was treated with dazomet. Again, no differences in effectiveness nor seedling characteristics were noted.

In the fall of 1988, the entire area to be fumigated was treated with dazomet. All went well for several days after the treatment. Then it was discovered that both 1-0 and 2-0 Western white pine in a field east of the treated area was starting to exhibit signs of chemical injury to the needles. The affected needles turned straw yellow to reddish brown within a period of one to three days from the first indications of trouble. This was quite a surprise to the management of JHSN. Up to this point, there had been no indication of trouble with seedlings in areas adjacent to areas treated with this product. There had been discussion with another nursery about observed trouble when it was applied near Western white pine. However, it was thought that being across a major field road which was a distance of over fifty feet would be sufficient to afford protection from any chemical or gaseous drift. In this case, the JHSN damage extended well over 200 feet into the seedbeds with occasional damage over 300 feet into the beds. The damage seemed to be quite selective. Even though there was a gradient of damage from heavy near the fumigation site to minor at a distance of 250-300 feet away from the treatment boundary, there was also a distinct pattern of individual seedlings. Near the treatment site, certain individuals would have 90-100% needle kill while neighboring seedlings would show only minor tip burn. Further away, there were seedlings with one half the length of nearly all their needles burned while adjacent seedlings showed no symptoms.

This event also surprised the chemical dealer and manufacturer. They had been involved with the JHSN testing and use from the very first tests. The application of the chemical had even been video taped at the JHSN location as a demo on how to apply it on a large scale operation.

Having experienced this event, the management of JHSN is looking at how to prevent a similar occurrence in the future. It is felt that this is an effective alternative to the use of MB-C and its continued use is justified. Proper precautions, however, must be taken when it is used in areas near plants which are apparently susceptible to it or its by-products.

The reasons for this incident and the causal agents have been discussed at length. We are virtually certain that the problem was not caused by drift of the product during application. The application was done under carefully monitored conditions and the damage did not appear for some days after application. It was noted that there had been a weather incident after the application during which there had been particularly still mornings. This is not unusual in the Rogue River Valley in which the nursery is located. This type of condition, known as an air inversion, traps air in the entire valley but is also noticeable within local areas of the valley when ground fog lays just a few feet off the ground and there is no noticeable movement of the local air. It is conjectured that such a condition led to the buildup of escaping by product gasses from the dazomet into some level of concentration at or near the ground surface. This concentration could have then moved slowly down drainage across the area of Western white pine. The affected area was located at a lower elevation than the treated area and the pattern of damage supports this idea.

Future use of this product must be more carefully planned. Among the measures being considered at this time include: Treating smaller areas within a given time frame (approximately 20 acres had been treated in one application day in the case of the damage to the Western white pine). Perhaps treatment with another fumigant should be used when the area is near the susceptible species. Better sealing techniques may be required such as using plastic. The weather patterns may be more carefully monitored to avoid still air and inversion conditions. Other more radical treatments have also been considered. Using a fan system such as used for slash burning or orchard frost protection may provide the air movement needed to prevent damage to susceptible species. A barrier such as a plastic covered fence may detour the air around the area to be protected. There may be other methods of protection as well.

A POST SCRIPT TO THE PAPER

Dazamet was used again in the fall of 1989. Prior to treatment, a few methods of protecting Western white pine seedlings which would again be near the treated area were evaluated. A barrier of plastic over shade frames was placed down slope between the Western white pine and the treatment area. Smoke from torches was released on the treatment side of the barrier on a "still" morning. The smoke simply built up and crawled over the 4-5 foot high fence. A large gas powered fan used to fire piles of forest logging slash was placed in different positions around the barrier. This offered little or no protection as the smoke went over, around, and past the fan.

Finally, it was decided that the only protection that could be counted on was distance or being totally down wind from susceptible species. A small contract was let to use MB-C adjacent to two areas of Western white pine. One area adjacent to Western white pine transplants was completely treated with MB-C. The other area was treated for a distance of 250 feet from the Western white pine. The results were that the area totally treated with MB-C has no noticeable affects from the fumigation. However, the Western white pine that was within 250 feet of the dazamet was again seriously affected. This time, no affects were observed for several days after treatment. Then, after another heavy-still morning, the needles on the Western white pine started turning. Again, a definite pattern is noticeable across the area of seedlings. A portion of the area which is at the same elevation or higher that the treated area had no damage. The damage also grades out as the distance from the treated field increases. There is again, a noticeable difference between damage to individual seedlings adjacent to each other.

THE FUTURE

The old adage "if he does it to me once, shame on him - if he does it to me a second time, shame on me" is beginning to nag at the management at JHSN. We know that dazamet is a useful tool and a good alternative to using MB-C. We feel that we need to keep both of these chemicals available for selective use as needed. The fact that Western white pine can be damaged when dazamet is used in the vicinity attests very strongly to the need for alternatives. We had sown the two age classes of Western white pine involved in this damage in the center of the nursery not anticipating any problems. Last spring (1989) we located the Western white pine in an area of the nursery which is up drainage and generally upwind from any other field at the nursery. We will continue to locate this species into areas which are not susceptible to the downwind or down drainage conditions which led to the damage of the past two seasons. In addition, we will be looking very hard at using MB-C in any area that is within 500 to 700 feet of Western white pine seedlings. We know now that preventive steps must be extra ordinary. The 250 foot buffer was simply not sufficient.

We have also been working on other treatments to give us additional tools in the fight against pathogenic fungi. We have participated with several other nurseries in a contract with a local University to study fusarium. This work has shed some light on management options which may one day help control this pathogen. Other treatments and management techniques will be evaluated in the future as organic methods become better understood and alternatives to chemical control are developed.

Methyl Bromide Fumigation at the Lone Peak State Forest Nursery, Utah[1]

David G. Grierson[2]

Abstract.--Methyl bromide-chloropicrin fumigation has been done at the Lone Peak State Nursery by staff members, which gives much more flexiblilty ot the process and ultimately, better control. The primary reason for fumigation at the site is for the control of weed and weed seed, and fumigation is an integral and strategic part of the long-term weed management plan.

BACKGROUND

The Lone Peak State Forest Nursery, located in Draper, Utah, has been on its present site for nearly 15 years. Prior to the nursery being located there, the site had been used for alfalfa hay and pasture and had then spent considerable time unused. As a result, a tremendous reservoir of weed and weed seed had built up, with a nearly unmanageable diversity of weed species. Additionally, the lack of shelterbelts around the nursery and a notorious, ever-present prevailing wind brought more weeds and weed seeds by the bucketfuls.

NURSERY DEVELOPMENT

Back in the mid 1970's pressure from management would not allow proper development of the nursery. Production of seedlings was paramount for the governor's "Million Trees for a Million People" program while sound nursery cultural practices fell by the wayside. In 1979, it was decided that the weed problem had top priority and finally a plan was set up to deal with the problem.

Fumigation was contracted out in 1980 on a trial basis and the results were mixed. Problems with contractor scheduling, wind, and soil moisture gave marginal results in some areas, and great weed control in others. It was great when it worked, but when it did not, it was costly.

The greatest problem encountered was the problem of contractor scheduling. The amount of fumigation done annually at the nursery is 4 to 6 acres which does not give contractors much profit motive to make a special trip to Salt Lake City. If they do decide to make the trip it was usually a stopover between Luck Peak Nursery and Mt. Sopris Nursery and contractors gave themselves a fairly narrow window for fumigating.

In 1983, an opportunity to purchase a used fumigator presented itself. The cost was $4500, from a contractor who just wanted to get out the business. The Lone Peak State Forest Nursery hired a consultant from North Carolina, Clarence Lemon, to assist in the start-up, safety and training in methyl bromide fumigation. The staff at the nursery has been fumigating the production blocks ever since.

The supplies needed for fumigation include: fumigant (67% methyl bromide, 33% chloropicrin), sprayable glue, 1 mil poly tarp and nitrogen to pressurize the fumigant tanks. The per acre cost of supplies are currently running about $700. Other cost include maintenance costs for hoses, and fittings.

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[1]Paper presented at Intermountain Forest Nursery Association Meeting, August 14-17, 1989.

[2]David G. Grierson is Nursery Manager, Lone Peak State Forest Nursery, Draper, Utah.

RESULTS

The biggest advantage the nursery has with doing its own fumigation is the flexibility in the control of weeds. For fall fumigation, the dates can be moved back as late as weather and soil temperatures permit, minimizing the late summer blow-in of weed seed. There also have been times when spring fumigation occurred when fall fumigation was unsuccessful.

Generally fumigation is done in the early morning before the afternoon winds begin to pick up. Morning fumigation allows the soil moisture to condense on the tarp under the heat of the sun. This allows added weight to the tarp to resist effects of the wind.

The weed control at the nursery is worth the time, effort and money. In 1986, funds were not available for fumigation and the results were disastrous. Conifer losses were up by 60% and hardwood production suffered similar losses.

Fumigation is an integral part of the nursery weed management plan. The future of fumigation is stable at the Lone Peak State Nursery although eventually it will be reduced to once every second or third rotation.

Because the nursery staff is trained to do its own fumigation the efficiency has been increased. The flexibility of scheduling and reduced lobor costs make up for the increased hassle. The costs to the beneficial soil borne micro-organisms may be high right now, but the benefits received as a result of the weed control outweighs that cost right now. The weeds sap more from the seedlings than the micro-organisms can contribute.

Dazomet Use for Seedbed Fumigation at the PFRA Shelterbelt Centre, Indian Head, Saskatchewan[1]

Lyle K. Alspach[2]

Abstract.--Testing was conducted at the Shelterbelt Centre to allow selection of a suitable fumigant for use in bareroot conifer seedbeds. The major concern was control of damping-off; weed control was secondary. Results of the trials, product handling hazards and ease of application were considerations when final selection took place. The chemical of choice was dazomet and the product currently in use is Basamid. The effectiveness of this product is dependent on careful adherence to application instructions.

INTRODUCTION

Bareroot conifers and hardwoods are produced at the PFRA Shelterbelt Centre, Indian Head, Saskatchewan. The trees go to clients throughout the prairies: primarily in Manitoba and Saskatchewan. Annual production ranges between seven and ten million, of which eight hundred thousand are conifers.

Dazomet is the fumigant currently used to control soil fungi in both the conifer and shrub seedbeds. It was tested in eight trials, over a number of years, at Indian Head. Few problems have been encountered, however, weed control has been inconsistent. Control of soil-borne fungi, especially those which cause damping-off, has been good.

DAZOMET TESTING 1963 - 1969

Dazomet, along with other soil fumigants, was tested during a six year period. Conifer species included Colorado spruce, white spruce and Scots pine.

The first two trials involved testing of dazomet, metam sodium, methyl bromide and allyl alcohol. This number was further reduced to include only damomet and metam sodium in four subsequent trials.

Summaries for the first two trials do not clearly outline the procedure used for fumigant application (ie. application method and incorporation) Morgan (1963 and 1964). The plots were irrigated after treatment and a waiting period of two to three weeks was allowed between application and sowing.

Allyl alcohol at 110-225 litres per hectare and metam sodium at 170-505 kg/ha provided excellent weed control with good conifer germination. Dazomet at 110 kg/ha provided poor weed control one year, excellent the next. At 225 and 335 kg/ha it provided fair weed control one year, excellent the next. Further to this variability, the stand of Colorado spruce and Scots pine was reduced by the two higher rates the first year, but not the second. Methyl bromide application rates seemed to be excessively high, based on current application rates at several nurseries. They ranged from 490 to 1465 kg/ha and this could account for the reduced conifer stands in the first trial. Seedling vigor and growth, in the second year trial, was generally greater in handweeded checks, than in fumigated plots. This could be attributed to reduced seedling density resulting in greater water and nutrient availability per check seedling. Similar conclusions have been drawn by Campbell and Kelpsas (1988).

Due to a concern over the acute toxicity and handling hazards of methyl bromide and the lack of availability of contract applicators, a decision was made to eliminate it from future trials and to concentrate on dazomet and metam sodium.

Rates of testing for metam sodium were initially 170 to 505 kg/ha, later increased to 240 to 575 kg/ha. The range of dazomet rates was increased from 110 to 335 kg/ha initially to 110 to 450 kg/ha. Application methods were inconsistent as summaries indicated that sometimes only irrigation was used for incorporation and sealing; on one occassion the metam sodium was injected and the dazomet was incorporated by tillage; on two occassions the plots were covered, once using burlap and once with polyethylene. The one consistent aspect of all

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[1] Paper presented at the Intermountain Forest Nursery Association Annual Meeting (Kirkwood Motor Inn, Bismark, N.D., August 14-18, 1989).

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the fumigant treatments was the application of irrigation, following treatment, to seal the soil surface.

Weed control in the fall fumigated, spring sown Colorado spruce and Scots pine seedbeds ranged from satisfactory to excellent. Weed control results in the fall sown white spruce were not as good. This could possibly be attributed to the longer period between treatment and the next growing season. The period between treatment and sowing was shorter than for Colorado spruce and Scots pine, but it is unlikely that would have a negative effect on weed control.

All of the fumigant treatments, with one exception, increased emergence and reduced seedling losses, due to damping-off, as compared to the handweeded checks. The single exception was the high rate of dazomet, in one trial, which failed to increase the emergence of Scots pine and white spruce over that in the handweeded check.

Additional Trials 1972 and 1978

Dazomet was adopted for use at the Shelterbelt Centre based on results of the preceding trials and on ease of handling and application. After a few years use, a couple of additional trials were conducted: one to assess polyethylene covered versus non covered plots and one to assess two product formulations, Mylone (50D) versus Basamid (98G) Anonymous (1972 and 1978). Weed control was better in plots where a polyethylene cover was used to provide a seal during treatment than in non covered plots. There was no difference in results between the two product formulations.

OPERATIONAL DAZOMET APPLICATION AT THE SHELTERBELT CENTRE

Application Equipment

As practical experience was gained in the use of dazomet, a refinement in application equipment took place. Originally a 'Gandy' granular spreader was used to apply dazomet (Mylone), followed by raking or shallow cultivation plus harrowing to provide incorporation. Irrigation was then applied to seal the soil surface. Polyethylene covers, to hold in the gases and to prevent the entry of fresh weed seeds, were not adopted for use due to the additional materials and labor costs.

With an innovative machinist on staff, and experience gained through practical application, improvements in application equipment were made. An applicator which applied and incorporated the Mylone in one pass, leaving a prepared seedbed, was designed and fabricated. It was used for a number of years, but gave way to a new applicator when the product Basamid replaced Mylone in the Centre's program. The new applicator was designed along the lines of its predecessor, but incorporated a custom lathed roller instead of a chain link floor mat to distribute the dazomet product. This change was necessitated due to the much finer particle size of Basamid compared to Mylone.

Application Procedure

Current fumigation practices, at the Centre, involve the use of Basamid for both conifer and deciduous shrub seedbeds. The interval between fumigation and sowing varies depending on species: the shortest interval is four weeks for choke cherry (*Prunus virginiana melanocarpa* (A. Nels.) Sarg.), red elder (*Sambucus racemosa* L.) and white spruce (*Picea glauca* (Moench.) Voss.); four to six weeks for Siberian crabapple (*Malus baccata* (L.) Borkh.), red-osier dogwood (*Cornus stolonifera* Michx.), Ussurian pear (*Pyrus ussuriensis* Maxim.), Tatarian honeysuckle (*Lonicera tatarica* L.) and sea-buckthorn (*Hippophae rhamnoides* L.); and eight to ten months for Colorado spruce (*Picea pungens* Engelm.) and Scots pine (*Pinus sylvestris* L.).

The seedbeds are prepared and left reasonably level. Five days before Basamid application, the moisture content of the soil is brought to at least 50% of field capacity. The Basamid is applied at 350 kg of product per hectare and incorporated to a depth of ten centimetres by means of the shop built equipment previously mentioned. Following application and incorporation, the seedbeds are lightly packed using a roller. Light irrigation, approximately six millimetres, is then applied to complete the seal. For a three to five day period following treatment, sufficient moisture is provided to prevent the soil surface from drying out. After the active fumigation period, the soil can be tilled to aid in the dissipation of any remaining gases. Care must be taken to avoid tilling to a depth greater than that of original application.

In order to be certain that no toxic methyl isothiocyanate or formaldehyde gases are present in the soil at sowing time, a germination test should be performed using a susceptible species such as lettuce or cress (fig. 1).

Figure 1.-- Germination test to detect the presence of methyl isothiocyanate and formaldehyde gases.

CONCLUSION

Basamid, correctly applied, can provide an acceptable degree of weed control and more importantly, at the Shelterbelt Centre, control of soil-borne fungi such as pythium, fusarium, phytophtora and rhizoctonia. This is especially important in the conifer seedbeds where seedling losses can be significant.

Seedbed fumigation programs need to be reviewed periodically to determine if they are meeting the original objectives and if they are required.

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Methyl Bromide Fumigation of Containers Filled with Growing Media[1]

T. R. Garren, T. D. Landis, and S. J. Campbell[2]

Abstract.--Containers filled with peat-vermiculite growing media were fumigated with methyl bromide/chloropicrin (98%:2%), which was more effective than heat sterilization in controlling a soilborne disease. Because small volumes of growing media are isolated in spacially separate containers, considerably lower fumigant application rates were effective. Economic analysis proved methyl bromide fumigation to be cost effective because seedlings grown in treated containers were consistently larger.

INTRODUCTION

The greenhouse complex at the W.H. Horning Tree Seed Orchard was built in 1976 and is operated by the USDI-Bureau of Land Management to produce seedlings for tree improvement activities in northwestern Oregon. Annual production in the two shelterhouse-style greenhouses averages around 650M seedlings, depending on which container size is used. Reforestation seedlings are grown in Ray Leach pine cells^R [4 in^3 (65 cm^3)], whereas grafting root stock and seedlings for progeny tests are produced in Ray Leach super cells^R [10 in^3 (164 cm^3)].

During the 1982 growing season, several Northwest container nurseries began noticing a needle tip twisting and necrosis of Douglas-fir [Pseudotsuga menziesii (Mirb.)Franco] and other conifer seedlings. These initial symptoms were followed by stunting, chlorosis, and sometimes death of the affected seedlings. Because this species was most commonly affected, this disorder became known as Douglas-fir dieback (Husted 1988). Dieback symptoms are characteristic of many different types of root injury, including damage from fungal pathogens which could be transmitted in certain batches of growing media.

[1]Paper presented at the Intermountain Forest Nursery Association Meeting, Bismarck, North Dakota, August 14-18, 1989.

[2]Terry R. Garren is Supervisory Horticulturist, W.H. Horning Tree Seed Orchard, Colton, OR; Tom D. Landis is Western Nursery Specialist, and Sally J. Campbell is Plant Pathologist, USDA Forest Service, Portland, OR.

Container nursery managers observed that the symptomatic seedlings were often restricted to individual containers or blocks of containers (fig. 1). This "block effect" could be caused by a problem with reusable containers, or contaminated batches of growing media. Because the disease was more prevalent in previously-used containers, one hypothesis was that some sort of biological pathogen was being carried over between crops in the growing media that remained in the used containers. Another possibility was that batches of the peat-vermiculite growing medium could have become contaminated with a soilborne pathogen, and then distributed to specific groups of containers.

CONTAINER/GROWING MEDIA STERILIZATION TREATMENTS

Beginning in 1984, a series of operational experiments were conducted at the Horning greenhouse to see if the dieback problem could be cured with sterilization treatments of the containers or growing media. A battery of 21 different treatments was tried on a small scale during the 1984 growing season (fig. 2), but the only promising one involved heat sterilization of the growing medium in an autoclave. The soilborne pathogen hypothesis was further strengthened by the fact that healthy seedlings could be grown in batches of "bad soil" (media collected from containers with symptomatic seedlings) after it was autoclaved. Contaminated containers were also a possibility because a test between new and re-used containers revealed that 94% of the seedlings in the used containers exhibited dieback symptoms, compared to only 6% in the new containers.

Figure 1 - The "block effect", in which disease symptoms are restricted to seedlings in certain used containers, is thought to be related to soilborne pathogens which are transmitted on particles of growing media or root pieces that remain in the container between crops.

Based on these promising initial trials, two different methods of heat sterilization of the growing media were tested during the 1985 growing season. One batch of growing media was again autoclaved, and another treatment consisted the standard horticultural practice of steam sterilizing growing media, which was contracted to a local ornamental nursery. The steam sterilization contract specified that the growing media be held at a temperature of 200 ^{o}F (94 ^{o}C) for 30 minutes, instead of the normal heat pasteurization treatment which consists of temperatures of only 140 to 177 ^{o}F (60 to 82 ^{o}C) for the same time period. Following these heat treatments, the growing media was loaded into containers, and sown in the normal manner. A third growing media sterilization treatment with methyl bromide fumigation was added to further test the soilborne pathogen hypothesis. In this treatment, containers were filled with peat-vermiculite growing media and then fumigated with 98% methyl bromide/2% chloropicrin (MBC-2). At the end of the specified aeration period these filled containers were sown and placed in the greenhouse, and the seedlings were grown under normal nursery culture.

The 1985 sterilization trials revealed that, although the steam sterilization treatment gave poor results, both the autoclaved growing media and the MBC-2 fumigation greatly reduced or even

Figure 2 - Early operational trials with a variety of different container and growing media treatments showed that heat sterilization greatly reduced the number of symptomatic seedlings.

Table 1 - Container and growing media sterilization trials at the W.H. Horning greenhouse in 1985

TREATMENTS	NUMBER OF SEEDLINGS TOTAL	SYMPTOMATIC	PER CENT OF TOTAL
STEAM STERILIZED GROWING MEDIA	154	49	31.8 %
AUTOCLAVED GROWING MEDIA	180	8	4.4 %
MBC-2 FUMIGATED GROWING MEDIA IN CONTAINERS[1]	194	0	0.0 %

[1] = Containers filled with growing media were fumigated with methyl bromide/chloropicrin (98%:2%)

eliminated the number of symptomatic seedlings (table 1). Note that the steam sterilization and autoclave treatments involved only the growing media whereas the methyl bromide fumigation treated both the growing media and the containers. Although the Horning nursery personnel did not routinely sterilize their containers between crops, they did clean and sterilize small test groups of containers with Physan 20[R] or a 10% chlorox solution. These surface sterilants have not proven to be effective in killing fungal pathogens on containers, however, so infected growing media could still be transmitted on the containers to reinfect the new growing media (James and others 1988). This could possibly explain why the heat treatments were less effective than the chemical fumigation. The high amount of disease in the steam sterilization treatment could be attributed to difficulties in achieving uniform heat penetration of large volumes of growing media, whereas the autoclaved growing media was more effective because it was treated in smaller batches. Although differences in sample sizes and cultural treatments made statistical analysis difficult, it was concluded that the MBC-2 fumigation showed promise as an operational way to treat large numbers of filled containers. Even though the autoclave treatment was more effective than steam sterilization, it was considered to be impractical for large-scale nursery operations and was therefore eliminated from subsequent tests.

Building on the successes of the previous season, it was decided to implement the growing media and container sterilization treatments on an operational scale during the 1986 season, using thousands of filled containers instead of only a few hundred. The steam sterilization treatment was attempted again because it was felt that heat penetration problem could be corrected. A large batch of growing media was again steam sterilized before the containers were filled, and another group of filled containers was fumigated with MBC-2. A 50 lb (22.7 kg) tank of MBC-2 was used to treat a space of approximately 300 yd^3 (230 m^3), which converts to an application rate of 0.17 lb/yd^3 (0.10 kg/m^3). The fumigant was applied under a polyethylene tarp, and the pressurized liquid was introduced into an evaporation barrel to promote complete vaporization. After a standard aeration period, the containers were then seeded and grown under the normal cultural regime in the greenhouse.

Table 2 - Operational scale container and growing media sterilization treatments at the Horning greenhouse in 1986

TYPE OF TREATMENT	TOTAL SEEDLINGS	SYMPTOMATIC SEEDLINGS NUMBER	PERCENT
STEAM STERILIZED GROWING MEDIA	58,016	3,091	5.3 %
MBC-2 FUMIGATED GROWING MEDIA IN CONTAINERS[1]	12,544	2	0.0 %

[1] = Containers filled with growing media were fumigated with methyl bromide/chloropicrin (98%:2%)

The results of the 1986 trials showed that chemical fumigation was again effective in treating the Douglas-fir dieback disease (table 2). The steam sterilization treatments were more effective than the previous year but still did not completely eliminate the disease symptoms. It is interesting to note that the MBC-2 fumigation treatment was again effective, even though the 0.17 lb/yd^3 (0.10 kg/m^3) rate was considerably lower than the 0.50 to 1.00 lb/yd^3 (0.30 to 0.60 kg/m^3) rate that is listed on the fumigant label for potting soil. Other sources also recommend higher application rates: Handreck and Black (1984) recommend a rate of 0.83 lb yd^3 (0.50 kg/m^3) for treating growing media, compared to Bunt (1988) who recommends 1.17 lb yd^3 (0.70 kg/m^3). This effectiveness at lower application rates may reflect the way that the MBC-2 is applied - the fumigant is able to penetrate the small volume of growing media in the individual containers much easier than a large pile of growing media.

Each year since 1986, the Horning greenhouse has used methyl bromide fumigation to sterilize their containers after they were filled with growing media, resulting in the elimination of Douglas-fir dieback. Although the actual cause of the Douglas-fir dieback syndrome was never identified at the Horning container nursery, the success of the methyl bromide fumigation suggests that it was caused by a biological pathogen, probably a root fungus. Research in British Columbia has shown that Pythium ultimum, a minor root pathogen, was associated with this disorder in Canadian container nurseries (Husted 1988).

CURRENT FUMIGATION PROCEDURES AND RESULTS

The following paragraphs describe the fumigation procedures currently in use at the W.H. Horning greenhouse.

The containers are filled with peat-vermiculite growing media in the normal manner, transported to the empty greenhouse, moistened to normal germination water content, and placed on the raised benches. Another layer of empty container racks is placed on top of the filled containers to provide an air space (fig. 3). The drain hole in the concrete floor is sealed to avoid leakage before the entire group of benches is covered with a 6-mil plastic tarp; this operation requires four people to make sure that the tarp does not hang up or tear on the corners. The tarp is then sealed around the bottom by wetting the concrete floor and placing bags of growing media around the edges. The temperature of the growing media is allowed to warm to around 60 °F (16 °C) through solarization, or the greenhouse is heated if the weather is cool and cloudy. It is important to moisten and warm the growing media in the containers to stimulate disease organisms, and make them more susceptible to the fumigant. Other container nursery managers have reported poor results when the containers were fumigated under dry, cool conditions (Jopson 1989; Schaefer 1989).

Figure 3 - Containers filled with moist growing media are fumigated with methyl bromide/chloropicrin (98%:2%) in a warm greenhouse by injecting the fumigant under a sealed polyethylene tarp.

The Horning greenhouse currently contracts with a private pesticide applicator to apply the methyl bromide after the filled containers are situated under the fumigation tarp. The contract applicator uses a "hot shot" application technique where the methyl bromide is injected over heated coils to produce more efficient vaporization; this technique allows them to use a very low MBC-2 application rate of 0.0035 lb/ft^3 (0.056 kg/m^3). Fumigation is normally done on a Friday to allow an exposure period of at least 3 days over the weekend; Handreck and Black (1984) recommend an fumigant exposure period of 2 to 4 days whereas Bunt (1988) specifies 4 to 5 days.

On the following Tuesday, the greenhouse cooling fans are used to exhaust any fumigant that may have escaped through the tarp. Next, the greenhouse is checked with a Draeger methyl bromide detector to make sure that it is safe to enter, because the concentration of methyl bromide in a work area should not to exceed 5 ppm. If it is safe to proceed, the fumigation tarp is removed from the benches, starting at the end near the exhaust fans. It is important to allow an adequate aeration period because some ornamental plants are sensitive to even small amounts of bromide. Methyl bromide can be difficult to remove from organic material, and so a 4 to 10 day period is usually recommended (Bunt 1988; Handreck and Black 1984). To make certain that it is safe to sow the seedling crop, lettuce seeds are sown in a couple of containers and the germinants are observed for a few days. If there are no problems, the filled containers are sown and placed in the greenhouse to begin the germination period.

Table 3 - Chemical fumigation produced larger Douglas-fir container seedlings for 2 consecutive growing seasons at the W.H. Horning greenhouse

GROWING SEASON	FUMIGATION[1] TREATMENT	FINAL SEEDLING SIZE HEIGHT (cm)	CALIPER (mm)
1988	UNFUMIGATED	25.4	2.88
	FUMIGATED WITH MBC-2	29.7	3.32
1989	UNFUMIGATED	17.4	2.33
	FUMIGATED WITH MBC-2	24.9	3.04

1 = Containers filled with growing media were fumigated with methyl bromide/ chloropicrin (98%:2%)

Increased seedling growth due to fumigation

Even though Douglas-fir dieback has not been a problem in recent years, the Horning greehouse still realizes a benefit of methyl bromide fumigation of the containers and growing media. In fact, all the different conifer species produced at the nursery have been grown in fumigated growing media with good results. A control treatment of unfumigated containers is left each year to check on fumigation effectiveness, and the growth of these seedlings is monitored during the growing season. In each of the last 2 years, the seedlings in the non-fumigated containers were initially chlorotic and stunted compared to the treated population. Although the seedlings eventually attained normal color and appearance, they remained measurably smaller throughout the growing season. When seedling height and caliper measurements between the two groups was compared, the seedlings in the non-fumigated containers were consistently smaller than the seedlings in the fumigated containers (table 3). Although the difference in seedling height may not be great enough to affect production, the smaller calipers could produce serious economic consequences. Many of the unfumigated seedlings would have to be culled using a 0.12 in. (3 mm) minimum caliper, which is common for coastal Douglas-fir seedlings in this size of container.

The economics of fumigation

Under the current system using a professional applicator, fumigation costs for a crop of 430,000 seedlings in 10 in^3 (164 cm^3) containers was:

Labor	
Nursery set-up labor	$ 700
Contract fumigation	1,700
Materials	
Fumigant	$ 400
Tarp	200
Total Cost	$3,000

Cost of fumigation per thousand (M) seedlings =

$3,000/430M = $6.98/M

A benefit:cost (B:C) ratio can be computed by comparing the $3,000 fumigation cost to the estimated increase in seedling yield. Average seedling losses to Douglas-fir dieback were estimated to be 11%, or 47.3 M of a 430 M crop. Using an average value for reforestation seedlings, the benefit of fumigation can be calculated:

47.3 M seedlings X $150/M seedlings = $7,095

For the more valuable tree improvement seedlings, the economic benefit is even greater:

47.3 M seedlings X $500/M seedlings = $23,650

A comparison of these benefits to the above costs produced favorable B:C ratios:

for reforestation seedlings

$7,095:$3,000 = 2.4:1

for tree improvement stock

$23,650:$3,000 = 7.9:1

CONCLUSIONS AND RECOMMENDATIONS

The W.H. Horning tree improvement greenhouse plans on continuing to fumigate their containers and growing media with methyl bromide as long as an economic benefit can be realized. The fumigation procedure outlined in this paper has proven to be safe and easy to monitor, and is not considered to be hazardous to nursery workers or the environment.

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A Review of Soil Solar Heating in Western Forest Nurseries[1]

Diane M. Hildebrand[2]

Abstract.--Eleven studies at 10 western forest nurseries are summarized. In 8 studies, solar heating resulted in significant reductions in populations of soil-borne plant pathogens. Five out of 8 studies reported significant reductions in weeds. Three out of 5 studies reported an increased growth reponse in a tree seedling crop. The best results are expected for a tree seedling crop sown soon after the solar heating treatment.

INTRODUCTION

Solar heating of soil, a technique for preplant pest control, was reported in 1976 by Katan and others working in Israel. Solar heating or solarization of soil is accomplished by sealing clear polyethylene sheeting over moist soil for several weeks during the summer. Soil temperature under the polyethylene is raised 8-15°C above that of uncovered soil by the prevention of evaporation and by the greenhouse effect (Mahrer 1979). Continuous or repeated sub-lethal temperatures under moist conditions over long periods of time, either kill pathogens and weeds directly or weaken them so they cannot survive (Pullman et al., 1981). Volatiles released from decomposing organic matter are trapped under the polyethylene and may also play a role in mortality of pests (Zakaria et al., 1980).

Because of successes in agricultural crops (Katan 1981), and in the search for alternatives to fumigation, the solar heating technique has been evaluated at forest tree nurseries across the West. This paper attempts to summarize the results of the various experiments with solar heating in western nurseries. The author apologizes for any studies overlooked or misinterpreted.

SUMMARY OF RESULTS

Six studies reported only the effects of solar heating on pest populations (Table 1). In Placerville, California (38°40' latitude), populations of Fusarium were significantly reduced, while those of Macrophomina were not, after 5 weeks of solar heating. (McCain et al., 1982). In Paradise, California (39°40' latitude), weeds were reduced while Fusarium populations were not after 3 weeks of solar heating[3]. After 8 weeks of solar heating nursery soil at Fort Collins, Colorado (40°30' latitude), populations of Fusarium and Pythium remained significantly reduced through the following spring, while weeds returned to pretreatment levels by the following spring (Hildebrand 1987). In one study in Halsey, Nebraska (41°30' latitude), populations of Fusarium, weeds, and plant-parasitic nematodes were significantly reduced after 6 weeks of solar heating, but the fall-sown crop of eastern redcedar was lost due to an untimely frost (Hildebrand and Dinkel, 1988). In Washington, Oklahoma (35° latitude), weeds (except for yellow nutsedge) and populations of Pythium and Fusarium were significantly reduced while those of Macrophomina were not, after 8 weeks of solar heating (Miles 1988). In Boscobel, Wisconsin (43°10' latitude), pathogen populations were not reduced after 8.5 weeks of solar heating (Zarnstorff and Berbee, 1983).

Five studies reported data on treatment effects on a tree seedling crop (Table 1). In Davis, California (38°30' latitude), Agrobacterium populations were significantly reduced, and walnut and peach showed increased height and weight (Stapleton and DeVay, 1982). In Ames, Iowa (42° latitude), after 4 weeks of solar heating, weeds were reduced and pine seedlings (sown after winter fallow) showed inconsistent growth effects: half of the red pine attained greater seedling height and half of the white pine attained greater seedling weight (Croghan et al., 1984). In another study in Halsey, Nebraska (41°30' latitude), populations of Pythium and weeds returned to pretreatment levels the spring following 8 weeks of solar heating. In this Nebraska study, the lodgepole pine seedlings sown the following spring showed no benefit, but

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[1]Paper presented at the Intermountain Forest Nursery Assoc. Meeting, Bismarck, North Dakota, August 11-14, 1989.

[2]Diane M. Hildebrand, Plant Pathologist, USDA Forest Service, Rocky Mountain Region, Lakewood, Colo.

[3]Adams, David. 1989. Personal communication about results at Magalia State Nursery. Calif. Dept. Forestry, Davis, Calif.

Table 1.--Summary of results of 11 solar heating studies in western forest nurseries.

LOCATION	PATHOGENS REDUCED	WEEDS REDUCED	TREE SEEDLING GROWTH EFFECTS
Davis, CA	+	--	+
Paradise, CA	no	+	--
Placerville, CA	+	--	--
Fort Collins, CO	+	no	--
Ames, IA	no	+	+
Halsey, NE	+	no	no
Halsey, NE	+	+	--
Washington, OK	+	+	--
Bend, OR	+	no	no
Central Pt., OR	+	+	+
Boscobel, WI	no	--	--

+ = Positive effect; no = No effect;
-- = Not reported.

but the winter cover crop of oats sown after solar heating showed an increased growth response (Hildebrand 1987). At Bend, Oregon, (44° latitude), Fusarium populations were significantly reduced, while weed populations and growth of ponderosa pine seedlings (sown after winter fallow) were not affected by 4 weeks of solar heating (Cooley 1983). At Central Point, Oregon, (42°23' latitude), populations of weeds and Fusarium, but not of Pythium, were reduced significantly, and dry weight of Douglas-fir seedlings (sown after winter fallow) increased significantly after 6.5 weeks of solar heating (Cooley 1985).

Five of the studies also compared solar heating with chemical treatments (Table 2). Where MC-33 (67% methyl bromide and 33% chloropicrin) was used, fumigation consistently resulted in better seedling survival, but not always better weed control or seedling growth.

Temperature data varied between studies. Highest temperatures reported under the polyethylene were as follows: at Placerville, California, 56.2°C at 10 cm depth and 39.6°C at 20 cm (McCain et al., 1982); in Ames, Iowa, 51°C at 5 cm and 41.5°C at 15 cm (Croghan et al., 1984); at Bend, Oregon, 50+°C at 5 cm (Cooley 1983); in Boscobel, Wisconsin, 49°C at 5 cm and 41°C at 15 cm (Zarnstorff 1983); in Halsey, Nebraska, 46+°C (offscale on

Table 2.--Summary of comparisons between solar heating and chemical treatments for effects on pest populations and tree seedling growth.

Parameter	Bend, Oregon (1)	Central Point, Oregon (2)	Halsey, Nebraska (4)	Halsey, Nebraska (6)	Ames, Iowa (3)	
PEST POPULATIONS						
Pythium	--	M > S = C	M > S = C	--	--	
Fusarium	M > S > C	M > S > C	--	M > S ≥ PB > C ≥ WB	V > S = C	
Pathogenic Nematodes	--	--	--	M = PB = WB > S >> C	--	
Weeds	M > S > C	M = S > C	M > S > C	S ≥ M ≥ WB ≥ PB ≥ C	S > C	
SEEDLING DATA						
Survival	M > S = C	M > S = C	M > S = C	--	V = S = C	
Species	Ponderosa	Douglas-fir	Lodgepole	--	White pine	Red pine
Height	--	M = S = C	--	--	1/2: S ≥ V ≥ C 1/2: C = S = V	V = S > C V = S = C
Weight	--	M = S = C	--	--	1/2: V = S = C 1/2: S > C > V	V = S = C V = S = C
Root Length	--	M = S = C	--	--	--	
Caliper	--	M = S = C	--	--	--	

M = MC-33; V = Vorlex; PB = Basamid sealed with polyethylene; WB = Basamid sealed with water; S = Solar heating; C = Check; > = Better than; ≥ = Better than or equal to; -- = Not reported or populations too low to show a treatment effect.

thermograph) for 6 hours at 8 cm and 44°C for 4 hours at 15 cm (Hildebrand 1987); at Central Point, Oregon 43°C at 5 cm (Cooley 1985); and in Fort Collins, Colorado, 41+°C (offscale of thermograph) for 10 hours at 8 cm and 41+°C for 8 hours at 15 cm (Hildebrand 1987).

In 8 of the 11 studies reviewed, solar heating resulted in significant reductions in pathogen populations. Of 8 studies reporting effects on weeds, 5 showed significant reductions in weeds. Of 5 studies reporting seedling growth effects, 3 studies showed an increased growth response in a tree seedling crop; and none showed increased seedling survival. In conifers sown the spring following solar heating, the increased growth response was inconsistent or non-existent. The best growth response was in a crop sown in the fall after solar heating, as reported for the walnut and peach in California (Stapleton and DeVay, 1982) or in the winter cover crop of oats in Nebraska (Hildebrand 1987).

The solar heating technique works well with only a few weeks of polyethylene cover in hot climates like southern California and Israel for crops sown immediately after solar heating. Here in the western United States, even 8 weeks of polyethylene cover have not proven reliable for controlling pests and increasing growth and survival of conifer crops sown the spring after treatment. The best results would be attained for a fall-sown crop. The effects of solar heating on eastern redcedar sown in late August, 1989, are currently being tested in Nebraska.

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Soil Fumigation in Southern United States Forest Tree Nurseries[1]

C. E. Cordell[2]

Abstract.--Soils in bareroot forest tree nurseries in the Southern United States have been safely and efficiently fumigated for three decades. The primary target organisms are the soilborne pathogenic fungi that cause root rot and damping-off on both conifer and hardwood seedlings. A formulation of 67 percent methyl bromide and 33 percent chloropicrin has consistently provided the most effective control of these diseases. Methyl bromide is presently used in over 90 percent of the southern nurseries. Alternative soil treatments are urgently needed. Guidelines and precautions on fumigants, application methods, benefits and costs, and registration and safety are presented. Factors affecting soil fumigation results are emphasized.

Additional keywords: Soil fumigants, nursery treatments, guidelines, precautions, benefits, costs, registration, and safety.

Soils in southern forest tree nurseries have been routinely fumigated for the past three decades. In more recent years, these chemical soil treatments have been utilized in nurseries in the Northeastern, Central, North-Central and Western United States. Mixtures of methyl bromide and chloropicrin, dicloropropenes, ethylene bromide, vapam, vorlex, and dazomet have been utilized with varying degrees of success. However, the methyl bromide-chloropicrin formulations have consistently provided the most effective and efficient results (Cordell, 1983; Seymour and Cordell, 1979; Cordell and Kelley, 1985). The vast majority (90+ percent) of southern nurseries presently utilize methyl bromide (Boyer and South, 1984). Approximately 2,400 acres are treated annually at an estimated cost of $1.9 million. The methyl bromide- 67%; chloropicrin - 33% (MC-33) formulation is routinely utilized where difficult-to-control root disease organisms are known to occur and highly susceptible seedling hosts will be grown. Alternative soil treatments are urgently needed and several chemical and nonchemical treatments are being tested as suitable alternatives to methyl bromide.

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APPLICATION METHODS

The methyl bromide-chloropicrin (MBC) soil fumigants are most commonly applied beneath the soil with a chisel injector (Cordell and Kelley, 1985). This tractor-drawn machine is equipped with chisels not over 30 cm. (12 inches) apart and adjusted to inject the fumigant at the optimum depth of 20-25 cm. (8 to 10 inches). More recently, machines have been developed that permit fumigant injections at soil depths of 30 cm. (12 inches) or more where particularly damaging disease organisms threaten the production of deep-rooted hardwood species, such as yellow-poplar (*Liriodendron tulipifera* L.), black walnut (*Juglans nigra* L.), and sweetgum (*Liquidambar styraciflua* L.), and where fine-textured soils reduce fumigant penetration (Cordell, 1983).

MBC fumigants can be applied to the soil surface (Cordell, 1983). For soil surface applications, the fumigant is released from pressurized containers into evaporation pans located under polyethylene covers. The polyethylene covers are raised above the soil surface to permit horizontal gas movement across the treated area. This method is most suitable for fumigating small seedbeds, transplant beds, and other localized areas. Advantages of this method include the relative low cost of the equipment and simplicity of application. A primary disadvantage is the time required to treat large areas. Several times more nursery acreage can be fumigated per day with the mechanized soil-injection machines than with the labor-intensive surface applications.

MBC mixtures also are used to fumigate bulk soil mixes and mulch materials such as grain straw, pine needles, and bark chips (Cordell, 1983). The soil mixes are used for container-grown seedlings, while the various types of mulches are used on bareroot nursery seedbeds.

Fumigant dosage rates are based on the amount of active chemical ingredient needed per hectare or acre. Rates vary by chemical, target organism, application method, soil type and environmental conditions. To be effective, a fumigant must remain in contact with the target organism for sufficient time and in sufficient concentration to kill. Therefore, the fumigant dosage must take into account the chemical concentration needed per unit of soil volume and the exposure period. For bulk soil and mulch materials, MBC (MC-33 or MC-2) fumigant application rates are 0.56 kg/m^3 (1.0 $lb./yd^3$)(Cordell, 1983).

The fumigated soil or mulch material must be adequately covered or sealed to promote maximum fumigation effectiveness. The most effective cover is polyethylene with sufficient strength and thickness to minimize fumigant escape. The fumigation and tarping can be done on entire fields or on alternate strips (Fig. 1). Fumigation of entire fields minimizes the opportunity for contamination from adjacent nonfumigated strips. In addition, the fumigation time requirement for continuous tarping is considerably shorter than for strips. Thus, an earlier planting date following spring fumigation is possible and the probability of unfavorable weather interference is reduced. A major disadvantage of continuous tarping is that the large covers that are required are much more subject to wind damage than the smaller covers used in strip fumigation (Cordell and Kelley, 1985).

Soil can be fumigated either in the spring or the fall. In the fall, soil temperature and moisture conditions in the Southern United States are near optimum for fumigation, and treatment then fits better into nursery work schedules. Spring fumigation has the major advantage of being closer to seed sowing time. As a result, the probability of recontamination of treated seedbeds is reduced. Spring soil fumigation is also highly recommended when the seedbeds will be artificially inoculated with ectomycorrhizal fungi (Marx and others, 1984).

FUMIGATION GUIDELINES

Soil fumigants are broad spectrum biocides - they can kill most living things - and they are relatively expensive to purchase and apply. Consequently, it is highly desirable to apply a soil fumigant under conditions and using equipment and procedures that maximize safety and effectiveness (Table 1). Safety and effectiveness have been considered in formulating guidelines for soil fumigation in the Southern United States (Seymour and Cordell, 1979; Cordell, 1983; Cordell and Kelley, 1985).

Figure 1.--Solid tarping (above) and strip tarping (below) are two alternatives when fumigating with methyl bromide.

BENEFITS AND COSTS

Specific fumigants vary in their effectiveness against specific soil organisms. MC-33 has repeatedly and consistently provided the most effective control of soilborne pathogenic fungi such as Machrophomina phaseolina and Fusarium spp., the causes of charcoal and black root rot; Phytophthora spp. Phythium spp., the causes of damping-off and root rot diseases; and Cylindrocladium spp., the causes of cylindrocladium root rot (Cordell, 1983; Cordell and Kelley, 1985; Seymour and Cordell, 1979; Smith and Bega, 1966; Johnson and Bigelow, 1975). These organisms are the primary targets of soil fumigation in southern nurseries. MBC formulations have also provided effective control of nematodes, soil insects, certain weed seeds, and other soilborne pathogenic fungi (Hansbrough

Table 1. Suggested guidelines and precautions for effective soil fumigation.[1]

Soil fumigation factors	Guidelines and precautions
Soil preparation	Work into fine, loose, friable condition to minimum depth of 20 to 25 centimeters. Soil should be as free of clods as possible.
Organic matter	Do not use nondecayed organic matter. Organic matter can render fumigant ineffective and harbor fungi and nematodes. Cut or chop green organic matter into the soil a minimum of 3 to 4 weeks prior to fumigation.
Soil moisture	Soil moisture neither too high nor too low. Coarse-textured sandy soils - 75 percent field capacity[2/] Fine-textured clay soils - 25 to 50 percent field capacity
Soil temperature	Soil temperature above 10C at 15-centimeter depth. Air and soil temperatures not usually correlated.
Soil fumigants and target pests	Mixtures of 98% methyl bromide/2% chloropicrin fumigant; broad spectrum for nematodes, weeds, insects, and most soilborne fungi. Mixtures of 67% methyl bromide/33% chloropicrin fumigant; particularly effective against soilborne fungi with tough resistant stages.
Calibrating and monitoring soil fumigation equipment.	Fumigant dosage = concentration X time. Dosage determined by injector nozzle size, fumigant pressure, and tractor speed. Fumigant injected at minimum 20-centimeter soil depth. Deeper soil injections for deeper-rooted species. Maintain constant pressure, tractor speed, and fumigant flow through all nozzles for uniform, effective coverage.
Soil tarping	Apply clear polyethylene tarp with adequate strength and thickness immediately after fumigation for maximum effectiveness. Alternate strips require longer fumigation and time intervals and afford opportunity for contamination from adjacent nonfumigated soil strips. Solid tarping requires shorter fumigation time interval and minimizes opportunity for soil contamination. Repair and seal any holes and open glue joints immediately.
Fumigation exposure period	Consult fumigant label for recommendations. Minimum of 48 hours at soil temperature above 15C at 15-centimeter depth. At lower temperatures and during wet weather (following fumigation) double the exposure period.
Fumigation aeration period	Consult fumigant label for recommendations Minimum of 48-72 hours; varies with fumigant, soil, temperature, moisture, and crop to be planted. Double aeration period in wet weather or at temperatures below 15C.
Extended aeration for seedbeds receiving artificial inoculations of ectomycorrhizal fungi	Aerate soil at least 3 weeks following mixture of 67% methyl bromide/33% chloropicrin fumigation. This strong fumigant has extended residual toxicity to all soil fungi, including those which form mycorrhizae.
Contamination of fumigated soils	Avoid possible contamination by movement of soil, plants, mulches, etc., into fumigated areas. Clean, by steam or equivalent, all equipment: plows, bed shapers, tractor tires, etc. Avoid transplanting from nonfumigated soils.
Fumigation of mulch materials	Prefumigate mulch materials such as pine needles, straw, and bark with mixture of 67% methyl bromide/33% chloropicrin or mixture of 98% methyl bromide/33% chloropicrin formulations at a dosage rate of 0.59 kg/m^3. Tightly compacted or baled materials should be a maximum of 45 centimeters deep. Loose pine needles, straw, etc., may be 0.8 to 1.2 meters deep. Fumigation procedures and precautions (tarping, temperature, moisture, exposure, aeration periods, etc.) are same as for soil fumigation.
Soil nutrient alterations	Level of soluble salts and ammonia nitrogen may be increased due to decreased populations of nitrifying bacteria. Do not use ammonia fertilizers on plants requiring nitrates or those sensitive to ammonia. Apply only nitrate fertilizers until seedlings are established and soil temperature is above 20C. Base your fertilizer applications on <u>soil tests</u> made <u>after fumigation</u>.
Water requirements	Water requirements per unit of plant <u>production</u> are <u>generally less</u>. Water requirements per acre are increased due to generally larger plants and increased production.
Cover crops	Green manure cover crop plants such as corn, peas, sorghum, and soybeans are highly susceptible hosts for the charcoal and black root rot fungi. Grain crops such as millet, sudan, and rye are considered nonhosts.
Safety	The methyl bromide/chloropicrin formulations are highly toxic to animals (including humans) and plants. Handle fumigants with care and only by <u>certified competent personnel</u>. **ALWAYS READ FUMIGANT LABEL PRIOR TO USE AND FOLLOW ALL DIRECTIONS AND PRECAUTIONS CLOSELY.**

1/ Seymour, C. P. and Cordell, C. E. 1979. Control of charcoal root rot with methyl bromide in forest nurseries. Southern Journal of Applied Forestry. Vol. 3:3. p. 104-108.

2/ Water-holding capacity of the soil against the force of gravity.

and Hollis, 1957; Hodges, 1960; Clifford, 1951; Hill, 1955; Foster, 1961; Thomason, 1959). In the past, annual weeds were the primary target pests in southern nurseries. However, the recent development of equally effective and less expensive herbicides has resulted in major modifications in nursery pest control objectives (South and Gjerstad, 1980). Soil fumigation with MBC formulations has also consistently improved seedling quality and reduced cull factors in nurseries (Clifford, 1963; Hodges, 1960; Rowan, 1971; Seymour and Cordell, 1979). Soil fumigation with MBC-2 in a Louisiana experimental nursery almost doubled the production of plantable seedlings and resulted in corresponding significant increases in seedling quality (Hansbrough and Hollis, 1957). Variable effects have been observed on nontarget organisms and other related soil factors (Foster, 1961, Hacskaylo and Palmer, 1957; Kelley and Rodriguez-Kabana, 1979). For example, the beneficial ectomycorrhizal fungi are usually only temporarily decreased, even after spring soil fumigation (Marx and others, 1984).

The present cost of soil fumigation in southern nurseries ranges between $2,000 and $2,500 per hectare ($800 and $1,000 per acre). The cost varies with the fumigant type and formulation, dosage rate, soil cover type and thickness, acreage fumigated, and whether the fumigant is commercially or privately applied. Based on the present average southern pine seedling production of 1.85 million seedlings per hectare (750,000 seedlings per acre), this cost ranges between $1.07 and $1.33 per thousand seedlings. Assuming an average pine seedling value of $30.00 per thousand, the present cost of fumigation is less than 5 percent of the seedling value.

REGISTRATION AND SAFETY

The chemical fumigants mentioned previously are specifically registered by the U.S. Environmental Protection Agency (EPA) as preplanting soil fumigants for the control of a variety of soil fungi, nematodes, insects, broadleaf weeds, and grasses in forest tree nurseries. Although most of these fumigants are highly toxic to humans, animals, and plants, they can be as safely employed as any other chemical pesticide by considering their potential toxicity and taking appropriate precautions.

The pesticide label for the specific fumigant type and formulation to be used should be read and understood prior to use. All handling and application directions and safety precautions should be closely followed. The fumigant must be applied only by nursery personnel who are certified by the respective State pesticide regulatory agency. Recommended protective equipment should always be utilized as directed.

Remember, fumigants such as MBC formulations are listed as restricted use pesticides by EPA. That designation means that use of them is restricted to the conditions, concentrations, and applications specified by EPA and listed on the pesticide label.

DISCUSSION AND CONCLUSIONS

When the cost of soil fumigation is compared with the benefits from its use, it becomes apparent that this practice is economically justified in southern nurseries. This is particularly apparent where damaging soilborne root diseases and susceptible seedling host species occur. Charcoal root rot caused the loss of approximately 16.5 million saleable seedlings of five species of southern pines in a Florida nursery in 1976 (Seymour and Cordell, 1979). Benefit/cost analyses in an Alabama State Nursery showed that soil fumigation with MBC was economically justified when seedling root disease caused a loss of 1.8 percent or more of the saleable pine seedlings (Kucera, 1981). Also, these benefits have been extended to the outplanting site, where increased survival and more rapid early growth have been observed on seedlings from fumigated nursery beds (Foster, 1961).

Effective, efficient, and safe soil fumigation has been repeatedly obtained with the techniques and procedures previously described. MC-33 has been most effective for controlling soilborne, fungus-caused diseases such as root rots which are the most damaging pests in southern nurseries. However, alternative soil treatments are urgently needed for the intensively utilized MBC fumigants. Withdrawl of these formulations from the current EPA pesticide registration list for nursery fumigation would severely limit the quantity and quality of seedling production in southern nurseries.

An alternative chemical fumigant, metam sodium (vapam, 33% a.i.) has possible applications in U.S. nurseries. It has proven effective in Israel for control of soil pathogenic fungi (Ben-Yephet and others, 1988; Widin and Kennedy, 1983). Application methods include broadcasting vapam granules and mixing them into the soil, drenching the soil with a liquid formulation, and application through the nursery irrigation system.

Recently, a soil solarization technique has been developed and perfected in Israel to control soil pathogens (Katan and others 1976). This technique has been independently tested with variable success in several countries (Horiuchi, 1984; Katan and others, 1976; Stapleton and DeVay, 1986). Soil solarization is a rather simple technique that involves covering wet soil with clear plastic covers to create a greenhouse effect with the natural sunlight for a period of 4 to 6 weeks during the hottest months of the year. This procedure raises the soil temperature high enough (40 to 50 C) to significantly reduce the populations of undesirable soil organisms. Two primary factors affecting the success of the technique are high soil temperatures and adequate moisture (Horiuchi, 1984). Solarization has failed to control certain soil pathogenic fungi, such as the charcoal or black root rot fungi which have relatively high temperature tolerances ($\geq$ 50C) (Mihail and Alcorn, 1984; Stapleton and DeVay, 1986; English, Mitchell, and Barnard, 1982). Effective results have been obtained with a combination of solarization and chemicals where the efficacy of the chemical was increased at the higher soil temperatures (Ben-Yephet and others, 1988).

MC-33 soil fumigation or its equivalent is presently considered mandatory in southern nurseries where susceptible seedling hosts and root rot disease fungi occur in combination. The previously described potential pest threats without fumigation, along with the consistent benefits derived from its use, clearly demonstrate the biological and economical advantages of this practice. It helps to ensure the sustained production of high-quality seedlings with improved survival and growth capabilites for field plantings. Consistently effective results can be obtained by considering the target organisms and the nursery environment when selecting and applying a soil fumigant.

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Use of VA Mycorrhizal Innoculum to Improve Growth of Forest Tree Seedlings in Fumigated Soil[1]

Tim Wood, Libby Nance, Steve Jedrzejek, and Greg Johnson[2]

Inoculation of fumigated nursery soils with VA mycorrhizal fungi improved the growth and quality of Russian olive, Sierra redwood, incense cedar and western red cedar seedlings in two West Coast forest nurseries. Experiments were used to identify superior fungal strains for use on acid, low-phosphorus soils. Commercial VA mycorrhizal inoculants, based on these strains, are under development.

INTRODUCTION

Forest nursery soils are often fumigated with methyl bromide to promote production of disease-free seedlings. Methyl bromide is a general biocide, and in addition to killing soil-borne pathogens, it eliminates beneficial vesicular-arbuscular (VA) mycorrhizal fungi. VA mycorrhizal fungi form symbiotic associations with the roots of some forest tree species (most notably redwoods, cedars, junipers and many broadleaf species), and they aid those plants in uptake of nutrients. Elimination of these fungi via fumigation can lead to plant nutrient deficiencies, stunting and crop loss, particularly on low-phosphorus and/or phosphorus-fixing soils.

The studies reported here compare the efficacies of several VA mycorrhizal fungi in promoting the growth and quality of tree seedlings on fumigated soils in two West Coast forest nurseries.

METHODS AND MATERIALS

In the spring of 1988, field trials were established at the California Department of Forestry nursery at Magalia, CA, and at the D.L. Phipps State Forest Nursery at Elkton, OR.[3] The soils at Magalia were acid clay loams (pH 5.0-5.3). They showed significant phosphorus (P) fixation capacities, and contained low levels of water extractable P (0.2 µg P/g soil as measured in 1:10 soil:water extracts). Elkton soils were acid sandy loams (pH 4.7-4.8). They showed moderate P fixation capacities, and contained variable levels of water soluble P (1.2-5.0 µg P/g soil).

Cultural practices and experimental procedures used at the two nurseries were similar. Seven months prior to the field tests, soils were fumigated with methyl bromide - chloropicrin mixtures at 393 kg/ha. In March, 1988, prior to seeding, ground was power harrowed and beds (1.2 m wide) were shaped. Beds were then measured off to delineate meter-long inoculuation plots separated by 3-4 m non-inoculated buffers. Plots were laid out in complete randomized blocks with 4-5 repetitions per tree species x inoculation treatment.

Three strains of VA mycorrhizal fungi were chosen for the field tests at each nursery. Selections were based on superior performance in greenhouse trials involving acid soils. Inoculants consisted of colonized root fragments and fungal spores in a moist sand carrier. Each treatment plot was inoculated by incorporating 750 g of this material uniformly into the upper 15-20 cm of the soil. Non-inoculated control plots received 750 g of sand carrier only.

Following inoculation, beds were seeded using an eight-row seed drill. Russian olive (*Elaeagnus angustifolia*), Sierra redwood (*Sequoia gigantea*) and incense cedar (*Calocedrus decurrens*) were sown at Magalia. Sierra redwood, incense cedar and western red cedar (*Thuja plicata*) were sown at the Elkton nursery. Seedlings were grown using cultural practices standard to the two nurseries.

In April, 1989, the seedlings were harvested. Thirty plants from each plot were selected at random and were measured to determine height and caliper. In addition, 50 seedlings of each species were subjected to dimension analysis. Equations for estimating seedling dry weight and seedling root volume from caliper measurements were developed. For all species, regression equations took the form:

$$\text{dry weight or root volume} = m\ (\text{caliper}^{2.5})$$

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3. The authors would like to acknowledge the assistance of Bill Krelle and David Pilz who oversaw site preparation and maintenance of the trials at the CDF and D.L Phipps nurseries respectively.

In all instances, correlation coefficients for these regression equations ranged from 0.80 to 0.98. Seedling dry weights and root volumes were then estimated for the 30 seedlings in each field plot using caliper data. Finally, for each tree species x inoculation treatment, means and standard deviations for seedling height, caliper, estimated dry weight and estimated root volume were calculated. Analyses of variance were run, and signifcant differences between inoculation treatments were determined using Tukey's *w* procedure, $p \leq 0.05$.

RESULTS

Inoculation of fumigated nursery soils with VA mycorrhizal fungi generally improved the growth of the tree seedlings tested. Importantly, there were significant differences in efficacy between fungal strains. Sample results are given in Tables 1 and 2.

Table 1: 1988 VAMF Strain selection trial with one-year Russin olive (E. angustifolia) seedlings. California Department of Forestry Nursery Magalia, Ca.

VAMF Strain No.	Seedling Height (cm)	Seedling Caliper (mm)
25	26.9±6.7[b]	2.8±0.6[b]
60	22.1±5.0[b]	2.6±0.3[b]
31	9.6±4.8[a]	1.4±0.4[a]
Control	9.0±3.8[a]	1.4±0.5[a]

VAMF Strain No.	Est. Seedling Dry weight (g)	Est. Seedling Root volume (ml)
25	3.0±1.3[b]	5.2±2.3[b]
60	2.1±0.5[ab]	3.6±0.9[ab]
31	0.6±0.4[a]	1.0±0.7[a]
Control	0.8±0.9[a]	1.3±1.5[a]

Mean separation within colums by Tukey's *W*-procedure ($p \leq 0.05$)

At the Magalia nursery, Strain 25, a Glomus intraradices isolate adapted to acid soils, proved to be superior. When applied to beds of Russian olive, it increased seedlings height growth three-fold, caliper growth two-fold, and estimated seedling dry weight and root volume more than three-fold (Table 1). Strain 60 also improved the growth of Russian olive. Seedlings inoculated with Strain 31 showed no improvements over non-inoculated controls. Similar responses to inoculation were observed with Sierra redwood and incense cedar at the Magalia nursery, and in each case, Isolate 25 was the superior inoculant.

VA mycorrhiza inoculation also improved seedling growth at the Elkton nursery, and again Isolate 25 was superior. In comparison to non-inoculated controls, incense cedar seedlings showed two-fold increases in height and caliper, and five-fold increases in estimated seedling dry weight and root volume when inoculated with this strain (Table 2). Isolates 31 and 54 also improved seedlings growth, but increases were only about half as large as those found with Strain 25. Similar responses to inoculation were found with Sierra redwood and with western red cedar at Elkton, and again, in each case, Isolate 25 produced superior seedling growth.

Table 2: 1988 VAMF Strain selection trial with one-year incense cedar (C. decurrens) seedlings. D.L Phipps State Forest Nursery Elkton, Or.

VAMF Strain No.	Seedling Height (cm)	Seedling Caliper (mm)
25	31.7±0.9[c]	4.5±0.6[c]
54	24.5±2.5[b]	3.4±0.7[b]
31	21.2±4.0[b]	3.2±1.0[b]
Control	14.6±3.8[a]	2.2±0.5[a]

VAMF Strain No.	Est. Seedling Dry weight (g)	Est. Seedling Root volume (ml)
25	3.9±1.5[c]	2.0±0.7[c]
54	2.2±1.1[b]	1.1±0.6[b]
31	2.0±1.6[ab]	1.0±0.8[ab]
Control	0.7±0.3[a]	0.4±0.2[a]

Mean separation within colums by Tukey's *W*-procedure ($p \leq 0.05$)

DISCUSSION AND CONCLUSIONS

Inoculation of fumigated nursery soils with VA mycorrhizal fungi significantly improved the growth of Russian olive, Sierra redwood, incense cedar and western red cedar in two West Coast forest nurseries. Several strains of fungi were compared, and in both nurseries and with all tree species tested, one isolate, a Glomus intraradices strain, was most efficaceous. This fungus gave two-to-five-fold increases in seedling height, caliper, dry weight and root volume over non-inoculated control plants. Of the other isolates tested, some gave intermediate responses, and some yielded no improvements in seedling growth.

These results underscore the importance of strain selection in the development and use of mycorrhizal inoculants. The VA mycorrhizal fungi tested in this study showed little if any host specificity in the sense that a single isolate gave the superior growth responses across all three species tested. However, in testing more than 100 strains in greenhouse experiments, we have found these fungi to be specific to soil type, and in particular to soil pH. Some strains work well in neutral-to-basic soils (pH 6.5 and above), while others, like Strain 25 in this study, give superior plant growth on acid soils below pH 5.5. In all cases, inoculation with VA mycorrhizal fungi is most efficaceous when soils have low levels of available phosphorus and/or significant phosphorus fixation capacities. Commercial VA mycorrhizal inoculants comprising the superior fungi indentified in these studies, are now being developed for use in forest nurseries.

Variable Seed Dormancy in Rocky Mountain Juniper[1]

W. J. Rietveld[2]

Abstract.-- Rocky Mountain juniper is difficult to grow in the nursery due to variable seed dormancy that spreads germination over time. In two experiments, six seed sources, five seed treatments, and 15 stratification treatments were tested. Although there were some seed source and stratification treatment differences, none of the treatments effectively enhanced germination amount or timing enough to be useful in nursery culture.

INTRODUCTION

Rocky Mountain juniper (Juniperus scopulorum Sarg.) (RMJ) is widely planted for windbreaks and wildlife habitat in the Great Plains. The popularity and importance of this species resides in its cold hardiness, tolerance to drought, and relative freedom from insect and disease problems. In a windbreak, junipers provide a dense barrier throughout the year, resulting in excellent wind protection and snow control.

Despite its popularity, RMJ is difficult to grow in the nursery. Variable seed dormancy, and consequent low and variable germination are the underlying causes of these problems. The degree of seed dormancy varies by seed crop, seed source, seed age, and probably among and within individual trees (Van Haverbeke and Comer 1985, Young et al. 1988). Berries persist on the tree for 2-3 years, so a single collection could contain berries of varying age, including immature berries (Johnson and Alexander 1974). While seed dormancy is an ecologically important device to optimize the distribution of the species in time and space, it is an obstacle in nursery culture where prompt, uniform, and complete germination is required in order to grow high quality planting stock.

Juniper seed has both seed coat and chemical dormancy (Gerbracht 1937, Pack 1921). The seeds have a thick, semi-permeable seed coat that must be conditioned to imbibe water. Efforts to increase the permeability of the seed coat of juniper seeds have included depulping (Afanasiev and Cress 1942); soaking seeds in sodium-lye (Webster and Ratliffe 1942), alcohol or boiling water (Chadwick 1946), concentrated sulfuric acid (Barton 1951), citric acid (Cotruto 1963, Van Haverbeke and Comer 1985), and hydrogen peroxide (Trappe 1961, Riffle and Springfield 1968); and freezing seeds in ice (Jelley 1937).

Although the usual method to overcome embryo dormancy of juniper seeds is classical cool/moist stratification for conifer seeds, stratification should not be restricted to cool temperatures. Van Haverbeke and Comer (1985) found that germination of eastern redcedar (Juniperus virginiana L.) seeds is enhanced by a combination of warm/moist stratification (75° F. for 6 weeks) followed by cool/moist stratification (41° F for 10 weeks).

The recommended stratification treatment for RMJ is warm/moist (68° F night/86° F day) for 45-90 days, followed by cool/moist (41° F) for 30-120 days to induce germination (Johnson and Alexander 1974). This procedure is generally followed in Great Plains tree nurseries. A typical procedure is stratification for 60-240 days, sowing in mid- to late-summer, mulching the seedbeds, and keeping them moist through the fall. Germination occurs the following spring when temperatures reach 50° F (Benson 1976). Individual nurseries differ in the type of stratification used, sowing date, and type of mulch used.

Having said all this, I would like to quickly point out that the actual success of applying all of these techniques to germinate RMJ seed has been minimal, typically 20-50% germination. Consequently, seed germination of RMJ is identified as being one of the highest priority problems in Great Plains nurseries. In response to a request for research assistance, the Rocky

[1] Paper presented at the Intermountain Nursery Association meeting [Bismarck, ND August 14-18, 1989].

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Mountain Station contracted research on "Development of pre-germination treatments to best achieve predictable and uniform germination of Juniperus scopulorum in the shortest time" with SWCA, Inc. in Flagstaff, AZ. This paper reports the results of that research.

MATERIALS AND METHODS

The study consisted of two experiments conducted in 1987-88 and 1988-89, which will be presented separately.

Experiment 1

The experiment tested three seed sources, five seed scarification treatments, and six stratification treatments. Mature berries were collected in late October, 1987 from 10-20 trees in Coconino County, AZ, elevation 6840'; Iron County, UT, elevation 6400'; and in Cassia County, ID, elevation 6100'. The locations represented a general north-south transect, well west of the range of Junipers virginiana to avoid any intermixing. Within 30 days of collection, seeds were depulped, floated, and soaked in isopropyl alcohol to remove residues. The seeds were temporarily stored at 50° F and 10% RH until early December.

The seed scarification treatments consisted of: (1) none, (2) seeds dropped in boiling water, then removed immediately from the heat and allowed to stand 24 hrs; (3) seeds soaked in concentrated sulfuric acid for 0.5 hr; (4) seeds soaked in 1% citric acid for 96 hours; and (5) seeds soaked in 30% hydrogen peroxide for 0.5 hr. Following chemical treatments, seeds were stratified in 4-mil zip-lock bags in a 1:1 peat/vermiculte medium that was fully dampened and treated with a fungicide to prevent molding. Stratification treatments (fig. 1) were combinations of warm/moist (86° F 8 hrs, 68° F 16 hrs) and/or cool/moist (38-41° F). Treatments began on December 8, 1987, and germination tests were completed on July 6, 1988.

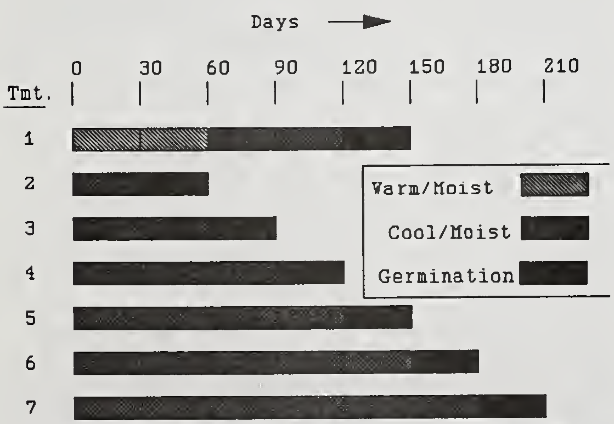

Figure 1. Stratification treatments and schedule for Experiment 1.

When stratification treatments ended the seeds were germinated in flats of 1:1:1 peat/vermiculite/perlite in a greenhouse. Each treatment combination was represented by 100 seeds; there was no replication of treatments. The flats were watered 3-4 times a week. Germination was checked daily for 30 days. Greenhouse temperatures during germination tests differed because of the varying duration of the stratification treatments:

	Jan	Feb	Mar	Apr	May	Jun
Avg.	54	56	60	60	64	69
Max.	67	70	75	74	79	78
Min.	38	45	45	45	51	61
Regime	2	3	4	1,5	6	7

Greenhouse temperature averaged 54-60° F during germination tests for treatments 1-5, and 64-69° F for treatments 6-7.

Experiment 2

The experiment tested four seed sources and eight stratification treatments. All seed was collected in fall, 1988. Seed from three sources was obtained from Great Plains tree nurseries, and the fourth was locally-collected by the contractor. They were: (1) Saguache County, CO, elevation 8500'(obtained from the CO State Nursery); (2) seed zone 600, Meade County, SD (obtained from Big Sioux nursery); (3) Cheyenne River, SD (obtained from USFS Bessey nursery; and (4) Coconino County, AZ, elevation 7000' (locally collected).

Other than depulping and lye-soaking the seed to remove residues, there were no seed scarification treatments in Experiment 2. The stratification treatments (fig. 2) consisted of combinations of warm/moist and cool/moist at the temperatures listed for Experiment 1, and freezing treatments at 5-10° F. Stratification treatments began on December 23, 1988 and germination tests were completed on July 24, 1989.

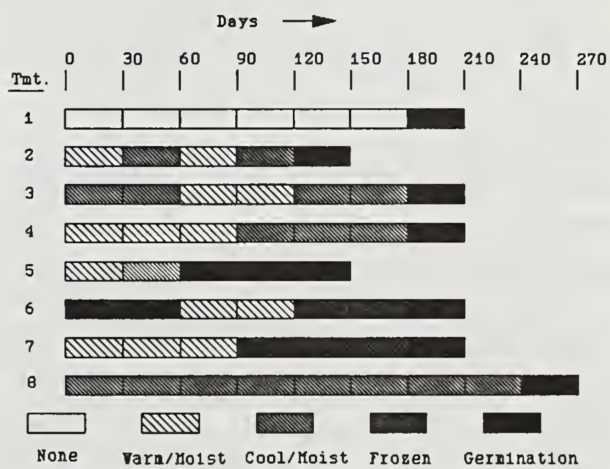

Figure 2. Stratification treatments and schedule for Experiment 2.

Seeds were germinated in the same medium and location as in Experiment 1. Each treatment combination was represented by five flats of 100 seeds. Germination temperatures were 71.5° F for stratification treatments 1-7 and 66.6° F for treatment 8.

RESULTS

Seed germination in Experiment 1 was very low; most treatment combinations had zero germination during the 30-day germination test. The only treatment that resulted in any seed germination was the combination of no seed scarification and warm/moist 60 days + cool/moist 60 days (stratification regime 1). Seed germination was 10%, 1%, and 3% for the Arizona, Utah, and Idaho sources, respectively.

In Experiment 2, samples of the seed were sent to the USFS National Tree Seed Laboratory for viability testing (tetrazolium method) before the stratification treatments were begun. Average percent viability was 70, 57, 82, and 71 for seed obtained from the Colorado State Nursery, Big Sioux Nursery, Bessey Nursery, and locally collected near Flagstaff, Arizona, respectively. Analysis of Variance of germination data and application of Tukey's Studentized Range Test revealed significant differences by seed source and stratification treatments. Treatment effects were the same using percentage germination data based on all seeds or viable seeds. For consistency with Experiment 1, germination data presented are based on all seeds tested.

Effect of seed source

Seed collected in Arizona had significantly lower germination rates than did seeds provided by the Bessey Nursery and Colorado State Nursery (Fig. 3). Germination of Arizona seeds was lower, but not significantly lower, than Big Sioux Nursery seeds. Big Sioux seeds, while lower in germination, were not significantly different from Bessey and Colorado State Nurseries.

Effects of stratification treatment

Stratification treatments 2-8 were not significantly different from the control (treatment 1) (Fig. 4). The lowest germination rate was from treatment 5. The highest germination rate was recorded for treatment 3; this stratification treatment was significantly different from all other stratification treatments.

Seed Source	% Germination	Significance
Bessey Nursery	2.8	
Colo. St. Nursery	2.6	
Big Sioux Nursery	1.8	
Arizona	0.7	

Figure 3. Percent germination by seed source for Experiment 2.

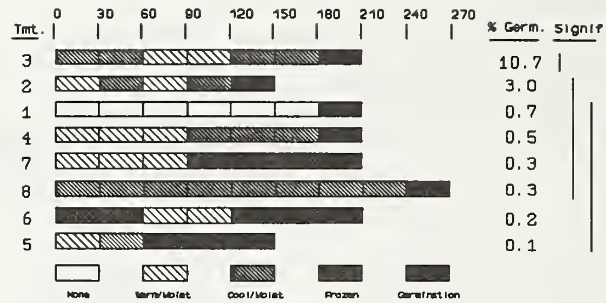

Figure 4. Percent germination by stratification treatment for Experiment 2.

Overall, the highest germination rates were recorded for Bessey Nursery seed (2.8%), and stratification treatment 3 (10.7%).

DISCUSSION

Seed germination was unexpectedly low in both experiments. In Experiment 1, the highest germination (10%) was attained for Arizona seed in stratification treatment 1 (warm/moist 60 days followed by cool/moist 60 days). In Experiment 2, the highest germination (18.6%) was attained for Bessey Nursery seed in stratification treatment 3 (cool/moist 60 days, followed by warm/moist 60 days, followed by cool/moist 60 days). Thus, the pattern was not consistent. Experiment 2 contained three stratification treatments with freezing treatments, which were intended to simulate a cycle of warm and cold seasons, but the resulting germination of seeds subjected to treatments including freezing ranked lowest in the experiment.

The low germination rates in both experiments suggests that some confounding factor was involved. Possible sources of the problem are: (1) collection of immature seed, (2) stratification of seed in plastic bags may have restricted air exchange, and (3) higher germination temperatures may have retarded germination. Collection of immature seed can probably be ruled out since seed obtained from three nurseries in Experiment 2 also had low germination. Restricted aeration from stratification in plastic bags can also be ruled out because 4-mil plastic is sufficiently thin to allow gas exchange (Bonner,1971). However, restricted aeration due to the impermeable seedcoat may be an important factor limiting the effectiveness of stratification, as discussed later. The most likely confounding factor in the experiments is high temperature inhibition of seed germination. Juniper seeds germinate best at 50-55° F, and germination is retarded above 65-70° F (Chadwick 1946, Meines 1965, Wycoff 1961). However, none of these authors specified whether these were average temperatures, or if the inhibition occurs when daily highs exceed 70° F. Average germination temperatures in Experiment 1 were generally favorable through May, however high temperatues exceeded 70° F as early as February.

In summarizing the results of 10 years of research to enhance seed germination of Utah juniper (Junipers osteosperma (Torr.) Little) and western juniper (J. occidentalis subsp. occidentalis Hook.), Young et al. (1988) reported 10 to 37% germination achievable through various stratification treatments. Variations in substrate, moisture content of substrates, or temperature were generally not effective in enhancing germination. An alternative method of stratification that enhanced germination was prolonged immersion in refrigerated (41° F) water baths where oxygen was kept near saturation in the water by actively bubbling compressed air into the bath. This treatment for 12-14 weeks brought germination up to 43 to 58%. Germination was not enhanced by prolonged soaking in nonaerated refrigerated water. Germination was further enhanced to 64 to 84% by addition of 0.284 m mol L^{-1} of Gibberellic acid to the oxygenated cool water baths. These results suggest that the key factors required to accomplish enhanced germination of juniper seed include: (1) time, because of the restricted permeability of the seed coat and slowness of the processes involved; (2) oxygenation; and (3) a growth promoter.

There are two concepts of seed dormancy that pertain to junipers. A brief discussion of these will assist in understanding the complexity of the problems. The hormone interaction model (Kahn 1975) asserts that dormancy or germination results from the balance among gibberellic acid (GA), cytokinins (CK), and an inhibitor (presumably abscisic acid, ABA). The model assumes that GA is a primary hormone that induces germinative enzymatic processes, and CK and ABA are secondary competitive factors. Cytokinins oppose (i.e. neutralize) the inhibitory effects of ABA. The hormonal balance changes during the after-ripening process, and eventually leads to a condition that allows germination. This may include: (1) the disappearance of ABA, or (2) synthesis of GA and/or CK. The model allows that seeds can be either dormant or capable of germination under several alternative hormonal conditions, for example:

#	GA vs.	CK vs.	ABA --->	Dorm. vs.	Germ.
1	+	+	+		x
2	+	+	-		x
3	+	-	+	x	
4	+	-	-		x
5	-	-	-	x	
6	-	-	+	x	
7	-	+	-	x	
8	-	+	+	x	

This model helps explain many of the anomalous hormonal situations in seeds, e.g. (1) dormancy without the presence of inhibitors (#5,#7), (2) germination in the presence of high levels of inhibitors (#1), and (3) dormancy in spite of high levels of GA or CK (#3,#7,#8). The response to the GA treatments by Young et al. (1988) could have been due to the existence of situations #7 or #8, resulting in germination as in situation #2 or #1, respectively. Their results also suggest that considerable time may be required for the changes to occur.

A second concept of seed dormancy pertaining to junipers is shifts in oxidative pathways (Roberts 1973). The change from dormant to germinating seeds is often accompanied by an increased functioning of the pentose-phosphate pathway of glucose use, an important pathway of respiratory metabolism in seeds. The model asserts that dormancy is caused by the enzyme catalase which causes the destruction of metabolically-derived hydrogen peroxide needed for the oxidation of $NADPH^{+}$. Dormancy release, resulting from the oxidative inactivation of catalase, would allow the respiratory pathway to function at an accelerated level. The results of Young et al. (1988) could also be explained by this model. The seed coat may restrict the entry of oxygen into the seed; but with high oxygen concentrations, sufficient oxygenation may occur over time to inactivate catalase. Once germination begins, the gibberellic acid is needed for germinative enzymatic processes, e.g. synthesis of hydrolytic enzymes which mobilize stored substrates.

Evidence to date does not support this model, but further investigation is clearly needed. Several investigators (e.g. Hendricks and Taylorson 1975) have reported that compounds such as nitrites and thiourea that inhibit catalase activity are effective in releasing seed dormancy in certain species. Bonner et al. (personal communication) have tested thiourea at 1% and 2% concentrations, with and without added cytokinin, on eastern redcedar seeds, and found that the treatments reduced germination. The concentrations applied were quite high, however, and likely caused germination inhibition from the thiourea. Hendricks and Taylorson (1975) found thiourea concentrations greater than 20 mM were inhibitory, and cautioned against using high concentrations for short periods of time.

A study on changes within the seeds of RMJ during the processes of after-ripening and germination (Afanasiev and Cress 1942) also introduces some uncertainty about the catalase-dormancy model. During stratification at low temperatures they found: (1) a slight increase in peroxidase content, (2) appearance of oxidase, and (3) an increase in catalase activity. During germination, the activity of oxidizing enzymes increased markedly. The increase in catalase activity associated with the completion of after-ripening and germination is the opposite of that asserted by the catalase-dormancy model, but the increase in activity of oxidizing enzymes is consistent.

CONCLUSIONS

Although there were some seed source and stratification treatment effects in Experiment 2, none of the treatments tested in this study effectively enhanced germination amount or timing to be useful in nursery culture.

Virtually every treatment known to seed technology has been tried with seeds of various species of junipers. The majority of experimentation, including the present study, has focused on seed scarification treatments and stratification treatments, with minimal success. What is truly needed is basic research to understand the physiological and biochemical mechanisms responsible for the dormancy. Then we will have the basis to develop treatments to achieve prompt and uniform germination.

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Seed Set and Germination of Eldarica Pine Influenced by Cone Hierarchy[1]

John T. Harrington, John G. Mexal, and James T. Fisher[2]

Abstract.-- Tree and cone hierarchy effects on eldarica pine seed quantity and quality are examined. Hierarchy, or location of cone whorl on a branch, and tree significantly influenced total number of seed/cone, number of viable seed/cone and percent viable seed. Whorl 2 cones, the distal whorl, had 54% more seed/cone and a 65% greater percent viable seed. Percent germination, total germination, G_{50} and number of cones/whorl were not effected by either tree or hierarchy. Relationships between total number of seed/cone and number of seed germinating/cone and percent germination are provided. Potential causes for hierarchal effects are discussed.

INTRODUCTION

Eldarica pine (*Pinus eldarica* Medw. (= *P. brutia* subsp. eldarica)) is a member of the *Pinus brutia* group of mediterranean pines (Spencer 1985). The only naturally regenerating population of eldarica pine occurs from 200 - 600 meters elevation in the semi-arid steppe region in the Russian republic of Georgia (Zimina 1978, Mirov 1967 as cited by Spencer 1985). This species, however, has been introduced to numerous countries in Europe, the middle east and Asia, as well as the United States and Australia (Fisher 1985). Eldarica pine was first introduced to the United States in 1961 in southern California (Spencer 1985).

Eldarica pine is used for Christmas and ornamental trees, and in windbreaks throughout its potential range (fig. 1). Eldarica pine can tolerate alkaline soils (Fisher 1985), high levels of salinity (Manuchia 1986) and demonstrates growth rates comparable to *Pinus radiata* and *Pinus caribaea* when well watered (Fisher et al. 1986). Eldarica pine's polycyclic growth habit and deep root system allow it to fully utilize the long growing seasons and deep soil moisture reserves found in regions of the southwestern United States. Furthermore, tests on the wood properties of eldarica pine indicate it has potential for manufactured wood, paper pulp and fuelwood production (Fisher 1985).

Figure 1.--Potential distribution of eldarica pine in the United States (Fisher 1985).

Russia, Iran, Afghanistan and Pakistan are the leading growers of eldarica pine worldwide. Because of international relations with these countries and the lack of a worldwide seed certification program for eldarica pine, obtaining seed can be time consuming, difficult and expensive. While seed companies in the United States sell eldarica pine seed, seed costs and quality vary dramatically. Costs incurred by local (Las Cruces, NM) nurserymen in 1989 ranged from \$110 to \$310 per kilogram (\$50 to 140/lb) and seed germination varied from 30 to 60% following float sorting of the seed.

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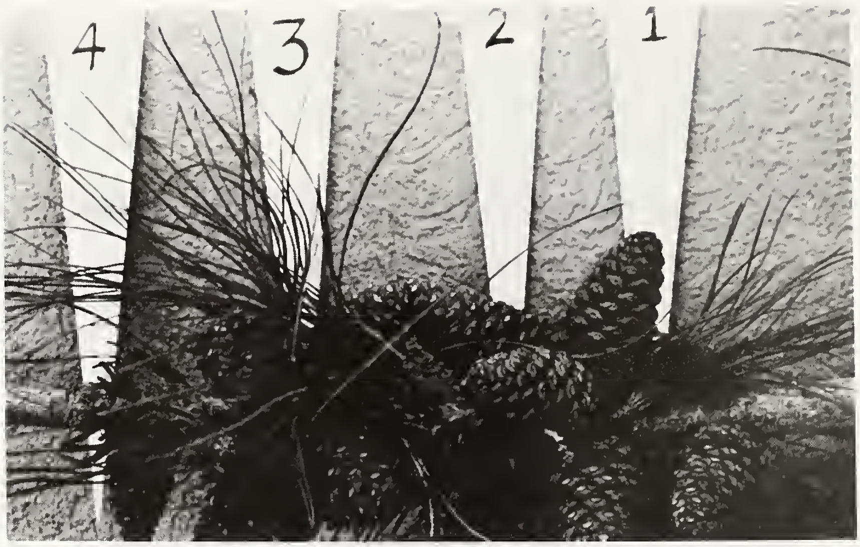

Figure 2.-- Photograph of 4 cone whorls produced on an 17 year-old eldarica pine branch growing in Las Cruces, New Mexico.

Eldarica pine has a relatively unique cone production habit, similar to *Pinus clausa* and *Pinus caribaea* (USDA 1974). Individuals can set multiple flushes or whorls of female cones during one growing season (fig. 2); however, this response is site specific (USDA 1974). This trait affords eldarica pine growers in this region the ability to produce large quantities of seed in a short time (relative to single whorl species). The purpose(s) of this study was to determine if cone heirarchy influenced seed quantity and quality in trees demonstrating this multi-whorl habit, and to examine the tree-to-tree variation in this response.

METHODS AND MATERIALS

Plant Material

Three, 10-year old plantation-grown eldarica pine trees at the Fabian Garcia Science Center in Las Cruces, NM were randomly selected and used in this study. The two most recently matured cone whorls were harvested on two branches of each tree on November 2, 1988. The two whorls of cones per branch were labelled. Whorl 1 was the first whorl of cones produced on the branch; therefore, the whorl closest to the bole of the tree. Whorl 2 was the second whorl of cones produced on the branch during the growing season, and was the whorl closest to the periphery of the crown. No information was taken on the difference in time between cone whorl production.

Eldarica pine has serotinous cones, so seed was extracted by hand using a grafting knife to peel back the cone scales and expose the seed. Total number of seed and total seed weight were recorded following extraction. Total number of seed includes all developed seed and large second year aborted ovules (i.e. pops). According to Bramlett et al. (1977), developed seed can fall into three catagories: filled, partially filled and empty seed (pops). Total seed number does not include first-year aborted ovules (seedless wings) that were observed but not counted. These terms are described in detail by Bramlett et al. (1977) and are addressed in the discussion section of this report.

Germination

Eldarica pine has no reported stratification requirement so none were performed. Following extraction, seeds were soaked for 10 hours in distilled water (25°C). The soaking served two purposes, it separated filled (sinkers) from unfilled (floaters or pops) seed, and allowed the seed to soak up enough water to initiate the germination process. The floaters were air-dried for 48 hours, and their weight and numbers were recorded. These seed were subsequently examined for filling and relatively few (ca 0.7%) were filled.

Filled seed was hand sown in flats of steam sterilized vermiculite, and covered with clear plastic to maintain a moist envirionment. Flats were placed on lab benches where temperatures ranged from 21 to 25°C. Germination was monitored for the next 30 days. A seed was considered germinated when the hypocotyl broke the vermiculite surface. Percent germination, total germination and G_{50} , or date at which 50% of the seed germinated, were determined from this information.

Statistical Considerations

The experimental design was a randomized complete block design with blocking by tree and branches serving

Table 1.--Analysis of variance partitioning of degrees of freedom for the study design.

SOURCE	df
Tree (Block)	2
Whorl	1
Interaction	2
Exper Error	7
Total	11

as repetitions per block. Table 1 illustrates the partitioning of the degrees of freedom of the design. Analysis of variance was performed to test the effects of source (tree) and whorl position on cone number per whorl, total number of seed per cone, total number of viable seed per cone, percent viable seed, mean weight of viable seed, total germination, percent germination and G_{50}. Analysis was performed using the PROC GLM of SAS Version 5 (SAS Institute Inc. 1989).

Regression analysis was performed using number of sound seed per cone as an independent variable on the dependent variables, number of seed germinating per cone and percent germination. Analysis was performed using the PROC REG of SAS Version 5 (SAS Institute Inc., 1989).

RESULTS

Tree significantly impacted both seed quality and quantity (table 2). Among individual trees, tree 2 had both the greatest number of seed per cone, number of viable seed per cone as well as the greatest percent viable seed. Tree 2 also had the highest percentage germination. While not statistically significant (alpha = 0.05), source appeared to influence mean weight of viable seed and G_{50} (PR > F = 0.116). Trees 1 and 3 had comparable numbers of viable seed per cone but total number of seed per cone and percent viable seed differed.

Cone heirarchy or whorl position also impacted seed quantity and quality attributes. Whorl 2 cones, those closest to the periphery of the crown and latest to develop, had significantly greater total seed, number of viable seed and percent viable seed (table 3). Mean weight of viable seed, percent germination and G_{50} were unaffected ($P < 0.05$) by cone position in this study. As was the case with source, whorl position did not influence the number of cones per whorl.

The relationship between the number of germinating seed and total number of seed extracted per cone (fig. 3) is a positive, linear relationship where an increase in the total number of seed per cone yields an increase number of seed germinating. Tree 1 data appear to follow a less steep, positive relationship than do data points from trees 2 and 3. When tree 1 data is dropped from the data set, the model improves with the line becoming steeper and the confidence interval narrowing.

Table 2.-- Mean cone and seed attributes and observed significance levels (**PR>F**) for the three plantation-grown eldarica pine. **Seed Wt. (mg)** = mean weight of sound seed; '-' = tree 1 material failed to reach 50% germination

Parameter	Tree 1	Tree 2	Tree 3	PR>F
Cones/whorl (no.)	3.8	3.3	2.8	0.488
Total Seed/Cone (no.)	54	103	62	0.004
Sound seed/cone (no.)	28.2	71.1	27.5	0.003
Sound Seed (%)	47.7	68.8	38.2	0.050
Seed Wt (mg)	70.7	56.9	61.7	0.116
Germination (%)	24.4	79.8	64.0	0.004
G_{50} (d)	-	12.9	21.3	0.262

Table 3.--Mean cone and seed attributes and observed significance levels (**PR>F**) for whorl 1 and whorl 2 of eldarica pine. **Seed Wt. (mg)** = mean weight of sound seed

Parameter	Whorl 1	Whorl 2	PR>R
Cones/whorl (no.)	3.2	3.3	0.804
Total Seed/cone (no.)	57	88	0.008
Sound Seed/cone (no.)	26.6	58.0	0.004
Sound Seed (%)	38.9	64.1	0.019
Seed Wt. (mg)	64.6	61.6	0.546
Germination (%)	51.1	60.8	0.333
G_{50} (d)	19.5	14.7	0.503

The relationship between germination percent and total number of extracted seed per cone is also positive and linear (fig. 4). However, this relationship is weaker as indicated by the lower correlation coefficient and the wider confidence limits.

DISCUSSION

The relatively large percentages of unfilled seed found in this study may be caused by three agents. First, several insects including seedbugs (*Tetyra bipunctata, Leptoglossus corculus*) attack southern pine cones (Bramlett et al. 1977). Second, attack by several species of fungi can cause unfilled or partially filled seed (Bramlett et al. 1977). A third potential cause for unfilled seed is selfing, or more precisely, homozygous recessive embryonic lethal genes. Most members of the *Pinus* genus have varying numbers of these genes (Bramlett pers. comm.[3]). When this condition occurs, it can result in either a first-year aborted ovule, (i.e. a seedless wing), or a second-year aborted ovule, (i.e. an unfilled seed). A seedless wing is an unfilled seed that never enlarges to full seed size, while an unfilled seed is a full-sized, empty seed

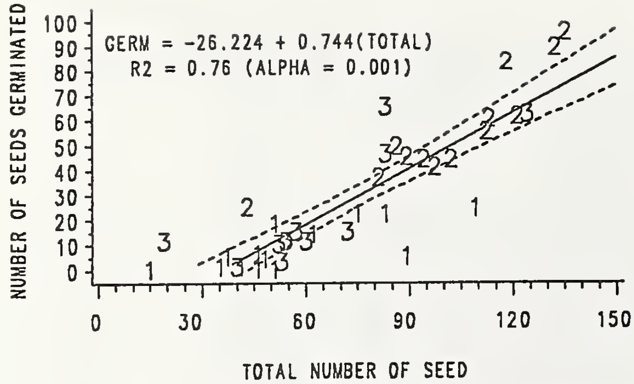

Figure 3.-- Relationship between total number of seed per cone and number of seed germinating per cone. Data points 1, 2 and 3 are those obtained from trees 1, 2 and 3 respectively. Solid line is calculated regression equation and dashed lines represent a 95% confidence limit on the mean.

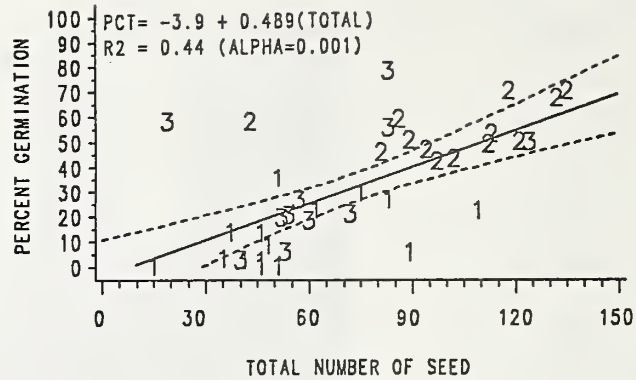

Figure 4.-- Relationship between total number of seed per cone and percent germination. Data points 1, 2 and 3 are those obtained from trees 1, 2 and 3 respectively. Solid line is calculated regression equation and dashed lines represent a 95% confidence limit on the mean.

coat. The material used in this study, while not examined microscopically, had no evidence of insect or fungal attack. This could indicate selfing as the likely cause of the empty seed and the greater percentage of empty seed in whorl 1 found in this study. Possibly, whorl 1 cone receptivity coincides with the time when its own pollen is shed, resulting in greater percentages of selfing in these cones.

The reduced total amount of seed (empty and filled combined) in whorl 1 may be attributable to selfing. Homozygous embryonic lethal genes may result in first-year aborted ovules. Seedless wings were observed in this study, but no data were recorded. If the timing of receptivity for the whorl 1 cones coincided with that of pollen dispersion for the same tree, this may have resulted in first-year aborted ovules, which would have decreased the total seed numbers in this whorl.

A second explanation for the decreased total number of seed in whorl 1 cones may be the result of an overall decrease in the amount of pollination of these cones. While pollen production and cone development timing were not examined in this study, whorl 1 cones possibly were receptive before the majority of pollen production in the stand. This would result in the reduced levels of seed production in these cones.

Cone hierarchy did not statistically impact G_{50} in this study. This may be because of the overall poor germination percentage of tree 1. Only one whorl of cones of this tree exceeded 50% germination during the evaluation period. Overall, whorl 2 seed of tree 1 germinated faster than whorl 1 seed. The approximate 5 days difference between the G_{50} , in the complete data set, of whorl 1 and whorl 2 cones amounts to a 25% decrease in G_{50} of whorl 2 cones.

The number of cones per whorl varied from three to five cones, and was not under any strong heirarchy or tree influence. Most eldarica pine grown in the plantation averaged between three and five cones per whorl. However, eldarica pine can set as many as 20 cones per whorl in southern New Mexico and southeastern Arizona (Harrington and Mexal pers. obs.). It appears number of cones per whorl is primarily environmentally controlled.

As would be expected, tree impacted some of the attributes examined in this study. While eldarica pine is believed to have originated from a relatively small, 550 ha, naturally regenerating stand in Soviet Georgia (Spencer 1985), its genetic base is variable enough to justify the implementation of some screening regieme when selecting potential seed trees.

Number of seed germinating per cone appears to be related to total number of seed per cone. However, this relationship is strongly influenced by tree. As can be seen in figure 3, tree 1 data appear to follow a less steep line than do data from trees 2 and 3. A positive relationship between these variables would be expected becasue more seeds per cone provides more opportunities for seed to germinate. The relationship may afford a grower a criterion suitable for selecting potential seed trees.

The relationship between percent germination and total number of seeds per cone is linear and positive, but is not as defined as the relationship between number of seeds germinating and total number of seeds per cone (r^2 = 0.44 vs. 0.76 respectively). While total number of seeds per cone accounted for only 44% of the variation in percent germination, this relationship was unexpected. A possible explanation for this relationship may be that more fertilized ovules result in a stronger carbohydrate sink such that seed vigor improves concomitantly with overall seed set. Shifriss (pers. comm.[4]) found pepper fruit size was positively correlated with number of seed set. Possibly as seed set increases, fruit size increases, and seed vigor, as measured by germination, improves. Further work is needed to identify easy-to-measure attributes that reliably predict seed quality and quantity

[3] Bramlett, D.L. 1989. Personal correspondance. USDA For. Ser. Southeastern Forest Exp. Station, Dry Branch GA 31020.

[4] Shifriss, C. 1989. New Mexico State University Seminar 9/15/89. The Volcani Center, Bet Dagan, Israel.

to be used when selecting potential seed trees. Attributes such as cone length or width may be potential candidates because they are measured easily in the field and may have predictive value.

IMPLICATIONS

Improving seed yields in eldarica pine cone crops may be dependent on supplemental pollination of whorl 1 cones and/or basal pruning seed trees. The majority of staminate cones are produced on the lower one-third of the crown. Removing this pollen source would decrease the likelihood of first and second-year aborted ovules resulting from genetic constraints. If a sufficiently large seed crop is produced, it may be feasible to preferentially collect whorl 2 cones to reduce costs of seed extraction by concentrating efforts and energy on cones with higher proportions of sound seed. Finally, further work is needed to determine the causes of empty seed in eldarica pine, to develop criteria for screening potential seed trees and to understand the influence of cone hierarchy on these criteria.

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Vegetative Propagation of 10-Year-Old Blue Spruce by Stem Cuttings[1]

Anne M. Wagner, James T. Fisher, and Greg A. Fancher[2]

Abstract-- Techniques for vegetative propagation of 10-year-old blue spruce (*Picea pungens* Engelm.) by stem cuttings were investigated. Month of collection of the cuttings and application of rooting hormones were examined. In addition, cutting position, cutting length and caliper were examined in relation to rooting response. December was the best collection date for rooting and root production. No hormone and 2500 ppm indole-butyric acid resulted in the highest rooting response. Hormone level and collection date interacted on root fresh weight. Shorter cuttings and cuttings from the lower two-thirds of the tree were more likely to root.

INTRODUCTION

Blue spruce (*Picea pungens* Engelm.) is used throughout the United States, primarily as an ornamental but also as a Christmas tree. The blue spruce's attractive natural form and broad ecological adaptiveness have made it a valuable ornamental. The natural range of blue spruce extends from southern Idaho to southern New Mexico. Hanover (1975) identified New Mexico sources as among the best for color development and rapid growth. Because distinct geographic ecotypes exhibit variations in form color and growth rates, which do not always breed true to type, the ability to vegetatively propagate superior trees would be advantageous in a tree improvement program.

Variable success has been reported in attempts to vegetatively propagate blue spruce. Hanover (1975) successfully rooted 85% of cuttings from seedlings 30 to 60 cm. tall. Rooting success of cuttings from 1-year seedlings varied from a low of 10% to a high of 80% (Struve, 1982). Thimann and DeLisle (1939, 1942) achieved 80% rooting success with cuttings taken in April from trees 10 to 20 years old. However, they had less success in November and no rooting in other months. Cultivars of blue spruce appear to root more reliably when cuttings are taken in January than in the summer months (Iseli and Howse, 1981). These differences may be the result of different growing environments and tree age. The consensus among growers appears to be, cuttings should be taken in late winter or early spring, and treated with rooting hormones to for maximum rooting response.

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Seasonal variation in rooting response is a major factor in vegetative propagation. Season obviously plays a role in physiological conditioning of the stock plant, which in turn, affects the rooting response of the cutting. Lanphear and Meahl (1963) found root-forming capacity of cuttings from two evergreen species was seasonal, peaking in late fall and winter. This relationship could not be altered by the application of an exogenous root-promoting auxin. Norway spruce rooted best when cuttings were taken in April and May, just before or during budbreak (Girouard, 1975). The second best rooting was obtained from cuttings taken in October to November, when bud dormancy was not yet complete.

Unlike some species with preformed root initials, rooting in conifers requires the synthesis of root primordia. Endogenous factors are known tc play a role in root primordia formation as well as root initiation and development. Smith and Thorpe (1975) identified two stages when the presence of auxin is essential in root initiation and development. The first stage is marked by the initial events leading to meristematic locus formation, and the second by events immediately preceding meristemoid development. A commonly accepted practice in vegetative propagation, particularly with the more difficult-to-root species such as conifers, involves the application of root-promoting hormones to compensate for a possible lack of endogenous levels of auxins.

In addition to differences in rooting ability described above, within tree differences are also seen. A phenomenon associated with aging is that tissues found at different locations on the same tree differ in juvenility. Paradoxically, tissues at the top of the tree are vegetatively mature, but are the youngest tissues in chronological age. Conversely, the oldest tissues found near the base of the tree tend to be more juvenile (Kester, 1976). Rootability has been related to crown position effects occurring in juvenile seedlings as well as sexually mature trees. Phillion and Mitchell (1984) found cuttings from the lower two-thirds of 15-month conifer seedlings rooted somewhat better than those harvested from higher positions, regardless of clone. However, the effect of crown position on rootability was most pronounced among clones yielding rootable cuttings exclusively from the lower one-third of the crown. It was speculated, because this clone was the tallest, it might be less juvenile and the drop in rooting the result of this difference in height, and perhaps greater maturity.

The objectives of this study encompassed several aspects, most of which involved techniques of propagating blue spruce. The primary objective was to determine if rooting success of cuttings differed among several collection dates. Secondary objectives included quantifying the effects of rooting hormone and their effect on root initiation and development. Tertiary factors of interest were the effect of cutting position, initial cutting length and basal stem caliper on rooting response.

MATERIALS AND METHODS

Stock plants were selected from a blue spruce provenance study planted in 1978, at the Mora Research Center, Mora, New Mexico. All trees were unsheared and the plot was thinned to a 1.7 m by 2 m spacing the previous year. No fertilizer had been applied during the previous growing season, but had been uniformly applied in 1985.

Because of the number of cuttings available from each tree, six collection dates were selected in an attempt to identify optimum collection date. Previous work conducted elsewhere (Hanover 1975) indicated blue spruce roots best from late winter to early spring. Collection dates were selected to permit harvest at 4-week intervals beginning in December 1986. Cuttings were harvested: December 20-21, 1986; January 17, 1987; February 14, 1987; March 13, 1987; April 19, 1987; and May 8, 1987.

Indolebutyric acid (IBA), a synthetic auxin, was used to determine if rooting potential could be altered by treatment with exogenous auxins. Three hormone levels were selected along with a control (no hormone). The four treatments were control, 2500 ppm IBA, 5000 ppm IBA and 10,000 ppm IBA.

Each tree was randomly assigned to one of the four hormone levels initially. The study required 12 cuttings from each tree. Cuttings harvested from each tree at the assigned intervals received the same hormone treatment throughout the course of the study to eliminate tree-to-tree variation. Two cuttings were taken from each tree at each collection time. For each collection, 240 cuttings were stuck, with 60 cuttings for each hormone level. A total of 1440 cuttings were used in the study.

Cuttings were harvested in the same manner each collection. Entire primary lateral shoots with terminal buds were harvested. Cuttings included only the growth produced the previous growing season. Tree height was recorded for each tree before cuttings were taken. As each cutting was taken, the vertical distance between the ground and the point of stem severence was recorded (cutting height). In the laboratory, the basal end of the cuttings were recut at a 45° angle, and old wood, if present, was removed. Initial cutting length and basal stem caliper were measured and recorded after recutting. Cutting lengths varied from 3.7 cm to 12.5 cm; all cuttings longer than 12.5 cm were cut at 12.5 cm. Needles were not stripped from the base of the cuttings.

Cuttings were then treated with a 5-second quick dip of the stem basal 2 cm in the preselected hormone treatment. The three hormone treatments containing indolebutyric acid (IBA) were dissolved in 50% isopropyl alcohol. Control cuttings were dipped in a 50% alcohol solution. After drying for 10 minutes; the basal portion of the cuttings were dipped in a 1:1 Captan fungicide/talc mixture. Treated cuttings were immediately stuck in 160 cm^3 polyethylene containers (Ray Leach tubes) containing a 1:1 vermiculite/ perlite mix (v/v), to a depth of approximately 2.5 cm.

Cuttings were then placed on a propagation bench, which was a mist bench system with bottom heat. The mist bench is a modification of the wet tent system designed by Whitcomb et al. (1982). Bottom heat was provided by a Biotherm® heating system at 20°C.

Relative humidity was kept high by the using two independent systems to apply moisture to the bench. A 100% polyester fabric draped over a pitched metal frame attached to the top of the bench provided the enclosure for maintaining relative humidity. The polyester fabric allowed air to circulate through the tent walls while keeping the humidity high. An automated track-mounted boom located 1.0 m above the bench was controlled by an automatic clock timer. The boom contained nine fan-type nozzles to provide uniform mist to the cuttings. Speeds and frequency were adjusted as needed to maintain humidity 65% +/- 10%. In addition, a fog system above the tent was controlled by an evaporative leaf moisture meter. The fog system kept the tent wet and helped maintain the humidity in the propagation bench. Cuttings were fertilized with Hoaglands complete nutrient solution applied with a hand applicator. Cuttings were fertilized three times a week to compensate for the effects of leaching from the mist applications.

Cuttings were removed from the bench after 20 weeks. Treatment blocks were removed individually, and all measurements were made within 72 hours of removal from the bench. If cuttings were removed in advance of evaluation, they were placed in a walk-in refrigerated cooler at 4°C. All cuttings were destructively sampled.

For each cutting the following attributes and measurements were recorded:
Cutting condition; dead, alive, callused or rooted; shoot elongation; shoot measurements; shoot length, shoot caliper, and shoot green weight;
root measurements; primary root number, primary root length, secondary root number (total), secondary root length (sum), tertiary root number (total), tertiary root length (sum) and total root fresh weight (primary and associated root total).

Primary roots were defined as originating from the cut end of the cutting, or callus tissue (if present). After evaluation, cuttings and roots were oven-dried at 65°C +/- 3°C for 60 hours.

The experimental design was a split-plot design. The whole plot treatment design was a 3 (source) X 4 (hormone) factorial. Collection date was the split factor. Cutting height to tree height ratio, final cutting length, basal stem caliper and cutting fresh weight were used as covariates. Statistical analyses were done using analysis of variance techniques (GLM, SAS Institute, 1985). Range tests were done using the Student-Newman-Keuls test. Discrete data were analyzed using categorical model analysis (chi-square tests) and logistic regression. For analysis, the total number of primary roots was used for each rooted cutting. Root length and root fresh weight were totaled to give a single value for each cutting. Height ratio was a variable created by taking the ratio of cutting height over the total tree height.

RESULTS

Rooting response

After restricting cutting condition classification to only two categories, rooted and not rooted, a categorical model analysis (SAS Institute, 1985) was used to test for significant effects. Overall rooting was low, with 107 cuttings out of 1440 rooted (7%). Collection date and hormone level showed significant effects on rooting response. Collection date was significant with a χ^2 value of 6.26 (probability < 0.0001). By collection date, rooting was highest in December at 15%, followed by 13% in February. There was a drop in rooting in January, and overall rooting declined steadily after February (fig. 1). Hormone level was significant at the 10% level (χ^2 = 6.26; probability = 0.0996). Best treatments were the control and 2500 ppm IBA with rooting percentages of 9% and 11%. Rooting success dropped at the higher levels of IBA (fig. 2).

Logistic regression was used to analyze rooting response in relation to height ratio, initial cutting length, initial caliper and initial fresh weight. The natural logarithm of the ratio of the probability of not rooting over the probability of rooting (called the logit response) was used as a response, and the slope and intercept of the line representing the relationship were calculated. Only height ratio and initial cutting length had detectable effects on rooting response. The relation between rooting and height ratio was seen when the height ratio data was transformed into categorical data (table 1). Vertical position of the cutting on the tree did influence rooting success. The chi-square test of independence showed rooting and cutting height are not independent factors. Cuttings from the lower third of the tree had rooting rates that exceeded the expected value.

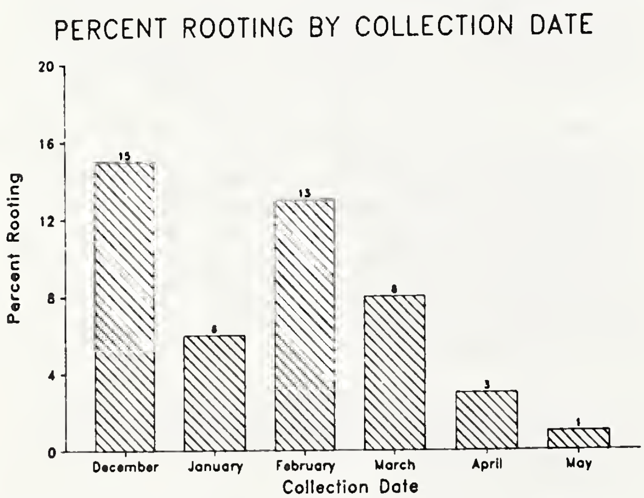

Figure 1.--Percent rooting of blue spruce cuttings by collection date. Based on 240 cuttings/collection date. χ^2 = 6.26, PR < 0.0001.

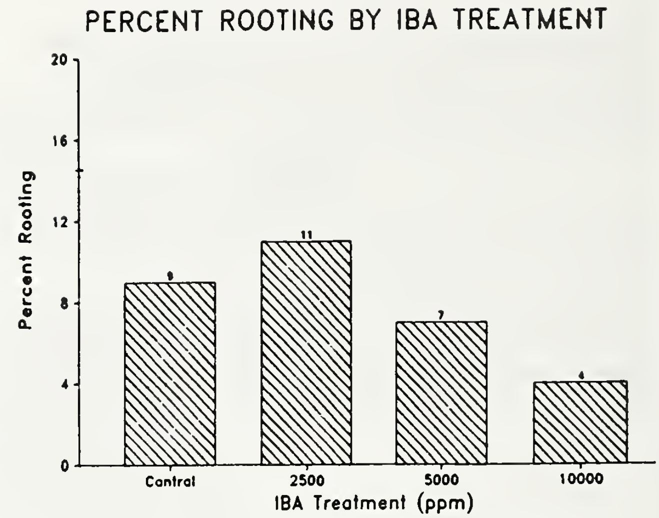

Figure 2.--Percent rooting by hormone treatment of blue spruce cuttings. Based on 360 cuttings/treatment. χ^2 = 4.65, PR < 0.0979.

There was a significant relation between initial cutting length and rooting (χ^2 = 54.95, probability < 0.0001). This relationship was positive and had a slope of 0.337, so as cutting length increased the probability of rooting decreased (fig. 3). Probabilities of rooting were generated using this relationship. For the shortest cutting, 3.7 cm, the estimated probability of rooting was 40%. The probability of rooting dropped significantly to 3% as cutting length increased to a maximum of 12.5 cm.

Table 1.--Frequency of rooting by height ratio. Height ratio = cutting height/tree height.

	Height ratio		
	0 - 0.33	0.34 - 0.66	0.67 - 1.00
No rooting			
Observed	29	696	608
Expected	35	702	596
Rooting			
Observed	9	62	36
Expected	3	56	48

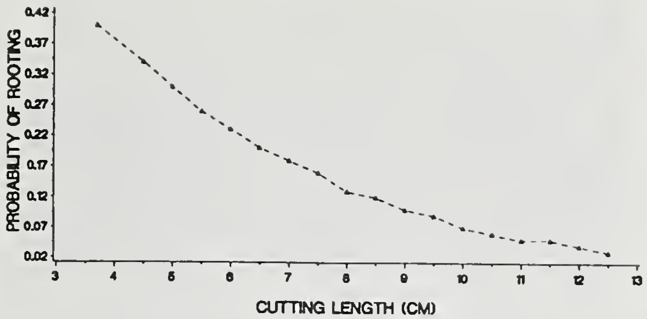

Figure 3.--Logistic regression of probability of rooting and initial cutting length (cm). LN (P0/P3) = -0.8317 + 0.3369 * (X). P0 = Probability of not rooting, P3 = Probability of rooting, X = initial cutting length.

Root analysis

For the analysis of root data, three variables were used as indicators of root quality. Root fresh weight, number of primary roots and root length were analyzed. Because of low rooting response for the April and May collections, those dates were omitted from further analyses of root data. Root data were analyzed using GLM (SAS Institute, 1985). Due to the small number of rooted cuttings, normality assumptions were not met and, while significant affects may be determined, p values may not be accurate.

Root fresh weight

Differences in root fresh weight were detected among collection dates. Root fresh weight was analyzed using the Student-Newman-Keuls test. December cuttings showed greater mean root weight than the other collection dates, which did not differ significantly. December cuttings had a mean root fresh weight of 0.124 g. The mean fresh weight for cuttings taken in March was 0.055 g, and 0.053 g for cuttings taken in February. January cuttings had the lowest root fresh weight with a mean of 0.028 g (table 2). Collection dates were significantly different with respect to root dry weight, which followed the same pattern as fresh weight. There were no significant interactions between root fresh weights by hormone level.

Differences were seen in root fresh weight in hormone by collection date (fig. 4). Examining the collection date by hormone interactions, the greatest root biomass production was the December sampling with the control treatment. Among December cuttings, biomass production decreased as hormone level increased. After December, IBA at the 2500 ppm level resulted in greater fresh weight production by treatment until March when 5000 ppm IBA resulted in a slightly higher fresh weight for the cuttings. Rooting among cuttings receiving the 5000 ppm level peaked in March, whereas the control and 2500 ppm IBA peaked in December. Rooting among cuttings that received 10,000 ppm IBA was low for all dates, but increased slightly in February.

Table 2.--Root fresh weight, number of primary roots and total root length by collection date. Numbers are averages of all 240 cuttings/collection date, including cuttings that did not root. Analyzed using Student-Newmans-Keuls test. Means in a column followed by the same letter are not significantly different. (α = 0.05)

Collection date	Root fresh weight (g)	No. primary roots	Root length (cm)
December	0.12454 A	0.6684 A	118.0 A
January	0.02805 B	0.1991 B	38.0 A
February	0.05257 B	0.3673 AB	24.0 A
March	0.05514 B	0.4615 AB	124.0 A

Primary root number

Differences in primary root number were seen among collection dates. Lack of normality was a problem in the analysis because of large numbers of missing values. Differences were seen between cuttings taken in December and January, but no differences were found among December, Feburary and March cuttings, or January, February and March cuttings (table 2). However, mean number of roots did drop for cuttings taken after December. The range test (Student-Newman-Keuls) did not indicate these in total number of primary roots by hormone level. This was probably the result of unequal sample sizes.

Height ratio was the only covariate with a significant effect on mean number of primary roots. The negative slope estimate of -1.61 indicates, as height ratio increased, number of primary roots decreased. Cuttings harvested from positions higher on the tree initiated fewer primary roots.

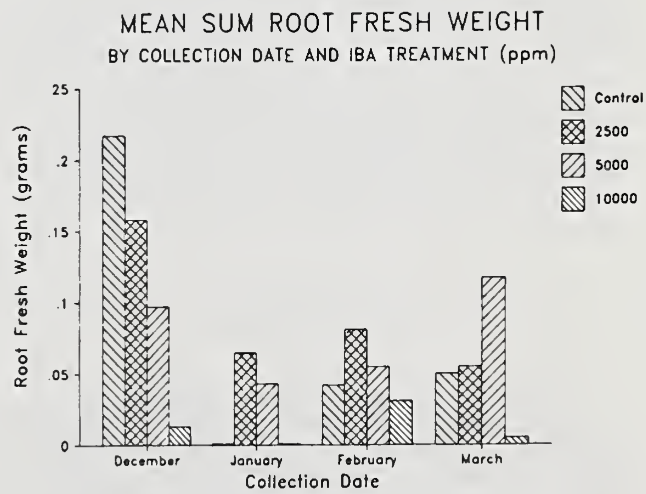

Figure 4.--Blue spruce root fresh weight (g) of all cuttings by collection date and hormone level (ppm IBA).

Root length

Root length for each cutting was analyzed using GLM (SAS Institute, 1985). Differences were seen by collection date, and collection date by hormone level by source. However, the Student-Newman-Keuls range test indicated no significant differences for collection date. This again was probably the reslt of unequal sample sizes. However, examining the means, March cuttings had a mean length of 124 cm., while February cuttings showed a mean length of 24 cm. December cuttings showed a similar response to March cuttings with a mean of 118 cm. January cuttings had a mean root length of 38 cm (table 2). There were no significant differences in root length among hormone levels.

DISCUSSION

Collection date

Although overall rooting success was low, it is possible to root stem cuttings from 10-year-old blue spruce. Collection date was the single factor significant for almost every response variable analyzed.

The best collection date was December, followed by February. The drop in rooting of cuttings taken in January was not expected. The expected rooting percentage was somewhere between the 15% in December and the 13% in February. One explanation is that January was not a favorable time for root initiation in stem cuttings. Perhaps there was some difference among December, January and February which favored root initiation among cuttings taken in December and February but not in January.

Except for the drop in January, it appears the best time to take blue spruce stem cuttings is during winter months, after the chilling requirement has been met (as determined by budbreak in the greenhouse). Rooting dropped off among cuttings collected in the late winter to early spring months, which had been recommended by some researchers (Hanover 1975). These results differ from studies indicating Norway spruce roots well in April and May (Girouard, 1975). However, Fraser fir, as well as other conifer species, roots well in January and February (Hinesley and Blazich, 1984). Thimann and DeLisle (1942) found blue spruce rooted best in April, with some rooting in November. But Iseli and Howse (1981) have more consistent rooting with blue spruce in January.

Hormone level

The best treatment for rooting success was the control followed by 2500 ppm IBA. However, there was little difference between the control and IBA at the 2500 ppm level. In another study with blue spruce cuttings taken in March, there were no differences in rooting responses of cuttings from 10-year trees when treated with no hormone, 2500 ppm IBA or 5000 ppm IBA. Cuttings from 1-year seedlings however, rooted at higher levels, with 100% rooting when treated with 5000 ppm IBA. Cuttings from 15-year old trees, on the other hand, had the highest rooting response (29%) when treated with 10,000 ppm IBA (Wagner unpublished data). Although the collection date by hormone treatment interaction was not significant in terms of rooting success, examination of the data indicates the control treatment in December and 2500 ppm IBA in February are the best treatment by collection date combinations. These results differ from other blue spruce studies indicating higher levels of auxins are necessary to promote rooting (Hanover, 1975; Struve, 1982)

Cutting characteristics

Shorter cuttings are more likely to root than are the longer cuttings. This may be, in part, be related to overall stock plant condition, which favors shoot extension to the detriment of rooting capacity. Farrar and Grace (1942) found some differences in rooting of Norway spruce. They found shorter cuttings may have higher success in rooting, but that shortening longer excised cuttings was of no benefit. Fraser fir, however, showed no effect of cutting length on rooting percentages, but longer cuttings tended to initiate more and longer roots (Miller et al., 1982). The question arises whether rooting success results from the growth form that involves short terminal shoots on the branches, a higher inherent rooting capacity, or a coincidental relationship with cutting length. Another possibility could be that shoot length is a function of crown position.

Cuttings from the lower portion of the tree were more likely to root. Phillion and Mitchell (1984) found similar differences, even in juvenile black spruce cuttings; cuttings from the lower two-thirds of the crown rooted better. There was no significant difference found between cutting stem caliper and cutting fresh weight and the probability of root intitiation in this study.

Root production

Several factors affected root quality. Collection date was significant for all root characteristics analyzed. As discussed above, rooting success was highest among cuttings taken in December, followed by February. December cuttings also showed the highest root biomass production, followed by March. Maximum number of primary roots was highest in December cuttings, followed by February, and root length was greatest in March cuttings, closely followed by cuttings taken in December. Overall, rooting percentages were relatively high for cuttings taken in February, but root quality was less optimal than in December. Considering all the factors of rooting and root quality, an overall recommendation would be to take blue spruce cuttings in December.

Root fresh weight was the only root characteristic to exhibit a significant collection date by hormone level interaction. Root fresh weight changed with hormone level as the season progressed. In December, the highest biomass production was seen with the control level. Cuttings made in January and February showed increased production with 2500 ppm IBA, and March cuttings showed the highest root fresh weight with 5000 ppm IBA.

Conclusions

In summary, the single factor that overrode every variable examined was collection date. Hormone treatment altered somewhat the inherent rooting capacity, but could not completely compensate for non-optimum collection date. Within a tree, cutting position and length do appear to influence rooting success. Overall, a general recommendation for rooting of 10-year-old blue spruce would be to take short cuttings from the lower portion of the tree in December with no hormone treatment. From the results, 10-year-old blue spruce does not appear to be easily mass propagated from field-grown stock plants. However, on a limited scale, such as propagation of superior trees for a breeding program, it would be possible to successfully propagate clones *en masse*, but perhaps with a narrowing of the genetic base.

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Seedbed Mulching with Stabilized Sawdust[1]

John R. Scholtes[2] and Thomas D. Landis[3]

Abstract.-- Discusses the development of a sowing "system" which uses sawdust as the covering for freshly sown seed. Contains a discussion of equipment modifications, material specifications, application techniques, results, and cautions.

MULCHING - BENEFITS AND PROBLEMS

The use of various types of materials to mulch freshly-sown seedbeds is not a new practice. Sand, sawdust, hydromulch, straw, marsh hay, hardwood leaves, pine straw, peat, burlap, thinly-woven cotton, both woven and unwoven poly materials and even plastic sheeting have been used to cover newly sown beds. (Stoeckeler and Jones 1957, Armson and Sadreika 1979). These materials have been used to produce a beneficial environment for seed germination by: controlling erosion from wind and water, preventing soil puddling and crusting, controlling frost heaving, reducing evaporative moisture loss, reducing soil splash, eliminating wicking of saline salts to the soil surface and minimizing surface soil temperature fluctuation. (Stoeckeler and Jones 1957, Armson and Sadrieka 1979, Duryea and Landis 1984)

The general literature dealing with nursery soil management, while mentioning the positive aspects of mulching, actually seems to delve more into the problems which can be associated with the use of mulch materials. Mulches can be expensive to collect or purchase and apply, and some require removal before they cause heat buildup. Others are unstable and blow or wash off the seedbed. Organic mulches can be contaminated with weed seeds or pathogens and may also induce nitrogen deficiency.

Many years of personal experience with mulches and soil amendments have taught that all of the positive as well as the negative statements above can be true. One must be extremely careful when introducing any material into a nursery site.

Seedbed mulches, like any soil amendment, affect the physical, chemical, and biological properties of the soil. Therefore, certain tests are required before any potential mulch material is introduced into a nursery. These include: 1) mechanical analysis to determine particle size and distribution; 2) chemical analysis to test for harmful salts and phytotoxic substances; and 3) biological analysis to look for unwanted and potentially damaging pathogens, seeds, rhizomes, etc.

The addition of a mulch over a seedbed is an amendment to the surface of that seedbed. The key here is the word "amendment". This material will change the condition of the soil and the seedbed. The nursery manager must take those changes into consideration when working with mulched seedbeds. Cultivation of the seedbed surface would destroy the mulch. The rate of application of pesticides, especially herbicides, may need to be adjusted. Irrigation for soil moisture and soil surface temperature control will definitely have to change. And the nursery survival factor will need to be adjusted higher to reflect better survival if the mulched seedbeds are properly sown and managed.

PREVIOUS EXPERIENCES WITH MULCHES

A popular seedbed mulch used at USDA Forest Service Nurseries in the west during the 1960's and 1970's was sand. In the late 1960's, the Coeur de Alene Nursery developed a sand spreader which mulched the entire surface of the seedbed with a uniform thickness of sand. During the early 1970's, two of these spreaders were obtained and used by the Lucky Peak Nursery near Boise, Idaho. Also during the early 1970's, the Mt. Sopris Nursery at Carbondale, Colorado was using a seed drill mounted sand spreader which distributed sand over the individual seedrows. These seedbed mulching "systems" all worked but they also had drawbacks.

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The Coeur de Alene sand spreader mulched the seedbed nicely but required large amounts of clean, relatively dry sand to cover the entire surface. Obtaining clean sand and drying it became a monumental task each spring. Loading and application was slow and the loaded spreader was difficult to maneuver around the nursery and down the seedbed paths.

The Mt. Sopris mulcher required much smaller amounts of sand but the sand had to be perfectly dry and clean to obtain a reasonable flow through the small metering holes and drop tubes. Drying and screening sand and storing it in five gallon containers was a full time spring project for two to three persons.

Over the years, all these nurseries have changed seedbed mulching equipment and even materials. The Coeur de Alene Nursery has gone to hydromulching over a soil cover. The Lucky Peak Nursery has changed to mulching individual seedrows with a commercially packaged sand material.

During the mid 1970's, the authors tested several sowing and mulching systems at the Mt. Sopris Nursery. Two different seed drills were used. The Love-Oyjord[R] utilized disc openers which opened an approximately 0.25 inch wide furrow. The seed was dropped into the furrow. The seed was either covered with soil using concave-shaped packing wheels which pressed the soil back into place or it was left uncovered by removing the packing wheels.

The second seed drill was custom-made and utilized a banded roller. Metal bands were spot welded around the roller, and left impressions for the seedbed rows; the seed was dropped into these impressions. A second banded roller followed the seed drop tubes to firm the seed down into the soil in the bottom of the impression (fig. 1).

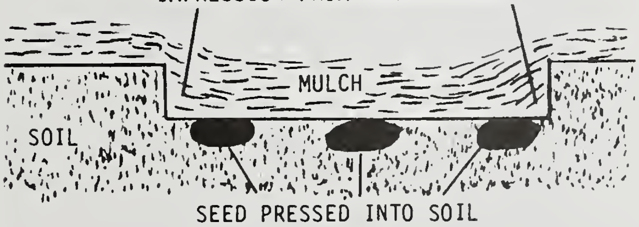

Figure 1.--The placement of seed into a seedrow using a banded roller. Notice that the seed is "firmed" or pressed down into the soil at the bottom of the impression. This is necessary because the mulch material placed over the seedbed will dry out rapidly. However, the soil surface beneath the mulch will remain moist providing a steady supply of moisture for the seed to germinate and the germinant to emerge from the seedbed as a vigorous seedling.

Several combinations of mulching materials were included in the Mt. Sopris trials. They included: covering with soil, sand, two rates of hydromulch, fresh sawdust held in place with hydromulch, and fresh sawdust held in place by staking 60% shade cloth over the seedbed (the cloth was removed at the start of germination). The results of one of these mulch trials has been published (Landis and others 1984).

Of all these trials, the sawdust/shadecloth and sawdust/hydromulch combinations proved superior. The sawdust/hydromulch combination was selected for further operational trials because of the labor of handling the shadecloth. This seed covering system eventually became the standard for operational sowing at Mt. Sopris Nursery.

The authors observed that covering seed with a sawdust mulch which was held into place with hydromulch ("stabilized mulch") had many beneficial effects upon the seedling crop and management of the soil, especially during the germination period:

1. Soil moisture around the seed is more uniform and stable. The mulch dries fairly quickly but moisture in the surface soil will not move into the mulch because of the textural differences between these materials. Another factor that reduces evaporative losses from a mulched seedbed is the insulation provided by the mulch, which lowers surface soil temperatures.

2. Salt accumulation on the soil surface is almost totally eliminated. The mulch slows upward capillary water movement ("wicking") through the soil profile and thus reduces the surface accumulation of soluble salts. High levels of salts at the soil surface bind soil particles into a crust, which can reduce air exchange, increase surface temperature, and reduce water infiltration rates. Also, total soluble salt levels on the soil surface can reach the point of becoming toxic to new germinants.

3. Irrigation requirements are reduced. Reduced evaporative loss from the soil surface significantly reduces the need to add moisture to the soil profile. Except during the germination period and irrigation for cooling or incorporating chemicals, general irrigation can be reduced by as much as 50% during the first year.

4. Improved seed performance because germination and early survival are substantially improved. Seed usage at the Mt. Sopris Nursery was lowered by an average of 20%. Although also affected by other management factors, seedbed mulching played a major role.

5. Improved seedling vigor and root growth. Little comparative data was taken but general observations were that seedlings grown in a mulched seedbed were larger, appeared healthier, and developed larger, more fibrous root systems than those in unmulched areas.

THE NEED AT J. HERBERT STONE NURSERY

These positive experiences with seed mulches were brought by the senior author to the J. Herbert Stone Nursery (JHSN). In the spring of 1986, the sowing practices at JHSN followed standard procedures for covering with soil. The nursery was using two Love-Oyjord seed drills for the majority of the conifer seed. A home-made seeder ("Stone Drill") was used to sow larger seed, such as Abies spp., which could not be sown and covered to the proper depth using the narrow disk openers of the Love-Oyjord drill.

The Stone drill was modeled after the Wind River Nursery seeder and had a shoe-type row opener which created an opening just over one inch wide. Although the Stone drill did an acceptable job, it required almost perfectly formed and surfaced seedbeds to allow covering the wide seedrow with the proper depth of soil. The surface of the seedbed had to be pulverized in order to prepare a suitable surface for sowing. The Love-Oyjord drill was also easier to calibrate and operate.

To get away from these problems with the Stone drill, the JHSN nursery staff decided to modify the Love-Oyjord seeder to hand all types of conifer seed. At the same time, the seed drill would be modified to work with a seed mulch.

SELECTION OF A MULCH MATERIAL

Aware that many different materials could be used as seedbed mulches, potential mulches that were locally available at JHSN were evaluated. In order to capture the full range of benefits, the decision was made to mulch the entire seedbed surface. Even though a suitable source of sand was available locally, the cost of procurement and application made this a very costly alternative. The same was true of hydromulch. The most economical material available was fresh sawdust, and so the decision was made to try sawdust as a seedbed mulch at JHSN. This decision was implemented in four phases: 1) Development of sowing equipment, 2) Procurement of suitable quality sawdust, 3) Uniform sawdust application, and 4) Stabilization of the mulch.

1. Development of sowing equipment

One of the Love-Oyjord seed drills was extensively modified to allow sowing the larger seed into wide drill rows and pressing the seed into the soil. Items that were changed or modified are listed below:

a. The smooth drum was replaced with a banded roller: a 1.50 inch wide by 0.38 inch deep steel strap was spot welded around the roller to press indentations into the seedbed surface and form the seedrows (fig. 1).

b. Large drop tubes of clear flexible plastic with an inside diameter of 1.38 inches were fit over the original boots of the seeder (The boots connect the drop tubes to the seed spinner or distribution head).

c. The disc openers were replaced with angled pieces of 1.50 inch muffler pipe bent at the local muffler shop to drop the seed into the rows with minimal bouncing of the seed out of the impressions.

e. The concave soil packing wheels were replaced with flat semi-pneumatic rubber wheels which were 1.50 inches wide to fit down the seedrow impressions and press the seed into good contact with the soil.

f. A seed hopper with a large tube was obtained to allow the large seed to flow into the seedwheel.

g. Larger guages were made to allow the hopper tube to be adjusted to as high as one inch above the seedwheel.

h. The seedwheel was modified by cutting out every other lamelli to allow the seed to drop more freely into the spinner.

i. The funnel between the seed wheel and the spinner was enlarged leaving as large an opening as possible.

j. The chain driver for the seed spinner was replaced with a hydraulic motor drive to allow very slow ground speeds as needed to handle larger Abies spp., while still maintaining approximately 800-1200 RPM on the Spinner.

Other "nice-to-have" modifications were also added to the seed drill. These include:

k. A heavy duty digital counter which can withstand more use than the mechanical counters.

l. The seat was offset towards the drive side allowing more room to get on and off the seeder from the left side (facing the rear of the seeder).

m. A step has been built onto the frame halving the distance to the ground.

n. A plexiglass "view window" has been placed into the cover over the gears.

o. The gears have been clearly numbered in the cover.

p. Green and amber lights have been mounted on the tractor with switches on the drill so the drill operator can signal when to stop and go.

q. An insulated box for seed has been built on the front of the seeder.

These modifications have improved safety, operation convenience, and seed care.

2. Procurement of suitable quality sawdust

There are several sources of sawdust available in Southeastern Oregon so prices are competitive. Sawdust must be of the proper size and not contain harmful materials (table 1). Past experience at JHSN had shown that poor quality sawdust can create soil conditions which are detrimental to seedling growth and can cause long-term nutrition problems. Wood from some species of trees can contain phytotoxic chemicals, and sawdust (especially "aged" sawdust) from some sources can contain high levels of soluble salts.

Table 1.--Physical and chemical standards developed for sawdust supply contracts at JHSN:

1. Physical Properties

   A. Particle Size - Must pass through a 2 cm mesh screen. Not more than 45 percent (by weight) will be fine enough to pass through a 2.0 mm mesh screen.

   B. Purity - No more than five percent by weight of foreign material will be allowed.

2. Chemical Properties

   A. Salinity - The electrical conductivity must not exceed 0.5 mmhos/cm. Total bases must not exceed 15 meq/100 grams of sawdust; of these, calcium levels must not exceed 12 meq and sodium levels must not exceed 0.8 meq.

   B. Phytotoxic Materials - Cedar or redwood sawdust are unacceptable.

During procurement, sawdust should never be stockpiled or dumped onto any portion of the nursery seedbed area because leachates from sawdust piles can be washed into the soil. Furthermore, piles can never be completely removed nor can they be uniformly spread. The tires of hauling, loading and spreading equipment will also work undesirably large quantities of mulch material into the soil in the stockpile area. Leachate concentrations and excess mulch material can cause nutrition and possibly other problems in subsequent crops. At the very least, this practice will result in a soil which has been "amended" into an hodge-podge which will be difficult to manage. It is difficult to resist the temptation of reducing application costs by cutting corners but the material must be stored off the production area and applied in a uniform manner to the fields.

3. Uniform Sawdust Application

After a suitable source of sawdust has been procured, the next concern is how to apply the desired depth of sawdust to the seedbed. A general rule of thumb is to cover the seed to a depth of 1.5 to 2 times the seed width. If the mulch layer is too deep it could physically inhibit germination or keep the soil too cool for maximum seedling emergence. Too shallow a layer would not provide adequate protection for the seed. An old adage is that "you have to leave a little seed showing to be sure that you are not sowing too deep". In reality, this is saying "we do not have suitable equipment or control needed to cover seed to the proper depth, so it is better to sow too shallow than too deep". Obviously, any seed drying under the direct rays of the sun is not likely to germinate. Perhaps one of the most valuable benefits of mulching is getting all the seed covered to a suitable depth.

The type of manure spreading mechanism used to spread sawdust at Mt. Sopris Nursery could not be located. A paddle-type manure spreader was modified and remodified many times in an attempt to get uniform covering over the seed. We were able to get a suitable covering for the larger-seeded species which can push through around an inch of mulch if necessary, and so this spreader was used for those species only. We did not wish to risk covering the smaller-seeded species with this unit although a few trials were promising.

A thorough market survey did not yield mulch spreading equipment which would handle the required minimum of 12 cu yds of material and distribute it uniformly. A contract was developed for someone to design and build a unit which would meet our specifications. After having no takers on this contract, we contacted a leading nursery materials handling manufacturer and obtained working drawings of basic materials handling methods. Following these drawings, we set up a few bench tests to determine our needs for belt speeds, opening heights, etc.

Using information gained through those tests, we have radically modified a manure spreader which has successfully applied a uniform layer of mulch over our seedbeds (fig. 2). Some of the major modifications are listed below:

a. Tapered internal walls to bring the bottom of the box down to a width only slightly wider than the seedbed.

b. A special type of conveyer chain in the bottom replaces the standard draper bars.

c. The conveyer runs on a special bottom layer of smooth plastic to reduce friction.

d. An adjustable tailgate has been fabricated into the spreader to allow for infinite adjustment of the opening above the conveyer.

e. The standard gearbox had to be replaced with a heavy duty box which could stand the drag of the conveyer.

f. A slip clutch was added to protect the gearbox and other drive mechanisms.

Figure 2.--A comercially-available manure spreader was modified with a mesh conveyor chain, a smooth plastic deck, and an adjustable tailgate (A); these modifications, plus the proper tractor speed, apply a consistent, uniform depth of sawdust mulch over the sown seedbed (B).

g. Several wide cross braces were added across the bed to buffer the downward weight of the material in the spreader box upon the conveyer.

h. A special undercarriage was built to fit the seedbed paths.

4. Stabilization of the Mulch

Once the sawdust mulch has been applied, the final problem is to keep it in place. Several different types of chemical "stickers" are commercially available. As previously discussed, hydromulch worked very effectively at the Mt. Sopris Nursery. This method of tacking down the sawdust was and still is an excellent option. However, lacking a hydromulch unit and recalling that this process was somewhat slow and labor intensive to mix and spread, led to the search for some other suitable material.

A brochure on a new material called Geotech[R] had recently been received from the Borden Chemical Corporation. This material was listed as a co-polymer resin and was advertised as having been used to bond sandy soils in southeastern nurseries. A call to the Auburn Nursery Cooperative yielded lots of information about the use of Geotech[R] on sandy soils but no information was available about using this material to bond sawdust. Another source had worked with unpigmented latex at the rate of one part latex to 50 parts water on sandy soil but again had no experience with sawdust. Neither source was optomistic about the effectiveness of either material on sawdust.

The decision was made to take the needed risk and extensively test Geotech[R] on seedbeds, along with a spot test of latex and water. The Geotech[R] was minimimally effective, and held most of the sawdust on our seedbeds most of the time. It must be emphasized that Geotech[R] forms only a rather weak bond between the particles of sawdust. Heavy winds, especially those associated with spring thunder storms, will loosen and blow the surface sawdust off the seedbeds. During the past three seasons in which we have used this bonding agent, we have experienced some blowing of the sawdust off parts of the sown area. This has not affected the germination of the seed because the sawdust in the actual seedrow depressions made by the drill has never been lost. This leaves adequate cover over the seed for germination. What is lost, however, is the benefit of having the entire bed surface mulched. In most cases, we have gone back in and remulched the affected seedbeds as soon as we could get back onto the area.

Only the general lack of wind in the Rogue River Valley which lowers the risk of catastrophic loss of covering during germination justifies the continued use of Geotech[R] at JHSN nursery. A much more dependable bonding agent for the sawdust covering in an area of more wind would be hydromulch.

We are still searching for a better bonding material. One other brand of co-polymer resin was tested this last spring but it had so much large particle material in each of two seperate shipments that we could not use it through our sprayer. We have also tried a material used for dust control on roads known as Lignite. This material seriously depressed both rate and total germination.

CONCLUSION

We have four years experience using a stabilized sawdust mulch at JHSN. We have developed the equipment and processes needed to grow seedlings with mulch. Most of the equipment has been modified several times. The change over to using mulch has not been easy but we believe that the payoff has been worth the effort. For instance, we now sow all our seed with just one type of drill which is easy to calibrate and use. Seedbed preparation is faster and we believe easier on the soil. A few small clods, twigs, slightly uneven surfaces are no longer problems. We have also seen payoffs in the seedlings. The first year we sowed Abies with mulch cover, we increased the anticipated survival by 10% and we still came up with surplus seedlings. The disadvantage of course was that we also had overly dense seedbeds. We are still working with our sowing factors and we are definitely sowing less seed per thousand seedlings shipped.

Seedlings are also growing faster than anticipated. This can be both "good" and "bad" from a managers view but having the capability of producing larger seedlings faster allows more flexibility in managing future crops. Root systems are also better developed with more branching of secondary permanent roots were up near the surface of the ground than had been observed before.

This last spring, we converted our second seed drill to utilize this mulching process. We have saved the original drill parts "just in case" but we really doubt that we would ever go back to trying to cover with soil.

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Soil Management Practices at the Big Sioux Nursery[1]

Blaine F. Martian[2]

Abstract: The Big Sioux Nursery was experiencing nutrient deficiencies brought on in part by the increased seedling production. A soil management plan was written to better utilize the resources available and give management a tool in which they can increase the potential and maintain the productivity of the soil.

Introduction

The Big Sioux Nursery has been producing conifer seedlings since 1957 and hardwoods since 1978. In this time period we went from around 600,000 seedlings of 6 different types of conifers to 2 million seedlings of 40 different species. This increased production and in particular the large increase in the number of tree species has placed an accelerated demand on the nursery's soil resource. Hardwood and conifer seedlings generally have different soil requirements and it is therefore important to identify the production potential of all management units.

The Big Sioux Nursery contains 154 acres of which 87.5 acres are into production ground. The land is divided into 18 production blocks varying from 2.5 to 13.8 acres. The majority of the blocks are in 4 acre increments.

Soils Inventory

As far as can be determined no intensive soil survey had been done until this plan was developed in 1982. Up until this survey, soil variation was not considered in the management of the nursery. Trees were sown in areas that had been out of production the longest. We experienced chlorosis, stunting, and irregular beds along with other various nutrient deficiencies. At this time we contacted Tom Landis and it was determined that a soil management plan needed to be written.

The first step in the soil management plan was to survey the soil. The nursery consist of two principal soil types with two inclusions for the nursery. The first soil type, Fordville-Renshaw soils are basically a fine sandy loam underlaid by coarse textured calcareous material. The second type, Egeland-Sioux soils are both finer-textured sandy loams on the surface but differ in subsoil texture. The Egeland subsoil is a heavy loam whereas the Sioux type contains sand and gravel in the subsoil; both are calcareous in nature. (USDA 66)

The second step was an intensive soil survey that was performed in 1982-83 with the USDA Forest Service. The nursery management units were analyzed individually for significant characteristics that would affect their productivity. A series of soil pits were dug in a regular pattern across the units. The analysis consisted of on site measurements of surface and subsurface soil texture, depth of arable soil, occurrence of restrictive layers and subsoil features relating to the presence of calcareous features. Soil samples were also collected from each management unit and one composite sample per unit was sent to Oregon State University for chemical analysis.

Physical and Chemical Soil Properties

As a guideline we used the soil productivity targets for the interior west. (Landis 1983) Soil texture is one of the most important properties of the nursery soil because it affects most other physical and chemical properties and because it is almost impossible to

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modify. The ideal nursery soil texture is a loamy sand or sandy loam. Out of the 18 management units at the nursery, 13 units were classified as loam and 5 as sandy loam. In general, the soil texture in most management units at the Big Sioux are slightly heavier than recommended but should prove to be acceptable for production of tree seedlings. The northern half is more suitable for conifer production than the southern half so this has played an important part in our planting plan.

Soil depth

The depth of the surface soil is important for the development of a good root system as well as for standard soil tillage. Seedling size specifications typically call for a root system that is 8 to 10 inches long and therefore the production soil must be at least 12 inches deep to permit proper lifting. Root culturing practices also occur in this area so the soils need to be deep enough to avoid bringing up calcareous material from the subsoil. Our survey revealed only one management unit "Q" with unsuitable soil depth. There are shallow spots in other areas of the nursery probably attributable to land levelling during nursery development that will have to be managed around.

Soil Reaction

The ideal soil pH for tree seedling nurseries varies from a range of 5.5 - 6.5 for most conifers to a 6.5 - 7.5 range for junipers and hardwoods. At the Big Sioux Nursery, the soil pH values ranged from a low of 6.6 in Unit K to 8.3 in Unit P. The overall objective of pH management at the Big Sioux Nursery is to lower pH gradually to the desirable ranges over a long period of time.

Organic Material

Organic matter levels are very good in all units ranging from 3.1 to 5.1 as compared to the recommended range of 2.0 to 5.0. No additional amendments have been made except for a green manure crop during the fallow year. Electrical conductivity has not been tested regularly because the initial test showed that all units were low. Considering the good internal drainage of the nursery's soil and with proper irrigation, salt buildup should not be a problem.

The cation exchange capacity was initially tested in 1983. The results showed the capacity of all management units at the nursery were very good, ranging from 13.2 to 21.1 meq compared to the recommended range of 7 - 12 meq. This is a reflection of the high organic content of the soil and the clay component of the loam soils. As long as the soil organic material is maintained, there should never be a problem with C.E.C. (Table 1)

Table 1. Physical and Chemical Soil Properties of Management Units at Big Sioux Nursery

Management Unit	Acres	Surface Soil Texture	Surface Soil Depth (in)	pH (units)	E.C. (mmhos)	O.M. (%)	C.E.C. (m.e.)	$CaCO_3$ (%)
A	4.3	Loam	12-15	7.3	0.08	5.1	21.1	-
B	4.3	Loam	12-15	7.5	1.10	4.3	17.0	2.5
C	4.4	Loam	15-20	8.1	0.70	3.1	15.2	3.6
D	4.2	Loam	15-20	7.7	0.60	4.2	19.2	2.3
E	3.9	Loam	15-20	7.4	0.60	3.3	15.9	-
F	4.3	Loam	15-20	7.2	0.40	3.4	14.0	-
G	4.1	Loam	15-20	7.5	0.50	3.8	16.1	1.9
H	4.2	Loam	15-20	7.4	0.90	4.3	18.1	-
I	6.8	Sandy Loam	10-15	7.4	0.35	3.9	14.5	-
J	6.3	Loam	10-15	7.3	0.90	3.5	17.0	-
K	3.6	Loam	10-15	6.6	0.50	3.8	13.2	-
L	4.0	Loam	12-15	7.7	0.60	3.7	14.1	2.3
M	4.1	Loam	12-15	6.8	0.90	3.5	14.9	-
N	4.1	Sandy Loam	10-15	7.4	0.30	5.0	16.6	-
O/P	13.8	Sandy Loam	15-20	7.0	0.40	4.1	14.6	-
Q	2.5	Sandy Loam	5-10	8.3	0.50	4.9	16.6	3.6
R	8.6	Loam	15-20	8.0	0.45	4.1	14.2	2.5

Present Practices

Now that we know what we have we can go about managing our soil to obtain its greatest potential. We began by changing how, when, and what types of fertilizer we used. When one management practice is changed it begins to affect many other areas, which in turn will need attention and is all part of fine tuning the operation.

Once we knew the physical properties of our soil we were able to look at the chemical properties. We concentrated our efforts in 5 areas, nitrogen, phosphorus, potassium, organic matter, and pH. (table 2)

Table 2. **Macronutrient Levels in Management Units at Big Sioux Nursery**

Management Unit	Total N 1/ (%)	P (ppm)	K (ppm)	Ca (meq)	Mg (meq)
A	-	22	105	15.4	5.2
B	-	23	86	15.1	4.3
C	-	20	109	17.0	3.7
D	-	14	90	15.3	.4.7
E	-	13	109	13.5	4.3
F	-	15	105	12.0	3.8
G	-	12	117	14.2	4.1
H	-	22	94	14.8	4.4
I	-	5	51	12.1	3.7
J	-	9	82	13.2	3.7
K	-	21	86	10.3	3.0
L	-	14	78	13.1	3.5
M	-	21	74	10.2	3.0
N	-	8	66	15.9	4.4
O/P	-	5	59	11.4	3.4
Q	-	6	82	28.5	4.2
R	-	3	59	14.4	3.3
Recommended Ranges:		20-50	100-150	2.5-5.0	1.0-2.0

We do not test for nitrogen because the standard test is not a good indicator of what is available for the plants because of the many organic and inorganic forms of nitrogen in the soil. Secondly, the available nitrogen forms are very transient in the soil and can be lost to leaching.

Prior to having a management plan, nitrogen was applied 1 or 2 times a year in the form of ammonium nitrate (34-0-0). We now use ammonium sulfate (21-0-0) at the rate of 150 lbs. of actual nitrogen per acre divided into 5 or 6 applications per year. (table 3)

Table 3. **Yearly Fertilizer Program for Big Sioux Nursery**

Fertilizer	Analysis	Nutrients Supplied	Application Procedure		
			Rates/Acre	Timing	Method
1. Ammonium sulfate	21-0-0	21% N 24% S	720 lbs at 120 lbs/app'n	6 app'n/yr	top-dressing
2. Concentrated superphosphate	0-46-0	46% P_2O_5	178-478 lbs. 1/	once in fallow year	incorporation
3. Potassium sulfate	0-0-54	54% K_2O 18% S	53-493 lbs. 1/	once before sowing	incorporation
4. Sequestrene 138 iron chelate	0-0-0	6% Fe	48-72 lbs.	once before sowing	incorporation

Phosphorus and potassium levels at the Big Sioux were below the recommended levels in all management units. They were higher in the areas that were under cultivation showing us that the native soils were low in both chemicals. To determine the amount that is needed, we had the soil tested and then determined how much was needed by computing the difference between the soil Phosphorus and Potassium level and the recommended range. Since the tests are calculated in ppm we have to convert the ppm to lbs. per acre. At this time you must convert the P to P_2O_5 and K to K_2O because these are forms in which the fertilizers are rated. Then you must figure in the % analysis, concentrated superphosphate (0-46-0) contains 46% P_2O_5, so you will need to divide by .46 to get the actual rate needed. The recommendation for the Big Sioux nursery was to use triple superphosphate (0-45-0) because of it's high analysis and low gypsum content. Phosphorus is not mobile in the soil, so we try to incorporate the phosphorus into the plow layer during the fallow year or prior to sowing.

Potassium sulfate (0-0-54) is used also for its high analysis, low cost, and acidifying affect on the soil. We incorporate this just prior to seeding. (Landis 1983) In the beginning we had to apply large amount of phosphorus and potassium but in the last few years the amounts have been very minimal. We try to have at least the areas just coming out of production soil tested. We usually take our soil samples in October and have them analyzed at Oregon State University in Corvalis, Oregon.

Organic Matter

The next area of treatment is in maintaining the organic content of our soils. We do this in a couple of ways. We use Piper sudan grass as a cover crop. We sow this in the spring on all areas that will be out of tree production for the year. We will allow this to grow about 3 to 4 ft. and then cut it and stack it for later use as a mulch over the seedbeds. With irrigation we try to get at least 3 cuttings a year. After the final cutting the areas are left until spring to help cut down on winter erosion. In the spring we will then disc these areas and plant. The second way in which we add organic material is by leaving as much as possible of the mulch from the beds in the pathways. This has been very effective plus it cuts down on the weeds in the pathways. By fall this material has deteriorated enough where it causes no problems in the tree lifting operation.

As stated earlier we are also trying to lower the pH of our soils. This management has been done by unit, taking into consideration the planned use for that unit. Since 1983 we have dropped the pH from 8.3 to 6.5 in unit C. Other units have not been as dramatic, but have had reductions of .3 to 1.0 over the years. However, as the land is utilized and concentrated in one area more than another, we will notice the pH gradually start to increase. Again at this time we have concentrated our efforts on the highest pH ground and mainly in areas where the conifers are planted. The present strategy is to apply prills of sulfur at about 800 lbs. per acre during the beginning of the fallow year. We have experimented with liquid sulfur directly over newly planted seedbeds of pine and spruce to get a quicker acidification. At this time we have not determined whether this was effective or not.

Conclusion

By having a detailed soil management plan and being able to follow it,we do not see the nutrient deficiencies, the beds are more uniform, and now that most of the blocks are in the recommended ranges we are not using as much fertilizer. Historically the nursery raised pine, eastern red cedar and Rocky Mt. juniper as a 3-0 seedling. Now we have consistently produced them in 2 years. We are also looking at cutting a year of production on several other species. To try to keep on top of our fertility we try to do soil tests on a yearly basis especially on those areas just coming out of tree production. By soil sampling and testing on a yearly basis we are able to track each block and are able to determine where we need more work. This has taken a lot of the guess work out of fertilizing and has enabled us to fine tune our operation.

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Operational Ectomycorrhizal Fungus Inoculations in Forest Tree Nurseries: 1989

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ABSTRACT. During the past 15 years, the mycorrhizal research and development program has evolved to the practical, efficient, and cost-effective application of the ectomycorrhizal fungus, Pisolithus tinctorius (Pt), in both container and bare-root nurseries. The benefits of Pt in reforestation, mineland reclamation, and Christmas tree production include significant increases in nursery seedling quality (reduced culls), and increased survival and growth in field outplantings. Four types of commercial inoculum are currently available, including vegetative mycelium, bulk spores, spore pellets, and spore-encapsulated seeds. Custom equipment has been developed and is commercially available for the operational application of vegetative inoculum in bare-root nurseries. The demand for custom-grown, Pt-inoculated seedlings for an expanding variety of forest applications continues to increase. Approximately 6.5 million seedlings were inoculated with Pt in 1989 in bare-root and container nurseries in the Southern, Central, and Eastern United States. Technology is being expanded to other ectomycorrhizal fungi, host tree species, forest applications, and geographic locations.

Additional Keywords: Ectomycorrhizae, Pisolithus tinctorius, bare-root nurseries, container nurseries, seedling quality, field forestation, mineland reclamation, Christmas tree production, commercial inoculum types, inoculation techniques.

During the past 15 years, the USDA Forest Service, in cooperation with a number of state and private forestry agencies, has been conducting extensive research on mycorrhizae and their applications in forest tree nurseries, forestation, mineland reclamation, and other related forestry uses such as Christmas tree production. The primary objective of this project has been the practical application of one ectomycorrhizal fungus, Pisolithus tinctorius (Pt), in forest land management. This fungus was selected because of its availability, ease of manipulation, wide geographic and host range, and demonstrated benefits to a wide variety of host trees. Pt is especially tolerant of extreme soil conditions, including low pH, high temperatures, and drought, that frequently either kill or inactivate other less tolerant ectomycorrhizal fungi and their host trees (Marx, Cordell, and others 1984).

During the past 10 years, the Pt ectomycorrhizal research and development program has evolved from the controlled nursery-plot research phase to relatively large-scale operational applications in both bare-root and container seedling nurseries. Ectomycorrhizae fungus technology is rapidly expanding to include additional fungi and tree hosts for a variety of forestation applications throughout the U.S. and in several foreign countries. Operational applications are expanding in the United States (Cordell, Caldwell, and others 1988; Castellano, Trappe, and Molina, 1985; Hung and Molina, 1986; Trappe, 1977), the Phillipines (Bartolome, de la Cruz, and others, 1989), France (LeTacon, Garbaye, and others, 1988), and Canada (Langlois and Gagnon, 1988). Effective Pt inoculum, along with the necessary equipment and technology for successful operational applications in bare-root and container nurseries, is now available to nursery personnel. However, the decision to incorporate ectomycorrhizal fungus inoculations into the nursery management program is shared jointly by the nurseryman and the forest land manager. Therefore, nurserymen, contract tree planters, mineland reclamation specialists, Christmas tree growers, and other forest land managers are challenged to become familiar with and evaluate the benefits and costs of custom-grown mycorrhizal-tailored seedlings.

Benefits

Pisolithus tinctorius, along with several other ectomycorrhizal fungi, have provided significant benefits for field forestation, Christmas tree production, and mineland reclamation projects. Numerous conifer and a few hardwood species have been artificially inoculated. National container and bare-root nursery evaluations have demonstrated the effectiveness of different formulations of the Pt inoculum on selected conifer seedling species (Marx, Ruehle, and others 1981; Marx, Cordell and others 1984). During the past 15 years, more than 100 bare-root nursery

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tests with Pt have been conducted in 38 states. Results obtained from 34 nursery tests showed that Pt inoculated southern pine seedlings had a 17 percent increase in fresh weight, a 21 percent increase in ectomycorrhizal development (Fig. 1), and a 27 percent decrease in the percent of cull seedlings at lifting time (Fig. 2). The few instances of negative results have been positively correlated with such factors as ineffective Pt inoculum, adverse environment, detrimental cultural practices, and pesticide toxicity.

Figure 1. 1-0 loblolly pine seedlings with Pt ectomycorrhizae (Left) and with only naturally occurring ectomycorrhizal fungi (Right)

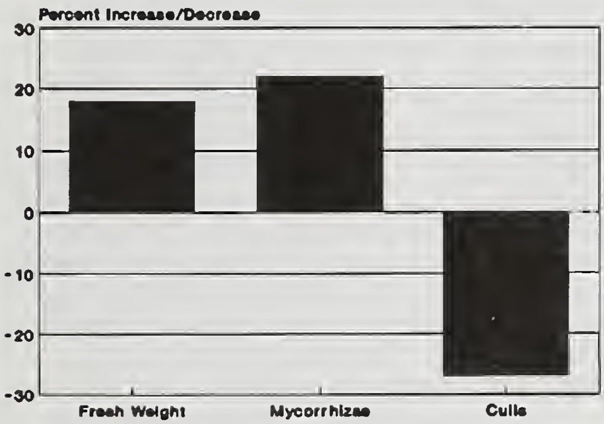


Figure 2. Effects of inoculation with Pt vegetative mycelium on southern pine seedlings in 34 bare-root nurseries.

Inoculated seedlings have been planted on a variety of routine forestation sites, mineland reclamation sites, kaolin wastes, and Christmas tree farms in locations throughout the United States. Over 100 Pt outplantings involving 12 species of conifers are being monitored in 20 states on a variety of forestation, mineland reclamation, and Christmas tree sites. Preliminary analyses show significant increases in tree survival and/or growth in over half of the 100+ field studies. Pt-inoculated loblolly pines (Pinus taeda L.) show significant increases in tree volume growth, when compared with uninoculated check trees on routine forestation sites in four Southern States (Fig. 3). Positive field responses have been correlated with successful Pt nursery inoculations (Pt index $\geq$ 50) and with periodic moisture stress. Results from outplanting studies in southern Georgia show that loblolly pine seedlings with abundant Pt ectomycorrhizae at planting date are more capable of withstanding certain site and/or environmental stresses than seedlings without Pt ectomycorrhizae. Rainfall deficiencies have been frequently associated with large growth differences. Results from two studies (Marx, Cordell and Clark 1988; Marx and Cordell, 1988) on routine forestation sites support the theory of greater drought tolerance of Pt-inoculated seedlings. After 4 years on a good-quality, formerly forested site in south Georgia (site index = 80 ft. at age 25), trees with only naturally occurring Thelephora terrestris ectomycorrhizae had significantly less growth during years of low rainfall than Pt-treated trees (Marx, Cordell, and Clark, 1988). During years with high moisture stresses, Pt ectomycorrhizae markedly improved diameter growth. The apparent effectiveness of Pt-inoculated pine seedlings in tolerating moisture stress on routine forestation sites is highly significant and should greatly expand the economic practicality of the Pt program in forest land management.

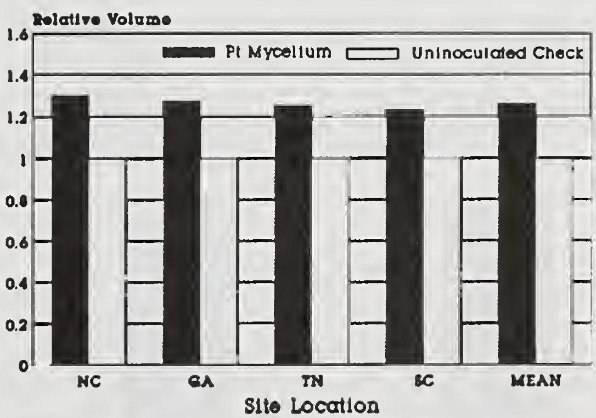


Figure 3. Positive growth responses to Pt inoculation by loblolly pine after 6 to 10 years on routine forestation sites in 4 southern states.

Extensive reclamation research has been conducted on seedlings custom grown with Pt ectomycorrhizae and outplanted on disturbed and adverse sites of various types in the Eastern U.S. In numerous field tests on abandoned mine sites, annual tree root evaluations have confirmed the ecological adaptation of Pt to these adverse sites. Without exception, seedlings with Pt ectomycorrhizae developed new roots very rapidly, and these roots were quickly colonized by the fungus. Root growth was also routinely followed by the prolific production of Pt fruiting bodies in the vicinity of trees with Pt ectomycorrhizae on their root systems. Outplantings established by the Ohio Division of Mineland Reclamation in southern Ohio during the past 7 years continue to show significant tree survival and/or growth increases for Pt inoculated Virginia (P. virginiana Mill.) eastern white (P. strobus L.), and loblolly x pitch (P. rigida Mill.) hybrid pines and northern red oak (Quercus rubra L.) seedlings over routine nursery seedlings (Fig. 4). More recently, Pt-inoculated eastern white and Virginia pines showed increased first-year survival results over uninoculated trees in Christmas tree plantings in North Carolina and Alabama (Fig. 5).

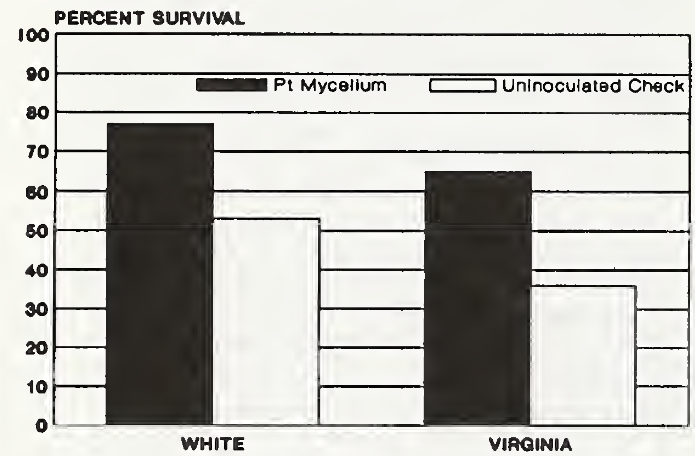
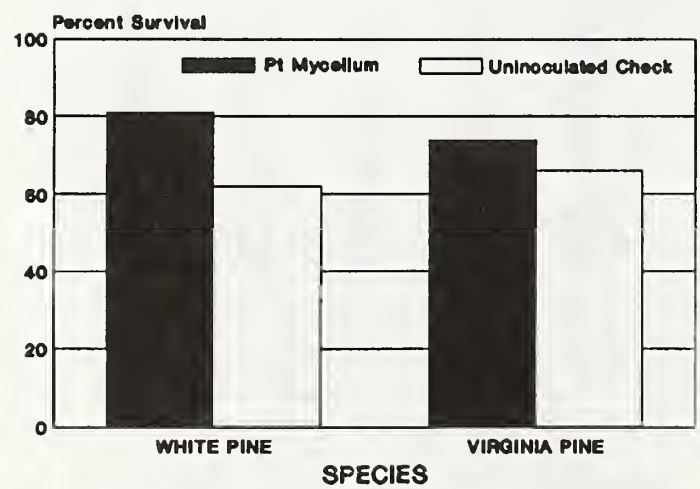


Figure 4. Survival of two pine species on mine reclamation sites in Ohio.



Fiigure 5. Survival of two pine species in two Christmas tree plantings after one year in the field.

Nursery Inoculations

The technology, commercial fungus inoculum, and inoculation equipment necessary to manage the Pt ectomycorrhizal fungus have been developed and are available to nurserymen for operational use. The types of Pt inoculum that are commercially available include vegetative inoculum from Mycorr Tech, Inc., University of Pittsburgh Applied Research Center, Pittsburgh, Pa.; and spore pellets, spore encapsulated seeds, and bulk spores from either International Tree Seed Co., Odenville, Al., or South Pine, Inc., Birmingham, Al. The ectomycorrhizal fungus inoculum applicator has been redesigned with considerable modifications to facilitate the efficient and effective application of Pt vegetative inoculum prior to sowing in bare-root nurseries. Additional improvements in technology and equipment include the development of a machine for side-banding vegetative inoculum between rows of established seedlings. Both applicators are commercially available from R. A. Whitfield Manufacturing Co., Mableton (Atlanta), Ga.

Nursery inoculation procedures vary, depending upon the type of inoculum used. However, with either vegetative or spore inoculum, the biological requirements of a second living organism are added to those of the seedling. As a result, special considerations and precautions are required for shipping, storage, and handling of the Pt inoculum, as well as controlling certain aspects of seedling production, lifting, handling, and field planting. Detailed procedures for handling and storage of the various inoculum types, along with alternative inoculation techniques in bare-root and container nurseries, have been presented (Cordell, Marx, and Owen 1986; Cordell, Owen, and Marx 1987). For successful Pt inoculation in bare-root seedbeds, populations of pathogenic, saprophytic, and native ectomycorrhizal fungi that may already be established in the soil must be reduced. Therefore, soil fumigation before seed sowing (preferably in the spring) with effective soil fumigants comparable to the methyl bromide-chloropicrin formulations is required.

Nursery Management Considerations

Guidelines for mycorrhizal nursery management are designed primarily to promote and maintain healthy seedling root systems (Cordell, Owen, and Marx, 1987). One must consider development and retention of seedling feeder roots and mycorrhizae from the time of seed sowing to seedling lifting in the nursery and subsequent tree planting in the field. Nurserymen, field foresters, reclamation speciallsts, Christmas tree growers, and tree planters must be made aware of the two symbiotic living organisms they are handling - the tree seedling and its complement of mycorrhizal fungi.

Mycorrhizae require generally the same moisture, fertility, and pH as their host tree seedlings, but tolerance for extreme or adverse conditions does vary. Soil and cultural factors that significantly affect mycorrhizae include pH, drainage and moisture, fertility, fumigation, pesticides, cover crops, shading and root pruning. Soil and water pH values are two of the most limiting factors in the development of ectomycorrhizae in both bare-root and container nurseries. In addition, seedling lifting, storage, and planting practices have significant effects on seedling feeder root and ectomycorrhizae retention, quality, and subsequent field survival and growth. Special care must be taken during all stages of seedling handling to maintain sufficient root systems and ectomycorrhizae. Ectomycorrhizae are delicate structures that can be ripped off and left behind in seedling beds during lifting, dessicated in storage, or cut off prior to field planting. To sustain seedling quality, lifting and handling techniques must be modified to minimize damage to feeder roots and ectomycorrhizae. Stripping of roots has severe negative impacts on seedling field performance (Marx and Hatchell 1986). Full bed seedling harvesters are generally less destructive on seedling roots and ectomycorrhizae than single- or double-row lifters. During transfer of the seedlings from the field to the packing room and at all other times when the seedlings are being handled, special care is required to avoid drying of the roots by exposure to wind and sun.

The procedure by which seedlings are packed influences their ability to endure storage and survive field planting. If extended refrigerated storage is required, Kraft paper (KP) bags with a polyethylene seal will maintain seedling moisture better than seedling bales. Cold storage is vital to minimize seedling respiration. Studies comparing packing materials have determined that seedling survival is better when peat moss, clay, or inert water-absorbents are used rather than hydromulch (Cordell, Kais, and others, 1984). Numerous studies have documented the adverse effects of long storage time on seedling quality. With notable exceptions for highly sensitive species such as longleaf pine (P. palustris Mill.), however, most tree species can be safely stored under refrigeration for 2 to 6 weeks.

Improper transportation to the planting site or rough handling during planting can also severely reduce seedling vigor. Tree planters should understand proper planting methods and the need for them. Where possible, seedlings should be transported under refrigeration. Otherwise, they should be covered and stacked with spacers to avoid high temperature buildup inside the seedling containers. Insulated storage boxes and heat reflective "blankets" have also been effectively utilized for seedling protection during short-distance transport and temporary storage at the planting site. For machine or hand planting, root pruning at the planting site should be avoided because it eliminates carefully nurtured feeder roots and mycorrhizae. High temperatures, wind, and low humidity dessicate and kill feeder roots and mycorrhizae very rapidly. The first priority in planting should always be to maintain seedling viability and vigor. The rate at which acres are planted is of no consequence if the seedlings do not survive.

Costs

There is a wide range in the cost of commercially available Pt inoculum (Table 1). Inoculum costs of other ectomycorrhizal fungus species, when available, are comparable to Pt. Some nurseries purchase the inoculum and add its cost to the seedling price, while other nurseries prefer that the buyer purchase the inoculum. The Pt vegetative inoculum is sold on a volume basis, while the spore inocula are all sold by weight. The cost of the most expensive vegetative mycelium inoculum ($7.50/1,000 seedlings) represents less than 5 percent of the total plantation establishment costs.

TABLE 1. COMMERCIAL Pt INOCULUM COSTS 1989.

Pt Inoculum Type	Inoculum Costs Per[1] 1,000 Seedlings	Hectare	Acre
Vegetative Mycelium	$ 7.50	$ 13.45	$ 5.45
Spore Encapsulated Seed	2.22	3.98	1.61
Spore Pellets	2.75	4.93	2.00
Double-Sifted Bulk Spores [2]	0:43	0.77	0.31

1-COSTS ARE FOR LOBLOLLY, EASTERN WHITE, AND VIRGINIA PINE BARE-ROOT NURSERIES (269 SEEDLINGS/SQ. M. - 25 SEEDLINGS/SQ. FT.) & FORESTATION PLANTINGS (1.8 x 3.0 M. - 6 x 10 FT. SPACING; 1794 TREES/HA. - 726 TREES/AC.) IN THE SOUTHERN AND EASTERN U.S.

2-DOUBLE SIFTING IS REQUIRED FOR EVEN FLOW THROUGH SPRAY NOZZLES. STANDARD SPORES ARE ONLY SIFTED ONCE.

Operational Applications

The demand for Pt-inoculated seedlings continues to increase. In 1988, 6 million seedlings at 12 bare-root and container nurseries in the Southern, Central, and Northeastern United States were inoculated with Pt. In 1989, the total rose to 6.5 million seedlings of eight conifer and one hardwood species (Fig.7).Also, several additional ectomycorrhizal fungus species were commercially produced and operationally utilized in 1989. Annually, since 1987, 1.5 million loblolly and 0.5 to 0.75 million longleaf pine seedlings have been successfully inoculated with Pt and custom grown at the Taylor State Nursery, Trenton, S.C., for forestation plantings at the Savannah

River Forest Station, Aiken, S.C. During each of the 1987-88 and 1988-89 planting seasons, four field demonstration plantings were established comparing various nursery and field treatments, including nursery seedling quality, Pt inoculation, pine species, tree spacing and site preparation. Field measurements of these comparative plantings show significant tree survival increases on Pt-inoculated vs. uninoculated pines. This operational project utilizes 3,500 liters of Pt vegetative inoculum in 35,000 linear feet (6.75 miles) of nursery seedbed annually and is apparently the largest single artificial ectomycorrhizal bare-root nursery inoculation project to date.

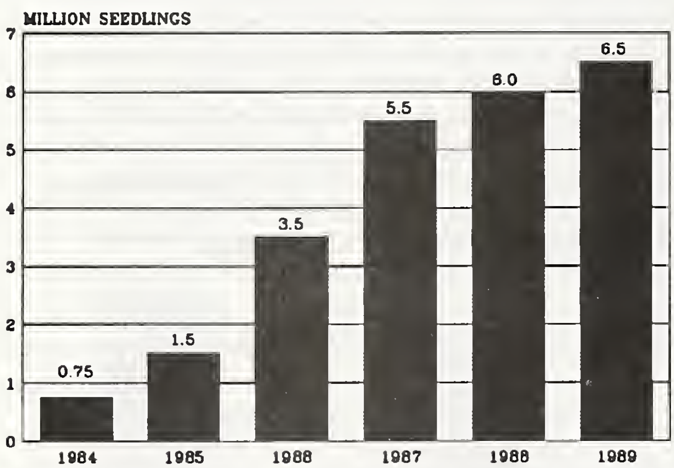


Figure 6. Operational Pt custom seedling production using commercial vegetative and spore inoculum in bare-root and container seedling nurseries, 1984-1989.

Interest in the use of Pt ectomycorrhizae in mineland reclamation has also increased steadily over the past 10 years. Since its inception in 1981, the Ohio Abandoned Mineland Reforestation Program has planted approximately 1.4 million Pt-inoculated seedlings on 810 acres of abandoned minelands in southern Ohio. This program has expanded annually, and in 1988-89 the Ohio Division of Reclamation planted approximately 0.5 million Pt-inoculated seedlings on 285 acres. Estimates for tree planting in Ohio through 1990 indicate further increases of an additional 2.6 million Pt-inoculated seedlings for plantings on 1,850 acres of abandoned mineland (Cordell, Caldwell, and others 1988).

National Forests, state forestry agencies, and a number of private companies have shown considerable interest in the use of Pt ectomycorrhizae on selected forestation sites in the United States. National Forests in Ohio and South Carolina have scheduled the annual production of Pt-tailored bare-root seedlings for selected forestation and reclamation sites. The Savannah River Forest Station, in cooperation with the U.S. Department of Energy (DOE) in South Carolina, has initiated a 5-year reforestation plan utilizing a minimum of 2.0 million Pt-tailored longleaf and loblolly pines annually. During 1989, Pt-inoculated seedlings are being produced for five state forest agencies and five forest products companies. Christmas tree growers have recently ordered Pt-inoculated seedlings, which are presently being produced in several southern nurseries. The demand for Pt-tailored seedlings is expected to substantially increase during the next 5 years due to the increased emphasis on forestation, mineland reclamation and other related forest projects.

Technology Transfer

In a special program, the USDA Forest Service continues to provide mycorrhizae technology to forest tree nurserymen, field foresters, mineland reclamation specialists, Christmas tree growers, and other concerned land managers throughout the United States and several foreign countries (Cordell and Webb 1980; Cordell 1985; Cordell, Owen, and others 1987). Initially, this program emphasized the use of Pt on selected forestation sites and in mineland reclamation programs. However, as previously related, the program is being expanded to a wider range of forestation sites, mycorrhizal fungi, and tree hosts over a broader geographic area. The expanded technology transfer program is acquiring international recognition.

Conclusions

Results obtained during the past several years consistently demonstrate that the Pt ectomycorrhizal fungus can be used operationally in container and bare-root nurseries to significantly improve survival and growth of seedlings for forestation, mineland reclamation, and Christmas tree production. Technology obtained from this pioneering project is being expanded to other ectomycorrhizal fungi, host tree species, forest applications, and geographic locations. Several types of effective Pt inoculum are commercially available, as are machines for vegetative mycelium inoculations in bare-root nurseries. These recent developments provide nurserymen, foresters, mineland reclamation specialists, Christmas tree growers, and other land managers with alternatives for using Pt, as well as other selected ectomycorrhizal fungi. The best field planting results continue to be obtained on adverse sites such as coal spoils and forestation sites with soil moisture deficits. In addition, results are consistently better when planted seedlings have Pt indices $\geq$ 50 (Pt incidence equal to or greater than other natural ectomycorrhizae incidence on seedling feeder roots). The cost of custom seedling inoculations with selected ectomycorrhizal fungi represents only a minor portion of the total tree planting expense (less than 5%), and high seedling quality is an obvious key to successful forestation, mineland reclamation and Christmas tree production. Consequently, the benefits of producing custom-grown seedlings with selected ectomycorrhizal fungi for specific forestation and mineland reclamation sites should greatly exceed the costs.

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Bacterial Inoculation of Lodgepole Pine, White Spruce, and Douglas-fir Grown in Containers[1]

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Abstract Inoculation of lodgepole pine and Douglas-fir with two Bacillus strains was shown to promote seedling growth. Strain L6 caused significant increases in lodgepole pine shoot and root dry weight, root surface area, and root collar diameter after eight weeks growth from seed. When 1-0 containerized stock was inoculated, shoot growth was increased, but root weight increases were not significant. Strain L6 also increased the root surface area of Douglas-fir 12 weeks after inoculation. Strain L5 significantly increased the rate of spruce seedling emergence and root surface area of lodgepole pine after 12 weeks growth but dry weight gains were not significant.

INTRODUCTION

Microbial activity in the plant rhizosphere has substantial effects on plant productivity (Gaskins et al. 1985). Bacteria are the most abundant type of rhizosphere microorganism reaching populations of up to 3×10^9 cells per gram dry weight of soil (Rouatt and Katznelson 1961). There have been numerous investigations centred on the possibility of enhancing agricultural crop productivity by inoculating seed or seedlings with beneficial rhizobacteria. Substantial gains in plant biomass due to bacterial treatment have been demonstrated (Gaskins et al. 1985; Schroth and Weinhold 1986). The term plant growth promoting rhizobacteria (PGPR) has been used to describe soil bacteria that are able to colonize plant roots and stimulate plant growth when applied to seeds, tubers, or roots (Kloepper et al. 1980). Seed inoculation with bacteria also has been shown to stimulate seedling emergence (Holl et al. 1988). Strains belonging to several genera have been demonstrated to promote plant growth but those belonging to Pseudomonas, Azospirillum, Azotobacter, and Bacillus are most commonly encountered (Gaskins et al. 1985).

The mechanism by which PGPR exert such effects remains unknown but several possibilities have been examined. These include: (i) increased availability of some limiting nutrient, usually phosphorus, through secretion of phosphorus solubilizing compounds; (ii) suppression of pathogenic or deleterious bacteria in the rhizosphere of crop plants through antibiotic production or direct competition; (iii) bacterial production of plant growth substances such as cytokinins, gibberellins, or

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auxins; and (iv) root-associated fixation of atmospheric nitrogen by diazotrophic microbes (Gaskins et al. 1985; Schroth and Weinhold 1986). Although not conclusively demonstrated, much experimental evidence suggests that bacterially-mediated phytohormone production is the most likley explanation for the acitivity of PGPR (Brown 1974; Tien et al. 1979; Holl et al. 1988).

Canada's productive forest land base of 251 million hectares currently contains 30 million hectares which are classified as not satisfactorily restocked (NSR) (Sutton 1985). Several factors contribute to seedling success in the field but the capacity for rapid and vigorous root growth after outplanting is essential. Inadequate root performance is a common characteristic of failing outplanted seedlings. Because PGPR have been shown to affect root characteristics such as branching, surface area, and biomass (Tien et al. 1979; Chanway et al. 1988a,b) they may be of value in current reforestation efforts.

The possibility of enhancing productivity of tree species by inoculation with bacteria has received little attention, however, growth promotion of deciduous species has been demonstrated (Gardner et al. 1984; Pandey et al. 1986; Caesar and Burr 1987). Only two studies with PGPR and coniferous species have been reported (Parker and Dangerfield, 1975; Pokojska-Burdziej, 1982). In both studies, positive effects due to inoculation were observed but neither study involved pure culture inoculation of seedlings in a standard seedling medium. Therefore, the objective of this study was to determine the effect of pure culture bacterial inoculation on emergence and growth of containerized lodgepole pine, white spruce, and Douglas-fir.

MATERIALS AND METHODS

Seed

Lodgepole pine (*Pinus contorta* Dougl.) was collected near Big Lake, British Columbia (52°22' latitude, 121°51' longitude) from an elevation of 945 m. Coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) was collected from McCall Hill, B.C., (52°25' latitude, 126°11' longitude) elevation 400 m. White spruce (*Picea glauca* Voss.) was collected near Quesnel, B.C. (53°12' latitude, 122°3' longitude) from an elevation of 1350 m. Douglas-fir and white spruce seed was stratified by in cold running water for 24 hours and storing at 4°C for 3 weeks after blotting dry. Lodgepole pine seed was used unstratified.

Microorganisms

Bacillus strains L5 and L6 were utilized as inoculants. These strains were isolated from the rhizosphere of a perennial ryegrass (*Lolium perenne* L.)-white clover (*Trifolium repens* L.) pasture and have been shown to stimulate the growth of various forage species (Holl et al., 1988; Chanway et al., 1988a).

Seedling growth in containers

Experiments were conducted in plastic cones (Pine Cell 64 cm^3, Ray Leach 'Cone-Tainer' Nursery, Oregon, USA) filled with a peat/vermiculite nursery mixture (peat 60 L, vermiculite 20 L, dolomite 190 g, Osmocote 285 g, and micronutrients (Nutritrace, Plant Products Company Ltd., Brampton, Ontario, Canada) 38 g. *Bacillus* strains L5 and L6 were grown separately in nutrient broth for 4 days, harvested by centrifugation (10,000 x g for 15 min) and resuspended in 20 mM potassium phosphate buffer pH 7.0 to a concentration of ca. 10^7 cells per mL (OD_{420}=0.15). Two (lodgepole pine and Douglas-fir) or 4 (white spruce) seeds were sown per cell. Cells were then inoculated with 1 mL of the appropriate bacterial suspension. Control cells received sterile phosphate buffer. Seed was then covered with ca. 10 mm granite grit (No. 1 Granite Grit, Imasco, Surrey, British Columbia, Canada) and cells were watered to saturation.

Seedlings were grown in a growth chamber (Conviron, Winnipeg, Man.) with a 16 h photoperiod, a day night temperature regime of 23:17°C, and photosynthetically active radiation at the canopy level of ca. 300 uE m^{-2}. Plants were watered to saturation every 3 days. Once a week, water was amended with .325 gL^{-1} of fertilizer (Plant-Prod 20-8-20; Plant Products Company Ltd., Brampton, Ontario, Canada) supplemented with 15 mg $FeSO_4$. Each month, 10-15 plants per treatment were harvested. Roots were separated from shoots and shoot height and root collar diameter were measured. Plant material was then dried for 2 days (70°C) before root and shoot weights were recorded and root surface area was assessed using a video image analyzer similar to that described by Cunningham et al. (1989).

Seedling growth in pots

Containerized lodgepole pine seedlings were obtained from the UBC nursery in May and planted in 1 L pots containing greenhouse soil previously described by Holl et al. (1988). Bacillus strain L6 inoculum was prepared as described above. A 1 mL aliquot of bacterial suspension was applied to seedlings above the root system. Control seedlings received sterile potassium phosphate buffer. Plants were grown in the greenhouse under natural light. After 8 weeks growth, seedlings were destructively harvested. Roots were separated from shoots and shoot height, root length and root collar diameter were measured. Plant material was then dried for 2 days (70°C) before root and shoot weights were recorded.

Experimental design and statistical analysis

Experiments performed in containers were arranged in a completely random design and were repeated at least once. Data from experiments were pooled and analyzed as a single experiment with individual experimental trials as an additional factor. A latin square design was utilized in the single experiment involving strain L6 and 1-0 lodgepole pine seedlings. After ANOVA, treatment means were separated using Fisher's Protected LSD or orthogonal contrasts in all experiments.

RESULTS

Strain L6 had a stimulatory effect on seedling emergence of containerized lodgepole pine in one of two trials (data not shown). Five days after sowing, 57% ($p<0.05$) more seedlings had emerged in L6-inoculated containers. The magnitude of the emergence stimulation decreased with time but when emergence was complete 11 days past sowing, L6-inoculated cavities had 12% ($p<0.1$) more seedlings than controls.

After eight weeks growth, seedlings from seed inoculated with strain L6 also showed significant gains in root surface area (23%) and root (17%) and shoot (17%) biomass ($p<0.05$) (table 1). Inoculation with strain L5 did not affect seedling biomass eight weeks after treatment. After 12 weeks growth, no effect of strain L6 could be be detected. However, L5-inoculated seedlings had 16% ($p<0.05$) greater root surface area. Neither strain affected growth of lodgepole pine 16 weeks after seed inoculation.

TABLE 1. EFFECT OF BACTERIAL INOCULATION ON GROWTH OF CONTAINERIZED LODGEPOLE PINE

		ROOT DRY WEIGHT (mg)	SHOOT DRY WEIGHT (mg)	ROOT AREA (cm2)	SHOOT HEIGHT (cm)	ROOT COL. DIAMETER (mm)
8 WKS	CONTROL	18	82	9.8	8.7	0.84
	STRAIN L5	16 (-11)	73 (-11)	8.0 (-18)	9.2 (+6)	NA
	STRAIN L6	21** (+17)	96** (+17)	12.0** (+23)	9.3* (+7)	0.92** (+10)
12 WKS	CONTROL	52	219	21.9	11.9	1.3
	STRAIN L5	51 (-2)	206 (-6)	25.3** (+16)	11.5 (-3)	1.2 (-8)
	STRAIN L6	48 (-8)	224 (+2)	23.3 (+6)	12.4 (+4)	1.3 (0)

* p<0.10 ** p<0.05 ()= % OF CONTROL

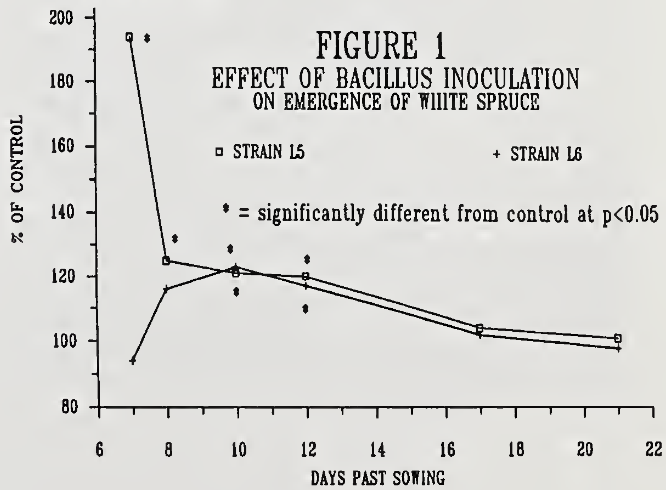
Bacillus strain L6 also stimulated growth of 1-0 bareroot lodgepole pine seedlings when tested in a pot assay in the greenhouse (table 2). Shoot dry weight was significantly higher in response to inoculation with Bacillus (17% $p<0.05$). Root dry weight and caliper also increased due to inoculation, but differences were not significant.

TABLE 2. EFFECT OF INOCULATION WITH STRAIN L6 ON GROWTH OF 1-0 CONTAINERIZED LODGEPOLE PINE

	ROOT DRY WEIGHT (mg)	SHOOT DRY WEIGHT (mg)	SHOOT HEIGHT (cm)	ROOT COL. DIAMETER (mm)
CONTROL	2.23	2.50	16.7	3.82
STRAIN L6	2.46 (+10)	2.93** (+17)	18.0 (+8)	4.01 (+5)

** p<0.05 ()= % OF CONTROL

Inoculation of white spruce with Bacillus strains L5 stimulated the rate at which seedlings emerged (figure 1). One week after sowing, L5-inoculated cavities had almost twice the seedlings (94%, $p<0.05$) when compared with controls. The magnitude of this effect decreased with time until 17 days past sowing when there was no difference between control and L5-treated containers. Strain L6 had no effect on the emergence of white spruce. Neither Bacillus strain affected the growth of white spruce.



Inoculation of Douglas-fir with Bacillus did not affect seedling emergence but significant growth effects were detected. Strain L5 stimulated a significant increase in stem diameter eight weeks after sowing but did not affect plant biomass or root surface area (table 3). Twelve weeks after sowing there were no detectable differences in the performance of L5-inoculated and control seedlings. Strain L6 did not affect seedling growth 8 weeks after inoculation, but a significant increase in root surface area (22%, $p<0.05$) was detected 12 weeks after treatment.

DISCUSSION

Our data confirm that bacterial inoculation of conifer species can stimulate seedling emergence or growth in containers. Uneven or protracted seedling emergence can result in additional costs to nursery operators due to oversowing and thinning operations. Seed inoculation with emergence-promoting bacteria would have obvious benefits in reducing costs associated with poor seedling emergence in the nursery. Bacillus strain L5 stimulated the rate of seedling emergence while strain L6 enhanced the number of lodgepole pine seedlings emerging in one of two trials. These bacterial strains were selected for study because they have shown growth promoting activity with agricultural crops (Chanway et al 1988a; Holl et al. 1988). Other bacterial strains specifically selected for conifer species may be more effective in promoting seedling emergence and require further study.

TABLE 3. EFFECT OF BACTERIAL INOCULATION ON GROWTH OF CONTAINERIZED DOUGLAS-FIR

		ROOT DRY WEIGHT (mg)	SHOOT DRY WEIGHT (mg)	ROOT AREA (cm2)	SHOOT HEIGHT (cm)	ROOT COL. DIAMETER (mm)
8 WKS	CONTROL	28.1	135.5	4.1	9.2	0.84
	STRAIN L5	31.6 (+13)	145.3 (+7)	4.6 (+12)	9.1 (-1)	0.97** (+16)
	STRAIN L6	27.9 (-1)	136.8 (+1)	4.1 (0)	9.2 (0)	0.85 (-1)
12 WKS	CONTROL	91.9	363.0	9.2	17.4	1.45
	STRAIN L5	92.1 (0)	366.0 (+1)	9.2 (0)	18.0 (+3)	1.41 (-3)
	STRAIN L6	102.9 (+12)	390 (+7)	11.2** (+22)	17.1 (-2)	1.55 (+7)

** $p<0.05$ ()= % OF CONTROL

The most consistent effect of seed inoculation on plant growth was an increase in root dry weight and/or surface area. Grossnickle and Blake (1987) have demonstrated the importance of new root growth in establishment of outplanted pine and spruce seedlings. Therefore, bacterial inoculation of seedlings before outplanting may be a useful technique to increase seedling survival in the field.

It is interesting to note that the response of Douglas-fir to inoculation with strain L6 took 3 months to develop. Eight weeks after bacterial treatment no difference due to inoculation could be detected, but 12 weeks after sowing, root surface area was 22% greater than controls. Parker and Dangerfield (1975) also reported a delayed response to microbial inoculation in Douglas-fir. Five weeks after inoculation treated plants were reported to be slightly smaller and weakly chlorotic but 13 weeks after treatment inoculated seedlings were visibly larger. In contrast, the stimulatory effect of bacterial inoculation on the growth of lodgepole pine decreased with time. This may be due to poor inoculum survival or to the restricted area in which root systems developed. Root colonization studies with antibiotic resistant mutants of strain L6, re-inoculation experiments, and experiments in larger size containers are underway to determine the cause of the time dependent decline in growth response. Results from our first re-inoculation experiment indicate that the growth response in pine can be maintained if seedlings are re-inoculated 8 weeks after sowing (data not shown). Further experiments with lodgepole pine, Douglas-fir, and Bacillus strain L6 are underway to determine the field response of seedlings to bacterial inoculation.

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The Effects of Mineral Nutrition on Hardening-Off of Conifer Seedlings[1]

Ivor K. Edwards[2]

Abstract.--Containerized lodgepole pine, jack pine, red pine, Scots pine, white spruce, and black spruce were hardened off under different nutrient regimes to determine the effect of nutrition on development of cold hardiness. There was only weak correlation between cold hardiness and nutrient concentration or uptake in the shoot of seedlings. In lodgepole pine, cold hardiness was associated with a low nitrogen regime and in all other species, it was associated with either high phosphorus or high potassium. The implication of a lower level of cold hardiness achieved in pines is discussed.

INTRODUCTION

Over 30 million containerized seedlings are produced annually in the prairie provinces and annual production is projected to be 50 million in three years.

Overwintering has become a very important phase in the production of containerized seedlings as double- and, in one instance, multiple cropping have become more common. It is necessary if outplanting of the first crop is not possible but it is mandatory in the case of the second or subsequent crop because the latter seedlings have attained their desired size too late in the year for outplanting to occur. In preparation for overwintering, the stock has to be hardened off. Dormancy (i.e., cessation of shoot growth and the initiation of terminal buds) is induced by reducing temperature, light intensity, and photoperiod. Following cessation of shoot growth, budset and bud development occur with a moderate amount of cold hardiness (Glerum 1985). With appropriate low temperature acclimatization, further cold hardiness is developed and the stock is ready for overwintering outdoors.

Nutrition during the conditioning phase to induce dormancy and cold hardiness is believed to be important. Unlike the rapid growth phase, when high nitrogen (N) is required for vegetative growth, low N and high phosphorus (P) and/or potassium (K) are required during hardening off (Levitt 1956). Timmis (1974) found that the level of cold hardiness developed in Douglas fir (*Pseudotsuga menziesii* [Mirb.] Franco) seedlings was not related consistently to bud development or individual N, P, and K regimes but was more closely related to K/N ratio in the foliage. The use of a finisher-type fertilizer containing low N and high P or K during hardening off is widespread in the seedling production industry in the prairie provinces. However, the practice resulted from advice given by fertilizer companies, based on research with other species and in other parts of Canada. Objective experiments, utilizing prairie conifers, were required. Lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.), jack pine (*Pinus banksiana* Lamb.), red pine (*Pinus resinosa* Ait.), Scots pine (*Pinus sylvestris* L.), white spruce (*Picea glauca* (Moench) Voss), and black spruce (*Picea mariana* (Mill.) BSP.), are grown in the prairie region for reforestation and it is necessary to work with appropriate provenances of these species. The objective of this study was to determine which nutrient regimes were associated with cold hardiness in the various conifer species and to determine if specific nutrient concentrations in plant tissue was required for development of cold hardiness.

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MATERIALS AND METHODS

Lodgepole pine and black spruce, jack pine and white spruce, and red pine and Scots pine were grown in the Northern Forestry Centre greenhouse (latitude 53°29' N, longitude 113°32'W) in 1985, 1986, and 1987, respectively. Conifer seeds were sown in peat in Spencer-Lemaire "Fives" containers (cavity volume = 55 cm^3) in February and allowed to grow for 14 weeks (Table 1). Prior to filling the trays, the peat was adjusted to pH 5.2 with calcium carbonate. Environment conditions in the greenhouse were as follows: temperature 24°C day and 16°C night; relative humidity 62-65%; light intensity (high pressure sodium lamps) photosynthetically active radiation (PAR) = 260 mol. $m^{-2}.s^{-1}$

Beginning 21 days after germination, fertilizer solution, recommended for pine and spruce (Carlson 1983) and containing 125mg/ℓ N, 60 mg/ℓ P, and 159 mg/ℓ K, was applied once per week. At fertilization, each cavity was completely saturated with nutrient solution. Other nutrients in the solution prescribed by Carlson (1983) were as follows: iron (Fe), 5.5 mg/ℓ; manganese (Mn), 0.34 mg/ℓ; boron (B), 0.30 mg/ℓ; zinc (Zn), 0.11 mg/ℓ; copper (Cu), 0.02 mg/ℓ; and molybdenum (Mo), 0.01 mg/ℓ. Between the weekly applications of fertilizer solution, the trays were watered as required.

At the completion of 14 weeks' growth, the seedlings were subjected to 12 weeks of conditioning (Table 2) which consisted of an initial two weeks during which supplementary lights were turned off, the trays were leached with water, and allowed to become dry. The drought stress was followed by an initial five-week period during which day and night temperatures were 24 and 16°C, respectively, in the greenhouse and a second five-week period in a growth chamber during which day and night temperatures were 10 and 2°C, respectively. During both five-week periods, a photoperiod of 8 hours was achieved, using a black-out cloth and one of five hardening-off solutions (Table 3) was applied. Solution III was the solution recommended to growers based on a review of the literature. Lower concentrations of N and higher concentrations of P and K were included in order to test their effect on hardening-off.

Table 1. Duration of each phase of the experiments

Phase	Duration
Growth	14 weeks
Conditioning	12 weeks
Cold Hardiness Test	24 hours
Assessment	6 weeks

Table 2. Details of conditioning phase

Time	Condition
Weeks 1-2	Supplementary lights off, leaching, drought stress
Weeks 3-7	Photoperiod 8 hours; Hardening-off solution 1x/wk; Day/night temperatures 24/16°C
Weeks 8-12	Photoperiod 8 hours; Hardening-off solution 1x/wk; Day/night temperatures 10/2°C

Table 3. Nutrient regimes used during the conditioning phase (hardening-off)

Solution	N	P	K
	--------mg/ℓ--------		
I	4.4	101	150
II	22	101	150
III	44	101	150
IV	44	202	150
V	44	101	300

Following conditioning, the seedlings were tested for cold hardiness by placing them in a -5°C or -10°C room for 24 hours. They were then returned to the 10/2°C regime in the growth chamber for 24 h before being placed in the greenhouse for a 6-week assessment. Degree of budset at completion of the conditioning phase was noted and survival and condition of shoot and roots were assessed after 6 weeks in the greenhouse. At the end of the assessment period, the seedlings were measured for height, root collar diameter, and shoot:root ratio (dry weight basis) and foliage was analyzed for N, P, and K. Assessment was conducted on a total of 192 seedlings for each treatment (hardening-off solution), comprised of 4 replicates of 48 seedlings each. Significance of differences of mean survival between treatments was assessed using Student's "t"-test (Steel and Torrie 1980). Correlation between survival and shoot concentration and uptake of N, P, and K, and the ratios N/P, N/K, and K/P was determined using the SAS procedure (SAS Institute Inc. 1985).

Nitrogen was determined by the Kjeldahl method (Bremner and Mulvaney 1982, Tecator 1985) and P and K were determined using ICAP spectrometry after nitric acid digestion (Hogan and Maynard 1984, Kalra et al. 1989).

RESULTS

For lodgepole pine, jack pine, white spruce, and black spruce, survival after cold-hardiness testing at -5°C was high irrespective of nutrient solution applied during hardening off (Tables 4 and 5). At -10°C, survival was associated with certain treatments or hardening-off solutions and were higher in spruce than in pine. Solutions I and III favoured survival of lodgepole pine whereas Solutions IV and V were associated with high survival in black spruce (Table 4). Survival of jack pine and white spruce at -5°C was equally high and was equally low at -10°C (Table 5). Solution IV was best for jack pine and Solution V was associated with highest survival in white spruce. The survival of red pine and Scots pine at either -5° or -10°C was lower than that of other pines in the study and there was a marked decrease in survival of Scots pine, especially, at -10°C (Table 6), indicating that it had developed very little cold hardiness. A summary of the effect of nutrient regime on hardening-off of the conifers tested is shown in Table 7.

Lower survival of pine compared to spruce in the study was correlated with the lower degree of budset observed in pine, following the 12-week conditioning period. White spruce set bud generally within 21 days after drought stress and the 8-h photoperiod were initiated. For black spruce, budset was achieved about five weeks after conditioning had begun. All pines were slower in their response to conditioning. Lodgepole pine and jack pine achieved only 50 and 30 percent budset, respectively, at the end of the 12-week conditioning period. Red pine and Scots pine were slowest to respond to the conditioning treatment and achieved only 10 and 1 percent budset, respectively, prior to the cold hardiness test.

Table 4. Survival (%) of lodgepole pine (LP and black spruce (BS) after cold treatment at -5°C and -10°C

Nutrient	Survival -5°C		Survival -10°C	
Solution	LP	BS	LP	BS
I	[1]100a	100a	82a	66c
II	97a	100a	68b	96a
III	100a	100a	78a	85b
IV	99a	97a	39d	100a
V	96a	97a	49c	99a

[1]Within a column, values followed by the same letter are not significantly different at P = 0.05 by Student's "t" test.

Nutrient concentration in foliar tissue was similar in seedlings tested at -5 and -10°C and, except for red pine and Scots Pine, results for -10°C will be discussed.

Table 5. Survival (%) of jack pine (JP) and white spruce (WS) after cold treatment at -5°C and -10°C

Nutrient	Survival -5°C		Survival -10°C	
Solution	JP	WS	JP	WS
I	[1]100a	96a	24c	40b
II	96a	88b	20c	21c
III	96a	96a	24c	8d
IV	100a	100a	56a	24c
V	100a	100a	32b	76a

[1]Within a column, values followed by the same letter are not significantly different at P = 0.05 by Student's "t" test.

Table 6. Survival (%) of red pine (RP) and Scots pine (SP) after cold treatment at -5°C and -10°C

Nutrient	Survival -5°C		Survival -10°C	
Solution	RP	SP	RP	SP
I	[1]85a	50c	46a	0
II	80a	61b	36b	0
III	71b	54bc	40b	0
IV	80a	56bc	26c	6
V	86a	75a	18c	0

[1]Within a column, values followed by the same letter are not significantly different at P = 0.05 by Student's "t" test.

Table 7. Summary of the effect of nutrient regime on hardening-off of conifer seedlings.

	Nutrient regime				
Species	1	2	3	4	5
Lodgepole pine	X				
Jack pine				X	
Red pine					X
Scots pine					X
White spruce					X
Black spruce					X

Concentration of N, P and K in shoot was not significantly correlated with cold hardiness as expressed by survival at different nutrient regimes (Tables 4, 5 and 6). The ratios N/P, N/K and K/P in shoot were calculated and they were only weakly correlated with survival after cold treatment. Only in the case of Scots pine was there a high and significant correlation (r = 0.89) between survival at -5°C and the N/P ratio in shoot. Nutrient uptake in the shoot (determined by multiplying ovendry weight of the tissue by nutrient concentration) was also found to be poorly correlated with cold hardiness.

DISCUSSION

The earlier initiation of budset in spruce, compared to pine, was a reflection of the sharper response (growth cessation) of spruce to a reduction of the photoperiod. The cessation of shoot growth, and formation of a terminal bud signal the onset of dormancy and are prerequisites for the development of cold hardiness (Glerum 1985). Under the conditioning procedure used, the degree of budset in both white spruce and black spruce was higher than in the pines and explains the greater degree of cold hardiness in spruce. Onset of dormancy in pine was obviously not achieved completely prior to the cold hardiness test and, consequently, plant tissue was prone to damage from freezing.

The pines, especially red pine and Scots pine, require further work in determining their requirements of light, temperature, water, and nutrients for hardening-off. Their relatively slow response under the conditioning regime used in this study supports the hypothesis[1], based on fluorescence and photosynthetic studies, that the triggering mechanism for onset of dormancy in pine is completely different from that in spruce, with regard to light and temperature requirements. Pine is able to maintain photosynthesis at lower photoperiod and temperature levels. Also, cold hardiness in roots develops as the growth medium freezes (Glerum 1985). Temperature of the root environment in this study was not monitored but it would not have been less than 2°C, prior to cold treatments. The role of nutrients in the development of cold hardiness is not well understood. In general, nitrogen promotes shoot growth and succulence, thus delaying the development of cold hardiness. Phosphorus and potassium, on the other hand, promote cold hardiness (Levitt 1956). However, research shows no consistent results. Timmis (1974) found no consistent relationship between development of cold hardiness and either bud development or level of N, P, and K in Douglas fir. He concluded that the K/N ratio of the shoot was inversely related to cold hardiness and suggested that a ratio of 0.6 was critical. The weak correlation between cold hardiness and nutrient concentration and uptake in shoot in this study may also indicate that, anatomically, the area of interest is inappropriate. Roots are more sensitive than shoot to damage by low temperature (Steponkus et al. 1976) and therefore nutrient concentration and uptake in this tissue should be examined also.

[1]Vidaver, W. 1989. Personal conversation. Department of Biological Sciences, Simon Fraser University, Burnaby, B.C.

Results from the present study indicate that a nutrient regime with low N was associated with cold hardiness in lodgepole pine, and regimes with high levels of P and K were associated with cold hardiness in jack pine and the other species, respectively (Table 7). Still, inconsistencies remain.

Although Benzian (1965) found a positive effect of K on cold hardiness of Western hemlock (Tsuga heterophylla) and sitka spruce (Picea sitchensis) in bareroot seedbeds, Christersson (1973) found no effect of K on cold hardiness of potted Scots pine. It is recognized (Glerum 1985) that, biochemically, solute concentration in cells increases as cold hardiness develops and N, P, and K contribute to the accumulation of biochemical constituents, depending on their amounts, relative proportion, and time of application.

Results of this study indicate that the nutrient regime presently recommended for hardening-off of prairie conifer species needs to be revised. The recommendation had been based on a review of the literature (Tinus 1974, Van Eerden 1974) but no work on prairie provenances and cultural practices had been conducted prior to this study.

CONCLUSIONS

Both white spruce and black spruce achieved budset more easily than the pines during conditioning and developed a greater degree of cold hardiness as shown by survival following cold treatment. Cold hardiness in spruce appeared to be related to the degree of budset, generally. The pines, especially Scots pine and red pine, respond more slowly to the stimuli of light and temperature used during conditioning and leads to the conclusion that the mechanism for induction of dormancy in this species is not well understood and is worthy of further research.

Except for Scots pine, the data indicated no significant relationship between degree of cold hardiness and nutrient concentration or nutrient uptake in the shoot of seedlings. Investigation of nutrient uptake in roots also merits further study in view of their lower resistance to freezing. However, the nutrient regime presently recommended during conditioning (hardening-off) should be amended. Low N enhanced cold hardiness in lodgepole pine, whereas high P and high K promoted cold hardiness in jack pine, and in the other tested species (red pine, Scots pine, white spruce and black spruce), respectively.

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Provenance Differences in Conifer Seedling Variable Chlorophyll Fluorescence Responses Detected Using the Integrating Fluorometer[1]

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Abstract.-- Differing from white spruce, Douglas-fir seedlings showed no day length-dependent inactivation of photosynthetic photochemistry. Seedlings of both species show reversible inactivation in response to temperature or drought stress. Provenance differences were observed in the responses of coastal Douglas-fir: high elevation seedlings appeared to be more sensitive to declining temperatures than low elevation seedlings.

INTRODUCTION

In common with other kinds of stress-resistant plants, temperate conifer species regulate photosynthetic activity in response to environmental variations (Pharis *et al, 1970;* Hawkins and Lister, 1985; Strand and Lundmark, 1987; Toivonen and Vidaver, 1988; Vidaver *et al*, 1988; 1989). Several temperate conifers, so far examined in our laboratory, are able to inactivate photochemistry in response to low temperatures or water stress and seedlings of at least one species, white spruce, demonstrate a progressive, daylength-dependent inactivation with the approach of fall (Vidaver *et al*, 1988; 1989). This ability to regulate photochemistry is believed to protect needle chloroplasts from stress-induced photodamage (Bolhar-Nordenkampf and Lechner, 1988; Vidaver *et al*, 1988; 1989). In contrast, daylength-dependent regulation of photochemistry was not detected in seedlings of two coastal Douglas-fir provenance types. However, provenance differences were observed in these Douglas-fir seedlings in the induction of inactivation by low temperatures: seedlings from a high elevation provenance began to inactivate at a higher temperature than seedlings from a low elevation provenance.

MATERIALS AND METHODS

2-0 white spruce (*Picea glauca* (Moench) Voss) and 1-0 coastal Douglas-fir (*Pseudotsuga menziesii*) (Mirb.) Franco) container-grown (PSB-313) seedlings were obtained from the B.C. Ministry of Forests nursery in Surrey, B.C. (approx. 49°08'N, 122°48'W). They were

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then maintained in a growing compound at Simon Fraser University (365 m asl), Burnaby, B.C., until tested. The white spruce seedlot was 8981 (origin 58°N, 120°W, 750 m asl) and coastal Douglas-fir seedlots used were 1273 (origin 49°N 122°W, 152 m asl), 6399 (origin 49°N 122°W, 760+ m asl) and 2968 (origin 49°N 125°W, 670 m asl).

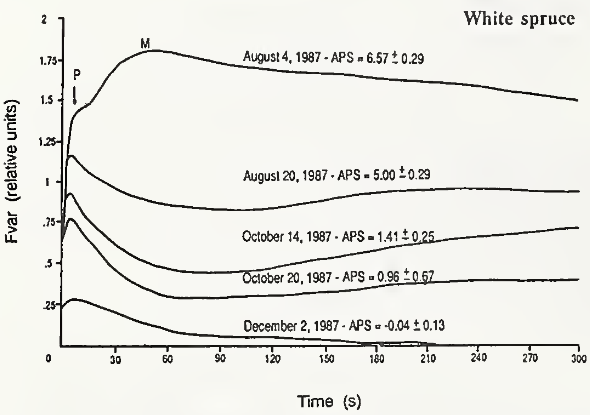

Figure 1.--F_{var} curves for seedlot 8981 white spruce seedlings during progression toward photosynthetic inactivation in 1987. Apparent photosynthesis (APS) shown as mg CO_2/g dry wt./hr. (Redrawn from Fig. 5 in Vidaver *et al*, 1988).

For the fluorescence measurements, shoots of dark-adapted, well watered seedlings were placed in the spherical cuvette of an integrating fluorometer and fluorescence emission (F_{var}) data were collected according to the methods of Vidaver *et al*, (1989).

RESULTS AND DISCUSSION

In white spruce, daylength-dependent inactivation begins around mid-August and usually nears completion by the end of October (Fig. 1). The timing of this progression toward inactivation is somewhat more advanced in higher latitude provenance types than for those more southerly (Vidaver *et al,* 1989). Transient, stress-dependent inactivation can be superimposed on this progression towards winter dormancy (Vidaver *et al*, 1989).

Although photochemical activity in Douglas-fir seedlings fluctuated markedly over the period of July to early December, there was no indication of progression toward fall inactivation (Fig. 2). Presumably, these fluctuations reflect levels of temperature and/or water stress (Vidaver *et al*, 1988) prior to and at the time of measurement.

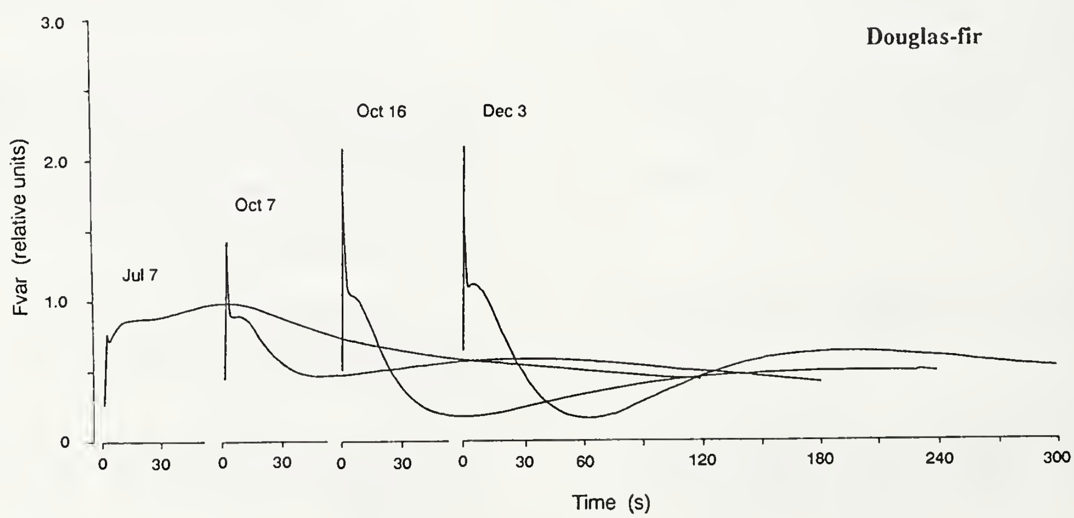

Figure 2.--F_{var} curves for seedlot 2968 Douglas-fir seedlings measured at intervals from early July until early December 1987. Note that except for July 7, the initial F_{var} spike is much more pronounced in these Douglas-fir seedlings compared to white spruce. The July 7 response is indicative of rather severe water stress (see Vidaver *et al*, 1988).

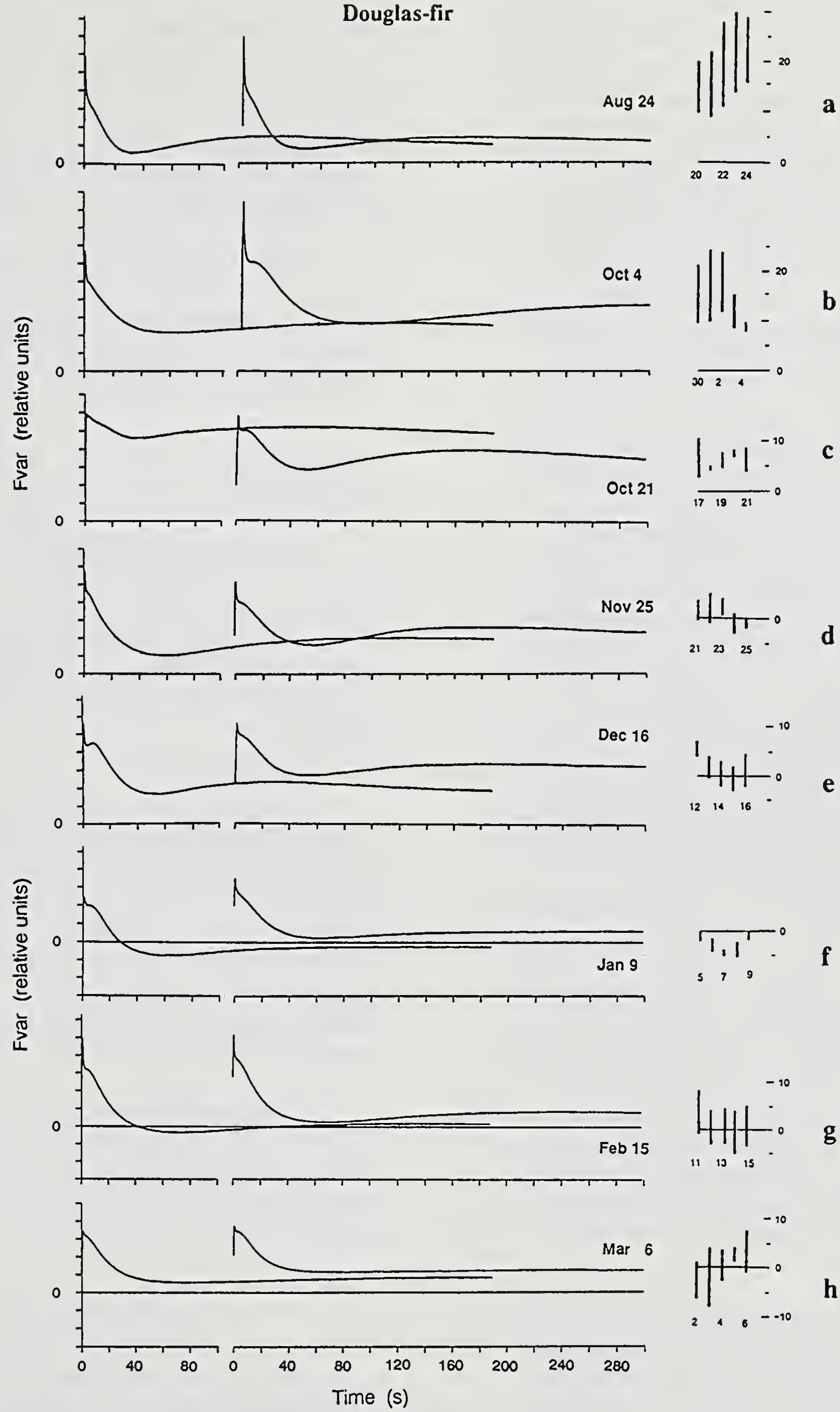

Figure 3(a-h).--F_{var} curves for high elevation (seedlot 6399) and low elevation (seedlot 1273) Douglas-fir seedlings measured over the period from late August 1987 until early March 1988. Responses of 1273 seedlings are shown on the left side of graphs, 6399 on the right. Bar graphs at right display temperature data for four days prior to and on the day of measurement.

Both high (seedlot 6399, 760m) and low elevation (seedlot 1273, 152m) coastal Douglas-fir seedlings displayed indications of water stress in late August when daytime temperatures were approaching 30ºC (Fig. 3a). By early October, when temperatures were dropping, seedlings of both provenances showed some recovery in activity but the high elevation seedlings were more active (Fig. 3b). By the third week in October, with further temperature decline, activity decreased in both seedlots but more so in the high elevation seedlings (Fig. 3c). In late November when sub-freeezing temperatures were experienced, activity in both seedlots was low but remained somewhat higher in the low elevation seedlings (Fig. 3d). Activities in both seedlots remained low on Dec. 16 following a period of nighttime frost. The greatest extent of inactivation of both seedlots was observed on Jan. 9 (Fig. 3e), at a time when daily temperatures did not exceed 0ºC. Considerable recovery was seen in both seedlots measured on Feb. 15 (Fig. 3g), coinciding with an increase in daytime temperatures. In early March following a period of low temperatures, activities had declined again in both seedlots. These results indicate that photochemical activity in both high and low elevation coastal Douglas-fir seedlings can decline during periods of high or low temperatures. Photochemical activity reached its lowest level during a period when daytime temperatures were below 0ºC (Fig. 3f), but higher activity levels were sustained during periods when daytime temperatures were relatively high even though subfreezing temperatures were experienced at night (Fig. 3e, g). These results indicate that inactivation is largely a response to light during low temperature exposure and is in agreement with reports of Strand and Lundmark (1988) and Strand and Oquist (1985). Since activities were relatively high in October when white spruce seedlings would show substantial inactivation (Fig. 1), it appears unlikely that activity in the coastal Douglas-fir seedlings we measured was appreciably affected by daylength. A greater decline in high elevation seedlings during a period of decreasing temperatures (Fig. 3b-c) may indicate that they are more sensitive to chilling than the low elevation seedlings.

Presumably, these response differences relate to ways the species are adapted to their environments (Rehfeldt, 1986). White spruce ranges over a habitat characterized by rigorous winters and the possibility of drought anytime during the growing season. The more severe climate of northern provenances probably accounts for the earlier inactivation of seedlings from such regions. White spruce tends to be a slow growing species but is remarkably resistant to low winter temperatures and summer drought. In part, its slow growth may be attributable to the early fall inactivation of photosynthesis which persists until dormancy is broken in the spring. On the other hand, coastal Douglas-fir is highly opportunistic: it appears to undergo transient inactivation in response to drought or low temperatures but photosynthesis resumes rapidly upon stress alleviation at any time during the year.

It is not yet known whether conifers other than Engelmann (unpublished data) and white spruce possess the daylength-dependent inactivation mechanism. The data presented here suggest it may not be present in coastal Douglas-fir.

OPERATIONAL USES OF F_{var} ASSESSMENT IN THE NURSERY

Variable chlorophyll fluorescence (F_{var}) assessment with an integrating fluorometer is a useful and reliable indicator of photosynthetic activity of intact conifer seedlings. For white spruce, because of the coincidence of photochemical inactivation and the progression toward dormancy, F_{var} data can be used by nursery growers to determine the optimum lifting window dates for this species.

F_{var} assessment also provides information about reactivation of photochemistry. This can be used to monitor seedling recovery from cold dark storage or from the effects of environmental stress. Knowledge of the differences in F_{var} responses can help to optimize nursery operations for the various conifer species and provenance types. Seedling genotypes could be identified using F_{var}, lessening the uncertainity of matching stock types with outplanting site selection.

A commercial version of the integrating fluorometer (Fluoroscan, Intec Inoventures Inc., Victoria, B.C.) is designed to be used operationally by nursery growers. Initial deployment of this system is expected to begin in September 1989.

ACKNOWLEDGEMENTS

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Causes and Control of Overwintering Damage in Nursery Stock[1]

James I. Reid[2]

Abstract.--The process of surviving through the winter in northern climates exacts a visible and invisible toll on tree seedlings. This affects their survival on the nursery, and in the field. The causes for and control of these adverse effects are summarized.

INTRODUCTION

I recently heard the thesis put forward that the "Greenhouse Effect" is in reality a "Ratchet Effect", not so much actively heating up the world's climate as limiting the "fall back" associated with the regular rise and fall of temperatures in the natural long and short term cycles of temperature change. The net effect of this in global terms amounts to heating, but the local effects are more along the lines of increased instability. If this thesis is correct, it means increasing problems for the nurseryman since it is frequently not the severity of conditions which proves to be damaging to stock but the rapidity of change. The prospect is then, if you subscribe to the theories of global climate change, that those nuserymen who have not already experienced damage to their stock will, and those who have, will experience more.

In northern climates winter is a period which can be particularly stessful for plants left in outdoor conditions. For the tree nurseryman the problem is the arrival at the time of shipping with a proportion of the crop in a physiological condition insufficient to ensure successful outplanting. The seedlings which began the overwintering period in apparently acceptable condition but have not survived, have "stressed out". They have succumbed to an accumulation of stresses beyond their resources to deal with. To successfully survive the inevitable stresses of overwintering, the seedlings must begin this difficult period with a minimum of accumulated stress and a maximum of stored reserves. The cultural implications of this are a secondary issue to this study. It must however remain, that our relative success, or lack of it to date, may have been strongly influenced by our ability to come to grips with the requirement to ensure a favourable physiological state.

The Nursery Technology Cooperative of the Oregon State University is currently using what they call "The Target Seedling Concept" as a focus for directed research studies. Simply stated it is:

targeting specific physiological and morphological seedling characteristics that can be quantitatively linked with reforestation success [Oregon State 1988].

It is the milepost at the transfer from nurseryman to field forester which will ensure the greatest likelihood of successful outplanting performance. This implies that the end product of the process of overwintering must not only survive but must possess characteristics assessed to be essential to the seedlings success beyond the nursery gate.

Leaving morphology aside and focusing on the successful plantation tree, what physiological characteristics are required of the seedling as it reaches the end of overwintering? Broadly speaking, stock must still possess sufficient dormancy and cold hardiness to carry it past the risk of

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frost damage in the field. Its' carbohydrate reserves must not be exhausted, and its' water relations should still be relatively favourable [Ritchie 1986a].

To complete a period of overwintering successfully, it follows that the seedling must begin with root and shoot sufficiently mature and acclimated to withstand the degree and rate of temperature decline which it will experience. It must have adequate carbohydrate reserves to cover losses to respiration during overwintering and have a substantial tolerance for dessication of roots and tops without damage [Ritchie 1984 and 1986b]. Moreover, to fulfill "The Target Seedling Concept" it should be at a sufficiently low level of stress and possess such additional carbohydrate reserves as are needed to successfully establish on a plantation site even under adverse environmental conditions.

THE NEGATIVE IMPACT OF OVERWINTERING

Assuming that we are able to begin overwintering with a "Target Seedling", the critical step is to preserve that seedling until time of planting by providing an environment which protects against excessive demands. Such demands may contribute to a level of "stress accumulation" which results in failure after outplanting. This is difficult to predict and harder to measure. Less frequently the effects of overwintering damage will be more obvious, appearing as physical signs of damage or outright death. These mechanisms are as follows:

Winter Dessication:

Dessication occurs when the rate of transpirational loss exceeds the rate of water uptake. While roots do not become dormant, low temperatures do inhibit activity, reducing the ability of root tips to compensate for rapid transpirational losses by absorbing water. The increasing viscosity of water with falling temperature further reduces the efficiency of water uptake to the point where freezing of the soil water and media halts it altogether. So long as the top is not frozen, the rate of transpiration increases along with increases in light intensity, temperature and wind speed, and in response to decreases in humidity. The disasterous combination of actively transpiring tops and frozen root systems is a condition particularly probable very early and very late in the outdoor overwintering period [Green 1985].

Freeze Damage:

Boreal forest species are among the most cold hardy plants known. Properly conditioned, species such as Jack Pine have been observed to tolerate temperatures as low as -196 degrees Celsius [Green 1985, Dymock 1987]. On the other hand, lush new foliage of these same plants may be severely damaged by any sub-freezing temperature. Frost killing temperature will vary widely depending on the manner of temperature change, the growth stage, the season and the physiological state of the plant. If the plant is inhibited by any of these factors from preventing intracellular freezing, damage will occur.

A major problem in overwintering container grown plants is that the roots are significantly less cold-tolerant than the shoots. This is because while shoot and bud acclimation is dependent on an array of environmental cues, root growth regulation is entirely dependent on temperature. Since roots are never truly dormant, low temperatures (i.e. less than 3 to 5 degrees Celsius) promote hardiness, whereas higher temperatures, at any time, cause deacclimation. Some experts suggest that deacclimation can be complete within 24 hours while full root acclimation may take up to three weeks. As in the case of shoots, freezing conditions during the period when the plant is unable to control intracellular freezing will result in damage [Green 1985, Dymock 1987, Havis 1976, Fuchigami 1982].

Frost Heaving:

Heaving occurs when the soil surface freezes usually during overnight cooling. This frozen layer grips the stems of the seedlings. Soil moisture trapped under this layer then forms ice crystals which lift the surface layer pulling out or tearing the root system . This is particularly a problem in heavier soils.

Frost Cracking:

The bark and outer layers of some species may crack as a result of differential expansion when the exterior thaws or the xylem freezes.

Winter Burn:

The sun can raise foliage temperatures above freezing in winter even when the air temperature is below freezing. At sunset the thawed foliage refreezes rapidly. The rapidity of the freezing causes winter burn [Burke 1978].

Winter Scald:

Winter scald is similar to winter burn but occurs in the bark of the bole.

Frost Smothering:

When saturated media freezes, little or no oxygen can reach tree roots. Since oxygen must be available to support plant metabolism, seedlings may die unless the media thaws and is allowed to release the water occupying the macropore space, normally occupied by air. Damage usually occurs if the situation persists over 48 hours [Burke 1978].

The Key Points

Considering all of the discussed influences likely to adversely affect the state of the crop, the achievement of increased success in overwintering lies in the following key points:

1. Seedlings to be overwintered must be fit. That is, all unnecessary stresses must be minimized, plant reserves maximized, top development and hardening completed and root chilling requirements fulfilled before the plant is subjected to winter conditions.

2. Storage temperature must be, to some degree, controlled. Once freezing has been achieved, it is undesirable for either the root or the shoot to slip into and out of that state and especially not out of syncronization with each other. The rapidity of temperature change may be more critical than the degree.

3. Higher levels of solar radiation should be avoided.

4. Exposure to moving air (over 4 mph) should be minimized.

5. Ambient humidities around the plants should be maximized.

6. Anaerobic conditions in the plant's rooting medium must be avoided.

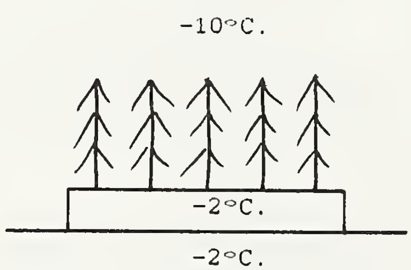
THE PRINCIPLES OF CONTROL

Temperature Control

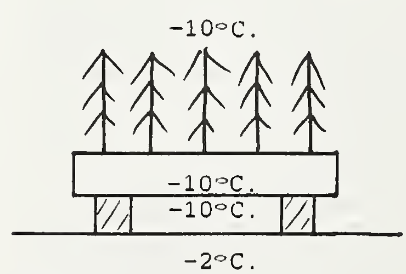
Thermal Mass.--The cheapest and most widely used means of temperature control is thermal mass. This is based on the principle that the greater the mass, the more calories of heat must be exchanged in order to affect a given change in temperature. Since the total amount of stored energy is proportional to the mass, the more mass that is involved the longer it will take to change temperature. In the case of container stock, by placing containers on the ground to create the least possible thermal barrier between the media and the ground we use the thermal mass of the earth to slow the rate of temperature change of the rooting medium.

Thermal Barrier.--Just as we minimize the thermal barrier between containers and the earth, we can also maximize the thermal barrier between any nursery stock and volatile conditions of the environment. This may take the form of a thin mulch barrier placed at the interface of shoot and root, permitting moderation of temperature change in the root and growing media but not the shoot. It can be deeper coverage which envelopes the entire shoot zone or it can be even deeper, resulting in the most extreme temperature conditions occurring well above the shoot zone.

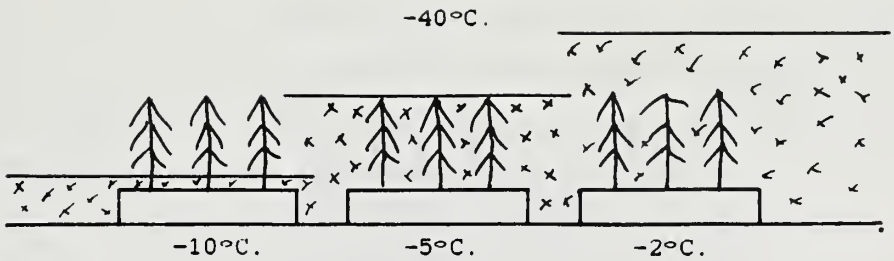
Any material possessing the property of thermal resistivity (R-factor) and inhibiting the exchange of air with the outside environment will insulate the conditions of the stock. The greater the R-factor of the material the slower will be the exchange of heat across it. The less the area of the material, the slower will be the exchange.



Media in trays in contact with the ground will show temperatures near those of the ground.



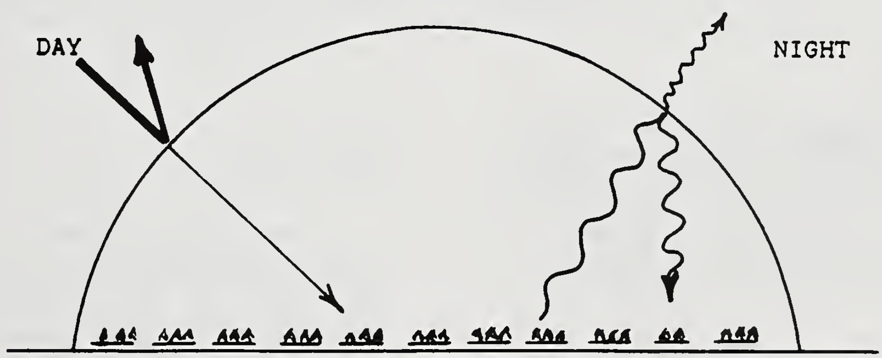
Media in trays not in contact with the ground will show temperatures near those of the air.



Increasing mulch/snow depth increases both the physical amount of the trees protected and the degree of protection afforded. (temperatures are examples only)

<u>Radiant Energy Control</u>.--The regulation of radiated energy by means of a light limiting barrier reduces daytime temperature rise caused by incoming sunshine converted to heat. It may also limit radiated heat loss by reflecting it inward, the overall effect of the two factors being to reduce the range of temperature fluctuation. Snow and mulch covers accomplish this as do most forms of structureless and structured cover.

<u>Environmental Control Systems</u>.--The temperature may be actively controlled by the provision of heating/refrigeration equipment capable of either partially or completely regulating storage temperatures. Provision of such support systems can probably only be practically accomplished within an insulated structure. The cold storage units used in many bareroot operations are good examples of this approach.



Even partial limiting of radiant energy exchange will dramatically moderate temperatures within the cover.

Wind Protection

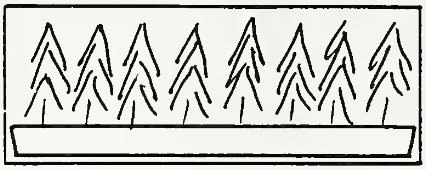
<u>Windbreaks</u>.--The rule of thumb in windbreak management is that the wind shadow effect of a vertical barrier exists for a distance equal to two times the height of the windbreak upwind and five times the height in the lee [Baldwin & Johnston 1985]. Following this assumption, any area encircled by a sufficiently high barrier is, to all intents, completely shielded from wind. If a non-solid material such as shade cloth is employed as the vertical barrier, performance is assumed to be somewhat reduced.

<u>Shade Houses</u>.--Complete enclosure within full walls and overhead cover of shade material may offer an additional increase in protection over walls alone of like material.

<u>Envelopment</u>.--Complete enclosure within an impermeable structure or within structureless covering materials offers complete exclusion of wind. However, free air space within structures may require internal barriers to convective currents.

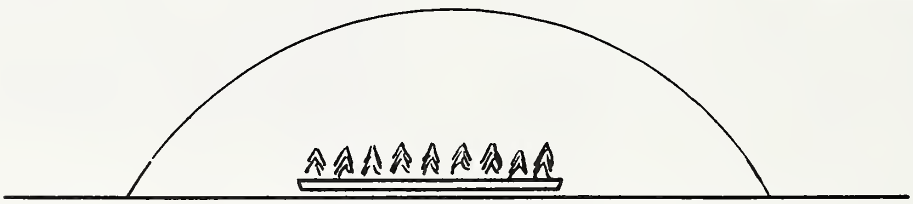
Envelopment may be approached at any level:

-by packaging within closed containers



-by employing structureless covers

-by housing within a closed structure (although some moisture is then shared with the large volume of enclosed air)

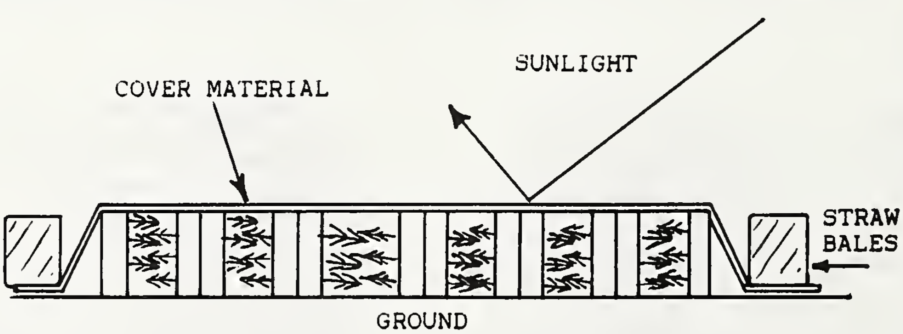


Moisture Control

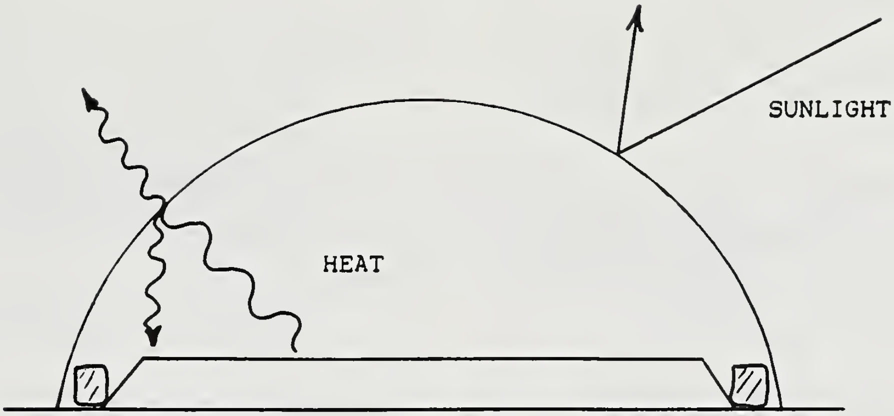
<u>Permeable Cover</u>.--Permeable covers will slow the escape of moisture from the plant environment. This includes fabrics, deep mulches, and snow. Of these, snow is probably the most beneficial. These covers are ineffective in the exclusion of undesirable additional moisture via rainfall.

<u>Envelopment</u>.--Closing the "system" within an impermeable cover retains the inherent plant moisture level. It is additionally effective in excluding unwanted additional moisture in the form of rainfall.

<u>Mechanical Systems</u>.--Mechanical systems designed to introduce humidity may be employed, but are difficult to operate below freezing point. As in the case of other mechanical systems, these are in practical terms best limited to formalized structures.



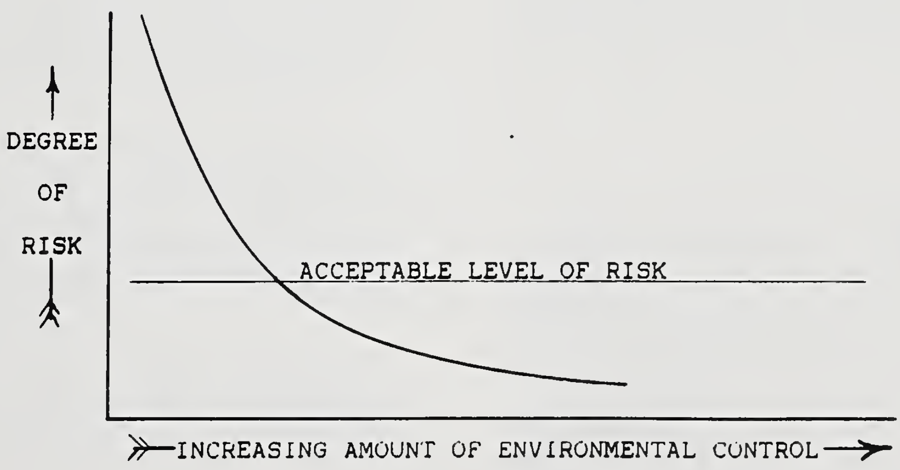
Containers which will stand on their edge facilitate the support of the cover materials. Rodent control can be critical since this is also an attractive overwintering place for such animals.



The use of a structured cover in conjunction with a structureless cover helps to further moderate the overwintering environment.

HOW MUCH CAN YOU AFFORD TO DO?

The bottom line for the nurseryman is not really what he can do but what he can afford to do. It is no surprise that by increasing our expenditure we can increase control and reduce risk. However, instability in weather means increased risk. The question could well become "how much can we afford not to do?"



Present overwintering practices would fall on the curve somewhere above the acceptable level line. Cold storage would be below the line. Placing of other methods requires more trial information.

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White Spruce: The Effect of Long-Term Cold Storage Is Partly Dependent on Outplanting Soil Temperatures[1]

G. Harper, E. L. Camm, C. Chanway, and R. Guy[2]

Seedlings of *Picea glauca* were freezer stored for 0 to 30.5 wks. at -5C, and thereafter grown at three different soil temperatures (3,7,11C). Root growth at 11C increased as seedlings received up to 14 wks. storage duration, and decreased thereafter. In contrast, root growth at the lower temperatures simply decreased with storage duration. Root growth performance and stomatal conductance data both suggest that storage duration greater than 22 wks. can be detrimental to seedling development.

INTRODUCTION

Conifer seedlings for freezer storage, lifted at their peak of cold hardiness and stress resistance, are stored from 4 to 8 months in British Columbia. During this period physiological changes occur which may affect subsequent outplanting vigor and survival. Our area of concem is the effect of storage duration on root growth of seedlings, since limited root growth has been implicated as contributing to failure of large plantations of white spruce (*Picea glauca* (Moench.)Voss.) in B.C. (Butt 1986).

The effect of storage on root growth is not straightforward. In general there is a long decline in root growth capacity with storage, although in Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) there is also a transient increase in root growth capacity after two months storage (Ritchie 1987). This temporary increase is also noted in winter-lifted interior spruce and to a lesser extent in lodgepole pine (*Pinus contorta* Dougl.) (Ritchie, Roden and Klein 1985).

The relationship between storage duration and root growth may be even more complex. Husted and Lavender (1988) tested root growth of white spruce seedlings before and after 6 months storage; there was no net change in root growth in 17C soil, which contrasted with a striking loss in root growth in similar seedlings planted in soil at 3C. The idea that the observed effect of storage duration might depend on the temperature at which seedlings were planted, formed the basis of the present experiment.

An additional factor which seemed relevant in this experiment was the role of stored and newly assimilated carbohydrate. One obvious effect of storage is in the depletion of stored carbohydrates. Carbohydrate depletion has been noted in Douglas-fir (Ritchie 1982), in Ponderosa pine (*Pinus ponderosa* Laws.) (Hellmers 1962), and in Engelmann spruce (*Picea engelmannii* Parry) (Ronco 1973), and poor seedling performance has been attributed to reduced carbohydrate levels (Ritchie 1982, Ronco 1973). However, in some cases, new photosynthate rather than stored carbohydrate appears to be critical for root growth. The development of new roots in Sitka spruce (*Picea sitchensis* (Bong.)Carr.) is partly dependent, and in Douglas-fir, entirely dependent upon the carbohydrate source from the shoots (Philipson 1988, van den Dreissche 1987). Whether new root growth is dependent on carbohydrate reserves or on photosynthate or both, is not understood, but it seemed that the seedling's ability to establish a new root system would be enhanced by an active photosynthetic process. We decided to examine in more detail the root growth of stored white spruce seedlings, at soil temperatures that might be encountered in planting sites, in conjunction with measurements of photosynthetic gas exchange during the first month of growth after storage.

MATERIALS AND METHODS

Container grown white spruce (1+0,PSB 313) obtained from the B.C. Forest Service, were lifted and cold stored at -5C for up to 30.5 wks. (7.5 months). All work was done under normal operational conditions. At approximately one month intervals, seedlings were removed, thawed, potted, and grown for 28 days in three soil temperature treatments (3,7,11C), in a growth chamber at U.B.C. (air temperature 11C, 480 µmol $m^{-2}s^{-1}$ PPFD, 16 hrs. photoperiod). During this period several gas exchange parameters such as net photosynthesis and stomatal conductance were followed using a Licor 6200 IRGA. Seedlings were measured at 680 µmol $m^{-2}s^{-1}$ PPFD. New root growth was measured at the end of each growth period.

[1]Poster presented at the Intermountain Forest Nursery Association Annual Meeting, Bismarck, North Dakota, August 14-18, 1989.

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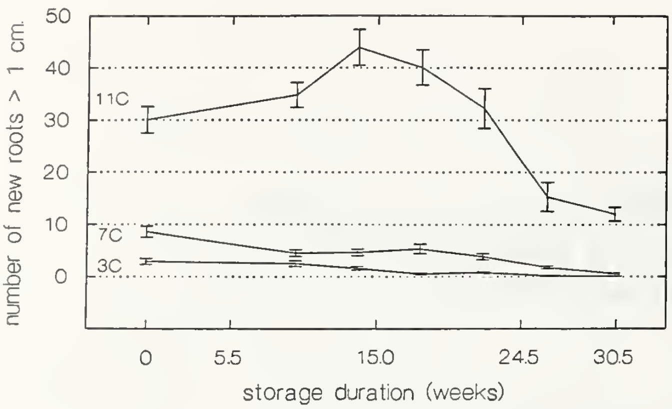

Figure 1 -- New root growth >1 cm. after 28 days at 3,7,11C soil temperatures, and dark freezer storage to 30.5 wks. Error bars are 1 SEM, n=40.

RESULTS

Root growth (as assessed by number of roots longer than 1 cm.) was lower at the colder temperatures (3,7C) than that at 11C over the entire range of storage durations (Fig. 1). In addition, an interaction between soil temperature and length of storage was evident: unstored seedlings (0 wks. storage) planted at 11C produced 3.5 times as many roots as those planted at 7C, although by 30 wks. storage the ratio had increased to 20 times. At this latter storage duration, root production at both temperatures had decreased. An increase in root growth over storage duration was evident only with the high soil temperature, and peaked at 14 wks. In contrast, the colder soil temperatures (3,7C) showed a negative effect on root growth over the entire storage range.

Stomatal conductance and net photosynthesis measurements were not strongly affected by soil temperature (data not shown), although both variables were affected by storage. The data shown in Figures 2 and 3 show similar patterns to those collected from seedlings growth at the other temperatures.

Figure 2 shows the effect of storage duration on stomatal conductance at various periods up to 28 days after outplanting. The first day after outplanting, stomatal conductance was low, and had the same value after all storage durations. However, by day 4 all seedlings showed an increase in conductance which we interpret as stomatal opening. Following this was a general increase in conductance during the rest of the 28 day period after outplanting (shown in Figure 2 as points vertically above each other). This is attributed to increased water loss by developing new foliage after bud break. Storage duration greater than 22 wks. had some effect on this pattern; seedlings stored for the longer periods showed a dramatic increase in conductance after day 1.

Just as with stomatal conductance, changes in net photosynthesis were observed in the 28 day growth period after each storage duration, and this pattern of change was affected by storage duration. With increased storage duration (up to 22 wks), the pattern became more complex, although there was a trend to generally higher levels of net photosynthesis. At longer storage durations, (longer than 22 wks.) the pattern changed; rates of photosynthesis started out low and rose to high levels during the observation period.

Figure 4 shows the effect of storage duration on the number of days from planting to terminal bud break (TBB). This interval was not directly affected by soil temperature, although there was a strong effect of storage duration. Over the entire 30.5 wks. storage period the interval to TBB was found to decrease from about 23 to 8 days (average of three soil temperatures).

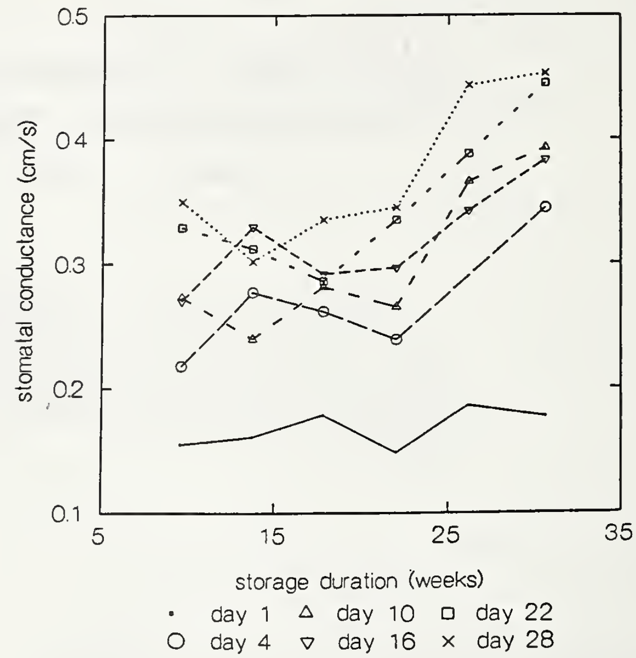

Figure 2 -- Stomatal conductance changes over 28 days growth at 3C soil temperature after varying storage durations, n=40.

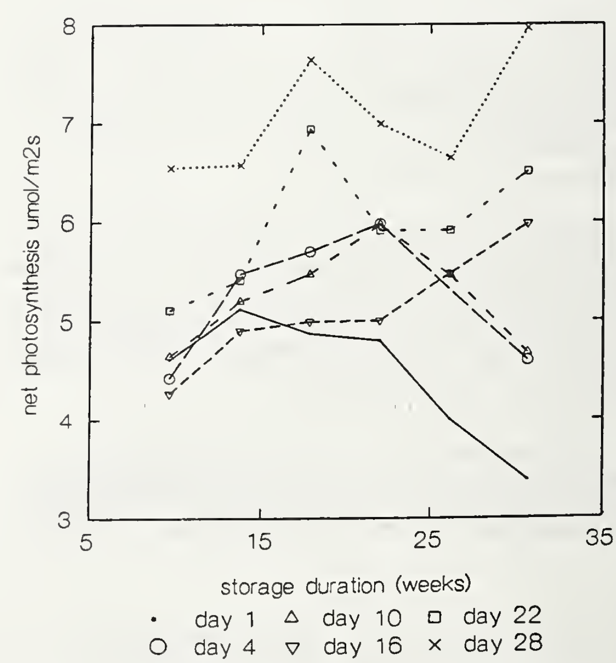

Figure 3 -- Net photosynthesis changes over 28 days growth at 11C soil temperature after varying storage durations, n=40.

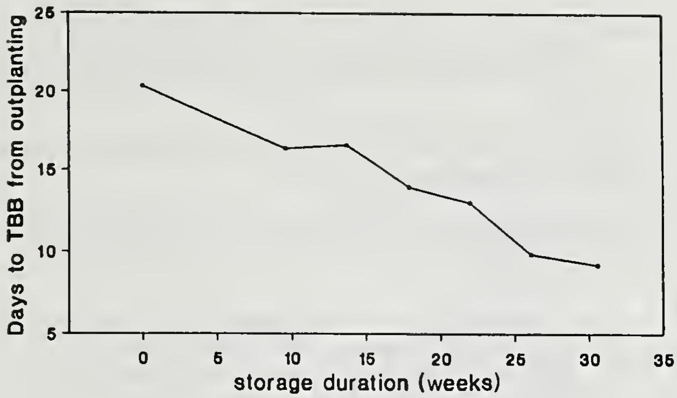

Figure 4 -- Days to terminal bud break (TBB) after varying storage durations, n=120.

DISCUSSION

In this study, we observed relatively little effect of soil temperature on the shoot, as judged by the response of photosynthesis, stomatal conductance and the interval to TBB. This is in direct contrast to the findings of DeLucia (1986), in which root temperatures below 8 degrees caused a strong effect on both photosynthesis and conductance in Engelmann spruce.

However, photosynthesis, conductance and interval to TBB were affected by storage duration. The effect on stomatal conductance was fairly straightforward. After all storage durations, the seedlings demonstrated relatively low stomatal conductance for the first 4 days after planting. We interpret this as part of the seedling recovery process after storage, and it may indicate stomatal opening upon relief of water stress. In the case of seedlings stored longer than 22 wks, we observed that the final stomatal conductance increased with extended storage duration. This general trend may be the result of hormonal activity; abscisic acid (ABA), which has been implicated in stomatal control (reviewed in Zeevaart and Creelman 1988) may decrease with long term storage. Abscisic acid has also been implicated in bud dormancy, suggesting that the increased conductance and shortened interval to terminal bud break (Fig. 4) may be both related to declining ABA levels.

After 22 wks. storage the reduction in net photosynthesis was not correlated with stomatal conductance. This suggests stomatal size was not limiting photosynthesis. After 22 wks. storage, a low photosynthetic rate during the initial 4 days of growth indicates impairment of the photosynthetic system.

In contrast to the shoot parameters, root growth was affected by both temperature and storage duration. With regard to temperature, there are several observations. First, there was much more root growth at 11C than at the lower temperatures. Even at the 11C lowest root growth (30.5 wks.), the number of new roots was 40% higher than the highest observed at the colder temperatures (0 wks.,7C). Second, root growth at 11 degrees showed a transient increase with storage, similar to that discussed in the Introduction. One suggestion to explain this pattern is that chilling is necessary to produce vigorous new roots (peak at 14 wks.) and, as suggested by Zaerr and Lavender (1974), and van den Driessche (1987), root development may be under hormonal control. The fact that this increase was not noted in roots from 3 and 7C soil suggests that the postulated hormonal effect is soil temperature dependent and that a threshold temperature exists for white spruce which is >7C and <11C. Below this threshold soil temperature, storage for any duration had a negative impact on root growth after outplanting. We note that this particular temperature threshold may be provenance or elevation specific.

With regard to the effect of duration, the 22 wks. point again seems important. Root growth at 11C indicates storage durations over 22 wks. severely reduce the seedling's ability to produce new roots. There is a 47% drop in root growth between 22-26 wks.

The decreased interval to TBB is also a factor in reducing root growth, although secondary to the effect of cold soil temperatures. Once bud break occurs, rate of new root development decreases (Mattsson 1981). It is the amount of time photosynthate is available for root growth prior to new foliage development coupled with favorable soil temperature that is important for seedling establishment.

This growth chamber study has shown the complexity of interactions between soil root temperature and storage duration, in relation to carbon fixation, stomatal conductance, and root growth. While this work needs to be followed by field studies, there are some silviculturally relevant implications:

1. Dark freezer storage of white spruce in excess of 22 wks. has a detrimental effect on seedling growth after outplanting. The decline in TBB period and its relationship to root growth has significant implications for nursery practises and planting recommendations.

2. Root growth potential measurements made at relatively warm temperatures may not reflect the actual ability of the seedling to produce roots at lower temperatures.

3. The fact that root growth at low temperatures was adversely affected by all storage durations in this experiment suggests that use of stored seedlings in cold soils may contribute to poor spruce plantation growth.

The key to good establishment depends upon root growth (Mattsson 1981), and as we have seen, root growth depends upon soil temperatures, length of cold storage, and days to TBB. In developing a successful reforestation program careful choice of planting date in consideration with root growth patterns and local planting conditions (soil and light parameters) is necessary to maximize growth potential.

ACKNOWLEDGEMENTS

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Evaluation of *Lonicera* Taxa for Honeysuckle Aphid Susceptibility, Winter Hardiness, and Plant Use[1]

Dale E. Herman and Lawrence J. Chaput[2]

Abstract.--One-hundred honeysuckle taxa were evaluated in North Dakota and/or reviewed in the literature for relative honeysuckle aphid [Hyadaphis tataricae (Aizenberg)] susceptibility, winterhardiness and landscape characteristics. Thirty-nine taxa were rated susceptible or highly susceptible, nine lightly susceptible and 45 with apparent resistance to aphid disfiguration. Only 12 taxa were selected in the very acceptable to highly recommended categories for landscape planting in USDA hardiness zones 2 through 5. Eight taxa were recommended for potential use in shelterbelt or conservation plantings.

INTRODUCTION

The Lonicera genus is a member of the Caprifoliaceae or honeysuckle family. Over 150 species of honeysuckles have been grown in America as well as a large number of cultivars (Bailey and Bailey 1976). Several species have been popular in the Midwest and Northern Plains because of their winterhardiness, adaptation to varied soil and moisture conditions, ease of propagation, and flowering and fruiting characteristics. Although several compact cultivars have been introduced, most species produce medium to large shrubs. Several species have vine-like characteristics. Unfortunately, many species display rather dull leaves by midsummer, lack attractive autumn coloration, and tend to become leggy and unkempt.

Over the past 10 years, the spread of honeysuckle aphid in North America has increasingly devastated many honeysuckles, particularly the species L. tatarica (tatarian honeysuckle), and its' cultivars. Honeysuckle aphid [Hyadaphis tataricae (Aizenberg)] was first reported and described in 1936 in Russia after which it was commonly reported in Europe (Grigorov 1965). Voegtlin (1982) hypothesized that this aphid is native to the area where its host plant, tatarian honeysuckle, is found; i.e., northern and western Asia. The aphid first entered North America in Quebec in the mid-1970's on infested plants from Europe (Boisvert et al. 1981). The earliest observation in the United States was in northeastern Illinois (Lake County) in 1979 (Voegtlin 1981). Since then, this aphid has spread over a vast area of the Midwest, Great Plains and Canada. Grigorov (1965) gives a detailed account of the insect's biology. Severe witches' brooming is the ultimate effect on susceptible honeysuckle species. Broom-deformed twigs die by fall or in the winter. Damage incurred to susceptible honeysuckles not only results in aesthetic impairment to shrubs in the landscape but sturdy plants may even be killed eventually. Newly planted seedlings or young vigorously growing plants with highly succulent tissues are particularly vulnerable. The damage caused by this insect precipitated a study to re-evaluate the honeysuckle genus for use in landscape and conservation plantings.

OBJECTIVES

The objectives of this study were to:

1) Evaluate 100 honeysuckle taxa for susceptibility to honeysuckle aphid.

2) Evaluate honeysuckle taxa with apparent honeysuckle aphid resistance for winterhardiness and landscape characteristics.

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[1]Poster paper presented at the Intermountain Forest Nursery Association Annual Meeting [Bismarck, N.D., August 14-17, 1989].

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3) Provide valid recommendations of honeysuckles for landscape and conservation plantings; particularly in USDA hardiness zones 2 through 5.

4) Initiate a selection program to potentially release one or more superior aphid-resistant cultivars.

METHODS

Sixty-five honeysuckle taxa were grown and evaluated in North Dakota State University (NDSU) research trials. Data on susceptibility to honeysuckle aphid was recorded for three years (1985-87) and data on winterhardiness and landscape characteristics for 5 to 10 years.

Seventy-one honeysuckle taxa were reviewed in the literature to obtain honeysuckle susceptibility ratings. Literature reviewed includes Boisvert et al. (1981), Cummings (1981), Evers[4] (1988), Funk (1982), Lewis (1982), Mainquist et al. (1982), Nielson (1982), Nixon (1983), Pellett et al. (1985a), Pellett et al. (1985b), Sydnor[5] (1988 and Voegtlin (1982). A total of 100 honeysuckle taxa were evaluated and/or reviewed.

Reports in the literature on honeysuckle taxa were invariably ranked for aphid susceptibility or resistance in an arbitrary manner. Definitive point systems or values were not reported. Efforts were made in this study to correlate NDSU evaluations with the literature reviewed by assigning four rating criteria as follows:

1) Highly susceptible - marked leaf and stem distortion, including numerous witches' brooms.

2) Susceptible - leaf and stem distortion visible, including scattered witches' brooms.

3) Lightly susceptible - slight visible distortion of leaves or stems but essentially devoid of witches' brooms.

4) Apparent resistance - no visible distortion of leaves or stems.

Honeysuckle taxa categorized with apparent honeysuckle aphid resistance were evaluated at NDSU and/or reviewed in the literature for winterhardiness zonation and landscape characteristics. Literature reviewed includes Bailey and Bailey (1976), Dirr (1983), Krussman (1977), Rehder (1940), Snyder (1980) and Wyman (1977). The above references were also used to verify scientific nomenclature. In addition, Standardized Plant Names (Kelsey and Dayton 1942) was used to corroborate common names. However, common names are lacking for a considerable number of honeysuckle taxa in the literature.

Primary criteria utilized in evaluating landscape qualities included foliage color, quality and duration; plant height, density and form; and to a lesser degree, flower and fruit characteristics.

Superior F_2 aphid-resistant honeysuckle seedlings are under evaluation from a putative open-pollinated F_1 hybrid. One or more selections may be named and introduced from this pedigree.

RESULTS

Information obtained from this study is summarized in tables 1 through 6. All honeysuckle taxa are listed alphabetically by scientific name. Common names are listed if cited in the literature.

Table 1 lists 39 honeysuckle taxa rated as susceptible or highly susceptible. These two categories are listed together, since both levels of susceptibility preclude recommendation of these taxa for planting.

The species L. tatarica, L. morrowii and L. ruprechtiana are all susceptible to honeysuckle aphid. This is also true for most cultivars and hybrids derived from these species. Seven additional species were also susceptible, including L. maackii var. podocarpa. However, other accessions of the latter species exhibited considerable resistance which is not readily explainable.

Table 2 lists nine honeysuckle taxa which were lightly susceptible to aphid attack. Most of these taxa are questionable in quality and are not commonly planted. L. fragrantissima (winter honeysuckle) has been planted to a limited extent in hardiness zone 5 of the Midwest. Why L. tatarica 'Sibirica' was damaged only lightly is open to question, since most cultivars of this species are highly susceptible.

Table 3 lists 45 honeysuckle taxa which display apparent resistance to honeysuckle aphid injury in NDSU trials and/or review of the literature. L. alpigena, L. caerulea, L. chrysantha, L. ferdinandii, L. maackii and L. xylosteum are all noteworthy examples of species showing resistance. Although L. korolkowii and L. x xylosteoides cultivars displayed resistance in this study, certain authorities question whether these honeysuckle taxa have complete

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[4]Evers, N.P. 1988. Personal Communication, Department of Horticulture, Landscape and Parks, South Dakota State University, Brookings, S.D.

[5]Sydnor, T.D. 1989. Personal Communication, Department of Horticulture, The Ohio State University, Columbus, OH.

Table 1.--Thirty-nine Lonicera (honeysuckle) taxa rated as susceptible or highly susceptible to honeysuckle aphid in NDSU evaluations and/or review of the literature.

Scientific Name	Common Name
L. x amoena[1]	Gotha H.
L. x bella[2]	Belle H.
L. x bella 'Albida'	White Belle H.
L. x bella 'Atrorosea'	Pink Belle H.
L. x bella 'Candida'	Candida Belle H.
L. x bella 'Dropmore'	Dropmore H.
L. 'Bouquet'	Bouquet H.
L. conjugialis	Purpleflower H.
L. discolor	-----
L. maackii var. podocarpa	Mongolian H.
L. microphylla	-----
L. x minutiflora[3]	Bunchberry H.
L. morrowii	Morrow H.
L. muendeniensis[4]	Muenden H.
L. muendeniensis var. xanthocarpa	-----
L. muscaviensis[5]	Muscovy H.
L. x myrtilloides[6]	-----
L. x notha[7]	Rutarian H.
L. olgae	Olga H.
L. orientalis	Buckthorn H.
L. rupicola	-----
L. ruprechtiana	Manchurian H.
L. tatarica	Tatarian H.
L. tatarica 'Alborosea'	-----
L. tatarica 'Angustifolia'	Narrowleaf H.
L. tatarica 'Beavormor'	Beavormor H.
L. tatarica 'Cardinal'	Cardinal H.
L. tatarica 'Carleton'	Carleton H.
L. tatarica 'Cheerio'	Cheerio H.
L. tatarica 'Grandiflora'	Bride H.
L. tatarica 'Hack's Red'	Hack's Red H.
L. tatarica 'Morden Orange'	Morden Orange H.
L. tatarica 'Mystic Melody'	Mystic Melody H.
L. tatarica 'Nana'	Low H.
L. tatarica 'Rosea'	Rosy H.
L. tatarica 'Valencia'	Valencia H.
L. tatarica 'Virginalis'	Maiden H.
L. tatarica 'Wheeling'	Wheeling H.
L. tatarica 'Zabelii'	Zabel's H.

PARENTAGE OF HYBRIDS:

[1] L. x amoena (L. korolkowii x L. tatarica)
[2] L. x bella (L. morrowii x L. tatarica)
[3] L. x minutiflora (L. morrowii x L. x xylosteoides)
[4] L. x muendeniensis (L. x bella x L. ruprechtiana)
[5] L. x muscaviensis (L. morrowii x L. ruprechtiana)
[6] L. x myrtilloides (L. angustifolia x L. myrtillus?)
[7] L. x notha (L. ruprechtiana x L. tatarica)

Table 2.--Nine Lonicera (honeysuckle) taxa rated as lightly susceptible to honeysuckle aphid in NDSU evaluations and/or review of the literature.

Scientific Name	Common Name
L. demissa	-----
L. fragrantissima	Winter H.
L. insularis	-----
L. insularis x L. tatarica (hyb.)	-----
L. ledebourii	Ledebour H.
L. maximowiczii	Manchurian H.
L. x salicifolia	Willowleaf H.[1]
L. tatarica 'Sibirica'	Red H.
L. tatarinovii	-----

PARENTAGE OF HYBRID:

[1] L. x salicifolia (L. ruprechtiana x L. x xylosteoides)

Table 3.--Forty-five Lonicera (honeysuckle) taxa with apparent resistance to honeysuckle aphid in NDSU evaluations and/or review of the literature.

Scientific Name	Common Name
L. alpigena	Alps H.
L. alpigena 'Nana'	Dwarf Alps H.
L. x brownii 'Dropmore Scarlet Trumpet'[1]	Dropmore Scarlet Trumpet H.
L. caerulea	Sweetberry H.
L. caerulea var. altaica	Altai H.
L. caerulea var. dependens	-----
L. caerulea (NC-7 Compact selections)	-----
L. caerulea var. edulis	Turkestan H.
L. caerulea 'Kanzu'	Kanzu H.
L. caerulea var. viridifolia	-----
L. chrysantha	Coralline H.
L. chrysantha var. latifolia	Turkestan Coralline H.
L. chrysantha var. villosa	Villous Coralline H.
L. dioica	Limber H.
L. ferdinandii	Ferdinand H.
L. 'Freedom'	Freedom H.
L. glaucescens	Douglas H.
L. x heckrottii[2]	Everblooming H.
L. x heckrottii 'Gold Flame'	Gold Flame H.
L. x heckrottii 'Summer King'	Summer King H.
L. involucrata	Twinberry or Bearberry H.
L. japonica 'Aureo-reticulata'	Yellownet Japanese H.
L. japonica 'Halliana'	Hall's Japanese H.
L. japonica 'Purpurea'	Purple Japanese H.
L. korolkowii	Blueleaf H.
L. korolkowii 'Floribunda'	Broad Blueleaf H.
L. maackii	Amur H.
L. maackii 'Cling Red'	Cling Red H.
L. maackii 'Rem Red'	Rem Red H.
L. maximowiczii var. sachalinensis	Sakhalin H.
L. prolifera	Grape H.
L. sempervirens	Trumpet H.
L. sempervirens 'Magnifica'	Magnifica Trumpet H.
L. spinosa	Thorn H.
L. spinosa var. albertii	Albert H.
L. syringantha	Lilac H.

Table 3.--Forty-five Lonicera (honeysuckle) taxa with apparent resistance to honeysuckle aphid in NDSU evaluations and/or review of the literature. (Continued)

Scientific Name	Common Name
L. syringantha 'Grandifolia'	-----
L. tatarica 'Arnold Red'	Arnold Red H.
L. x tellmanniana[3]	Tellmann H.
L. vesicaria	-----
L. x xylosteoides 'Clavey's Dwarf'[4]	Clavey's Dwarf H.
L. x xylosteoides 'Hedge King'	Hedge King H.
L. x xylosteoides 'Miniglobe'	Miniglobe H.
L. xylosteum	European Fly H.
L. xylosteum 'Emerald Mound'	Emerald Mound H.

PARENTAGE OF HYBRIDS:

[1] L. x brownii (L. hirsuta x L. sempervirens)
[2] L. x heckrottii (L. x americana x L. sempervirens)
[3] L. x tellmanniana (L. sempervirens x L. tragophylla)
[4] L. x xylosteoides (L. tatarica x L. xylosteum)

resistance. Additional time may be needed to make a final judgment. It is noteworthy that nearly all of the vine honeysuckle species show resistance. In addition, the apparent resistance of L. tatarica 'Arnold Red' is quite important. Based on this study, it is the only tatarian honeysuckle cultivar recommended for general planting since the honeysuckle aphid entered and began to devastate honeysuckles in North America.

Table 4 lists seven taxa which were not categorized in this study due to insufficient and/or conflicting data concerning aphid attack.

Based upon NDSU evaluations and/or review of the literature, table 5 is a summation of honeysuckle taxa with apparent resistance to aphid attack recommended for planting in USDA hardiness zones 2 through 5. Landscape qualities of the species or cultivar, in addition to aphid resistance, determine the category in which the plant appears. Hardiness zones and approximate plant heights are also included.

Only four taxa were highly recommended. Brief descriptive features of these plants are as follows:

L. x brownii 'Dropmore Scarlet Trumpet' (Dropmore Scarlet Trumpet H.). A hybrid vine introduced by the late F.L. Skinner, Dropmore, Manitoba with significantly greater winter hardiness compared to other commonly grown vine honeysuckles. It is quite sterile and produces showy orange-scarlet tubular flowers from June to November.

L. maximowiczii var. sachalinensis (Sakhalin H.). A large shrub with bright green, attractive foliage and good shrub density.

Table 4. Seven Lonicera (honeysuckle) taxa which were not categorized for honeysuckle aphid susceptibility or resistance due to insufficient and/or conflicting data.

Scientific Name	Common Name
L. x amoena 'Alba'	White Gotha H.
L. x amoena 'Arnoldiana'	Arnold H.
L. nigra	-----
L. obovata	-----
L. tatarica 'Alba'	White H.
L. tatarica 'Des Moines'	Des Moines H.
L. x xylosteoides	Vienna H.

Leaves often display a reddish cast on new growth. Purple flowers, dark red fruit. Native to Korea, Japan and Sakhalin Island, USSR.

L. x xylosteoides 'Miniglobe' (Miniglobe H.). An introduction from the Morden Research Station, Morden, Manitoba which is superior to 'Clavey's Dwarf' in form, compactness and foliage color. It has a distinct winter hardiness advantage over 'Emerald Mound' in northern zones. It produces creamy colored flowers and very dark red fruits, both somewhat inconspicuous.

L. xylosteum 'Emerald Mound' (Emerald Mound H.). An excellent compact mound-like honeysuckle with emerald-green leaves. Dull creamy-yellow flowers, dark red non-showy fruits. It is not sufficiently winterhardy in northernmost zones. Apparently identical to 'Compacta', originally named in Poland in 1931. The cultivar 'Nana' is also a synonym in the U.S.

The primary reason for not placing 'Arnold Red' and 'Clavey's Dwarf' honeysuckles in the highly recommended category is a general

Table 5.--Lonicera (honeysuckle) taxa with apparent resistance to honeysuckle aphid recommended for landscape planting in USDA hardiness zones 2, 3, 4 and 5.

Lonicera taxa	Hardiness zone recommendation	Shrub height (ft.);vine (v)
Highly Recommended		
L. x brownii 'Dropmore Scarlet Trumpet' (Dropmore Scarlet Trumpet H.)	2b,3,4,5	v
L. maximowiczii var. sachalinensis (Sakhalin H.)	3,4,5	6-9
L. x xylosteoides 'Miniglobe' (Miniglobe H.)	2,3,4,5	3-4
L. xylosteum 'Emerald Mound' (Emerald Mound H.)	4,5	3-5
Very Acceptable		
L. alpigena 'Nana' (Dwarf Alps H.)	4b,5	3
L. caerulea (NC-7 compact selections of Sweetberry H.)	2,3,4,5	2-4
L. korolkowii 'Floribunda' (Broad Blueleaf H.)	3,4,5	6-7
L. maackii (Amur H.)	2,3,4,5	9-12
L. maackii 'Cling Red' and 'Rem Red' (Cling Red and Rem Red H.)	4b,5	9-12
L. tatarica 'Arnold Red' (Arnold Red H.)	2,3,4,5	10
L. x xylosteoides 'Clavey's Dwarf' (Clavey's Dwarf H.)	2,3,4,5	6-7
Fairly Acceptable		
L. caerulea (Sweetberry H. and its var's. and cv.'s)	2,3,4,5	5-6
L. dioica (Limber H.)	2,3,4,5	v (shrubby)
L. ferdinandii (Ferdinand H.)	4b,5	8-9
L. fragrantissima (Winter H.)	5	6-8
L. 'Freedom' (Freedom H.)	3,4,5	8
L. glaucescens (Douglas H.)	2,3,4,5	v (shrubby)
L. heckrottii (Everblooming H., including 'Goldflame' and 'Summer King')	4b,5	v
L. korolkowii (Blueleaf H.)	4,5	9-10
L. japonica cultivars (Japanese H.)	5	v
L. sempervirens (Trumpet H., including 'Magnifica')	4,5	v
L. spinosa (Thorn H., including var. albertii)	3b,4,5	2-3
L. syringantha (Lilac H., including 'Grandiflora')	4,5	6
L. x tellmanniana (Tellmann H.)	4,5	v
L. x xylosteoides 'Hedge King'(Hedge King H.)	3,4,5	5-6
L. xylosteum (European Fly H.)	3,4,5	9
Undesirable		
All 39 Lonicera taxa in Table 1 which proved susceptible or highly susceptible to honeysuckle aphid, plus the following additional taxa.		
L. alpigena (Alps H.)	4,5	8-9
L. chrysantha (Coralline H. & var's. latifolia & villosa)	4,5	8-10
L. demissa	3,4,5	10-12
L. involucrata (Twinberry or Bearberry H.)	4,5	6
L. prolifera (Grape H.)	4,5	v (shrubby)
L. X salicifolia (Willowleaf H.)	3,4,5	9

deficiency in foliage quality. 'Arnold Red' also becomes quite tall and leggy. Plants listed in the fairly acceptable category are certainly usable but deficient in one or more landscape qualities. Nearly 50% of the honeysuckle taxa in this study are included in the undesirable category due to aphid susceptibility and/or unsatisfactory landscape qualities.

Table 6 lists eight honeysuckle taxa which are recommended for potential use in shelterbelt, farmstead windbreaks, reclamation and wildlife plantings. All of these are medium-tall to tall in size which may make them more useful for shelterbelt and conservation purposes.

The Lonicera genus has often been relegated to a lower rung on the woody plant generic ladder as far as providing choice landscape plants. Many honeysuckles are characterized by dull foliage, leggy growth habits and a seemingly lifeless appearance in winter. Yet, this genus has provided a very useful group of shrubs due to their winterhardiness and adaptability. Although numerous honeysuckle taxa are very susceptible to honeysuckle aphid, there is still a significant pool of resistant honeysuckles to draw upon in making recommendations. The use of honeysuckles in our landscapes is not a dead issue. Hopefully, as breeding and selection programs progress, the inventory of honeysuckles with landscape merit may be expanded in the future.

CONCLUSIONS

1) Thirty-nine honeysuckle taxa were rated susceptible or highly susceptible, nine lightly susceptible and 45 exhibited apparent resistance to honeysuckle aphid infestation, respectively. Seven taxa were not classified because of insufficient or conflicting data. L. tatarica, L. morrowii and L. ruprechtiana, including cultivars and hybrids derived from these species, were particularly susceptible.

2) All taxa with apparent aphid resistance were evaluated for hardiness zone assignment and landscape qualities. Only four taxa were highly recommended for landscape use, including L. x brownii 'Dropmore Scarlet Trumpet', L. maximowiczii var. sachalinensis, L. x xylosteoides 'Miniglobe' and L. xylosteum 'Emerald Mound'. Eight taxa were rated as very acceptable and 28 taxa as fairly acceptable. All 39 taxa which proved susceptible or highly susceptible to honeysuckle aphid, plus eight additional taxa, were rated as undesirable. These 47 taxa represent nearly 50% of the taxa evaluated in this study.

3) Eight taxa were recommended for potential use in shelterbelt or conservation plantings as replacements for aphid susceptible Lonicera taxa.

4) Selection of apparent aphid resistant superior hybrid seedlings for potential release is proceeding.

Table 6. Eight Lonicera (honeysuckle) taxa recommended for propagation and potential use in shelterbelt or conservation plantings as replacements for aphid susceptible taxa.

Lonicera taxa	Hardiness zone recommendation
L. chrysantha (Coralline H. and botanical varieties)[1]	3,4,5
L. 'Freedom' (Freedom H.)[2]	3,4,5
L. korolkowii (Blueleaf H.)[1]	3b,4,5
L. korolkowii 'Floribunda'(Broad Blueleaf H.)[2]	3b,4,5
L. maackii (Amur H.)[1]	2,3,4,5
L. maximowiczii var. sachalinensis (Sakhalin H.)[1]	3,4,5
L. tatarica 'Arnold Red' (Arnold Red H.)[2]	2,3,4,5
L. xylosteum (European Fly H.)[1]	3,4,5

[1]Since honeysuckle species hybridize freely, there is risk in obtaining true to type honeysuckles if seed is collected from plants growing in close proximity to other species or hybrids.

[2] In order to maintain these cultivars as true clones with apparent resistance to honeysuckle aphid, they must be vegetatively propagated by cuttings, not sexually by seed.

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Summary of Meetings and Contents of Proceedings of the Intermountain Forest Nursery Association: 1960-1989[1]

Marvin D. Strachan[2]

This historical account of 30 years' progress of the Intermountain Nursery Association is included in these 1989 proceedings, and will serve as a Table of Contents for past proceedings. Each of the proceedings is summarized--indicating the host nursery, location, host nurseryman, dates of the annual meetings, and attendance numbers; interesting meeting highlights are also included. The title of each paper, presented together with the author, is listed. The business meeting decisions are also noted.

A complete set of each of the past meeting proceedings are deposited at the library of the U.S.F.S. Rocky Mountain Forest & Range Experiment Station, Fort Collins, Colorado. If more information on a particular paper with any proceedings is desired, you may contact:

Librarian, USDA Forest Service
Rocky Mountain Forest & Range Exp. Station
240 West Prospect
Fort Collins, CO 80526

ANNOTATED RECORD OF MEETINGS

1st Meeting, known as the organizational meeting, was held at the Big Sioux Conifer Nursery at Watertown, South Dakota on August 20, 1960. Marvin Strachan, host nurseryman, presided. Nine nurserymen and support persons attended the meeting, and all presented input pertaining to the need to form a regional nursery association.

Significant actions taken during the meeting were:

1. ORGANIZATIONAL NAME: Intermountain Nurserymen's Association.

2. MEMBERSHIP: Nurseries within the Great Plains and Rocky Mountain region growing or providing seedling trees for conservation and/or reforestation purposes.

3. OBJECTIVES:
   (a) Provide a forum for nurserymen and affiliate personnel to meet and exchange technology, ideas, information, and techniques.

   (b) Exchange equipment and supplies, or information thereof, between states and nurseries, particularly a clearing house of information on surplus and shortages of nursery seedlings.

   (c) Provide research organizations with specific nursery and seedling needs.

   (d) Provide forest nursery needs and accomplishments on a regional basis, particularly coordinated grade stock standards and genetic tree improvement.

4. OFFICERS AND MEETING DATES: Annual meeting to rotate around participating nurseries. Host nurseryman to be in charge of the program, arrangements, dates of the meeting, and preparation of the proceedings. No formal officers or membership dues.

A tour of the nursery and facilities was conducted, and the group agreed to meet at the Bessey Nursery in Nebraska in 1961.

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[1] This information was prepared for the Intermountain Forest Nursery Association meeting, Bismarck, ND, August 14-18, 1989.

[2] Marvin D. Strachan is retired Nursery Manager, Colorado State Forest Service, Ft. Collins, CO and former Nursery Manager and founder of the Big Sioux Nursery, Watertown, SD.

CHRONOLOGY OF PAST MEETINGS ------ INTERMOUNTAIN NURSERY ASSOCIATION

MEETING	HOST NURSERY	LOCATION	NURSERY MANAGER	DATES	ATTENDANCE
1	Big Sioux Conifer	Watertown, SD	Marv Strachan	Aug. 20, 1960	9
2	Bessey	Halsey, NE	Red Meines	Sept. 14-15, 1961	21
3	Monument	Monument, CO	Ed Palpant	Sept. 13-14, 1962	20
4	Montana State	Missoula, MT	Don Baldwin	Sept. 11-13, 1963	28
5	Lucky Peak	Boise, ID	Leroy Sprague	Aug. 19-20, 1964	--
6	Mt. Sopris	Carbondale, CO	Sid Hanks	Sept. 14-16, 1965	40
7	Colorado State	Ft. Collins, CO	John Ellis	Aug. 30-31, 1966	28
8	PFRA- Indian Head	Indian Head, SASK.	Sandy Patterson	Aug. 1-4, 1967	66
9	Green Canyon	Salt Lake City, UT	Clyn Bishop	Aug. 6-8, 1968	21
10	Lincoln-Oakes/Towner	Bismarck/Towner, ND	Lee Hinds/ Jerry Liddle	Aug. 5-7, 1969	31
11	Coeur d'Alene	Coeur d'Alene, ID	Bud Mason	Aug. 4-6, 1970	63
12	Oliver	Edmonton, Alberta	D. Hillson	Aug. 3-5, 1971	54
13	Mike Webster/IFA/ Weyerhaeuser	Olympia, WA	H.Anderson/ R. Eide/J. Bryan	Aug. 8-10, 1972	117
14	Big Sioux Conifer	Watertown, SD	Don Townsend	Aug. 7-9, 1973	35
** The North American Containerized Forest Tree Symposium was held in 1974 instead of the annual meeting.					
15	Montana State	Missoula, MT	Willis Heron	Aug. 5-7, 1975	65
16	Green Timbers/Surry	Richmond, B.C.	Bayne Vance	Aug. 9-12, 1976	120
17	Kansas State	Manhattan, KS	Bill Loucks	Aug. 9-11, 1977	65
18	Humboldt	Eureka, CA	Don Perry	Aug. 7-11, 1978	189
19	Mt. Sopris	Carbondale, CO	John Scholtes	Aug. 13-16, 1979	124
20	Lucky Peak	Boise, ID	Dick Thatcher	Aug. 12-14, 1980	116
21	Oliver/Pine Ridge	Edmonton, Alberta	Ralph Huber	Aug. 11-13, 1981	94
22	J. Herbert Stone	Medford, OR	Frank Morby	Aug. 10-12, 1982	183
23	Nevada State	Las Vegas, NV	Pat Murphy	Aug. 8-11, 1983	78
24	Coeur d'Alene	Coeur d'Alene, ID	Darrell Benson	Aug. 14-16, 1984	190
25	Colorado State	Ft. Collins, CO	Marv Strachan	Aug. 13-15, 1985	83
26	Webster/Mima/IFA	Tumwater, WA	J. Bryan/ K. Curtis/ K. O'Hara	Aug. 12-15, 1986	187
27	Oklahoma State	Oklahoma City, OK	Al Myatt	Aug. 10-14, 1987	80
28	Skimikin	Vernon, B.C.	Ralph Huber	Aug. 8-11, 1988	328
29	Lincoln-Oakes/Towner	Bismarck, ND	Greg Morgenson/ Roy LaFramboise	Aug. 14-17, 1989	77
30	D. L. Phipps	Roseburg, OR	Paul Morgan	Aug. 13-17, 1990	--

The 2nd Meeting of the Intermountain Nurserymen's Association was held at the Bessey Nursery, Nebraska National Forest, Halsey, Nebraska on September 14-15, 1961. Twenty-one people participated. M. K. Meines, host nurseryman, presided as Chairman and introduced Milt Andrews, Timber Management staff, USFS, Denver, who welcomed the group.

AGENDA

Panel discussion topics and the leaders were as follows:
E. Palpant - Monument Nursery - Maintenance of Soil Fertility and the Interpretation of Soil Tests
D. Baldwin - Montana State Nursery - Green Manure Crops
M. Strachan - South Dakota Nursery - Commercial Fertilizers
R. Meines - Bessey Nursery - Soil Fumigants and Fumigation
P. Salisbury - Canadian Forestry, Indian Head - Nematodes
W. Bagley - Univ. of Nebraska - Herbicides for Nursery use
S. Hanks - Bessey Nursery - Mineral Spirits
A. Engstrom - Oklahoma Nursery - Other Chemicals for Nursery Weed Control
S. Hanks/H. Gallaher/J. Ellis - Over Winter Storage of Planting Stock
R. Read - USFS, Lincoln, Nebraska - Nursery Stock Standards - Quality Morphological and Physiological, Caliper, Top Root Balance, Shoot, Height, Age Class and Site Demands on Quality of Stock
P. Salisbury - Canadian Forestry, Indian Head - Insects and Disease Problems and their Control

BUSINESS MEETING

Ed Palpant invited the group to meet at the Monument Nursery at Monument, Colorado in 1962. A tour of the Bessey Nursery was conducted by the host nurseryman.

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The 3rd Meeting of the Intermountain Nurserymen's Association was held at the U.S. Forest Service Monument Nursery, Monument, Colorado on September 13-14, 1962. Twenty people were in attendance for the 2-day meeting. Ed Palpant was the host nurseryman and presided as chairman.

AGENDA

The entire program was structured, so a discussion leader introduced a designated topic, and the participants all assisted with their experience, questions, and knowledge. The discussion leaders and topics were as follows:

J. Nishimura - Soil Scientist, USFS - Soil Texture and Structure Management
M. Strachan - South Dakota Nursery - Plant Growth Response to Various Soil Structure, Texture and Fertility Levels at Various Nurseries
M. Andrews - USFS, Denver - Nursery Administrator - General
E. Priegal - USFS, Denver - Seed Handling Techniques

The discussion topics led to a very good round-table discussion and analysis of the related and some unrelated subjects.

Host nurseryman Ed Palpant and Mr. Harvey Koller, U.S. Air Force Academy, took the group on a field trip to the nearby Air Force Academy to observe the planting reforestation efforts and to view the academy grounds in general. A tour of the Monument Nursery was also accomplished to view the nursery beds, seed extraction, facilities, and experimental hybrid plantings. A banquet was held in the evening at a local restaurant. Don Baldwin invited the group to meet at the Montana State Nursery in Missoula in September 1963.

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The 4th Meeting of the Intermountain Nurserymen's Association was held at the State Forest Nursery in Missoula, Montana on September 11-13, 1963. Don Baldwin, host nurseryman, presided. Twenty eight people registered for this meeting. Gareth Moon, Montana State Forester, welcomed the group. Moon explained that the Montana Nursery had recently been transferred from Montana State University to the Montana State Forestry Department and he was looking forward to seeing the nursery grow and develop to better serve a stepped-up tree planting program.

A structured program with speakers and prepared papers was not planned by the host nursery. Instead, round-table discussion periods were held.

Office Procedures and Records - William Poulsen, Utah, led the discussion period. Each of the participating nurseries stated how tree order forms were handled, tree orders received, and how trees were distributed or delivered to landowners. Each of the nurserymen also described their nurseries, type and amount of production, and the involvement in nursery "paper work"; such as seed records, seeding schedules, investigation reports, treatment plans, seed catalogs, annual stock inventory reports, stock shipment summaries, stock survival records, financial records, and personnel files.

Free-For-All Discussion - Marvin Strachan, South Dakota, led the discussion period. Participants brought up their individual problems, and the answers were fielded and answered by the participating group. Problems discussed were mainly in regard to cold storage, seed stratification, heel-in beds, and weed control.

Two days were spent in touring and visiting the member nurseries in the area. The Montana State Forest Nursery, Missoula - Don Baldwin, Superintendent. Mountain Home Nursery, DeBorgia - Jack Callen, Owner/operation. Savenac Nursery and Seed Extractory, USFS, Haugan - Bud Mason, Superintendent. The new Forest Service Nursery and Seed Extractory at Coeur d'Alene, Idaho, Jim Augenstein, Superintendent was also visited and still under construction.

The business meeting reviewed the progress of the sub-committee on grading stands - Red Meines, Chrm., Ellis (Colorado) and Baldwin (Montana). The committee's recommendations were adopted, but further work was suggested.

Augenstein, a member of the Western Forest Nursery group, announced their 1964 meeting would be held at Lucky Peak Nursery, Boise, Idaho - Leroy Sprague, nurseryman, suggested a joint meeting of the Intermountain and Western Forest Nurserymen. The group agreed to a joint meeting at Boise in 1964.

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The 5th Meeting was held at the U.S. Forest Service Lucky Peak Nursery, Boise, Idaho on August 19-20, 1964. The number and names of attendees was not available, but a rather large attendance was on hand. The meeting was chaired by F. Leroy Sprague, host nurseryman. This meeting was the regularly scheduled meeting for the Western Forest Nurserymen. The Intermountain Nurserymen were invited to meet jointly with the Western Forest Nurserymen, and several were in attendance.

TECHNICAL AGENDA - Papers by:

L. Hojem- Production of Larger Douglas-fir seedlings by Fall Sowing
L. Mason- Methods and Time of Sowing
F. Deffenbacher- Sowing Dates and Rates and Their Effect on Production of Stock
H. Ward- New Nursery Equipment and Processes
J. Long- Summary of Progress in the Production of Interior Spruce in British Columbia
J. Christner- New and Better Ways of Packing and Shipping Seedlings
J. Betts- Tree Lifting and Packing Methods at the Bend Nursery
R. Bega- Disease Control in Forest Nurseries
J. Revel- Planting Study of 2-0 Douglas-fir Culls
C. Bigelow- Intensive Soil Management vs. Fumigation in the Control of Weeds
R.J. Boyd- Soil Fumigation Studies at the Cour d'Alene and Savenac Nurseries
H. Anderson- An Economic Study of Weed Control with Four Herbicides in a Forest Nursery
D. Baldwin- Mechanical Means of Weed Control in Forest Nurseries
S. Hanks- The Use of Solvents for Nursery Weed Control
M. Meagher- Growth of Spruce
J. Dick- Report of Committee on Planting Stock Description
J. Trappe/K. Krueger- Seeding Biographies-- Keys to Rational Nursery Practice
C. J. Eden- Use of X-Ray Technique for Determining Sound Seed
L. Baker- Shading and Irrigating

Separate business meetings of the two nursery associations were held. The Intermountain Nurserymen's Association agreed to meet in 1965 at the Mt. Sopris Tree Nursery, Carbondale, Colorado.

The Western Forest Nursery Council agreed to meet in 1966 at Placerville, California. An organizational charter was presented and accepted; selecting the organization name, membership, objective, meeting dates, officers and duties, and terms of office.

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The 6th Meeting, forty people attended the meeting at the Mt. Sopris, USFS Nursery near Carbondale, Colorado on September 14, 15, 16, 1965. Chairman for the meeting was Sid Hanks, host nurseryman. Kenneth Scholz, Forest Supervisor, White River National Forest, welcomed the group.

TECHNICAL AGENDA - Papers by:

G. Peterson - Rocky Mt. Forest and Range Experiment Station - Notes on Soil Fumigation in Forest Tree Nurseries
M. K. Meines - Bessey Nursery - Lower Seedbed Densities Can Improve Survival of Pines and Cedars Planted in the Great Plains
R. Read - Rocky Mtn. Forest and Range Experiment Station - Selection of Ponderosa Pine for Plains Planting
J. Ellis - Colorado State Forest Service - Morphological Qualities Contributing to Grade
Marvin Strachan - South Dakota - Physiological Qualities Contributing to Grade
C. Pierce - U.S.F.S. State and Private Forestry - Past Recommendations on Grade by the Grading Standards Subcommittee, Intermountain Nurserymen's Assoc.
S. Hanks - Host Nurseryman - What Constitutes Grade - A Grading Exercise and Panel Discussion

A tour of the Nursery and a Seed Extractory demonstration was held.

BUSINESS MEETING

Since the majority of this meeting centered on grade stock standards, and no conclusive agreement could be attained by the organization on what constitutes grade, it was moved, seconded, and passed that the Subcommittee on Grading Standards be terminated.

Discussion of an annual meeting vs. bienniel meeting. The annual meeting was approved.

Meeting locations and dates were selected as follows:

1966 - Colorado State Forest Service, Fort collins, Colorado.
1967 - Indian Head, Saskatchewan.
1968 - Salt Lake City, Utah.

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The 7th Meeting, twenty eight people attended the meeting in Ft. Collins, Colorado on August 30-31, 1966. Field tours were conducted to the Colorado State Forest Service Nursery, where a potting demonstration and field production fields were inspected. John Ellis, host nurseryman, served as chairman, but since Ellis was preparing to leave the position, he was assisted by the new nursery manager, Marvin Strachan and the field superintendent, Claude Heflin with the tour and arrangements. Tom Borden, State Forester, gave the welcome to Ft. Collins and CSU.

TECHNICAL AGENDA - Papers by:

L. Hinds - Lincoln Oaks Nursery - Nursery Equipment
A. C. Patterson - Indian Head, Saskatchewan - Nursery Equipment
D. Baldwin - Montana State Forest Service - Fertilization
J. Christner - Nevada State Forest Service - Fertilization
D. Tinus - USDA Horticulture - Physiology of Plants
G. Peterson - Problems of a Researcher in the Nursery
E. Heikes - Extension Weed Specialist - Weeding in the Nursery
R. Ulinger - Geneticist, U.S.D.A. - Plant Genetics
M. K. Meines - Bessey Nursery - Winter Storage of Seedlings
S. Hanks - Mt. Sopris - Winter Storage of Seedlings
D. Baldwin/M. Strachan/C. Bishop/M.K. Meines - Growing Methods Used for Spruce, Blue and Engelmann
J. Kepler - Use of Potted Material in Kansas

BUSINESS MEETING

The session was devoted to the availability of surplus trees and setting the 1967 meeting in August at the Indian Head, Saskatchewan Nursery.

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The <u>8th Meeting</u> of the Intermountain Nurserymen's Association was held at Indian Head, Saskatchewan, Canada on August 1-4, 1967. Sixty-six people registered for the first meeting held outside of the United States. The meeting was chaired by Sandy Patterson, host nurseryman. William Cram, Superintendent PFRA, introduced M. J. Fitzgerald, Director PFRA, who gave the welcome address. A banquet was held in Indian Head, as well as a barbecue at Lake Katepwa Provincial Park. Tours and demonstrations were conducted on the nursery, as well as a tour of the Outlook PFRA Development Farm, the Gardener Dam, and over 1,000 miles of single-row field shelterbelts in Conquest, Sask. area.

TECHNICAL AGENDA - Papers by:

M. Andrews - A Continuous Flow Seed Extractory
L. Mason - Seed Handling
R. Knowles - Seed Viability
L. Carlson - Control of Nursery Diseases
L. Peterson - Control of Injurious Nursery and Shelterbelt Insects
L. Sonmer/D. Benson - Irrigation on the Nursery
J. A. Menzies/R. Tinus - Farm Shelterbelts
R. Ulinger/W. CRAM - Tree Improvement
R. Read/D. Christie/J. Chedzoy - Storage Requirements for Nursery Stock
M. K. Meines - Nursery Programming

BUSINESS MEETING

A letter from Gary Moon, State Forester, Montana was read which urged the Intermountain Nurserymen and the Western Forest Nursery Council to merge into a single nursery association. He pointed out that the Intermountain State Foresters and the Western State Foresters had merged to form the council of Western State Foresters and the nurserymen might want to do likewise.

It was agreed that the 1968 meeting would be in Salt Lake City, Utah, and the 1969 meeting be held in Bismarck, North Dakota.

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The <u>9th Meeting</u> was held at Salt Lake City, Utah on August 6-8, 1968. Twenty-one people registered. Clyn Bishop, host nurseryman, presided as chairman. 1-1/2 days were spent on technical papers; 1 day on a field trip tour of the Utah State Nursery; and part of 1 day on a business session. Richard Klason, Deputy State Forester, gave the address of welcome and explained how the Utah State Forestry agency operates.

TECHNICAL AGENDA - Papers by:

J. Murphy - Lower Seedbed Densities Can Improve Survival of Conifers
S. Patterson - Conventional Farm Sprinkler System Vs. The Skinner System
B. Ellis - Herbicides for Nursery Use
G. Tyson - Mechanical Weed Control in the Nursery
M. Strachan - Over Winter Storage of Planting Stock
L. Hinds - New and Better Ways of Packing and Shipping Seedlings
L. Sprague - New Equipment and Processes
H. Ward - Maintenance of Soil Fertility
D. Townsend - 2-0 Root Pruned Stock Vs. 2-1 Stock
L. Mason - Shading and Irrigation

BUSINESS MEETING

Bud Mason asked that Coeur d'Alene Nursery be given consideration for the 1970 meeting and explained that the Western Forest Nursery Council would meet there at that time. The group accepted the invitation.

Lee Hinds reminded the group that the meeting in 1969 would be in Bismarck, North Dakota.

* * * * *

Thirty-one people attended the 10th Annual Meeting in North Dakota on August 5-7, 1969. Lee Hinds, host nurseryman, presided as chairman. The first day of reports and discussion was held at the Theodore Roosevelt National Memorial Park in Medora. The second day was a tour of the Lincoln-Oakes Nursery and SCS Plant Materials Center. The third day consisted of a tour of the North Dakota State Towner Nursery, the Denbigh Dunes Experimental Forest, and the USFS Sheltebelt Laboratory, all near Towner, North Dakota. Of particular interest, in addition to the production processes at Lincoln-Oakes and Towner, was the growth retardants studies at Lincoln-Oakes and the growth increase studies by Dr. R. Tinus at Towner.

TECHNICAL AGENDA

The following nurserymen reported on activities, new developments, production problems, and production shipped-- followed by discussion:

L. Sprague - Boise ID - Lucky Peak Nursery
R. Clark - Milbank, S.D. - Clarkdale Nursery
M. Strachan - Ft. Collins, CO - Colorado State Forest Service
D. Townsend - Watertown, S.D. - Big Sioux Conifer Nursery
H. Ward - Olympia, WA - Mike Webster Forest Nursery
A. C. Patterson - Indian Head, Sask. - PFRA Nursery
C. Bishop - Salt Lake City, UT - Green River Nursery
D. Force - Glenwood Spgs., CO - Mt. Sopris Nursery, USFS.
R. Huber - Winnepeg, Canada - Manitoba Experimental Nursery
W. Heron - Missoula, MT - Montana State Forest Service
J. Chedzoy - Oliver, Alberta - Alberta Provincial Nursery

BUSINESS MEETING

The invitation from J. C. Chedzoy to meet in Alberta in 1971 was accepted. The group will meet in Coeur d'Alene in 1970.

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The 11th Meeting of the Intermountain Nurserymen's Association was held jointly with the Western Forest Nursery Council at Coeur d'Alene, Idaho on August 4-6, 1970. Sixty-three people attended. One day was spent on a field trip tour of the USFS Coeur d'Alene Nursery, and 2 days were devoted to technical presentations. Lee Mason and Steve McDonald served as Co-Chairmen.

TECHNICAL AGENDA - Papers by:

S. Evans - Comments on Changes in Nursery Management in the Northern Region
R. Bingham - Progress in Breeding Blister Rust Resistant Western White Pine
C. Sinclair - Fall Vs. Spring Planting Study
R. Boyd/S. Sinclair - St. Joe National Forest Spring-Fall Planting Study
J. Bryan - Tree Seedling Harvester
R. Shearer - Problems Associated with Western Larch Planting Stock
J. Bryan - Container Planting
E. Hardin - Quick Methods of Determining Viability
R. Boyd - Use of Modern Climatic Data in Nursery and Planting Operations
B. Patee - Freezing of Nursery Stock
R. Ellis - Use of Herbicides
H. Jones - Wilbur Ellis Company
P. Owston - Effect of Storage on Vigor of Douglas-fir Stock
R. Hallman - Mechanized Cone Collection
H. Ward - Soil Fertility
H. Ward - Packaging Large Planting Stock

BUSINESS MEETING

Separate business meetings were held for each of the attending nursery associations.

The Intermountain Nurserymen, chaired by Lee Hinds, North Dakota, spent time and discussion regarding lists of surplus nursery stock. It was recommended that the Division of State and Private Forestry, USFS, to assist and distribute the surplus lists.

It was recommended that the Intermountain Nurserymen meet jointly with the Western Forest Nurserymen in Olympia, Washington in 1972. The 1971 meeting is scheduled to be held at Edmonton, Alberta.

The Western Forest Nurserymen, chaired by Steve McDonald, proposed the consolidation of the two nursery associations, but the plan was tabled and the invitation was extended to meet in 1972 in Olympia.

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The 12th Meeting was held jointly between the Intermountain Nurserymen's Association and the Western Forest Nursery Council in Edmonton, Alberta, Canada on August 3-5, 1971. In spite of airline strikes and schedule interruptions in the United States, 54 persons registered for the second meeting held outside the United States. One day was spent at the Provincial Tree Nursery of the Province of Alberta. An enjoyable picnic lunch was enjoyed, as well as the evening banquet where the honorable Dr. Grant McEwan, Lieutenant Governor, Province of Alberta, spoke to the group and reminded all that the world extends beyond the limits of your own back yard.

TECHNICAL AGENDA - Papers by:

R. C. Hallman - Mechanized Cone Harvesting
A. Radvanyi - Use of R-55 As a Rodent Repellant on Coniferous Seeds
R. W. Tinus - Growing Conifer Seedlings In a Controlled Environment
D. Hillson - The Provincial Tree Nursery; a brief account of its history and function
D. L. Mitchell/ W.C. Kay - Production and Characteristics of Sausage Containers
D. Hocking - Requirements for Successful Seedling Storage
F. W. Deffenbacher - Frost Damage to Nursery Stock, Wind River Nursery
A. C. Patterson - Electronic Seedling Counting
R. Esau - Chemical Weed Control in Tree Nursery Crops
J. W. Edgren - Survival and Growth of Undercut Douglas-fir

BUSINESS MEETING

No official business meeting was called, but the Intermountain Nursery group agreed to meet jointly with the Western Nursery group in Olympia, Washington in 1972.

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The 13th Meeting meeting of the Intermountain Nurserymen's Association met in conjunction with the Western Forest Nursery Council in Olympia, Washington August 8-10, 1972. Hosts for the meeting were the Washington State Department of Natural Resources, the Weyerhaeuser Company, and the Industrial Forestry Association. The proceedings of this meeting were dedicated in honor of Homer S. "Red" Ward, Nurseryman for the Washington State Department of Natural Resources, who passed away in February 1972. The Intermountain Nurserymen will remember "Red" Ward for his attendance at the early meetings of the Intermountain Association and his encouragement, knowledge, and friendship. One hundred and seventeen persons registered for the 3-day meeting. One day was spent in visiting the State operated "Mike" Webster Nursery, the Weyerhaeuser Nursery, and the Industrial Forestry Nursery. An interesting tour of the Olympia brewery was also enjoyed. The welcoming address by Mr. Bert L. Cole, Washington State Commissioner of Public Lands, was followed by an opening address by Mr. D. N. Jeffers, Weyerhaeuser Company, pertaining to some prognostications about the future nursery.

TECHNICAL AGENDA - Papers by:

J. Edgren/C. Bigelow - Sizing Seed Reduces Variability in Sowing Ponderosa Pine
E. Arnold - Effects of Sowing Accuracy on Seedling Size 1-0 and 2-0 Douglas-fir
J. McClellan - Operation and Evaluation of the Stan Hay Drill
P. Owston - Cultural Techniques for Growing Containerized Seedlings
R. H. Hillson - Production of Container Seedlings in Alberta
W. Hite - Controlled Environment Seedling Production
M. Strachan - Production of Container Seedlings in Colorado
R. Holland - Production of Container Seedlings in Washington
E. Van Eerden - Planting and Production of Container Seedlings in British Columbia
W. Hoenke - Growing and Planting Container Stock in Oregon
H. Friese - Tree Seed Certification
J. Isaacson - Stratification Methods and Seed Testing at Coeur d'Alene Nursery
Y. Tanaka - Study of the Pre-Germination Treatment of Douglas-fir Seed in Nursery Use
J. Wheat - Northwest Seed Orchard Status Report
H. Rodger Danielson - Quick-Tests for Determining Viability of Douglas-fir Seed
L. Carlson - Forest Tree Nursery Disease Control
K. Russell - Nursery Soil Disease Assay
J. Zaerr - Lifting Dates and Storage of Douglas-fir Nursery Stock
D. Ray - Seedling Storage and Packing Containers
C. Chaterton - Soil Amendments for Lucky Peak Nursery Soils
S. Hee - Monitoring Soil Fertility at Weyerhaeuser Company's Forest Nurseries
J. Betts - Soil Monitoring at Wind River Nursery
J. Isaacson - Native Shrub Regeneration
D. Lavender - Growth Regulators and How They Effect the Initiation of Dormacy of Nursery Seedlings
H. Jones - Charcoal Row Banding as an Aid to Weed Control in Newly Seeded Forest Nurseries
C. J. Allison - Freeze-Damage Control at the Weyerhaeuser Washington Nursery
F. Deffenbacher - Frost Damage to Nursery Stock
J. Lott - Evaluation of the New Zealand Root Pruner
R. Gray - Grayco Harvester
J. Storms - J. E. Love Seedling Harvester
R. Homes - Sumation and Evaluation 1972 Nurserymen's Meeting

BUSINESS MEETING

The Western Forest Nursery Council and the Intermountain Nurserymen's Association each held separate business meetings. It was agreed that the Intermountain Nurserymen would meet in 1973 at the Big Sioux Conifer Nursery in Watertown, South Dakota in August.

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The 14th Meeting, thirty five people attended the meeting of the Intermountain Nurserymen's Association in Watertown, South Dakota on August 7-9, 1973. Don Townsend, Nursery Manager, presided. Millard Braden, South Dakota State Forester, gave the welcome address. A tour of the Big Sioux Nursery and a catered luncheon at the nursery was enjoyed by all. Tony Dean was a guest speaker at the Wednesday Banquet-"South Dakota of all Places."

TECHNICAL AGENDA - Papers by:

L. Rempel - The Paper Pot System
F. Deffenbacher - Seed Certification in the Northwest
R. Read - Great Plains Tree Improvement
M. Strachan - Green House Production
J. Otta - Seedling Disease Problems
D. Gruber - Chemical Weed Control
All Nursery Representatives - Reports and Discussion - New Developments, Machines, Methods and Problems
G. Naughton - Walnut and Cottonwood Improvement Program
B. Ekblad - Green House
D. Hallman - Survey of Nursery Equipment Needs
J. McConnell - Eastern Tree Seed Laboratory
R. Tinus - Improvements in the Greenhouse Container Process for Raising Tree Seedlings
R. Clark/R. Rulon - Tree Seed Panel

BUSINESS MEETING

The Intermountain Nurserymen agreed to postpone the 1974 official meeting in lieu of the scheduled International meeting of the North American Containerized Forest Tree Symposium in Denver, Colorado. They also agreed to meet at the State Forest Tree Nursery in Missoula, Montana in 1975.

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The 15th Meeting of the Intermountain Nurserymen's Association was held at Missoula, Montana August 5-7, 1975. Sixty five people attended the meeting hosted by the State Forest Tree Nursery, Department of Natural Resources and Conservation. Willis Heron, Nursery Supervisor, was host. Gareth Moon, State Forester, welcomed the group to Montana, and Wayne Hite, U.S. Plywood Corporation, gave the keynote address. The group enjoyed a banquet one evening and tours of the State Forest Tree Nursery in Missoula, U.S. Plywood greenhouse in Bonner, and viewed out-planted seedlings of container and bare root stock in the area.

TECHNICAL AGENDA - Papers by:

E. Salmonson - Future Needs From Intermountain Nurseries
B. Heintz - Shelterbelts
R. Meyn - Mine Reclamation
R. Tinus - Are Bare Root Nurseries Obsolete
L. Mason -
S. Kohler - Insect and Disease in Nurseries
R. Williams - Study of Soil Fungi in Coeur d'Alene Nursery
R. LaRue - Pesticide Laws and Regulations
T. Landis - Mycorrhizae Culturing for Test Nurseries
S. McDonald - Frozen Stock Storage Studies
M. Morton - Genetic Improvement
R. Cunningham - GP-13 Juniperus Study
F. TerBush - Tree Seed Zones
L. Hinds - Seedling Grade
L. Nicholson - Environment
R. Hallman; J. Lott; D. Rising - Equipment Catalog, equipment survey, precision seeder, monitoring greenhouse environment, small seed lots, intensive nursery culture
R. Tinus - Observations and New Information on Greenhouse Container Systems
S. McDonald - Grayco Lifter Modification
G. Naughton - Germination Curves for Kansas Black Walnut

BUSINESS MEETING

The Nurserymen agreed to meet in British Columbia, Canada in 1976 and Kansas in 1977. No further business evolved, but the merits of meeting every other year with the Western Forest Nursery Council was discussed.

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The 16th Meeting was held at Richmond, British Columbia, Canada on August 10-12, 1976. One hundred twenty people registered for the joint meeting of the Intermountain Nurserymen's Association and the Western Forest Nursery Council. The Vancouver airport Hyatt House was the location of the meeting, with Bayne Vance presiding as chairman. Mr. E. L. Young, Chief Forester, British Columbia Forest Service, gave an inspiring welcome address. A banquet was held one evening, and nursery tours were made to Green Timbers Nursery near Whalley; Corbetts Nursery at Aldergrove, and the Surrey Nursery which demonstrated container and bare root production, the paper pot containers, and automated container sowing equipment.

TECHNICAL AGENDA - Papers by

R. Danielson - New Seed Stratification Techniques for Ponderosa Pine and Douglas-fir
J. Lott - Testing of Bareroot Sowing Equipment
J. Arnott - Container Production of High Elevation Species
J. Bryan - Operational Experiences with the Stan Hay Bare-Root Precision Seeder
J. Sutherland - Nematode Control
J. Dangerfield - Mycorrhizae and Conifer Seedling Production

W. Lopushinsky - The Significance of Shoot-Root Ratio for Survival and Growth of Outplanted East-Cascade Douglas-fir and Ponderosa Pine
J. Edgren - Seedbed Density and Recovery of Douglas-fir
D. Lavender/R. Hermann - Effect of Length of Pruned Roots Upon Performance of Douglas-fir Planting Stock
E. VanEerden - Liming of Container Growing Media
S. Slayton - Top Pruning For Size Control
J. Kinghorn - Irrigation of Container Seedlings
P. Hahn - Mechanical Handling and Growing Seedlings in a Quarterblock System
R. Hermann - Herbicide Trials
N. Pelton - Mudpacking
W. Stein - Conifer Seedlings Packaging and Storage
A. Todd - Packaging and Cold Storage Procedures
S. Cowles - Nursery Bedhouse Trials
J. Sweeten/J. Arnott/B. Devitt/E. Van Eerden/W. Revel - Panel Members: The Relationship Between Container and Bareroot Stock Size and Outplanting Survival

BUSINESS MEETING

The Intermountain Nursery group re-confirmed their wishes to meet in Manhattan, Kansas in 1977.

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On August 9-11, 1977, the Intermountain Nurserymen's Association held their 17th Annual Meeting at Manhattan, Kansas. The host was William Loucks, State and Extension Forestry Department of Kansas State University. Sixty-five people were registered. A banquet and field trip were enjoyed, including a tour of the Kansas State Greenhouse and Lath House operations.

TECHNICAL AGENDA - Papers by:

P. Hoekstra - The Washington Scene
S. McDonald - Western Nursery Situation
C. Lantz - Eastern Nursery Situation
R. Read - Tree Improvement in the Great Plains
R. Cunninghan - Certification, Registration, and Release of Tree and Shrub Reproductive Material
E. Belcher/R. Karrfalt - Better Seeds for Nursery Sowing
P. Laird/R. Boyd - Results of Fall Lifting and Overwinter Storage Trials at the Coeur d'Alene Nursery
W. Rietveld/R. Williams - Detection of Dormancy in Black Walnut Seedlings with the Shigometer and an Oscilloscope Technique
J. Riffle - Ecyomycorrhizal Inoculation of Nursery Seedbeds and Container Growing Media
R. Sandquist - Pesticide Regulations as They Effect Nurserymen and Herbicides in the Nursery
H. Thompson - Insecticides for Use in the Nursery
D. Dutton - Uses of Organic Fertilizer at Wind River Nursery
T. Landis - Analysis and Interpretation of Foliage Nutrient Levels in Tree Seedlings
W. Stein - Production and Use of Container Seedlings in the West
R. Tinus - Production of Container Grown Hardwoods
J. McClatchey - Biodegradable Containers
G. Peterson - Fungicides in Tree Nurseries
J. Lott - Progress Report Missoula Equipment Development Center
E. Perry - The Construction and Use of the Humboldt Nursery Tarp Roller
L. Rempel - Mechanization of Saskatchewan Nurseries
J. McCutcheon - Saskatchewan Nursery Operations
B. Elliott - New Developments at Albuquerque Tree Nursery
R. Fewin - A New Windbreak Nursery Facility for Texas
R. Laframboise - Containerized Greenhouse at Towner Nursery
J. Scholtes - Recent Development at Mt. Sopris Tree Nursery
W. Prather - Utah State Nursery Developments and Future Nursery Plans
P. Etheridge - Pine Ridge Forest Nursery Development and Design
E. Perry - Development and Expansion of the Humboldt Nursery
F. Morby - New Developments at Medford Forest Nursery
M. Strachan - Colorado State Forest Service Nursery
D. Miller/R. Schaefer III - Potlatch Begins Container Production at Lewiston, ID
G. Finger - An Introduction to Weyerhaeuser Southern Nursery Operations
M. Frolich - Development of New Production Facility in Southern Nevada
F. Ter Bush - Publication
S. McDonald - Forest Tree Nursery Energy Considerations

BUSINESS MEETING

A short business meeting was held to decide that the 1978 Intermountain Nurserymen's Association meeting would be held in Eureka, California in conjunction with the Western Forest Nursery Council. The 1979 meeting is being planned for the Mt. Sopris, Colorado area.

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The 18th Annual Meeting of the Intermountain Nurserymen's Association was held in conjunction with the Western Forest Nursery Council on August 7-11, 1978 in Eureka, California. Don Perry was chairman and host for the conference, which caused problems as facilities were not planned for the large attendance. A dinner was held at the Samoa Cookhouse, where Stan Schmidt spoke of "The Fabulous Redwood Empire." Simpson Timber Company hosted a California wine tasting experience and a salmon barbecue. The 1-day field trip toured the Clotilde Merlo Forest Nursery, the Humboldt Nursery, and the Simpson Forest Nursery. The keynote address was given by Huey Johnson, California Secretary for Resources.

TECHNICAL AGENDA - Papers by:

F. Morby - An Approach to Fertilization of Bare Root Conifer Seedlings
P. Hahn - Nutrient Requirements of Containerized Nursery Stock
S. McDonald - Irrigation Monitoring in Western Forest Tree Nurseries
J. Lemhouse - Managerial Accounting: Enterprise Cost Accounting for Nurserymen
L. Nickolson - Double or Triple Sorting of Tree Lots
T. Williams - Observation of Coast Redwood Bare Root Seedlings
H. Baer - Redwoods - How to Grow Them in Containers
J. Rydelins - Korbel Forest Nursery: Purpose, Production, Species, and Progress
J. Edgren/M. Greenup/J. Reynolds - An Operational Root Wrenching Trial at Humboldt Nursery
J. Jenkinson/J. Nelson - Seed Source Lifting Windows for Douglas-fir in the Humboldt Nursery
W. Stein - An Integrated Study of Nursery Stock Conditioning Preliminary Observations on Stock Performance
A. Jaramillo - An Integrated Study of Nursery Stock Conditioning: Oscilloscope Readings and Cold Hardiness
C. Cordel/D. Marx - National Pisolithus tinctorius Ecomycorrhizae Nursery Evaluation
M. Srago - The Establishment of Mycorrhazae Using Excised Roots as Inoculum
R. Sandquist - Status of Western Nursery Herbicides Screening Project
R. Stewart/R. Owsten/H. Weatherly - Evaluation of Six Herbicides for Weed Control in Pacific Coast Forest Nurseries
M. Srago - Nursery Disease Problems: Sirococcus Strobilinus
M. Srago - Nursery Disease Problems: Phoma Blight
A. McCain - Nursery Disease Problems: Containerized Nurseries
L. Gillman/R. James - Nursery Disease Problems: Fungicidal Tolerance of Botrytis Cinera
R. Tinus - Shelterbelts for Nurseries
F. Ter Bush - Seedling Production Contract Growing
E. Belcher - Service at the Eastern Tree Seed Laboratory
T. Greathouse - The Importance of Matching Forest Tree Seed Source with Reforestation Site
B. Lowman - Dewinger for Small Seed Lots
J. Campini - Recent Seed Processing Machinery and Techniques
J. Thomas - Principles of Gravity Separation
F. Deneke/T. Landis - The Value of Quality Seed in Forest Tree Nursery Operations and Reforestation Programs
R. Danielson - Methods of Measuring Seed Quality
R. Silen/C. Osterhaus - Reduction of Genetic Base by Sizing of Bulk Douglas-fir Seedlots
R. Tinus - Effect of Parent Tree and Crop Year on Scots Pine Seed Weight
E. Belcher - Aspects of Seed Quality
L. Hinds - Special Processing Techniques of Hardwoods and Shrubs
A. Plummer/K. Jorgensen - Harvesting, Cleaning, and Storing Seed of Western Shrubs
F. Ter Bush - Commercial Services
J. Rydelius/E. Belcher - Cleaning Redwood Seed
S. McDonald - Report to the Intermountain Nurserymen's Association by the Nursery Stock Grading Standards and Nomenclature Committee
S. McDonald - Forest Tree Nursery Soils Testing Program
J. Lott - Overview of the Missoula Equipment Development Center's Current Reforestation Program

BUSINESS MEETING

Steve McDonald submitted his report to the Forest Tree Planting Stock Standards Committee and his report on the nursery soil testing program. The Intermountain Nurserymen were invited to hold their 1979 meeting in the Mt. Sopris Nursery in Colorado.

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The 19th Meeting of the Intermountain Nurserymen's Association met on August 13-16, 1979 at Aspen/Snowmass, Colorado. John Scholtes was the host nurseryman. Attendance was 124. A banquet and luncheon were held at the Snowmass Inn. The field tour for 1 day was held at the Mt. Sopris Federal Nursery, and mine spoil revegetation was observed near Redstone.

TECHNICAL AGENDA - Papers by:

R. Huber - Nursery Scene in Western Canada
C. Lantz - Progress Report: Seedling Production in the South
F. Ter Bush - The Northwest Scene
S. McDonald - The Nursery Situation in the Interior West in 1979
K. Goldsberry - Greenhouse Safety - For Plants and People Alike
R. Ryker - Western Nursery Herbicide Study - 1979 Update
N. Callan - Dacthal Injury on Douglas-fir and True Firs at the Medford Forest Nursery
R. Sandquist - Registration of Herbicides for Use on Forest Nursery Seedbeds
C. Cordell/D. Marx - National Pisolithus tinctorius Ectomycorrhizae Nursery Evaluation Results - 1978
J. Lott - Nursery Equipment Development at Missoula Equipment Development Center
F. Solan/D. Bickelhaupt/A. Leaf - Soil and Plant Analytical Services for Tree Nurseries
S. McDonald - The Soil Testing Program for Tree Nurseries and the Soil Management Workshop
T. Williams - Nursery Management Information System
D. Wermlinger - Contract Pulling
P. Au/T. Hale - Pine Ridge Forest Nursery Container Filling and Seeding Systems
J. Myers - Greenhouse Cropping and Container Washing
B. Elliott - Albuquerque Tree Nursery
F. Morby - Developing a New Nursery
P. Guthrie - Bureau of Indian Affairs Reforestation Policies and Programs
M. Becwar/M. Burke - Low Temperature Extremes: Their Effect on Plants at Timberline
J. O'Brien/J. Fisher - Seed Handling and Large Scale Production of New Mexico Native Junipers
T. Landis - The Saline Soil Syndrome and its Effect on Bare-Root Production in Two Rocky Mountain Area Nurseries
C. Kerr/J. Stehlik/R. Stakes - Trees in the Tundra
G. Walters/H. Horiuchi - Containerized Seedlings: Key to Forestation in Hawaii

BUSINESS MEETING

The Intermountain Nursery group agreed to meet at the Lucky Peak Nursery in Boise, Idaho in 1980.

The Intermountain Nurserymen also expressed interest in attending the North American Forest Tree Nursery Soil Management Workshop to be held in Syracuse, New York in July 1980.

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The 20th Meeting of the Intermountain Nursery Association met in conjunction with the Western Forest Nursery Council on August 12-14, 1980 at the Lucky Peak Nursery in Boise, Idaho. Richard Thatcher, host nurseryman, was chairman of the meeting. One hundred sixteen persons were in attendance. Ralph Peinecke of the Boise Cascade Corporation gave the welcome address, and R. Max Peterson, Chief of USDA Forest Service, addressed the group on present and future trends. A tour of the Lucky Peak Nursery was experienced by the entire group.

TECHNICAL AGENDA - Papers by:

R. Huber - Canadian Nursery Update
R. Tinus - Forestation Concepts and Practices Developing in New Zealand
T. Landis - Report of the North American Forest Soils Workshop
L. Hinds - The American Association of Nurserymen and its Government Nursery Production Committee
R. Ryker - Evaluation of Herbicides for Weed Control in Rocky Mountain- Great Basin Nurseries
D. Edwards - The Western Forest Tree Seed Council
R. Matye - An Introduction to the Westfir Transplant Nursery

C. Cordell/D. Marx - Ectomycorrhizae: Present Status and Practical Application in Forest Tree Nurseries and Field Plantings
S. McDonald/R. Tinus/C. Reid - Root Morphology Control in Forest Tree Seedling Containers
A. Borchert - Quality Cone Collection
A. Elliott - Use of Solar Energy to Dry Cones at the Albuquerque Tree Nursery
D. Altmann/P. Au/L. Lafleur - Production Seed Processing at Pine Ridge Forest Nursery
D. Edwards - A New Prechilling Method for True Fir Seeds
F. Zensen - Seed Processing: Management Techniques
E. Hardin - Quick Test Vs. Standard Germination Test
J. Zaerr/B. Cleary/J. Jenkinson - Scheduling Irrigation to Induce Seedling Dormancy
M. Triebwasser/D. Overhaulser - The Cranberry Girdler in Conifer Nurseries of Western Washington and Oregon
A. Jaramillo - Review of Techniques Used to Evaluate Seedling Quality
J. Hinz - Techniques of Quality Control for Seedling Lifting Operations
D. Dutton - Quality Control: Tree Processing Operation
M. Shearer - Requirements for Quality Irrigation
G. Jacobsen - Field Handling
A. Dahlgreen - Field Handling and Planting
D. Jensen - Mine and Roadside Revegetation in Montana
M. Frolich - IMpact of Desert Forestry on the Plant Materials System of Nevada
T. Williams - Nursery Management Information System

BUSINESS MEETING

The Intermountain Nurserymen agreed to meet in Edmonton, Alberta, Canada in August 1981.

A discussion was held as to the merits of joining the Intermountain Nursery group with the Western Forest Nursery Council. No decision was made.

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The 21st Annual Meeting of the Intermountain Nurserymen's Association was held in Edmonton, Alberta, Canada on August 11-13, 1981. Ralph Huber was host nurseryman and chairman of the Meeting. Ninety four persons registered for the meeting which was marred by the inability of several nurserymen to use air transportation because of strikes in the Untied States. A banquet and luncheons were sponsored by several Canadian companies. A 1-day tour of the Alberta Forest Service Pine Ridge Forest Nursery and the Alberta Tree Nursery (Oliver Nursery) were experienced by the entire group.

TECHNICAL AGENDA - Papers by:

C. Dermott - Reforestation at the Ridge Forest Nursery
H. Oosterhuis - Alberta Tree Nursery and Horticulture Centre
A. Kiil - Reforestation Research in the Prairies: An Overview
S. Wallner/J. Bourque/T. Landis/S. McDonald/R. Tinus - Cold Hardiness Testing of Container Seedlings
R. Tinus - Successful Overwintering of Container-grown Seedlings
H. Spencer - The Painful Problems of Pioneer Propagation Plans and Other Adventures
I. Edwards - Maintaining Soil Fertility in Forest Nurseries in the Prairie Provinces
F. Morby - Irrigation Regimes in a Bare-Root Nursery
T. Landis - Irrigation Water Quality in Tree Nurseries in the Inland West
R. Esau - Herbicide Investigations in Coniferous Tree Nurseries in Saskatchewan and Alberta
G. Brown - Field Vacuum Seeder
B. Polhill - Monitoring Growth Progression Through Root Collar Diameter Measurements
R. Day - Evaluating Root Regeneration Potential of Bare-Root Nursery Stock
A. Wynia - Using Cost Accounting in Nursery Management
R. Bell - IFSCO Cone Handling and Dry Kiln System
R. Schaefer - Cone Handling System From Field to Processor
A. Suhrbier - Avoiding the Nursery-customer war (more aptly, keeping the battles down to only customers you really don't want to deal with anyway)

BUSINESS MEETING

A motion was made for the Intermountain Nurserymen's Association to merge into one single group with the Western Forest Nursery Council. The motion carried. The Western Forest Nursery Council planned to vote on the merger at its 1982 meeting.

The Nursery group agreed to hold their 1982 meeting as a combined meeting in Medford, Oregon. The 1983 meeting was planned for Las Vegas, Nevada.

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The 22nd Meeting was held on August 10-12, 1982. The Intermountain Nurserymen's Association met in a combined meeting with the Western Forest Nursery Council in Medford, Oregon. Frank Morby was the host nurseryman and chairman for the joint meeting. Robert Devlin, Forest Supervisors of the Rogue River National Forest, gave the welcome address. A 1-day tour of the J. Herbert Stone Nursery was experienced by the group. A banquet and luncheons were very successful. One hundred eighty three registered for attendance.

TECHNICAL AGENDA - Papers by:

B. Sery - Small Seedlot Extractory Dorena Tree Improvement Center
M. Hale - Seed Cone Processing at the Bend Pine Nursery
R. Guariglia - True Fir Stratification - A Field Test
R. Tinus - Sand and Hydrogel Seed Covering Improves Germination of Several Hardwoods in Soil That Crusts
D. Hansen - Bedhouse Seedling Production
R. Adams - Irrigation According to PMS and Tensiometer Instruments
R. Eide - Cultural Practices in Growing Western Hemlock and Sitka Seedlings
D. Dutton - Chinese Weeder Geese - Do They or Do They Not Weed in the Nursery
C. Chatterton - Residual Napromide and its Effect on Western Larch at Coeur d'Alene Nursery
C. Youngberg - Soil Testing and Soil Fertility
J. Jenkinson/J. Nelson - 1-0 Douglas-fir: A Bare-Root Planting Option
L. Heidmann - An Initial Determination of the "Lifting Window" for Ponderosa Pine Seedlings Raised at Albuquerque, New Mexico
B. Thompson - Why Fall Fertilize
J. Fischer - Response of Douglas-fir and Ponderosa Pine to Phosphorous Fertilization at the J. Herbert Stone Nursery
J. Laturner - The Belted Seedling Lifter
P. Heide - The Fobro 1500 Forest Nursery Tree Lifter
J. Sedore - Trends in Container Seedling Production
P. Hahn - Containerized Seedling Production in a Shelter House System
R. Schaefer/F. Kidd - Root Egression From Potlatch Corporation Containerized Seedlings
K. Doughton - Transplanting the Douglas-fir Plug
H. Oosterhuis - The Production of Coniferous Transplants Using Spencer Lemaire Containers
J. Lott - Missoula Equipment Development Center - Reforestation Program
D. Lavender/D. McCreary - Effects of Harvest and Packing Technique on Douglas-fir Seedlings
L. Nicholson - The Importance of Good Nursery Quality Control Part 1
C. Hayhurst - The Importance of Good Nursery Quality Control Part 2
K. Seppa - What's New in Herbicides
J. Chandler - Nursery Management Information System
R. Schaefer - Potlatch's Reporting System for Tracking seedling Crops From Requisition to Plantation
R. Thatcher - Contract Grading - Boom or Bust
R. Miller - USDA, Forest Service Nursery Capacity and Stock Needs
S. Schalla - The Capability of Private Nurseries to Meet Federal Long-Term Needs
J. Edgren - Should Private Nurseries Produce Seedlings for Federal Reforestation Programs

BUSINESS MEETING

The meeting was chaired by Frank Morbey, host nurseryman. The subject of combining the Intermountain Nurserymen's Association and the Western Forest Nursery Council was discussed and voted on by the Western Forest Nursery Council membership. A vote was taken and a count of 29 against and 24 for was gathered. The Intermountain Nurserymen voted for merging the two organizations in 1981 at the Edmonton meeting. The two organizations will remain separate at this time. The opportunity to attend the meeting of both groups continues to remain available to all.

The Intermountain Nursery Group will meet in Las Vegas, Nevada in August 1983.

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The 23rd Meeting of the Intermountain Nurserymen's Association was held on August 8-11, 1983 in La Vegas, Nevada. Pat Murphy, Assistant State Forester hosted the meeting. Seventy eight registered for the meeting. Native Plant Materials was the theme for the meeting. Field tours were held at the Nevada State Nursery and Greenhouse.

TECHNICAL AGENDA - Papers by:

J. Young/J. Bundy/R. Evans - Germination of Seeds of Windland Plants
N. Shaw - Producing Bareroot Seedlings of Native Shrubs
T. Landis/E. Simonich - Producing Native Plants as Container Seedlings
S. Monsen - Use of Shrubs on Mine Spoils
D. Nelson - Toward Producing Disease-Free Container-Grown Native Wildland Plants
R. James - Biology and Management of Botrytis Blight
R. Tinus - Salt Tolerance of Ten Deciduous Shrub and Tree Species
J. Sedore - Containerized Seedling Production for Forest Regeneration in the Pacific Northwest
M. Duryea/S. Omi - The Nursery Technology Cooperative: A Coordinated Effort to Improve Seedling Quality
D. McCreary - Using a Pressure Chamber to Detect Damage to Seedlings Accidentally Frozen During Cold Storage
R. Champbell, Jr. - Asexual vs. Sexual Propagation of Quaking Aspen
J. Fisher/G. Fancher - Effects of Soil Amendments on Aspen Seedling Production
H. Khatamian/F. Al-Mana - Growth of Austrian Pine and Norway Spruce Seedlings in Mini-Containers
R. Hallman - Equipment for Revegetating Disturbed Lands
R. Karrfalt/R. Helmuth - Preliminary Trials on Upgrading Platanus Occidentalis with the Helmuth Electrostatic Seed Separator
J. Budy/E. Miller - Survival, Growth, and Root Form of Containerized Jeffrey Pines 10 Years After Outplanting
T. Smith - Growing Containerized Tree Seedlings in a Shadehouse

BUSINESS MEETING

The Intermountain Nurserymen's Association agreed to meet in 1984 in Coeur d'Alene, Idaho in conjunction with the Western Forest Nursery Council. The 1985 meeting was planned for Ft. Collins, Colorado.

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One hundred ninety persons registered for the 24th Meeting of the Intermountain Nurserymen's Association meeting in Coeur d'Alene, Idaho August 14-16, 1984. The meeting was held in conjunction with the Western Forest Nursery Council. This was the largest attendance to date for the joint meeting. Darrell Benson, host nurseryman, was chairman for the meeting. Luncheons and a catered dinner on a recreation boat on Coeur d'Alene Lake were enjoyed by all. Field tours were held at the USDA Coeur d'Alene Nursery.

TECHNICAL AGENDA - Papers by:

S. Altsuler - Plug Seedling Success in the High Country
D. Miller/R. Schaefer - Effects of Container Size on White Pine and Douglas-fir Survival and Growth in North Idaho
J. Arnott - Photoperiod Control of Container Seedling
T. Jopson/J. Paul - Influence of Fall Fertilization and Moisture Stress on Growth and Field Performance of Container-Grown Douglas-fir Seedlings
J. Lott - Forest Service Equipment Development Reforestation Program
R. Thatcher - Contract Grading
F. Zensen - Lift and Pack Procedures at the J. Herbert Stone Nursery
R. Darbyshire - Impacts of Nursery Processing on the Survival and Growth of 2+0 Douglas-fir
J. Jenkinson/ J. Nelson - Cold Storage Increases Resistance to Dehydration Stress in Pacific Douglas-fir
S. Cooley - Solarization in Two Pacific Northwest Forest Nurseries
D. Booth - Fluid Drilling for Wildland Plantings: Some Preliminary Studies
R. Huber - New Seeding and Lifting Concepts in British Columbia
M. Hale - Designing the Bend Nursery Tree Inventory System
A. De Haas - The Placerville Nursery Seedling Lifting Bar
R. Langmo/J. Washburn - Seedling Net-Spreading Aid
J. Scholtes - Update on Northeastern Nurseries
P. Au - Pre-emergent Herbicide Trial in White Spruce at Pine Ridge Forest Nursery
J. Doty - Top Mowing at Viewcrest Nurseries
W. Ellington - New Ideas in Fall Planting
B. Thompson/J. Faulconer - Benefits of Knowing Seedling Quality
R. Guariglia/B. Thompson - The Effect of Sowing Depth and Mulch on Germination and 1+0 Growth of Douglas-fir Seedlings
L. Heidmann/S. Haase - Herbicides for Controlling Weeds at the Albuquerque Forest Tree Nursery
P. Malone - Germination of Western White Pine Seed
F. McElroy - Soil Pest Management Programs for Bareroot Nurseries
R. Moreno - Maximum Germinants/Unit of Seed as a Tool for Calculating Bareroot and Container Sowing Calculations

F. Rothe - "Grow and Plant"--Another Way to Do the Job
W. Schroeder - Field Production of Rooted Poplar cuttings for Prairie Plantings
J. Sedore/W. Fangen - Transplant Comparisons at the Webster Nursery Plug-1s and Bareroot 2-1s
W. Sery - Growing Seedlings in Pallet-sized Containers
G. Shrimpton - Four Insect Pests of Conifer Nurseries in British Columbia
W. Stein - Effects of Wrenching Douglas-fir Seedlings in August
N. Vance - Light Reduction and Moisture Stress: Effects on Containerized Western Larch Seedlings
C. Youngberg - Organic Matter-How Much is Enough?

BUSINESS MEETING

The meeting was chaired by Darnell Benson. It was announced that the 1985 meeting of the Intermountain Nurserymen's Association would meeting in Ft. Collins, Colorado in August. The joint meeting of the Intermountain Nurserymen and the Western Forestry Nursery Council will meet in Olympia, Washington in 1986. The Intermountain Nurserymen's Association will be in Oklahoma in 1987.

Tom Landis indicated that a problem exists on how to finance the publication of the proceedings of the nursery conference meetings. A show of hands indicated they would support the printing of proceedings through an additional reasonable fee collected from the membership.

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The 25th Meeting of the Intermountain Nurserymen's Association was held in Ft. Collins, Colorado on August 13-15, 1985. Marvin Strachan, host nurseryman, was meeting chairman. Eighty three people registered for the new concept meeting which featured four concurrent groups to discuss priority topics. Tours included the Colorado State Forest Service Nursery and ecological conditions in Rocky Mountain National Park. A luncheon was held at CSU and a western cookout at Estes Park. Several commercial exhibitors were present.

TECHNICAL AGENDA - Papers by:

S. Dronen - Value of Windbreaks
R. Tinus - In-bed Herbaceous Windbarrier Produced More Ponderosa Pine Seedlings
A. Myatt/M. Vorwerk - Administrative, Economic, and Technical Observations in Developing and Maintaining an Effective Weed Control Program
G. Neill - Nursery Research: A Practical Approach
S. Omi - Soil Compaction: Effects on Seedling Growth
J. Grebasch - Computer Use in Nursery Management
W. Crenshaw - Recent Developments in the Management of Nursery Pests
K. Burr - Greenhouse Production of Quaking Aspen Seedlings
K. Eggleston/R. Sharp - Fertilizer Trials on Containerized Red Pine
R. Danielson - Stratification and Germination of Western White Pine Seeds
J. Hamilton - Development of Underground Cold Storage at Pine Ridge Forest Nursery
J. Barnett/J. Johnson/N. Stumpff - Effects of Ethylene on Development and Field Performances of Loblolly Pine Seedlings

WEED CONTROL PANEL:
L. Alspach - Herbicides for Weed Control in Tree Nurseries
L. Abrahamson - Forest Tree Nursery Herbicide Studies in the Northern Great Plains & Herbicide Phyototoxicity Tables
R. Darbyshire - Herbicides for Conifers: What's New

SEEDLING QUALITY PANEL:
K. Munson - Principals, Procedures, and Availability of Seedling Quality Tests
D. Simpson - When to Measure Seedling Quality in Bareroot Nurseries

C. Johnson - How to Use Seedling Quality Measurements in Container Nurseries

BAREROOT SEEDLING FERTILIZATION PANEL:
T. Landis/J. Fischer - How to Determine Fertilizer Rates and Application Timing in Bareroot Forest Nurseries
R. Selig - Soil Mapping and Testing
I. Edwards - How to Maximize Efficiency of Fertilizers in a Forest Tree Nursery

POSTER PAPER:
K. Burr/S. Wallner/R. Tinus - Cold-Hardiness Testing of Conifer Seedlings

BUSINESS MEETING

The meeting was chaired by Marv Strachan, host nurseryman, following the noon lunch at Lyons Park during the Field trip. It was reconfirmed that the 1986 joint meeting would be held in Olympia, Washington. The Oklahoma delegation stated that plans were proceeding for the Intermountain Nurserymen to meet in Oklahoma in 1987. The Utah delegation offered to host the Intermountain Nursery group in 1989. A motion was made, seconded, and carried by a majority vote to change the name of the Association from "Intermountain Nurserymen's Association" to "Intermountain Nursery Association."

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The 26th Meeting was held on August 12-15, 1986. The Intermountain Nursery Association met in a combined meeting with the Western Forest Nursery Council in Tumwater, Washington. Jim Bryan, Ken Curtis, and Kevin O'Hara were the host nurserymen and chairpersons for the meeting. John McMahon, Weyerhaeuser Company, gave an inspiring opening address. One hundred eighty seven registered for the meeting. Field tours of the I.F.A. Toledo Nursery, the Weyerhaeuser Mima Nursery, and the Washington State Webster Nursery were experienced by the entire group.

TECHNICAL AGENDA - Papers by:

R. Shearer - Western Larch Cones and Seeds - Current Intermountain Research Station Studies
R. Piesch - Tree Improvement Comes of Age in the Pacific Northwest: Implications for the Nurseryman
T. Smith - Stratification Reduced Germination of Ponderosa Pine Seed Collected in New Mexico and Southern Colorado
C. Gansel - Comparison of Seed Stratification Methods for Western White Pine
W. Johnson - Excised Embryo Test for Western White Pine
M. Coleman/J. Dunlap/D. Dutton/C. Bledsoe - Nursery and Field Evaluation of Compost-Grown Coniferous Seedlings
S. Omi/G. Howe/M. Duryea - First-year Field Performance of Douglas-fir Seedlings in Relation to Nursery Characteristics
J. Jenkinson/J. Nelson - Winter Sowing for Production of 1-0 Douglas-fir Planting Stock
E. Olson - Weed Control - Alternatives to Herbicides
S. Steinfield - Seedling Monitoring During the 1-0 Growing Season
T. Smith - Growing Seedlings on a Production Scale in a Shadehouse
G. Ritchie - Some Effects of Cold Storage on Seedling Physiology
S. Hee - Freezer Storage Practices at Weyerhaeuser nurseries
R. Danielson - Seed Laboratory Computerization: A Database for the Forest Tree Seed Industry
V. Wyant - Nursery Crop Management Computer System
D. Bluhm - Using the HP71 Hand-Held Computer for Seedling Inventory
G. Hileman - Root Growth Capacity System
D. Dolata - Root Regeneration Potential
R. Tinus/K. Burr/S. Wallner/R. King - Relation Between Cold Hardiness, Root Growth Capacity, and Bud Dormancy in Three Western Conifers
K. Burr/R. Tinus/S. Waller/R. King - Comparison of Four Cold Hardiness Tests on Three Western Conifers
W. Rietveld - A New, More Efficient Method to Evaluate Root Growth Potential of Planting Stock Using a Root Area Index
R. Laacke/C. Weatherspoon/R. Tinus - Monitoring Cold Hardiness of Tree Seedlings by Infrared Thermography
B. Dunsworth - Root Growth Potential in Coastal Container Species: Trends From Operational Testing and Prediction of Outplanting Performance
P. Hamm/E. Hansen - Stem Canker Disease of Douglas-fir in Nurseries
R. James - Occurrence of Fusarium on Conifer Tree Seed from Northern Rocky Mountain Nurseries
A. Kanaskie - Management of the Top Blight Disease Complex
P. Hamm/E. Hansen - Phytophthora Root Rot in Forest Nurseries of the Pacific Northwest
S. Cooley - Management of Phytophthora Root Rot in Pacific Northwest Conifer Nurseries
G. Shrimpton - Some Insect Pests of Conifer Seedlings in British Columbia
K. Russell - Reducing Fusarium Top Blight in 1-0 Douglas-fir by Irrigation Scheduling
F. McElroy - Options in Controlling Soilborne Peats
F. McElroy - Use of Meta-Sodium and Dazomet Fumigants
Y. Tanaka/K. Russell/R. Linderman - Fumigation Effect on Soilborne Pathogens, Mycorrhizae, and Growth of Douglas-fir Seedlings
D. Overhulser/P. Morgan/R. Miller - Control and Impact of Lygus Damage on 1-0 Douglas-fir Seedlings

BUSINESS MEETING

The 1988 meeting was scheduled for Vernon, British Columbia with Ralph Huber as host. The 1989 meeting of the Intermountain Nursery Association is scheduled for Bismarck, North Dakota. The 1990 joint meeting is scheduled for the Phipps Nursery in Elkton, Oregon.

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On August 10-14, the Intermountain Nursery Association met for the 27th Meeting in Oklahoma City, Oklahoma. .l Myatt and Clark Fleege were host nurserymen and chairmen for the meeting. The theme was "Meeting the challenge of the nineties." Eighty people registered. A luncheon and cookout were featured, along with a rare treat of rattlesnake handling. Al Engstrom, former nurseryman and retired Oklahoma State Forester, was present and spoke to the group.

TECHNICAL AGENDA - Papers by:

C. Whitcomb - Seedlings, Service, Insights
J. South - Communication as a Design Consideration in Developing a Computerized Nursery Management Environment
W. Rietveld/R. Ryker - Applications of Portable Data Recorders in Nursery Management and Research
R. Erazo - Superabsorbent Hydrogels and Their Benefits in Forestry Applications
J. Mexal/J. Fisher - Organic Matter: Short-Term Benefits and Long-Term Opportunities
R. Oswald - The Trees Unlimited Program: An Experiment in Establishing Seedling Plantings
K. Conway - The Potential of Soil Solarization in Nurseries to Control Soilborne Diseases
K. Fleege - Seedling Production at Oklahoma Forestry Division Forest Regeneration Center
S. Hallgren - Priming Treatments to Improve Pine Seed Vigor
J. Brissette/W. Carlson - Effects of Nursery Density on Shortleaf Pine
W. Carlson/J. Anthony/R. Plyler - Polymeric Nursery Bed Stabilization to Reduce Seed Losses in Forest Nurseries
J. Barnett/J. Brissette - Improving Outplanting Survival of Stored Southern Pine Seedlings by Addition of Benomyl to the Packing Medium
R. Karrfalt - Measuring Tree Seed Moisture Content Now and in the Future
L. Abrahamson - Forest Tree Nursery Herbicide Studies at the Oklahoma Forest Regeneration Center
D. Bickelhaupt - Use of Sulfur to Correct Soil pH
T. Boggus - Certified Vendor Program
W. Rieveld/R. Tinus - Alternative Methods to Evaluate Root Growth Potential and Measure Root Growth
D. Burr/R. Tinus/S. Wallner/R. King - Comparison of Time and Method of Mist Chamber Measurement of Root Growth Potential
S. Hallgren/C. Tauer - Effects of Lift Date, Storage, and Family on Early Survival and Root Growth Potential of Shortleaf Pine
S. Omi/U. Schuch - Fall Lifting: Its Effects on Dormancy Intensity of Ponderosa Pine Seedlings - A Preliminary Investigation
B. Lowman - A Status Report on Nursery and Reforestation Projects at the Missoula Technology and Development Center
G. Kranzler/M. Rigney - Grading Pine Seedlings with Machine Vision
C. Cordell/J. Owen/D. Marx - Mycorrhizae Nursery Management of Improved Seedlings Quality and Field Performance
T. Filer, Jr./C. Cordell - Integrated Pest Management in Forest Nurseries
W. Rietveld/P. Owston/R. Miller - The USFS Reforestation Improvement Program
T. Landis - Government vs. Private Nurseries: The Competition Issue
K. Atkinson - Working Group Sessions on Communications and the Government/ Private Nursery Issue.
Session I: Communications
Session II: Government vs. Private Nurseries

BUSINESS MEETING

The proceedings of this meeting will be published by the Rocky Mountain Forest and Range Experiment Station. The 1988 joint meeting between the Intermountain Nursery Association and the Western Forest Nursery Council will be held in Vernon, British Columbia, Canada. The 1989 meeting of the Intermountain Nurserymen will be held in North Dakota in August.

Marv Strachan has volunteered to prepare historical summary of past nursery proceedings and index them for reference.

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On August 8-11, 1988, the joint meeting of the Intermountain Nursery Association and the Western Forest Nursery Council met at Vernon, British Columbia. This was a very large group in attendance, with three hundred twenty-eight in registration. Ralph Huber, B.C. Forest Service, served as the host nurseryman and chairman for the meeting. Thirty exhibitors showed and demonstrated their products during the conference. A cookout dinner was enjoyed at the local O'Keefe Ranch, together with observation of antique farm and home equipment. A tour of the B.C. Skimikin Nursery near Salmon Arm was experienced by the nurserymen.

TECHNICAL AGENDA - Papers by:

C. Leadem - Dormancy and Vigour of Tree Seeds
R. Bowden-Green - Province of British Columbia Ministry of Forests Seed Centre
J. Maxwell - Macro and Micronutrient Programmes in B.C. Bareroot Nurseries
W. Stein - Nursery Practices, Seedling Sizes, and Field Performance
W. Rietveld - Effect of Paclobutrazol on Conifer Seedling Morphology and Field Performance
D. Simpson - Fixing the Edsel--Can Bareroot Stock Quality be Improved?
G. Hunt - Effect of Controlled-Release Fertilizers on Formation of Mycorrhizae and Growth of Container-Grown Englemann Spruce
D. Wenny - Growth of Chemically Root-Pruned Seedlings in the Greenhouse and the Field
J. Arnott/B. Dunsworth/C. O'Reilly - Effect of Nursery Culture on Morphological and Physiological Development of Western Hemlock Seedlings
C. Hawkins/D. Draper - Height Control of Interior Spruce by Means of Photoperiodic Induction
C. Hawkins/D. Draper/R. Eng - Heating System, Germination Temperature, and Post Germination Fertilizer Regime Effects on White Spruce Nursery Growth
C. Hawkins/B. Hooge - Blackout and Post Planting Bud Phenology in SxS Spruce Seedlings
K. Odlum/S. Colombo - Short Day Exposure to Induce Budset Prolongs Shoot Growth in the Following Year
R. Scagel/G. Davis - Recommendations and Alternative Growing Media for Use in Containerized Nursery Production of Conifers: Some Physical and Chemical Properties of Media and Amendments
I. Armit - The "Izing" of British Columbia Nurseries
M. Pelchat - Managing Nursery Information in the 1980's
U. Wallersteiner - Cumulative Trauma Disorders in Forest Nursery Workers
S. Grossnickle/J. Arnott/J. Major - A Stock Quality Assessment Procedure for Characterizing Nursery-Grown Seedlings
J. Faulconer - Using Forest Hardiness as an Indicator of Seedling Condition
I. Dymock - Monitoring Viability of Overwintering Container Stock in the Prairies--An Overview of a 5-Year Lodgepole Pine Study
T. Landis/S. Skakel - Root Growth Potential as an Indicator of Outplanting Performance: Problems and Perspectives
W. Binder/R. Scagel/G. Krumlik - Root Growth Potential: Facts, Myths, Value
D. Simpson/A. Vyse/C. Thompson - Root Growth Capacity Effects on Field Performance
W. Binder/P. Fielder - The Effects of Elevated Post-Storage Temperatures on the Physiology and Survival of White Spruce Seedlings
W. Vidaver/P. Toivonen/G. Lister/R. Brooke/W. Binder - Variable Chlorophyll Fluorescence and its Potential Use in Tree Seedling Production and Forest Regeneration
K. Burr/R. Tinus - Effect of the Timing of Cold Storage and Cold Hardiness and Root Growth Potential of Douglas-fir
D. Hildebrand/G. Dinkel - Basamid and Solar Heating Effective for Control of Plant-Parasitic Nematodes at Bessey Nursery, NE
R. James/R. Dumroese/D. Wenny - Occurrence and Persistence of Fusarium Within Styroblock and Ray Leach Containers
R. Sturrock/J. Dennis - Styroblock Sanitization: Results of Laboratory Assays From Trials at Several British Columbia Forest Nurseries
R. Dumroese/R. James/D. Wenney/C. Gilligan - Douglas-fir Seed Treatments: Effects on Seed Germination and Seedborne Organisms
L. Husted - Douglas-fir Dieback
S. Campbell - Update on the Environmental Impact Statement for Pest Management at the Federal Nurseries in the Pacific Northwest Region
R. Klapprat - Greenhouse Transplants for Bareroot Stock Production
S. Hee/T. Stevens/D. Walch - Production Aspects of Mini-Plug Transplants
Y. Tanaka/B. Carrier/A. Dobkowski/R. Figueroa/R. Meade - Field Performance of Mini-Plug Transplants
M. Rigney/G. Kranzler - Computer Vision for Grading Tree Seedlings
C. O'Reilly/J. Ownes/J. Arnott/B. Dunsworth - Effects of Nursery Treatment on Shoot Length Components of Western Hemlock Seedlings During the First Year of Field Establishment
C. Sutherland/T. Newsome - Field Performance of Five Interior Spruce Stock Types With and Without Fertilization at Time of Planting
B. Dunsworth - Impact of Lift Date and Storage on Field Performance for Douglas-fir and Western Hemlock
J. Sloan - Auger Hole Shape, Size, and Tree Placement Affect Survival and Root Form of Planted Ponderosa Pine in South Central Idaho
D. Draper/D. Spittlehouse/W. Binder/T. Letchford - Field Measurement of Photosynthetically Active Radiation

BUSINESS MEETING

No official business meeting was held for the Intermountain Nursery Association because of the small number of Intermountain Nurserymen present and the large number of Canadian and Western Forest Nursery Council attendance.

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Minutes of the Annual Business Meeting

The annual business meeting of the Intermountain Forest Nursery Association was called to order at 12:30 P.M. on August 17, 1989 by Ad Hoc chairperson Tom Landis. The first order of business was to discuss the Historical Account of the Association that was developed by Marv Strachan. The group decided that the publication was a valuable record of past meetings and should be included in the Proceedings of this year's meeting. The Proceedings will be published by the USDA Forest Service, Rocky Mountain Station as a General Technical Report; this project will again by funded by Cooperative Forestry.

The next topic was the location of future meetings. Tom announced that the 1990 meeting would be a joint meeting with the Western Forest Nursery Council which would be held in Roseburg, OR on August 13-17, 1990. There was some discussion about the best location for the 1991 meeting and Dave Grierson offered to host the meeting in Salt Lake City, Utah or one of the surrounding ski resort areas. Tom volunteered to work with Dave to organize the meeting.

The treasurer reported that there was some surplus funds left over from the registration fees, and that the monies would be used to sponsor a happy hour later in the day. All remaining funds of the organization will be forwarded to Dave Grierson to help plan the 1991 meeting.

There was no further new business, and so the meeting was adjourned.

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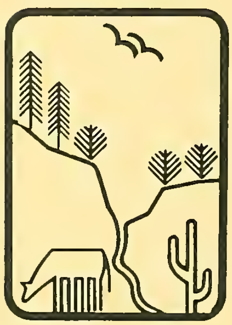
Forest Service

Rocky Mountain Forest and Range Experiment Station

Rocky Mountains



Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect Rd., Fort Collins, CO 80526