Methyl Bromide Fumigation: Alternatives And New Directions

Jill D. Pokorny'

Chemical fumigants have been used in forest nurseries since the early 1900's, and chemical fumigation of seedbeds has become an accepted and widespread pest control practice. A 1981 survey of southern and eastern nurseries reported that over 90 % of the nurseries used fumigants to control weeds, diseases and insect pests. Around 90% of all soil fumigation was done with methyl bromide/chloropicrin (MBC). A more recent survey of federal nurseries in Washington and Oregon reported that fumigants accounted for 93 % of annual pesticide usage, with MBC and dazomet accounting for 66 and 27%, respectively (13). In the northeastern area, the J. W. Toumey Federal Nursery reports that approximately 80 % of the chemical pesticides presently applied are fumigants, with MBC and dazomet being used on nearly an equal basis (Barb Jones, personal communication).

Methyl bromide was recently identified as a potentially significant contributor to ozone depletion, according to "Scientific Assessment of Ozone Depletion: 1991", an assessment paper prepared by a panel of international experts under the auspices of the Montreal Protocol (16). The ozone depletion potential (ODP) of various substances was evaluated, and the report stated that the best estimate of the ODP for methyl bromide was 0.6. Section 602(a) of the Clean Air Act provides that all substances with an ODP of 0.2 or greater be listed as Class I substances. Once listed, Class I substances must be phased out of use by the year 2000. On December 3, 1991, several environmental groups petitioned the Environmental Protection Agency (EPA), under the provisions of the Clean Air Act, to add methyl bromide to the list of Class I substances. The petition also requested that methyl bromide be subjected to an accelerated phaseout period and be banned from use by January 3, 1993.

The findings of the Montreal Protocol may not go unchallenged. In fact, the assessment paper acknowledges that many unanswered questions remain as to how much, if any, man-made bromide reaches the stratosphere, how long it persists and what chemical reactions occur. The chemical industry has formed a Methyl Bromide Users Group to monitor the situation and provide support to research efforts focused on finding answers to the many questions. As of the date of this writing, the EPA has not yet made a decision regarding the petition. It appears that the Office of Management and Budget is favoring a delay in the listing of methyl bromide as a Class I substance due to the present scientific uncertainty and lack of acceptable substitutes.

'Plant Pathologist, USDA Forest Service, State and Private Forestry, 1992 Folwell Ave., St. Paul, MN.

Clearly, the fate of methyl bromide is uncertain. There is a serious threat that it will be banned from use in the near future. Other fumigants may also face a similar fate in the years ahead. As nursery managers and researchers, we must be proactive in our approach to dealing with this situation and begin exploring alternative pest management practices. The principles of integrated pest management (IPM) provide a basis for selecting and evaluating alternatives to methyl bromide fumigation in forest nurseries.

A central concept of IPM is the maintenance of pests at tolerable levels, utilizing management practices which were selected for their effectiveness as well as their impact on economics, human health and the environment. The decision-making process for implementing IPM provides the structure for selecting and evaluating alternative pest management practices. Key steps in the decision-making process include: 1.) assessment of the situation to determine if there is a disease problem in need of treatment; 2.) determination of available/alternative management methods; 3.) selection of the best method(s), based on analysis of benefits and drawbacks; 4.) implementation of selected management method(s) and 5.) evaluation and documentation of the effectiveness of selected management method(s). The purpose of this paper is to provide basic information on disease assessment and explore possible alternatives to the use of methyl bromide fumigation in northern forest nurseries.

Integrated Pest Management Approach

DISEASE ASSESSMENT

Assessment of the situation to determine if there is a disease problem in need of treatment is the first step in implementing IPM. This is best determined by reviewing the past history of disease problems on the site, conducting regularly scheduled field inspections to record disease incidence and severity and laboratory analysis of symptomatic seedlings to identify any pathogenic fungi. Since chemical fumigants are applied on such a widespread basis, a test to determine the benefits of fumigation is also helpful in evaluating disease pressure and the need for treatment. "Check" or untreated blocks should be left in seedbeds and seedling yield information such as height, caliper, biomass and root growth collected and compared between fumigated and unfumigated blocks. A final test is to harvest and grade seedlings and compare the number of shippable seedlings and income generated between fumigated and unfumigated blocks. Income generated can then be compared directly to the cost of chemical fumigation.

DETERMINATION OF AVAILABLE/ALTERNATIVE MANAGEMENT METHODS

Alternative Fumigants

All currently registered fumigants do a reasonably good job of managing common soilborne pathogenic fungi, especially at the higher rates. Some researchers have observed less than satisfactory results; however, in managing Fusarium root rot of white pine, even when applying the higher rates of MBC and dazomet (Jennifer Juzwik and Sylvia Greifenhagen, personal communication). Only MBC-33 has been documented to control Cylindrociadium spp. and Macrophomina phaseolina which form resistant structures called sclerotia (10).

The fumigant, dazomet, will likely be the most frequently applied alternative fumigant, should methyl bromide be banned. Dazomet is a microgranular formulation which poses fewer human health risks, requires no tarp or highly specialized application equipment and is not a restricted use chemical.

Seed Quality Testing

Our current knowledge of seedborne pathogens and their impact on forest nursery production is limited. Testing to determine seed quality and vigor has not been routinely conducted, making it impossible to accurately predict losses due to seedborne pathogens. Germination testing is done on a more routine basis; however, test results provide very little useful information. For example, the germination test determines only the number of seeds which are able to germinate and does not account for those seeds which die from seedborne damping off diseases, after germination.

A three tier seed quality test consisting of a germination test, a culture test, and a seedling vigor test would assist managers in determining the need for seed treatments or in furrow soil drenches and/or selection of a new seedlot. The germination test would be included for a direct comparison to the seedling vigor test. The culture test would involve culturing 100 surface disinfected seeds to determine the numbers and kinds of seedborne fungi present. The seedling vigor test would involve planting 100 seeds in sterilized growing media and maintaining them in the greenhouse at temperatures typical of spring field conditions. After 4-6 weeks, emergence counts and seedling vigor would be recorded. The seedlings exhibiting poor vigor (stunting, stem and root lesions) would be recorded and this number would be subtracted from the total number of emerged seedlings to determine the potential stand count. Based on the potential stand count and culture test results, decisions could be made regarding the need for seed treatments, in furrow soil drenches, modifying sowing densities and/or selection of a new seedlot.

Seed Treatments

In the past, nursery managers routinely treated seed with fungicides prior to sowing. Currently, fungicide seed treatments are applied less frequently due to the phytotoxic effects on germinating seeds, narrow window of control, reduced availability of fungicides labeled for use as seed treatments, and possible adverse effects on human health and the environment.

Cleansing or surface disinfection of the seed is becoming increasingly popular as a method to manage seedborne pathogens. A running tap water rinse has proven effective in reducing disease inoculum, without phytotoxic effects. Effective surface disinfection methods using bleach, ethanol and/or hydrogen peroxide have been documented for Douglas-fir and several species of pine; however, additional testing is necessary for other tree species (1,4,11,15).

Further research is warranted in the following areas: 1.) refinement of a seed quality test to determine the need for seed treatment or selection of a new seedlot; 2.) pathogenicity testing and determination of economic impact of seedborne fungi; 3.) testing of "safe" surface disinfection methods on other tree species; 4.) efficacy testing and phytotoxic screening of systemic fungicide seed treatments; 5.) investigation of new seed treatment technologies which may reduce phytotoxicity to germinating seed and improve seed storability; and 6.) investigation of the application of beneficial microorganisms to seeds to provide control of root diseases and enhancement of plant nutrient uptake and growth.

Fungicide Soil Drenches

The effectiveness of fungicide soil drenches in managing root diseases in forest nurseries is variable. Their effectiveness is often reduced because of rapid microbial inactivation or binding or organic matter or clay particles. Several nurseries in our area; however, report consistent success in raising jack and red pine with application of fungicide seed treatments and soil drenches, in the absence of soil fumigation. We must closely examine their management practices for information on kinds, rates and dates of fungicides applied, cropping history and cover crops, past history of disease and look for common threads which may have contributed to their success.

The efficacy of the thiophanate methyl fungicides (Topsin M and Cleary's 3336), which are systemic in their mode of action and provide longer lasting control, show potential and should be investigated under various application regimes. In furrow application of fungicides should receive particular attention. In furrow application would physically place the fungic2ide on and near the seed, and possibly eliminate the problem of limited mobility of fungicides in the soil their inability to reach the seed zone when applied as soil drenches.

Cover Crops

The influence of cover crops and soil amendments on pathogen populations and seedling survival and quality is currently being researched. Recent experiments show that the incorporation of beans, pea or sudan grass cover crops increased population levels of *Fusarium* sp. and *Pythium* sp. in unfumigated soils (5). Bare fallow treatments resulted in significantly increased seedling survival and quality over cover crop treatments, regardless of whether the soils were fumigated. Legume cover crops harbored higher pathogens levels and resulted in greater seedling mortality levels than sudan grass cover crop treatments.

Other studies are investigating the potential of *Brassica* sp. cover crops as natural fumigants (Hansen et.al., unpublished). *Brassica* sp. contain glycosinulate which breaks down to methyl isiothiocyanate gas and possesses biocidal activity. Rape seed also contains glycosinulate and is currently being investigated as an amendment to *Brassica* sp. cover crops.

Bare fallowing, as a cultural practice to reduce soil pathogens populations and assist in the management of root diseases in forest nurseries, shows excellent potential and should be further investigated. Researchers are currently working to develop methods to minimize soil erosion losses on fallow soils such as the application of latex forming material, hydromulch and recycled paper mulches.

Composts

Composting of crop residues, if properly done, generates lethal temperatures for most plant pathogens, except some viruses. During the past two decades, various composted organic wastes prepared from tree barks, municipal solid wastes and sewage sludges have partially replaced peat in container media used for the production of ornamentals Recycling of these wastes has been adopted in many parts of the world because the cost of composts may be lower than those of peats and production costs often are decreased since some of the composted-amended with composted bark suppress soilborne plant pathogens and reduce plant losses.

Composted tree bark has been used successfully for control of some soilborne diseases and has been most widely adopted for the production of containerized nursery stock such as azalea, Easter lily, ferns, poinsettia and rhododendron. In these cropping systems, it has eliminated the need for sterilization of media and reduced the need for application of soil fungicides (25).

Suppressive effects of compost-amended substrates are largely due to natural recolonization of composts by antagonist fungi and bacteria after peak heating. Fungal antagonists that are the most effective for control of various soilborne plant pathogens in bark-composted amendments are Trichoderma spp. and Gliocladium virens. A variety of bacteria antagonists, all of which are rapid colonizers of organic matter, also play a role and include Flavobacterium balustinum, Pseudomonas putida and Xanthomonas maltophila. Some composts, particularly those prepared from hardwood and pine barks, release inhibitors with fungicidal activity. These inhibitors primarily affect Phytophthora spp. and some nematodes, but do not affect Rhizoctonia solani. Other factors such tree species, particle size, pH and the C:N ratio of the compost influence the suppressive nature of composts (2,8,9).

The use of composted hardwood and pine bark, as a component of container media and as a mulch to minimize erosion losses on bare fallow seeded soils, shows excellent potential in forest nurseries as a tool in managing damping off diseases.

Solarization

Solar heating (solarization) of soil for control of certain soilborne pathogens is a successful diseases management practice for agricultural crops grown in regions with high summer temperatures (13). Solarization works well with only a few weeks of polyethylene cover in hot climates like southern California and Israel for crops sown immediately following solar heating. Solar heating of soils in conifer tree nurseries is been evaluated in western, central and some northern regions of the United States. Solar heating of soils in these cooler regions, even with 8.5 weeks of polyethylene cover, did not proven reliable in increasing seedling survival and quality when conifer crops were sown in the spring following treatment (3,6,7,17).

Solarization of seedbeds, followed by fall sowing or bare fallowing, may prove to be a successful alternative to methyl bromide fumigation in northern forest nurseries.

Summary

Clearly, the fate of methyl bromide is uncertain. Although a decision to ban the use of methyl bromide in the U.S. by January 1993 is unlikely, the continued use of methyl bromide is under EPA review and is being closely scrutinized. In the past, the universal acceptance of methyl bromide fumigation as the best method of managing root rot diseases and weeds, pre-empted interests in investigating alternative management practices. Now, many researchers and nursery managers realize that we can no longer rely on a singular management approach; that we must be proactive and begin exploring alternative management practices immediately. IPM offers the structure for selecting and evaluating alternative pest management practices, and progressive nursery managers which implement IPM have the basic tools to tackle this issue. I have suggested some alternatives for discussion and possible future investigation. I am confident, with cooperation between researchers and nursery managers and newly available funding, we can identify successful alternatives to the use of methyl bromide fumigation in our northern nurseries.

LITERATURE CITED

1. Campbell, S.J.; Landis, T.D. 1990. Managing seedborne diseases in western forest nurseries. Tree Planters' Notes 41: (4)3-7.

2. Chung, Y.R.; Hoitink, H.A.J. 1990. Interactions between thermophilic fungi and Trichoderma humatum in suppression of Rhizoctonia damping- off in a bark compost-amended container media. Phytopathology 80:73-77.

3. Crogan, C.F.; Gresbasch. J.; Jacob, R. 1984. Evaluation of the effectiveness of soil fumigation and solarization on soilborne organisms and seedling production. USDA Forest Service, NE Area, Forest Pest Management Field Note 84-6. St. Paul, MN. 13p.

4. Dumroese, R.K.; James, R.L. ; Wenny, D.L.; Gilligan, C.J. 1980. Douglas-fir seed treatments: effects on seed germination and seedborne organisms. **In:** Proceedings, Combined Meeting of the Western Forest Nursery Council and Intermoutain Nurserymen's Association, Landis, T.D., technical coordinator. Tech. Rep. RM-167. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. pp. 155-160.

5. Hamm, P.B.: Hansen, E.M. 1990. Soil fumigation, cover cropping and organic soil amendments: their effect on soilborne pathogens and the target seedling. In: Target Seedling Symposium: Proceedings, Combined Meeting of the Western Forest Nurserymen's Association, Rose,R.; Campbell, S.J.; Landis, T.D., eds. Tech. Rep. Rm-200. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. Fort Collins, Co. pp. 174-180.

6. Hildebrand, D.M. 1985. Soil solar heating for reductions in populations of Pythium, Fusarium, nematodes and weeds at Bessey Nursery, Halsey, Neb. USDA Forest Service, Rocky Mountain Region, Tech. Rep R2-34. Lakewood, Co. 16 p.

7. Hildebrand, D.M. 1989. A review of soil solar heating in western forest nurseries. In: Proceedings, Intermountain Forest Nursery Association, Landis, T.D., ed. Tech. Rep RM-184. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. Fort Collins, Co. pp. 49-51.

8. Hoitink, H.A.J. 1980. Composted bark, a lightweight growth medium with fungicidal properties. Plant Disease 64:142-147.

9. Hoitink, H.A.J.; Fahy, P.C. 1986. Basis for control of soilborne plant pathogens with composts. Ann. Rev. Phytopath. 24:93-114.

10. James, R.L. 1989. Effects of fumigation on soil pathogens and beneficial microorganisms. In: Proceedings of a Meeting of the Intermountain Forest Nursery Association, Landis, T.D., technical coordinator. USDA Forest Service General Technical Report RM-184. Fort Collins, CO. pp. 29-34.

11. James, R.L.; Genz, D. 1981. Ponderosa pine seed treatments: effects on seed germination and disease incidence. Northern Regional Report 81-16. USDS Forest Service, Northern Region, Missouli, MT.

12. Jarvis, W.R. 1992. Managing diseases in greenhouse crops. American Phytopathological Society Press, 3340 Pilot Knob Road, St. Paul, MN. 288 p.

13. Katan, J. 1981. Solar heating (solarization) of soil for control of soilborne pests. Ann. Rev. Phytopath. 19:211-236.

14. Landis, T.D.; Campbell, S.L. 1989. Soil Fumigation in bareroot tree nurseries. In: Proceedings of the First Meeting of IUFRO Working Party S2.07-09 (Diseases and Insects in Forest Nurseries), Information Report BC-X-331, pp. 191-205.

15. Littke, W. 1990. Seed fungi. In: Growing Healthy Seedlings: Identification and Management of Pests in Northwest Forest Nurseries, Hamm, P.B.; Campbell, S.J.; Hansen, E.M., eds. Special Publication 19. Forest Research Laboratory, Oregon State University. Corvallis, OR. pp. 22-24.

16. World Meteorological Organization. 1991. Scientific assessment of ozone. United Nations Environment Programme, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration and U.K. Department of Environment. pp. 22-24.

17. Zarnstorff, J.C.; Berbee, J.C.; Cummings, J. 1983. Effects of soil solarization and of amending soil with soybean meal on populations of three soilborne fungi. Phytopathology 73:821 (Abstr. A 432).

PERSONAL COMMUNICATIONS

1. Barb Jones, assistant manager, J.W. Tourney Federal Nursery, Watersmeet, MI.

2. Jennifer Juzwik, USDS Forest Service, Forest Research, North Central Forest Experiment Station, St. Paul, MN.

3. Sylvia Griefenhagen, Forest Health and Protection Branch, Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario.