



# Using Chemicals to Control Root Growth in Container Stock: A Literature Review

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NEST Technical Report TR-026  
April 1996

by  
Faye Johnson





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## INTRODUCTION

Container stock use has increased in prominence in Ontario since first introduced in the 1960s. Containers represent over 50 percent of the stock planted on Ontario's Crown lands. While many types of containers have been tested in Ontario nurseries, there is no single container that will meet every reforestation need.

One concern with container-grown seedlings is restricted root growth and the potential problems of root bound plugs after planting (Landis *et al.*, 1990). Tree seedling survival and growth are directly related to the ability of the root system to promptly regenerate new roots and grow out into the surrounding soil. There are a number of ways of controlling root growth including physical methods such as cutting or surface air pruning or by chemical methods such as the use of copper products.

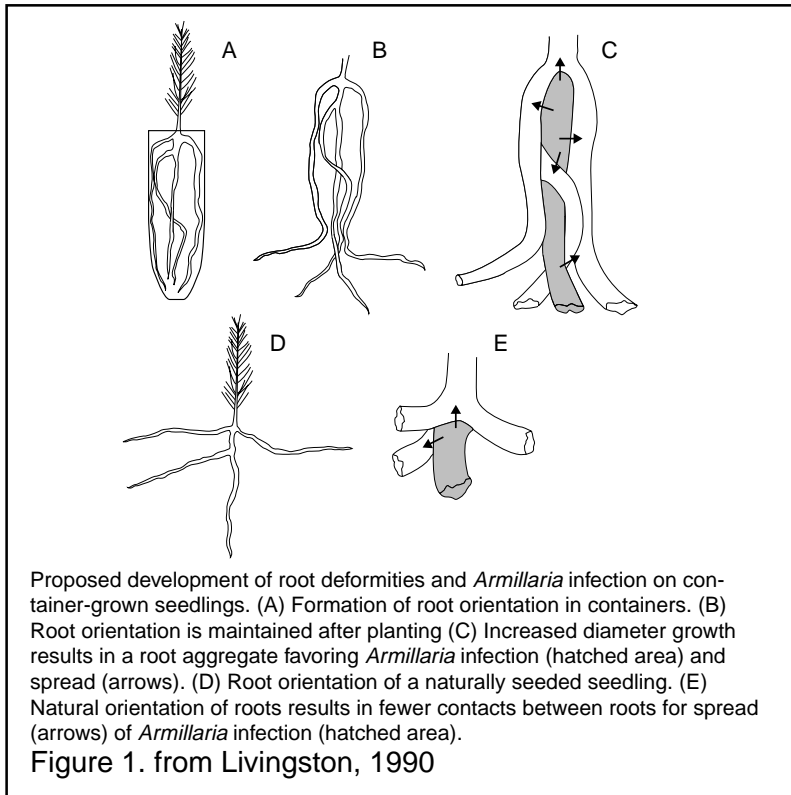
The purpose of this report is to summarize our knowledge of the use of chemical growth inhibitors to control root form in container stock.

## ROOT DEVELOPMENT

Root morphology differs between natural and container-grown seedlings. Naturally generated seedlings usually develop a well distributed lateral root system which allows for mechanical stability and maximum growth potential (Stein 1978). Roots growing in a hard-walled container will grow outward to the side of the container and then downward (Whitcomb 1982). In a round container, the roots will follow the contour and turn up to one full circle before reaching the bottom. At the bottom, the roots will continue to elongate and may circle the container up to five times before being air-pruned at the drainage hole (Whitcomb 1982, Wenny 1988). The result is a seedling with a dense root mass clustered at the bottom of the plug. In the field such seedlings often have limited lateral root elongation from upper portions of the plug but a high concentration of root elongation from the plug base (Wenny *et al.* 1988). Restricted root growth could reduce potential survival, growth and mechanical stability (Wenny 1988, Arnold and Struve 1989a).

Encircling roots may also disrupt nutrient and water movement in the roots (Nelson 1989) resulting in a root that does not function effectively. These faults are eliminated by using square rather than round containers or by incorporating ridges to guide the roots downwards to a hole at the base where the roots are pruned (Nelson 1989). However, a guided root system results in a strong vertical orientation of the root tips or forms an inadequate lateral root system (Tinus 1978, Barnett 1981). Seedling vigor may also be impaired by a strongly vertical oriented root system since it is less favorable to mycorrhizal infection (Barnett 1982, Ruehle 1985).

The root form of seedlings after outplanting is affected by species rooting characteristics, type of planting tool, tree nursery cultural practices,



and soil characteristics of the planting site (Landis *et al.* 1990, Wenny, 1988). Seedling performance has also been strongly correlated to the number and distribution of lateral roots (Mexal and Burton 1978).

Root deformities, frequently associated with growing tree seedlings in containers, are thought to predispose outplanted trees to *Armillaria* root disease (Figure 1) (Maynard and Livingston 1990). Controlling root growth and improving root form at the nursery may aid in reducing infections of *Armillaria* after planting. In a recent study of plantations of white spruce (*Picea glauca* (Moench) A.Voss) and black spruce (*Picea mariana* (Mill.) BSP) the accumulated mortality averaged 10-

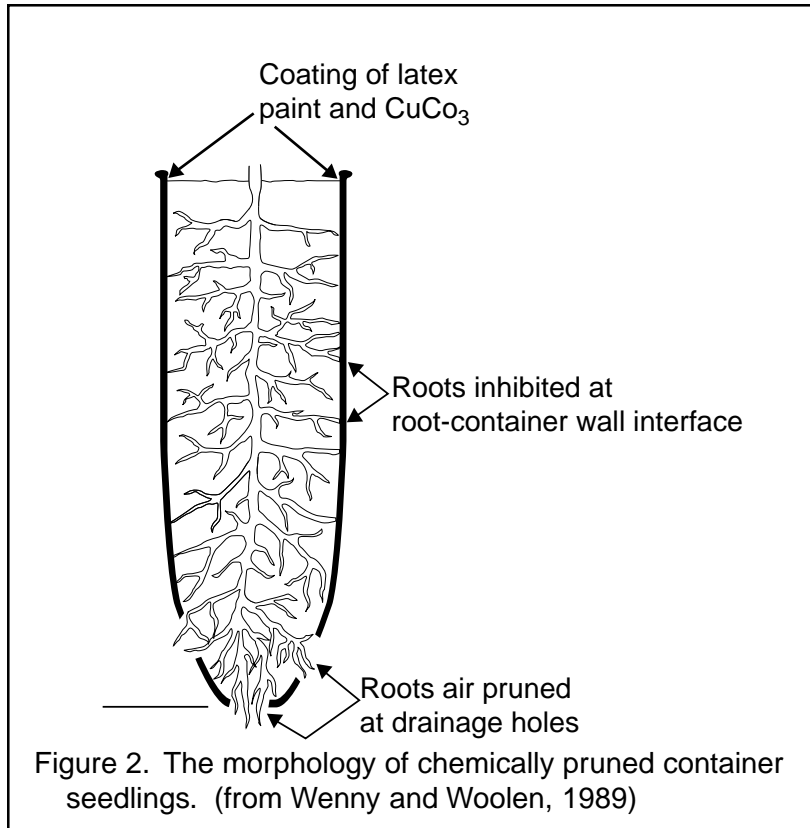
15 percent of the planted trees ten years after planting (Whitney 1988). In these plantations one to two percent of the planted trees were recently killed by *Armillaria* and cumulative mortality was creating obvious gaps in the stand. Improving root form at the nursery may decrease lethal infections of *Armillaria* after planting.

## ROOT CONTROL

Container nursery managers and field foresters are interested in any cultural treatment which will generate a better root system in their containerized stock.

Root tip removal has shown to enhance root branching in several cases (Street 1969). After transplanting, pruned lateral roots either elongate normally or produce several higher order lateral roots which grow radially. This occurs whether roots are pruned by physical methods such as cutting or surface air pruning or by chemical methods such as the use of copper compounds or an auxin oxidase promoting compound (Nelson 1989). The improved growth of pruned seedlings after transplanting (Burdett 1981) is probably related to the importance of lateral roots to seedling growth (Mexal and Burton 1978).

Also, pruning roots on the container surface appears to reduce the detrimental effect of crowding in the containers if there happens to be a delay in planting out (McDonald *et al.* 1981a).



## CHEMICAL ROOT PRUNING

One method of chemical root pruning is to coat the inside wall of the container with a chemical that inhibits root growth (Figure 2). This method has been tested with satisfactory results in many species (Burdett 1978, McDonald *et al.* 1981a, Dong and Burdett 1986, Wenny *et al.* 1988). Most container manufacturers and container growers use a paint based carrier with copper as the active ingredient. The only alteration to nursery practice is the container treatment prior to filling and sowing (Nelson 1989).

Chemicals for root pruning must inhibit root growth throughout the growing season and must not become phytotoxic

to the seedlings. These chemicals must also not be toxic to nursery personnel or the environment (Landis *et al.* 1990). Tinus (1987) (in Landis *et al.* 1990) tested a number of heavy metals such as copper, silver, nickel, lead, zinc, and antimony and found that only copper would stop root growth without injuring the seedling.

Little is known about the long-term effects of chemical root pruning at this time. However, it is known that the effect of nursery treatment and planting on tree root form diminishes with time. What is more important is how the effect of chemical root control on outplanted seedling growth could influence plantation performance by affecting the ability of it to contend with competition (Burdett *et al.* 1983). For that reason, some of the more commonly used chemicals are presently being tested for long-term effects (Kooistra 1991).

## COPPER PRODUCTS

The option of lining the interior walls of containers with chemicals that inhibit root growth has been studied extensively since the development of container products. Saul, as early as 1968, suggested the use of copper to restrict root growth.

Copper sheet, or mesh, or copper-painted trays have often been used to prevent the roots of forest tree seedlings from growing from the bottom of

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seedling containers (Barnett and McGilveray 1974, Saul 1968). Copper naphthanate and cupric sulfide applied to the bottom of seedling flats or to the pot wall have been used, at least experimentally, to prune the tap root and pinch the lateral roots of several ornamental species ( Furuta *et al.* 1972). A container wall coating of cupric carbonate in latex paint has been found effective for pruning the lateral roots of two species of pine (Burdett 1978, McDonald *et al.* 1981b). The treatments stimulated lateral root development and thus promoted the development of a compact, fibrous root system which made the seedlings well-suited for transplanting.

Although the use of copper treated containers has not been operationally implemented in Ontario, it is being investigated on a trial basis. Rainy River Forest Products Inc. is using copper-treated Ventblocks® in the production of black spruce, white spruce and red pine (*Pinus resinosa* Ait.) container stock (Keene 1994, pers. comm.). Hills Greenhouses Ltd. is also growing some two-year-old copper treated Ventblocks® (Duckett 1994, pers. comm.).

The use of copper treated containers for production of one-year old pine has been in operational use in British Columbia for the last ten years. Presently approximately 30 million seedlings, mainly lodgepole pine (*Pinus contorta* Dougl.), are grown annually using this treatment (Ostafew 1994, pers. comm.). The containers are treated with one of four types of copper compounds: copper carbonate, copper hydroxide, copper oxichloride, or copper silfide.

Lodgepole pine, a principal tree species in British Columbia, became a topic of concern over a decade ago when the toppling of some interior trees led investigators to study the root development of planted containers. These studies resulted in the recommendation that the chemical root pruning of lodgepole pine with a cupric form of copper be introduced in order to promote development of lateral roots (Kooistra 1991). The results of a number of trials (5-10 years old) were summarized by Kooistra and are as follows:

- Copper pruning causes significant changes to the Lodgepole pine root system whereby it more closely resembles the natural root form. It is expected that this type of root system will increase the stability of the tree.
- There is no evidence that copper pruning increases height growth and/or root collar diameter.

It should be noted that the Ministry of the Environment in British Columbia is receiving concerns from the public about the effects of copper leaching into the soils at the nurseries and at the planting sites (Ostafew 1994, pers. comm.).

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An unpublished study by Kerry Odlum (1994, pers. comm.) on jack pine (*Pinus banksiana* Lamb.) and black spruce in Ontario showed similar results. Seedlings from Copperblocks® were compared with seedlings from Ventblocks®. Seedlings from Copperblocks® had greater root mass in the upper part of the plug, less root mass in the lower part of the plug and less root mass overall. Tap root diameter of jack pine seedlings was enhanced and the concentration of copper in the roots of both species was as much as 15 times greater. In Root Growth Potential tests, new root growth in the upper part of Copperblock® plugs was greater. There were no differences in survival and growth of seedlings from the two container types, up to three years after planting.

#### CUPRIC CARBONATE

Cupric carbonate ( $\text{CuCO}_3$ ) has been the most popular root pruning chemical used. The carrier used is usually latex paint which is mixed with the copper solution and painted onto the container wall. The recommended rates vary from 60 to 200g/l depending on the species and container type used (Landis *et al.* 1990).

Since cupric carbonate is highly insoluble in water (Merck Index 1976), its toxic effects occur only along the container wall and not throughout the volume of the growing medium. To make this system work, containers must be watered from above and the solution allowed to drip from the egress hole. This laminar flow of nutrient solution through the growing medium assures that the toxicity remains against the container wall (Landis *et al.* 1990) There is little indication of seedling phytotoxicity to the latex paint carrier (Arnold and Struve 1989a, Wenny and Woollen 1989).

Burdett and Martin, 1982, tested ten species from six genera that were raised in styrofoam block containers painted with cupric carbonate in latex paint. They found that the effectiveness of the treatment varied with species, container size, growing medium, and concentration of cupric carbonate with which the container wall was painted.

Wenny *et al.* (1988) grew ponderosa pine (*Pinus ponderosa* Laws.), western white pine (*Pinus monticola* Dougl.), and douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) in cupric carbonate lined containers. Their results suggested that cupric carbonate altered root distribution in the plug, whereby the proportion of new roots in the top and middle zones was increased without increasing total new root production. The seedlings treated with cupric carbonate developed a more natural root system. This may improve seedling stability by promoting the development of lateral roots growing straight out from the tap root close to the soil surface (Burdett *et al.* 1983, Burdett 1978, Wenny *et al.* 1988).

Further studies by Wenny and Woollen, 1989, on the same species, found that mean total new root length increased, perhaps due to the chemically pruned lateral roots resuming growth in the upper part of the root

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system after planting. The unpruned seedlings did not resume growth in the upper portions of the root system, nor did they produce higher order laterals at the same rate as chemically pruned roots. Also, the number of roots reaching the drainage hole at the bottom of the container was less for chemically treated containers than for untreated containers. This type of root development may indirectly improve drainage hence reducing problems from high salt content, fungal disease, chlorosis and stunting.

There is no indication that stock grown in cupric carbonate treated containers are adversely affected by the treatment after planting (Burdett and Martin 1982). Wenny and Woollen (1989) and Wenny *et al.* (1988) reported that seedling height and diameter were not affected by the treatment one year after outplanting. Burdett *et al.*, 1983, found that the growth of chemically root pruned lodgepole pine stock, four years after planting, was significantly greater than that of unpruned stock. This was probably because the lateral roots of pruned stock developed in a different soil layer than did the roots of unpruned seedlings. The pruned roots, growing closer to the soil surface, would have the benefits of increased soil fertility, moisture, temperature as well as less dense soils.

There are some disadvantages of copper treatment. Watson (1995) found that seedlings grown in Copperblocks® grew slightly slower than untreated containers and therefore took longer to grow a root-firm plug. Copper paint treatment is less effective with older and larger seedlings because roots eventually find their way under the tube wall producing a root mass in the bottom of the holding tray. The problem is aggravated when seedlings are over-wintered (Scarrat 1972). Also, Burdett and Martin (1982) found that high concentrations of cupric carbonate (500 mg/l) inhibited shoot growth. Foliar toxicity, on the other hand, is easy to correct with chelate iron spray and all signs of the problem disappear after the plants are removed from the containers (Struve and Rhodus 1990).

Less information is available on the use of cupric carbonate for container grown hardwoods. Arnold and Young (1991) found cupric carbonate at 100 g/ liter in a paint carrier applied to interior container surfaces effectively prevented root deformation in container-grown apple (*Malus domestica* Borkh.) and green ash (*Fraxinus pennsylvanica* Marsh.) seedlings. Red Oak (*Quercus rubra* L.) subjected to the same treatment also responded in similar manner (Arnold and Struve 1989b).

#### CUPRIC SULFIDE

Another successfully used chemical pruning agent is cupric sulfide (CuS). Dong and Burdett (1986) soaked kraft paper with cupric sulfide and then dipped it in sodium sulfide to precipitate copper in the paper as cupric sulfide. The treated paper was washed to remove excess sodium sulfide and sodium sulfide produced in the reaction and dried. The paper

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was formed into square tubes and seeded with Chinese Pine (*Pinus tabulaeformis* Carr.). Although both treated and untreated kraft paper decomposed within 13 weeks, the treated containers still maintained a chemical barrier between plugs which prevented roots from growing between containers. Once roots reached the barrier, they stopped growing but continued to form secondary and high order laterals, thereby creating a fibrous root system. In this experiment, copper impregnated containers showed no symptoms of copper toxicity, were larger than control seedlings, and had a root growth capacity comparable to that of the control seedlings. Cupric sulfide may be an economical and effective way to raise container stock as the reagents are easily purchased and relatively inexpensive.

Some disadvantages of cupric sulfide is that it may slowly oxidize to form cupric silfide if exposed to moist air. In addition, it releases hydrogen sulfide when dissolved in an acid solution (Wenny and Woollen, 1989).

#### COPPER SCREEN

The investigation of copper screens and copper plates began shortly after the introduction of the Ontario tubes in 1965. It was soon discovered that seedlings grown in tubes for an extended period of time developed roots that extended beyond the tube and intermingled with roots of other seedlings (Saul, 1968).

Saul, 1968, tried copper metal, copper-armored fibrene, and copper paint applied to the bottom of container trays of red pine, white pine (*Pinus strobus* L.), white spruce, and black spruce to inhibit root elongation outside of the plug. All treatments were successful in restricting the elongation of roots without harming the seedlings.

Subsequent to this experiment, Barnett and McGilvray (1974) tested the use of copper screening as a liner below loblolly pine (*Pinus taeda* L.) and longleaf pine (*Pinus palustris* Mill.) Japanese paper pots. This study concluded that copper screen prevented roots from emerging from the bottoms of the tubes, but had no effect on the dry root weight of either species. The copper screen treatment did not affect the field growth of either species, but the results did indicate that root pruning with copper screen improved seedling survival by twenty-three percent sixteen months after outplanting.

#### ETHEPHON

Ethephon ((2-chloroethyl) phosphonic acid)) is a water soluble (Saini *et al.* 1986) ethylene releasing agent (Mekki and Leroux 1991). Ethephon's effect on conifers results from the uptake of the compound by the roots, after which it decomposes to produce ethylene (Livingston 1991). Ethylene is a plant hormone which acts as a plant growth regulator and elicits

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changes in root growth. Root tissues respond to ethephon by stopping elongation and increasing root diameter (Livingston 1991).

In cases where rigid container walls do not exist between seedling plugs, ethephon may be one way in which inter-rooting between plugs can be avoided.

Livingston's studies with Jiffy Peat Pellets™ (1991) show that ethephon treatments consistently reduced the inter-rooting between Jiffy Peat Pellets™ for black spruce (at rates of 80 and 120 ppm) and red pine (at rates of 50 and 75 ppm). He reported that ethephon treatments improved the ease of separating black spruce and red pine: 80 to 100 percent of the pellets could be separated without difficulty while the amount of broken roots was three to seven times higher in the control compared to the seedlings treated with 120 ppm of ethephon.

However, ethephon treatment of jack pine did not prevent inter-rooting of containers. He suggested that future studies using rates of 75 to 150 ppm may reduce root growth in jack pine.

Ethephon treatments alter root growth of some container-grown conifers resulting in decreased lateral root length (Maynard and Livingston 1990, Wilson and Field 1984, and Livingston 1991). Watson (1995) observed that lateral roots of ethephon treated seedlings, especially red and white pine appeared to be coarser than non-treated seedlings. Ethephon can also increase the proportion of ectomycorrhizal short roots on seedlings. Thus, ethephon treatments in combination with ectomycorrhizal inoculations may be useful in reducing root elongation and resulting root deformities in containerized seedlings (Maynard and Livingston 1990).

Livingston (1991) and Maynard and Livingston (1990) found that ethephon may reduce the growth of the seedlings before and after planting. It has also been found that ethephon treatments may improve seedling resistance to cold temperature damage and drought stress (Livingston 1991, Maynard and Livingston 1990). However, sometimes the treatment increased seedling susceptibility to winter damage, especially if they have symptoms of nutrient deficiency. Although ethephon treatment did not cause mortality in the seedlings (Maynard and Livingston 1990), treated seedlings did exhibit phosphorus deficiency symptoms (Livingston 1991).

In order to reduce adverse effects of ethephon treatment, Livingston (1991) recommends that treated seedlings be adequately fertilized and that ethephon treatments only be utilized if inter-rooting is expected to be a problem.

Ethephon treatments have the potential to be a viable, simple method to control root growth of container-grown pine seedlings. Because ethephon can be applied as a root drench through the watering system, the treatments could easily be incorporated into existing practices at tree

nurseries (Maynard and Livingston 1990). However, studies of ethephon treated seedlings outplanted in the field should be carried out to determine if there is any long-term effects of ethephon on root growth into the surrounding soil.

## OTHER PRODUCTS

Little research has been completed on the use of other chemicals to control root growth. McDonald *et al.* (1981b) tested the chemical root pruning response of ponderosa pine to trifluralin herbicide, indole-3 butyric acid (IBA), and cupric carbonate. Trifluralin had a harmful effect on the seedlings and was dropped from the test. The overall performance of IBA at 50g/l was judged to be slightly less than that of cupric carbonate at 100 g/l.

## CONCLUSION

Since root form of seedlings after outplanting is affected by many factors including species rooting characteristics, nursery cultural practices and site type, the resource manager should consider the objective of the plantation prior to prescribing a stock type for establishment. If container stock is an option and the malformations of the roots is a concern, the use of chemical root inhibitors should be considered.

Cupric carbonate is in operational use in other parts of the country and has some benefits to offer the resource manager. However, there may be an environmental concern when using this chemical. Ethephon, on the other hand, is a chemical which has shown promise for non-walled containers but has yet to be developed to an operational level.

Although correcting root deformities will have a price associated with it, any practical, cost effective system which improves the quality of stock should be considered. The investment of chemical pruning becomes a viable option if the alternative is plantation failure a decade or two after establishment.

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## PERSONAL COMMUNICATIONS

- Duckett, S., Ont. Ministry of Natural Resources, Thunder Bay, Ont.
- Keene, J., Rainy River Forest Products Inc., Fort Frances, Ont.
- Odlum, K., Ontario Ministry of Natural Resources, Sault Ste. Marie, Ont.
- Ostafew, S., British Columbia Ministry of Forests. B.C.
- Watson, S., Ont. Ministry of Natural Resources, Fort Frances, Ont.

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## NOTES

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## NOTES