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Modification of Ponderosa Pine Root Systems in Containers[1]

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Abstract

Coating the inside surfaces of containers with cupric carbonate ($CuCO_3$) caused roots of ponderosa pine (*Pinus ponderosa* Laws.) to stop growth when they contacted the container wall. Higher order laterals then proliferated and were arrested when they, in turn, encountered the container wall. These roots resumed growth radially when the container was removed. Indolebutryic acid (IBA) caused a similar, but not as dramatic effect as $CuCO_3$.

Index words: Container, seedling, root, ponderosa pine, copper, inhibitor

Introduction

Natural seedlings develop long lateral roots a short distance below the soil surface that provide a widespread support system (6). Roots of planted trees are forced vertically downward into the planting hole. Renewal of horizontal growth requires development of new lateral root tips on older roots near the soil surface (10). The number and distribution of loblolly pine lateral roots is positively correlated with seedling performance, suggesting a fibrous lateral root system can better utilize available nutrients following transplanting (8).

Burdett (2) reported success in modifying root systems of container grown lodgepole pine (*Pinus contorta* Dougl. ex Loud.) through the use of cupric carbonate ($CuCO_3$) which inhibited elongation of lateral roots while in the container. These roots resumed growth when the tree was removed from the container. Consequently, the tree soon acquired a root system similar to that of a naturally established tree. These findings are of particular interest because tree seedlings grown in containers sometimes become stunted and/or die several

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years after outplanting (8) or become prone to windthrow because they lack lateral roots near the soil surface (3, 5). By and large, these effects are attributed to root deformation occurring in the container prior to planting (1, 4, 7).

Two experiments were conducted with ponderosa pine seedlings (*Pinus ponderosa* Laws.) to determine how their roots reacted to: 1) cupric carbonate container treatment; 2) selected other container treatments; and 3) crowding in the presence of inhibitory chemicals.

Materials and Methods

Experiment 1. Cupric carbonate ($CuCO_3$), Indolebutyric acid (IBA), and trifluralin (Treflan) herbicide, all inhibitory to root growth, were combined at various concentrations (Table 1) with exterior acrylic latex house paint, brushed on the interior walls of containers and allowed to dry. Containers used were Spencer-Lemaire "Tinus" Roottrainer® polystyrene thermoformed (book type) tree seedling containers. Each book is a module of 4 cavities of about 492cm³ (30 in³) volume per cavity. Each treatment was applied to 12 container cavities (3 books). The books were folded and assigned into 3 internally randomized replications (12 trees total per treatment) and placed in metal racks which held 10 books each. The containers were then filled with growing medium composed of a 1:1 (v/v) mixture of sphagnum peat and poultry grade vermiculite (about horticultural grade No. 2) plus 3 percent pine duff as a mycorrhizal fungus inoculum.

Three seeds of ponderosa pine seed source 824-N1 (from Colstrip, Montana) were sown in each container. Seeds were covered with a 4 mm (0.25 in) depth of sieved perlite containing no particles smaller than 2 mm (0.1 in) in diameter. The racks of containers were then randomly placed on greenhouse benches where the seedlings were grown. The greenhouses were doublewalled polyethylene-covered units located at the Rocky Mountain Forest and Range Experiment Station at Bottineau, ND. The seedlings were reared using standard methodology as described in USDA Forest Service General Technical Report RM-60 (11). Following germination excess seedlings in each container were removed leaving only 1 tree per container.

After 26 weeks, half the seedlings (6) in the treatments were measured (top height, number of needle fasicles, average length of secondary needles, number of roots air pruned, number of roots encountering the wall and turning downward, and root and top dry weight). At the same time, the other 6 trees of each treatment were removed from the containers and planted in a 20 cm² (8 in²) grid pattern in damp vermiculite in a greenhouse bench. After 5 weeks at 20°C (70°F) these trees were carefully removed from the vermiculite. The number and length of roots extending from the sides and the bottom of the original root "plug" were measured.

Experiment 2. Ponderosa pine seedlings were reared in treated Ray Leach® super cells using the same growing procedures described for Experiment 1. Ray Leach® super cells are tubular tapered polystyrene containers with an internal volume of 328 cm³ (20 in³), 11

Table 1. Effects of Treflan, $CuCO_3$, and IBA container wall treatment on ponderosa pine seedling growth.

Container Wall Treatment (gm/l)	Shoot Ht. (mm)	Shoot Dry Wt. (gm)	Root Dry Wt. (gm)	Roots Deflected Downward at Container Wall (no)
Treflan				
0.00 (paint only)	44.2[z]	0.48	0.35	11.2
0.56	43.7	0.43	0.38	11.8
2.84	44.3	0.48	0.34	7.3
14.00	29.5	0.16	0.08	0.8
70.00	20.0	0.12	0.04	0.0
$CuCO_3$				
0.00 (paint only)	46.8	0.51	0.35	18.2
0.1	44.2	0.49	0.35	12.1
1.0	48.7	0.60	0.39	7.5*[y]
3.0	54.8	0.92	0.54	9.0*
10.0	54.8	0.81	0.48	9.7*
100.0	65.2*	1.00**	0.61	3.7**
IBA				
0.0	44.2	0.48	0.35	12.2
0.0005	48.8	0.51	0.34	12.0
0.005	71.3	1.00	0.74	11.0
0.05	55.5	0.46	0.39	14.2
0.5	52.8	0.68	0.41	8.2
5.0	77.5	1.02	0.61	7.7
50.0	61.0	0.83	0.49	1.5*

[z]All figures shown are means of 6 trees.

[y]Mean separation within treatments computed using the Student's 't' test. Differences at the 5% level indicated by * and at the 1% level by **, resp. (No statistical significance calculated for Treflan due to seedling damage.)

cm (4.3 in) in diameter at the top and approximately 2 cm (0.75 in) in diameter at the bottom. Four container treatments were used: (1) no treatment, (2) $CuCO_3$ in latex paint at 50 gm/l painted on the inside of the cells, (3) IBA at 5 gm/l in paint as in (2), and (4) a mechanical treatment consisting of slots cut into the wall of the cell. For the mechanical treatment, the cell was cut with a radial arm saw at a right angle to the long axis of the cell at 4 and 8 cm (1.5 and 3 in) from the top of the cell. These incisions were through the outer shell of the container and deep enough to sever the internal root control rib of the cell. The depth of the cut(s) were what was necessary to cut through the rib. A pair of such cuts (at 4 and 8 cm) was centered on each of the 3 root control ribs of the container. The seedlings were grown from early June to late November. Apical buds were then set by a brief moisture stress and withdrawal of extended photoperiod lighting. Root growth was then continued for 1, 2, 3, or 4 months before being stopped. Ninety-eight (one complete rack of containers) seedlings were grown in each of the 16 (4x4) treatments. Following a sub-freezing cold storage period 2 months long, 10 trees of each container treatment/root development combination were randomly selected and measured (caliper, top height, number of roots deflected downward at the container wall, and number of roots at the drainage hole). At the same time 10 other randomly selected trees from each container treatment/root development combination were transplanted into 7 l pots filled with moist peat. These transplanted trees were allowed to grow for 2 additional months in a shadehouse. They were then removed from the pots. The peat was carefully removed from the roots extending beyond the original container root plug. Side and bottom roots were counted and fresh weight, stem height and root collar caliper measured.

Results and Discussion

Experiment 1. Treflan (trifluralin) at the higher concentrations stunted or killed the seedlings (Table 1). The highest concentration of $CuCO_3$ (100 gm/l) reduced root deflections compared to the lowest concentration (0.1 gm/l) (from an average of 12.1 per tree to 3.7 per tree) and resulted in significantly bigger trees (48 percent taller and 74 percent heavier) (Table 1). However, paint alone significantly reduced seedling growth compared to trees from wholly untreated containers (Table 2). High concentrations of $CuCO_3$ in the paint apparently override this negative "carrier" effect (Table 1).

High concentrations of IBA significantly reduced root deflections (Table 1) and appeared to cause trees to grow better than those reared in the "paint only" treatment, but the effect was not significant when compared to the $CuCO_3$ effect.

Trees treated with $CuCO_3$ at 100 gm/l and reared in the vermiculite bench for 5 weeks after container removal had: 1) 3 times more roots emerging from the original container 'plug' as side roots than did untreated trees; 2) 3 times more side root length than untreated trees; 3) about the same total emerged root length (side *and* bottom) as untreated trees; and 4) significant increases in height growth over untreated trees (Table 3).

Post transplanting data for seedlings grown in containers treated with IBA were so variable that no treatment effect was statistically significant.

A few generalizations can be made from this first study: Treatment of the containers with the higher concentrations of $CuCO_3$ resulted in a greater proliferation of side roots of ponderosa pine seedlings following greenhouse transplanting. Lower concentrations were relatively ineffective. The carrier, latex paint, may be phytotoxic, but the effect is apparently over-ridden by

Table 2. Comparison of seedlings grown in painted and unpainted containers.

Treatment	Shoot Ht. (mm)	Secondary needle Length (mm)	Shoot dry wt. (gm)	Root dry wt. (gm)	Roots Reaching the Drainage Hole (no)
No paint	58.8[z]	107	0.78	0.50	28.2
Paint only	46.8*[y]	75*	0.51*	0.35*	18.2**

[z]Means of measurements of 6 trees.

[y]Mean separation within treatments computed using the Student's 't' test. Differences at the 5% level indicated by * and at the 1% level by **, resp.

Table 3. Effect of $CuCO_3$ treated containers on ponderosa pine seedlings after transplanting.

Treatment $CuCO_3$ Concentration (gm/l paint)	Side Roots as % of Total Roots (%)	Length Side Roots (cm)	Total Root Length (cm)	Caliper at Root Collar (cm)	Stem Height (cm)
No Paint	7.8	19.3	248.5	2.8	58.0
0.0	9.4	12.0	64.0**	3.0	59.3
1.0	4.7	3.7*	78.8**	2.2	38.7*
3.0	12.1	19.1	158.0	3.0	64.3
10.0	12.0	25.7	214.3	3.3	63.8
100.0	27.1*[y]	61.2**	226.0	3.3	70.0*

[z]Means of measurements of 6 trees.

[y]Mean separation within treatments computed using the Student's 't' test. Differences at the 5% level indicated by * and at the 1% level by **, resp.

the $CuCO_3$ treatment at higher concentrations. Another carrier might be better. Treflan (trifluralin), at the concentrations tested, is too phytotoxic for use in this manner.

Experiment 2. The added time allowed for root development in the Ray Leach containers had little effect on any measurements. However, when container treatments were compared, fewer roots were deflected from copper-treated container walls than from untreated walls regardless of time allowed for root development (Table 4). Containers with slots deflected fewer roots. However, average seedling survival in these mechanically-treated containers was only 39 percent; versus 93 percent in containers with no slots. Containers with slots allowed the growing medium to dry out under a normal greenhouse irrigation regime.

Measurements of the seedlings transplanted from the Leach containers to pots for added growth were compared in a two-way analysis of variance. Container treatments were significant for all growth parameters measured. Duration of root development period after stoppage of top growth had little effect. This could indicate that the root development differential was insufficient to induce an effect or that the container treatment(s) lessened the effect of root crowding in the containers.

Transplanted seedlings' growth parameter means for each container treatment were compared using Duncan's multiple range test (Table 5). Perforated containers, although significantly increasing the proportion of root weight in side roots, also significantly stunted the seedlings. On the other hand, $CuCO_3$-treated trees were the largest in all categories except the number of bottom roots (Table 5). The synthetic auxin analog, IBA, was again a weak substitute for $CuCO_3$.

Significance to the Nursery Industry

Coating the interior of containers with a mixture of acrylic latex paint and cupric carbonate at concentrations of 50 to 100 gm/l causes lateral root growth of ponderosa pine to be arrested at the root-container wall interface. This subsequently leads to a proliferation of higher order laterals which similarly are arrested. These arrested root tips resume growth after the seedling is removed fro the container and planted. Consequently more roots emerge from the sides of the transplanted root plug than is the case with seedlings are growh in untreated containers. Other specific observations from the experiments include:

1) The highest rate of cupric carbonate container treatment generally caused ponderosa pine seedlings to be taller and heavier than control seedlings.

2) The carrier, acrylic latex paint, was apparently phytotoxic. However, the $CuCO_3$ effect over-rides this phytotoxicity. The paint can be used until a better carrier is found.

Table 4. Effect of various container treatments on morphology of ponderosa pine seedlings.

Container Treatment	Stem Ht. (cm)	Caliper at Root Collar (mm)	Roots deflected (no)	Roots at drain hole (no)
None	7.90[y]	2.76	29.6	20.4
Holes[z]	6.15	2.41	20.0*[x]	20.0
$CuCO_3$	7.92	2.95	15.00**	17.3
IBA	7.78	2.71	28.4	19.8

[z]Signifies slotted containers described in text.

[y]Means of 10 trees.

[x]Mean separation within treatments computed using the Student's 't' test. Differences at the 5% level indicated by * and at the 1% level by **, resp.

Table 5. Measurements of ponderosa pine seedlings transplanted from treated containers to pots.

Parameter	Unit of Measurement	Container Treatment			
		None	IBA	$CuCO_3$	Holes
Height	mm	108 a[y,z]	110 a	114 a	75 b
Caliper	mm	3.93 a	3.91 a	4.08 a	3.34 a
D^2H	mm^3	1730 a	1729 a	1949 a	882 b
Side roots/total[x]	gm fresh wt	0.210 a	0.259 a	0.352 b	0.324 b
Side roots/total[x]	no	0.313 a	0.418 bc	0.458 c	0.400 b
Bottom root[x]	gm fresh wt	3.84 a	3.64 a	3.99 a	2.66 b
Side root[x]	gm fresh wt	1.00 a	1.27 a	2.18 b	1.01 a
Bottom root[x]	no	21.60 a	16.22 b	15.10 b	14.67 b
Side root[x]	no	9.92 a	11.85 b	13.00 b	0.10 ab

[z]Means of 10 trees.

[y]Means within column followed by the same letter or letters are not significantly different at the 5% level using Duncan's Multiple Range Test.

[x]"Root(s)" refers to those roots which grew beyond the original root plug cylinders.

3) A mechanical container treatment (slots in the containers) was not useful. The growing medium tended to dry out in a normal greenhouse growing regime and seedlings were stunted or died.

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Effect of $CuCO_3$ Container Wall Treatment and Mycorrhizae Fungi Inoculation of Growing Medium on Pine Seedling Growth and Root Development[1]

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Abstract

Coating the inside surfaces of containers with cupric carbonate ($CuCO_3$) stopped lateral root growth of ponderosa pine (*Pinus ponderosa* Laws.) and lodgepole pine (*Pinus contorta* Dougl.) at the container wall. Subsequent higher order laterals proliferated and were similarly arrested. The $CuCO_3$ treatment was compatible with inoculation of the growing medium with the mycorrhizae fungi *Pisolithus tinctorius* (Pers.) Coker and Couch and *Suillus granulatus* (L. ex. Fr.) O. Kuntze. Combined inhibitor—inoculum treatments resulted in pine seedlings that were bigger, had more lateral roots, and greater mycorrhizal infection rates than untreated seedlings.

Index words: Container, mycorrhizae, ponderosa pine, lodgepole pine, inoculum, inhibitor

Introduction

Cupric carbonate ($CuCO_3$) applied to container walls to control root development of conifer seedlings has resulted in increased lateral root development (2, 5, 6). Ponderosa pine (*Pinus ponderosa* Laws.) and lodgepole pine (*Pinus contorta* Dougl.) root growth is arrested when root tips encounter a container wall painted with $CuCO_3$ (50 to 100 g/l of exterior latex paint). Subsequent higher order lateral roots then proliferate from the inhibited primary laterals and are similarly arrested, but resume growth upon removal from the container. Consequently, tree seedlings treated in this manner should develop greater wind firmness soon after planting.

Standard procedures for rearing containerized ponderosa pine seedlings (7) includes the addition of 3% pine duff by volume to the growing medium for mycor-

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