Growth of Chemically Root-Pruned Seedlings in the Greenhouse and the Field'

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Abstract. -- Cupric carbonate treated containers produced ponderosa pine, western white pine and Douglas-fir seedlings with a more natural lateral root distribution than controls. Treatment has not increased survival or height growth after three field seasons.

INTRODUCTION

Root morphology differs between natural and container-grown seedlings. Natural seedlings generally develop a well distributed lateral root system providing mechanical stability and maximum growth potential (Stein 1978). Container-grown seedlings frequently have long lateral roots directed downward along the container wall until air-pruned at the drainage hole. In the field, such seedlings often have limited lateral root egress from upper portions of the plug but a high concentration of root egress from the plug base. Restricted root egress may reduce potential survival, growth, and mechanical stability, particularly on drier sites. Burdett (1978a,b) reported root elongation of container-grown lodgepole pine (*Pinus contorta* Dougl.) seedlings was completely inhibited upon contact with container walls coated with cupric carbonate. After outplanting, lateral roots of treated seedlings egressed from the upper portion of the root plug in a pattern similar to a natural root system (Burdett 1981; Burdett and others 1983). McDonald and others (1981) found similar results with ponderosa pine (*Pinus ponderosa* Laws. var. *ponderosa* Engelm.). Wenny and Woollen (1988) used this cupric carbonate technique for root pruning northern Idaho sources of western white pine (*Pinus monticola* Dougl.), ponderosa pine, and Douglas-fir (*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco) seedlings. We found a significant increase in root egress from the upper portions of the plug in growth room tests. First year field results of these seedlings did not increase significantly in growth or survival rates (Wenny and others 1988).

METHODS

Northern Idaho sources of Douglas-fir, ponderosa pine, and western white pine seedlings were chemically root-pruned while growing in the University of Idaho Research Nursery greenhouse. Two Ray Leach® pine cell trays (200 cells per tray) and two Styroblock 4A trays (198 cavities per tray) were used for each species. Forty pine cells per tray and 39 cells per styroblock (each 66 cm^3) were randomly assigned one of five treatments: an unpainted control; or a latex paint coating containing cupric carbonate at concentrations of 0, 30, 100 or 300 gL^{-1}. Since previous research with chemical root pruning by Burdett (1978) and McDonald (1981) found a concentration of 100 gL^{-1} CuC03 was effective in inhibiting root growth, the 30, 100, and 300 gL^{-1} concentrations were chosen in an attempt to bracket an optimal concentration for the species studied. Containers were filled with 1:1 peat:vermiculite forestry potting mix. Seeds were sown and the containers placed on greenhouse benches to receive species specific Research Nursery growing regimes (Wenny and Dumroese 1987a,b). Seedling height and root collar diameter measurements were taken at monthly intervals during the growing season. Data collected were subjected to conventional analyses of variance and Fisher's protected LSD.

Growth Room Tests

Dormant seedlings were removed from the containers (February), and placed into cold storage at 2°C. A root growth potential test (Duryea 1984) was initiated to evaluate effects of chemical root pruning on root system morphology. Ten seedlings from each container type and treatment combination were planted into 1-gallon pots containing 1:1 peat:vermiculite forestry potting mix. The potted seedlings were placed in a growth room following a split plot randomized complete block design. Growth room

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temperatures were 27°C during the 16 hour day and 21°C at night. To obtain a 16 hour photoperiod, light energy reaching the canopy at an intensity of 220 $uEm^{-2}s^{-1}$ was provided by fourteen 96 inch Grow-Lux fluorescent bulbs. Root measurements were collected from three zones: top, middle, and bottom. New roots, longer than 1 cm, emerging from the plug were measured, counted and weighed for each separate zone. Root dry weights were obtained after oven drying at 60°C for 24 h. Seedling height, root collar diameter, shoot dry weight, the number, length, and dry weight of new roots by root zone, and total root length values were subjected to conventional analyses of variance and Fisher's protected LSD.

Field Tests

In April, seedlings were planted on the University of Idaho Experimental Forest. A randomized complete block design with three replicates was used. Ten seedlings of each species for each tray type and treatment combination were randomly assigned within a block. After the first growing season, survival, height, root collar diameter, shoot and root dry weights, and new root number were measured. Survival and growth data were collected after the second and third growing seasons. The plantation will be re-examined in the future.

RESULTS & DISCUSSION

Greenhouse and Growth Room

Shoot growth was uninfluenced by treatment during greenhouse culture. Height and root collar diameter measurements were not significantly different at any time during the growing season (April - October). Observation of root development showed nontreated seedlings had many more long, lateral roots running longitudinally along the plug wall, while treated seedlings had most lateral roots pruned at the plug wall.

Growth room data indicate seedling height, root collar diameter, and shoot dry weight was unaffected by treatment, regardless of species and container combinations. Root development did show a treatment affect with greater new root numbers, dry weights, and lengths in the top and middle plug zones of cupric carbonate treatments. These results were significant for most species and container combinations and are best illustrated by combining total new root length for the upper zones (Table 1). Increases in total length and total number of roots from chemical root pruning probably occurred because 1) primary, secondary, and tertiary chemically pruned lateral roots resumed growth from the upper portions of the root system after planting and 2) pruning enhanced initiation of higher order laterals. In contrast, unpruned seedlings, with primary and secondary lateral root tips at the plug bottom, lack this growth resumption in the upper portions of the root system. Although unpruned seedlings still initiate higher order laterals in the upper root plug, it is not at the enhanced rate of chemically pruned roots.

Field Performance

After one field season, all $CuCO_3$ treatments display a trend of greater new root numbers in

Table 1. Mean total root length (cm) in the top and middle root zones for Douglas-fir, ponderosa pine, and western white pine.

	SPECIES/CONTAINER					
	DOUGLAS-FIR		PONDEROSA PINE		W. WHITE PINE	
TREATMENT	Leach	Styro 4A	Leach	Styro 4A	Leach	Styro 4A
Control	730 BC	1304 AB	431 B	276 C	567 B	783 C
Paint	550 C	646 B	908 B	144 C	736 B	1137 C
30 gL^{-1}	739 BC	1610 AB	2292 A	1134 AB	1061 B	3088 A
100 gL^{-1}	1528 AB	2046 A	2347 A	1433 A	1306 B	2531 AB
300 gL^{-1}	2292 A	1628 AB	897 B	874 B	3782 A	1382 BC
LSD	800	1091	1352	520	1165	1250

Means followed by the same letter were not significantly different when subjected to Fisher's LSD test at the alpha = 0.05 level.

the upper two-thirds of the plug for all species, but the difference is not significant for all container types (Table 2). A trend of reduced new root numbers in the lowest root zone occurs with CuC03 treatment, but is not significant with all tray types (Table 3). No trend appears when new root numbers throughout the plug are totaled (Table 4). This suggest cupric carbonate treatments did not increase the total number of new roots, but altered root distribution within the plug, increasing the proportion of roots in the upper two-thirds of the plug.

Examination of new root dry weights in the upper plug shows a general increase with a CuC03 treatment (Table 5). New root dry weights tend to decrease with treatment in the lowest root zone (Table 6). In neither case are differences significant with all species and tray type combinations. When root dry weight data is combined for all root zones (Table 7), no trend is apparent. Some seedlings had few new roots but their dry weights were high because of secondary, tertiary, and higher order lateral roots. Conversely, some seedlings had many new primary roots yielding low dry weights.

Seedling survival, height growth and root collar diameter after outplanting was unaffected by treatment during the first three years. Root redistribution, with greater numbers and lengths of new roots in the upper portions of the plug, did not result in seedling growth differences. Burdett (1981) also found seedling growth was not increased until after the third growing season when a 15% height increase was detected. Root egress on sampled seedlings did not differ between controls and treated seedlings for Douglas-fir. For pines, root egress was greater from the upper portions of the plug since the controls had more long laterals directed downward along the plug walls.

Management Implications

A planted seedling's root morphogenesis is dependent upon the elongation of existing roots and the initiation of new roots along the plug wall. Root elongation and initiation are influenced by 1) nursery cultural practices, 2) planting medium, and 3) planting tool. Our field results, to date, have not shown benefit from chemical root-pruning treatments. This may be due to the high degree of nontreated seedling root egress. In circumstances where cultural or handling/storage practices produce seedlings with excessive long lateral roots or media is compacted in the planting operation, chemical root-pruning may prove to have more immediate benefit.

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LITERATURE CITED

Burdett, A.N. 1978a. Root form and mechanical stability in planted lodgepole pine in British Columbia. pp. 162-165. In: Van Eerden, E. and Kinghorn, J.M. (Eds) Proceedings of the Root Form of Planted Trees Symposium. B.C. Ministry of Forests/CFS Joint Report No.8, Victoria, B.C.

Table 2. Mean number of new roots (> 1 cm) in the top and middle root zones for Douglas-fir, ponderosa pine, and western white pine.

	SPECIES/CONTAINER					
	DOUGLAS-FIR		PONDEROSA PINE		W. WHITE PINE	
TREATMENT	Leach	Styro 4A	Leach	Styro 4A	Leach	Styro 4A
Control	20 A	16 BC	13 B	14 A	18 C	19 B
Paint	18 A	14 C	13 B	17 A	27 B	22 B
30 gL^{-1}	23 A	31 A	23 A	20 A	34 AB	35 A
100 gL^{-1}	21 A	27 AB	28 A	17 A	38 A	28 AB
300 gL^{-1}	26 A	27 AB	27 A	17 A	28 B	25 AB
LSD	NS	11	8	NS	8	12

Means followed by the same letter were not significantly different when subjected to Fisher's LSD test at the alpha = 0.05 level.

Table 3. Mean number of new roots (> 1 cm) in the bottom root zone for Douglas-fir, ponderosa pine, and western white pine.

	SPECIES/CONTAINER					
	DOUGLAS-FIR		PONDEROSA PINE		W. WHITE PINE	
TREATMENT	Leach	Styro 4A	Leach	Styro 4A	Leach	Styro 4A
Control	30 A	16 A	16 A	15 A	24 A	17 A
Paint	16 B	12 AB	10 A	16 A	23 A	13 AB
30 gL^{-1}	12 B	15 AB	11 A	14 AB	13 AB	12 AB
100 gL^{-1}	7 B	7 B	11 A	7 B	24 A	10 AB
300 gL^{-1}	9 B	9 AB	10 A	12 AB	11 B	5 B
LSD	10	9	NS	7	11	8

Means followed by the same letter were not significantly different when subjected to Fisher's LSD test at the alpha = 0.05 level.

Table 4. Mean number of new roots (> 1 cm) in all root zones for Douglas-fir, ponderosa pine, and western white pine.

	SPECIES/CONTAINER					
	DOUGLAS-FIR		PONDEROSA PINE		W. WHITE PINE	
TREATMENT	Leach	Styro 4A	Leach	Styro 4A	Leach	Styro 4A
Control	49 A	32 AB	29 AB	29 A	42 B	35 A
Paint	34 B	26 B	23 B	33 A	50 AB	35 A
30 gL^{-1}	35 AB	46 A	35 A	34 A	46 B	47 A
100 gL^{-1}	27 B	33 AB	39 A	24 A	61 A	38 A
300 gL^{-1}	35 AB	35 AB	36 A	29 A	40 B	31 A
LSD	15	17	11	NS	14	NS

Means followed by the same letter were not significantly different when subjected to Fisher's LSD test at the alpha = 0.05 level.

Table 5. Mean new root dry weight (gm) in the top and middle root zones for Douglas-fir, ponderosa pine, and western white pine.

	SPECIES/CONTAINER					
	DOUGLAS-FIR		PONDEROSA PINE		W. WHITE PINE	
TREATMENT	Leach	Styro 4A	Leach	Styro 4A	Leach	Styro 4A
Control	0.43 B	0.40 B	0.31 B	0.37 A	0.77 A	0.92 B
Paint	0.38 B	0.47 AB	0.50 AB	0.41 A	0.97 A	1.00 B
30 gL^{-1}	0.73 A	0.85 A	0.80 A	0.56 A	1.29 A	1.47 A
100 gL^{-1}	0.52 AB	0.58 AB	0.69 AB	0.49 A	1.05 A	1.14 AB
300 gL^{-1}	0.61 AB	0.65 AB	0.72 AB	0.76 A	1.06 A	1.07 AB
LSD	0.27	0.38	0.43	NS	NS	0.46

Means followed by the same letter were not significantly different when subjected to Fisher's LSD test at the alpha = 0.05 level.

Table 6. Mean new root dry weight (gm) in the bottom root zone for Douglas-fir, ponderosa pine, and western white pine.

	SPECIES/CONTAINER					
	DOUGLAS-FIR		PONDEROSA PINE		W. WHITE PINE	
TREATMENT	Leach	Styro 4A	Leach	Styro 4A	Leach	Styro 4A
Control	0.30 A	0.33 A	0.33 A	0.52 A	0.53 A	0.48 A
Paint	0.20 AB	0.26 AB	0.39 A	0.32 A	0.57 A	0.59 A
30 gL^{-1}	0.15 AB	0.28 AB	0.41 A	0.41 A	0.45 A	0.55 A
100 gL^{-1}	0.07 B	0.11 B	0.31 A	0.23 A	0.57 A	0.58 A
300 gL^{-1}	0.10 B	0.17 AB	0.12 A	0.50 A	0.41 A	0.30 A
LSD	0.16	0.20	NS	NS	NS	NS

Means followed by the same letter were not significantly different when subjected to Fisher's LSD test at the alpha = 0.05 level.

Table 7. Mean new root dry weight (gm) in all root zones for Douglas-fir, ponderosa pine, and western white pine.

	SPECIES/CONTAINER					
	DOUGLAS-FIR		PONDEROSA PINE		W. WHITE PINE	
TREATMENT	Leach	Styro 4A	Leach	Styro 4A	Leach	Styro 4A
Control	0.73 A	0.73 AB	0.64 B	0.89 A	1.30 A	1.40 A
Paint	0.58 A	0.73 AB	0.87 AB	0.73 A	1.55 A	1.59 AB
30 gL^{-1}	0.88 A	1.13 A	1.21 A	0.97 A	1.74 A	2.01 A
100 gL^{-1}	0.61 A	0.69 B	1.00 AB	0.73 A	1.62 A	1.72 AB
300 gL^{-1}	0.71 A	0.83 AB	0.84 AB	1.23 A	1.47 A	1.37 B
LSD	NS	0.41	0.56	NS	NS	0.61

Means followed by the same letter were not significantly different when subjected to Fisher's LSD test at the alpha = 0.05 level.

Burdett, A.N. 1978b. Control of root morphogenesis for improved mechanical stability in container-grown lodgepole pine. Canadian Journal of Forest Research. 8:483486.

Burdett, A.N. 1981. Box-pruning the roots of container-grown tree seedlings. pp 203-206. In: Scarratt, J.B. et al. (Eds) Proceedings Canadian Containerized Tree Seedling Symposium. Ontario Ministry of Natural Resources, Toronto, Ontario.

Burdett, A.N., Simpson, D.G. and Thompson, C.F. 1983. Root development and plantation establishment success. Plant and Soil 71:103-110.

Duryea, M.L. (Ed.) 1984. Evaluating seedling quality: principles, procedures, and predictive abilities of major tests. Forest Research Laboratory. Oregon State University.

McDonald, S.E., Tinus, R.W. and Reid, C.P.P. 1981. Root morphology control in forest tree seedling containers. pp. 40-45. In: Proceedings of Intermountain Nurseryman's Association and Western Forest Nursery Council. USDA Forest Service Inermountain Forest and Range Experiment Station, Ogden, UT. General Technical Report INT-109.

Stein, W.I. 1978. Naturally developed seedling roots of five western conifers. pp 28-35. In: Van Eerden, E. and Kinghorn, J.M. (Eds) Proceedings of the Root Form of Planted Trees Symposium. B.C. Ministry of Forests/CFS Joint Report No.8, Victoria, B.C.

Wenny D.L. and R.K. Dumroese. 1987a. A growing regime for containerized ponderosa pine. Idaho Forest, Wildlife and Range Experiment Station Bulletin No. 43.

Wenny D.L. and R.K. Dumroese. 1987b. A growing regime for containerized western white pine. Idaho Forest, Wildlife and Range Experiment Station Bulletin No. 44.

Wenny D.L. and Woollen, R.L. 1986. An evaluation of a chemical root pruning technique for improving root system morphology in containerized seedlings. Western Journal of Applied Forestry [in press (January 1989)].

Wenny, D.L., Y. Liu, R.K. Dumroese and H.L. Osborne.1988. First year field growth of chemically pruned containerized seedlings. New Forests 2:111-118.