Effect of Styroblock Design and Copper Treatment on Morphology of Conifer Seedlings[1]

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Abstract.--Interior Douglas-fir, lodgepole pine, and white spruce were used to determine the effects of cavity volume, styroblocks modified with vertical ventilation holes, and copper coating on seedling morphology.

Decreasing cavity volume from 60 to 50 ml resulted in smaller shoots and heavier roots in Douglas-fir and spruce and could be an aid to limiting height growth.

Venting did not affect morphology greatly, but modestly increased height, diameter, and total seedling weight in Douglas-fir. In pine grown in 39 ml cavities, venting was detrimental to overall balance.

Copper treatment stimulated shoot growth in Douglas-fir, but had little effect on growth of pine shoots. Copper increased root fibrosity and stimulated growth of the mycorrhizal fungus *Thelephora terrestris* in pine.

Judicious selection of container type can help nursery managers obtain desired morphology, minimize cull, and improve the potential for good field performance.

INTRODUCTION

Morphological characteristics of seedlings often affect field performance. The primary goal of manipulating seedling morphology is to produce stock capable of tolerating stresses likely to be encountered on planting sites. In the Interior of British Columbia (B.C.), the primary stresses are frost, drought, heat, and mechanical damage.

Changing the spacing and volume of cavities can be used to alter seedling morphology (Tanaka and Timmis 1974). Growth data from seedlings grown in styroblocks with varying density and volume can be used to determine which block types have the greatest potential to optimize specific parameters such as height, diameter, or root weight. The objectives of cavity volume experiments were to find alternative block types that (1) improve height control in spruce and (2) improve root weight and overall balance in Douglas-fir.

Venting is a recent addition to styroblock design. Holes a few millimeters in diameter extend through the body of the styroblock at every intercavity intersection. The holes increase ventilation in the seedling canopy by allowing air to circulate between the top and bottom of the block. Studies have demonstrated that incidence and severity of gray mold *(Botrytis cinerea)* are reduced by venting (Peterson and Sutherland 1990). The objective of this experiment was to determine if venting alters morphology in Douglas-fir or lodgepole pine.

Coating containers with latex paint containing cupric carbonate ($CuCO_3$) is an effective way to increase the number of fine roots and root growth, especially in the upper part of the root plug (Burdett and Martin 1982, Wenny and Woollen 1989). However, these changes have not generally been reported to improve field performance (Wenny 1988). The objective of this experiment was to determine if copper coating altered root weight or shoot growth in Douglas-fir or lodgepole pine.

Nursery managers can take advantage of the diverse types of styroblocks available commercially and use them as an additional tool to obtain desired morphology.

METHODS

Seeds were sown at the Heffley Reforestation Centre Ltd., Kamloops, B.C. (Lat. 50° 51' N, Long. 120° 16' W). Studies were conducted during 1989 except the cavity volume experiment with white spruce which was done in 1988. The growing medium was composed of peat and vermiculite (4:1, v:v) with 1.4 Kg/m^3 dolomite lime. Micromax Micronutrients (Sierra Chemical Co.) was incorporated at 385 g / m^3.

Table 1 lists the types of styroblocks (Beaver Plastics, Edmonton, AB) tested. Type 198/50 was used in the copper treatment experiment. Comparison of vented and nonvented blocks was done in type 198/50 for Douglas-fir and type 240/39 for lodgepole pine.

Seedlings were reared in a greenhouse until mid-June, when the greenhouse cover was removed. Seedlings were lifted in November. Photoperiod was extended to 18 hours until 29 June using high pressure sodium lamps.

Soluble fertilizer was applied in all experiments according to the following sequential schedule: Peters Conifer Starter (7-

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40-17, W. R. Grace Co.) was applied over 5 weeks, beginning 4 weeks after sowing, at an average rate of 28 ppm N; Peters Conifer Grower (20-17-19) for 8 weeks at 80-100 ppm N; and Plant-Prod Finisher (8-20-30, Plant Products Co. Ltd.) for 12 weeks at 50 ppm N.

Table 1. Types of styroblocks used in this study

Metric		US	Cavities/ Block	Cavity Volume (ml)	Density Cav./m^2
240/39	(211A)	2A	240	39	1238
198/60	(313A)	4A	198	62	1000
198/50	(312)	---	198	50	1012
112/106	(415B)	6	112	106	571

To assess growth, 30 trees (5 from each of 6 blocks) were selected randomly from each treatment. The outer two rows of trees in a sampled container were excluded to remove edge effects. Shoot length and root collar diameter were recorded. Seedlings were separated at the root collar, dried at 100°C for 24 hours, and weighed.

Growth was compared to B.C. Forest Service standards for each species which indicate cull and target values for height, root collar diameter, and root weight (Table 2). Standards have not been established for the other parameters listed in the growth tables. The Dickson Quality Index (Dickson *et al*. 1960) is a measure of seedling balance and is calculated as: dry weight / [height-diameter ratio + shoot-root ratio].

Table 2. B.C. Forest Service target and cull specifications for stock types used in this study

Tree Species	Stock Type	Height (cm)	Diameter (mm)	Root Dry Wt. (g)
Douglas-fir	[1]198/60	18[2][12 & 25]	3.0[2.2]	0.6[0.4]
	112/106	20[15 & 30]	3.5[2.8]	0.8[0.5]
Lodgepole pine	240/39	12[7 & 17]	2.5[2.2]	0.5[0.3]
	198/60	15[7 & 20]	3.0[2.5]	0.7[0.5]
White Spruce	198/60	17[12 & 25]	3.0[2.4]	0.7[0.5]

[1]Standards for 50 ml stock types are the same as 60 ml for the respective species. [2] Numbers in brackets are cull specifications; heights are minimum and maximum.

To determine recovery, the average percentage of acceptable seedlings (according to B.C. Forest Service standards) from five randomly selected blocks per treatment was calculated.

Data were subjected to analysis of variance and the F-test (P = 0.05) used to separate treatment means except in the Douglas-fir cavity volume experiment where significant differences were indicated by the Scheffe' method of multiple comparisons (P = 0.05).

RESULTS

Cavity Volume

Douglas-fir reared in 50 or 106 ml cavities differed substantially from 60 ml controls for most measured parameters (Table 3). Seedlings from 50 ml cavities had similar overall balance and recovery, but smaller shoots, more root mass and lower shoot-root ratios than controls. Stock from 106 ml cavities differed from 60 ml controls in all parameters except shoot-root ratio. Quality Index of the larger trees was more than twice the controls while recovery improved by about 30%.

Table 3. Growth of Douglas-fir reared in 50 ml, 60 ml (control), or 106 ml containers

	60 ml	50 ml	106ml
Shoot Height (cm)	26.4a	17.9b	30.1c
Diameter (mm)	2.87a	2.65b	3.95c
Shoot Weight (g)	1.60a	1.01b	2.77c
Root Weight (g)	0.65a	0.72a	1.23c
Shoot:Root Ratio	2.5a	1.4b	2.4a
Height:Diameter Ratio	9.3a	6.8b	7.8c
Total Weight (g)	2.26a	1.73b	4.00c
Quality Index	0.20a	0.22a	0.42b
Recovery (%)	66a	67a	86b

Reading across, means within rows followed by a different letter are significantly different by the Scheffe' method (P = 0.05).

Compared to controls, spruce grown in 50 ml cavities (Table 4) had shorter shoots, a substantially greater root mass, and somewhat better balance. Diameter and total weight did not differ significantly between treatments.

Table 4. Growth of white spruce reared in 50 ml or 60 ml containers

	60ml	50ml
Shoot Height (cm)	1.96a	17.5b
Diameter (mm)	2.99a	2.84a
Shoot Weight (g)	1.78a	1.62a
Root Weight (g)	0.71a	0.92b
Shoot:Root Ratio	2.6a	1.9b
Height:Diameter Ratio	6.6a	6.2b
Total Weight (g)	2.49a	2.53a
Quality Index	0.27a	0.32b

Reading across, means within rows followed by a different letter are significantly different by the F-test (P = 0.05).

Vented Styroblocks

Venting affected growth of Douglas-fir and lodgepole pine (Tables 5, 6). Venting significantly increased shoot height, diameter, total weight, and recovery in Douglas-fir. In pine, venting increased height, but reduced diameter, root weight, and Quality Index.

Table 5. Growth of Douglas-fir reared in vented or nonvented 50 ml containers

	Nonvented	Vented
Shoot Height (cm)	17.9a	20.3b
Diameter (mm)	2.65a	2.83b
Shoot Weight (g)	1.01a	1.25b
Root Weight (g)	0.72a	0.77a
Shoot:Root Ratio	1.4a	1.6b
Height:Diameter Ratio	6.8a	7.2a
Total Weight (g)	1.73a	2.02b
Quality Index	0.22a	0.23a
Recovery (%)	67a	83b

Reading across, means within rows followed by a different letter are significantly different by the F-test (P = 0.05).

Table 6. Growth of lodgepole pine reared in vented or nonvented 39 ml containers

	Nonvented	Vented
Shoot Height (cm)	18.3a	20.5b
Diameter (mm)	2.96a	2.50b
Shoot Weight (g)	1.11a	1.11a
Root Weight (g)	0.58a	0.46b
Shoot:Root Ratio	2.0a	2.5b
Height:Diameter Ratio	6.4a	8.2b
Total Weight (g)	1.57a	1.69a
Quality Index	0.21a	0.15b
Recovery (%)	69a	70a

Reading across, means within rows followed by a different letter are significantly different by the F-test (P = 0.05).

Copper Treated Styroblocks

Copper treatment produced larger shoots, greater dry weight, and higher recovery in Douglas-fir compared to controls (Table 7). Root weight and Quality Index were not affected by copper treatment.

In lodgepole pine, copper treatment had little effect on morphology or recovery (Table 8). The treatment increased diameter and decreased root weight somewhat compared to controls.

DISCUSSION AND CONCLUSIONS

Conclusions about the effect of seedling morphology on performance after outplanting are valid only if it is known that the seedlings tested had approximately the same physiological condition. Because physiological condition is generally not reported in published studies comparing morphology, it is often difficult to separate the influence of morphology and physiology on performance.

In general, seedlings with suitable diameter and good shoot-root balance can best avoid or tolerate stresses common on plantation sites in B.C. (Mitchell *et al.* 1990, Chavasse 1980, Thompson 1985).

Table 7. Effect of copper treated styroblocks on growth of Douglas-fir reared in 50 ml containers

	Control	Copper
Shoot Height (cm)	17.9a	19.8b
Diameter (mm)	2.65a	2.86b
Shoot Weight (g)	1.01a	1.26b
Root Weight (g)	0.72a	0.79a
Shoot:Root Ratio	1.4a	1.7b
Height:Diameter Ratio	6.8a	6.9a
Total Weight (g)	1.73a	2.04b
Quality Index	0.22a	0.24a
Recovery (%)	67a	81b

Reading across, means within rows followed by a different letter are significantly different by the F-test (P = 0.05).

Table 8. Effect of copper treated styroblocks on growth of lodgepole pine reared in 50 ml containers

	Control	Copper
Shoot Height (cm)	20.217.9a	19.7a
Diameter (mm)	2.675a	3.04b
Shoot Weight (g)	1.32a	1.42a
Root Weight (g)	0.66a	0.57b
Shoot:Root Ratio	2.0a	2.6b
Height:Diameter Ratio	7.4a	6.5b
Total Weight (g)	1.98a	1.98a
Quality Index	0.21a	0.22a
Recovery (%)	72a	70a

Reading across, means within rows followed by a different letter are significantly different by the F-test (P = 0.05).

Cavity Volume

Douglas-fir 50 and 60 ml Cavities

The smaller shoots of seedlings grown in 50 compared to 60 ml containers resulted in greater sturdiness as indicated by the smaller height-diameter ratio. Generally, for sites in B.C., height-diameter ratio should be less than 8 (Mitchell *et al.* 1990). Stockier trees could be an advantage on some sites; they provide better support and resist bending from debris, snow, or trampling.

A shift in biomass distribution from shoots to roots is expected when the ratio of cavity density to soil volume is increased (Tanaka and Timmis 1974). Data comparing 50 and 60 ml cavities for both Douglas-fir and spruce (Tables 3,4) conform to this principle, i. e., shoot weight decreased while mean root weight increased in 50 ml cavities. Other factors that may have influenced growth include reduced nutrient availability in 50 ml cavities due to smaller root volume and reduced height of 50 ml cavities. The cavity size and density provided by 198/50 containers appears to be an effective way to keep height closer to target level and reduce shoot-root ratio.

Overall balance, as indicated by the Quality Index, was not affected by reducing cavity volume from 60 to 50 ml. The positive effect of improved shoot sturdiness in 50 ml cavities was offset by reduced total weight.

Douglas-fir 60 and 106 ml Cavities

Based on data from the Heffley Reforestation Centre and other sources (Dickson *et al.* 1960, Payandeh and Wood 1988, Roller 1977), we have established a minimum value of 0.20 for the Quality Index of Douglas-fir and spruce grown in 50 or 60 ml cavities. The substantially greater Quality Index of the 106 ml stock (Table 3) may be significant for plantation performance (Ritchie 1984). Payandeh and Wood (1988) found that Quality Index was a significant factor in predicting performance over a variety of site conditions in northern Ontario.

Where high temperature is a problem, large diameter stock is more resistant to damage because of better heat dissipation away from the stem (Cleary *et al.* 1978). Given equal physiological condition, seedlings grown in larger containers have better performance potential than those grown in small containers (Cleary *et al.* 1978). However, improved performance of larger stock may not offset the higher cost. Douglas-fir 112/106 seedlings sell for 8 to 10 cents Canadian (50-63%) more than 198/60 stock in B.C. Additional tests are needed to establish the field conditions under which large stock types are cost effective.

The 20% greater recovery in larger stock is enough to be a significant cost factor to nursery operations. Analysis of culls indicated that the major reason for improved recovery was fewer over-height/under-diameter trees.

White Spruce 50 and 60 ml Cavities

Although shoot-root ratio, height-diameter ratio, and Quality Index of 50 ml stock were statistically improved compared to 60 ml stock, the differences are not likely to be biologically significant. Measurements of both treatments were well within acceptable standards. As in Douglas-fir, it may be easier to limit height and boost root weight by use of the smaller cavity size.

Vented Styroblocks

Douglas-fir

Taller shoots of Douglas-fir and pine stock grown in vented blocks was not expected. Vented blocks dried out more rapidly than unmodified blocks (up to 30% faster, G. Hunt unpublished data) and presumably were under greater moisture stress during some of the growing season. The unusually cloudy and rainy summer weather experienced in the southern Interior in 1989 may have minimized this drying effect. Greater dry weight of seedlings in vented blocks suggests that improved air circulation resulted in a higher rate of photosynthesis or that growth was suppressed in nonvented blocks. Slower drying of nonvented blocks following irrigation may have resulted in longer penods of saturation accompanied by anaerobic conditions in the root zone; perhaps this reduced root respiration and nutrient uptake.

Reasons for the increased recovery from vented blocks is not clear. Analysis of culls was not conducted on these treatments. Because Douglas-fir did not have a high incidence of gray mold at the nursery last year (losses ranged from 0 to 18% in other stock types), it is unlikely that this accounted for the recorded increased recovery. This study is being repeated in 1990 for clarification.

Lodgepole Pine

Stock from vented blocks was not of high quality (Table 6). Increased height and reduced diameter resulted in greater losses due to over-height/under-diameter. Analysis showed that 35% of culls from vented blocks were defective due to over-height/ under-diameter compared to 2% for stock from unmodified blocks. In addition, vented stock had an average root weight below target (0.5 g) and a height-diameter ratio exceeding the recommended value of 8 (Mitchell *et al.* 1990). Data on Quality Index for pine (Hunt, unpublished) indicate that the score of 0.15 recorded for vented stock is quite low. Stock grown at this relatively high density and small cavity size sometimes does not achieve a Quality Index of 2.0, but scores below 0.18 are not common.

The incidence of gray mold did not differ significantly between block types and resulted in losses of about 10% in both treatments. This contrasted with stock from 198/50 vented and nonvented blocks where venting resulted in an 8% reduction in loss due to gray mold (data not shown). Perhaps the denser canopy in 240/39 blocks did not permit significantly increased air flow in spite of venting.

Copper Treated Styroblocks

Douglas-fir

Copper treatment clearly altered root morphology by increasing root branching and the number of fine roots. Perhaps the increased absorption area improved nutrient uptake resulting in larger seedlings. It is unlikely that higher levels of copper in the tissue stimulated growth. Nontreated seedlings were not copper deficient and contained 11 ppm copper (4-20 ppm is the optimum range) at season’s end. This compared to 22.3 ppm copper in treated seedlings.

The altered root morphology may have contributed to improved recovery, but data were not recorded to confirm this. Inadequate root development, particularly in the upper part of the root plug, is a common problem in Interior Douglas-fir.

Lodgepole Pine

Copper treatment substantially increased root branching and root system fibrosity. Because the tap root is usually pruned and fewer large diameter lateral roots are present, treated root plugs are more flimsy and lack the rigidity of nontreated plugs. This may make them more susceptible to "J rooting" from improper planting. Copper treatment did not reduce cull due to poor roots; 36% of culls in both treatments had inadequate root development.

Tissue copper level increased somewhat in treated seedlings. Levels for control and copper treated stock were 12 and 17 ppm, respectively.

Growth of the mycorrhizal fungus *Thelephora terresrris* was substantially better in copper treated plugs. Although more than 90% of roots were colonized in both treatments, the amount of extramatrical mycelium and mycelial strands was far greater in treated plugs. The larger number of root tips available for colonization or altered physical environment of the plugs produced by increased fibrosity may have stimulated fungal growth. Growth hormones produced by mycorrhizal fungi stimulate root branching (Slankis 1973) resulting in additional root fibrosity. Increased root fibrosity improves root growth capacity and therefore may be important in outplanting success (Deans *et al.* 1990).

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