Nutrition and Performance of Container-Grown Japanese Black Pine Seedlings[1]

Robert D. Hathaway and Carl E. Whitcomb[2]
Department of Horticulture
Oklahoma State University
Stillwater, OK 74078

Abstract

Growth of Japanese black pine *(Pinus thunbergi* Parl.) seedlings in containers was enhanced by incorporating a slow-release fertilizer (Osmocote) and micronutrient source in the growth medium while dolomite was detrimental. Seedlings transplanted into the field showed excellent survival, regardless of propagation treatment, however, plants grown with Osmocote and micronutrients in the container medium were significantly larger after 1 growing season. Root-to-shoot ratio was not related to survival or growth. Container-grown seedlings were larger after 3 months than 2-year-old conventional bed-grown plants and continued to outgrow the bed-grown seedlings after one year in the field.

Index words: Field production, transplant

Introduction

Procedures for growing seedlings in ground beds are well documented (4, 13, 15). Plants are crowded and competition for light, water and nutrients is keen. Removal of the plants from the seed bed must be accomplished during the dormant season and roots are lost. Survival and growth of bed-grown seedlings after transplanting is a significant problem (3, 15). Some species are transplanted to allow more room for development and to cull, stunted or inferior seedlings. Roots of seedlings may be undercut and when practiced correctly promotes secondary and tertiary root formation. However, root pruning usually results in reduced growth, increasing the time required for production.

Millions of conifer seedlings are produced annually in containers but fertility is often out-of-balance in order to achieve desired root:shoot ratios and dormancy requirements thought to be desirable on adverse planting sites.

While containers allow the seedling to be transplanted without the shock of root disturbance, research has shown that confinement to a container for an extended period may create a malformed, contorted root system which ultimately restricts growth (4, 5).

The behavior of roots in a round container with a bottom is part of the root girdling problem. When a growing root confronts a barrier it cannot penetrate, it turns and follows the contour of the barrier or buckles. In a cylindrical container roots start a spiral growth pattern. Davis and Whitcomb (1) found that by using square, bottomless containers on wire benches, roots grew laterally until contacting the container sides, then proceeded to the 90 degree corner and grew downward. Roots reaching the container bottom were 'air pruned' by desiccation. Pruning of primary roots induces development of lateral roots which in turn are 'air pruned' as they reach the bottom. A fibrous root mass with no spiral growth results.

If optimum growth is to be achieved, a continuous and adequate supply of all required nutrients must be available to the seedling. The medium, container volume and fertilizer used, all influence plant response (2). Nutrition may be the limiting factor in achieving optimum seedling growth (11).

Hathaway (8) incorporated Osmocote 18N-2.6P-10K (18-6-12) into the medium and germinated *Quercus acutissima, Pinus thunbergi, Betula nigra* and *Quercus shumardi* without seedling damage up to 12 kg/m^3 (20 lbs/yd^3) of Osmocote. Hathaway and Whitcomb (7) used 3 sizes of bottomless containers and 5 levels of Osmocote 18N-2.6P-10K (18-6-12) top-dressed on the germinating medium after seedling emergence and found the growth of *Quercus shumardi* to be significantly increased by the 3 highest rates of Osmocote (4.5, 6.5 and 9 kg/m^3) (8, 11 and 16 lbs/yd^3). The 4.5 kg/m^3 rate (8 lbs/yd^3) produced seedlings essentially the same size as the unfertilized control seedlings at the end of the 90 days, but were significantly larger one year later. This suggests that fertility in the germinating medium influences plant growth long after the propagation phase. Maggs (11) found that neither the root nor shoot continuously limits growth as both usually operate considerably below their maximum efficiently. He suggested nutrition as a means of increasing growth.

The objectives of this research were to investigate a container system and to develop a controlled-release nutritional system for the production of high quality tree seedlings.

Materials and Methods

Japanese black pine (*Pinus thunbergi* Parl.) seed was sown April 13, 4 to 5 seeds per container and thinned to 1 by hand after emergence.

Containers were 7 cm^2 (2.75 in^2) paper milk cartons, 14 cm (5.5 in) tall with a volume of 683 cm^3 (41 in^3). A mixture of ground pine bark, peat and sand (2:1:1 by volume) amended with 1.5 kg/m^3 (2.5 lbs/yd^3) of single superphosphate 0N-8.6P-0K (0-20-0) constituted the

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[2]Director of Horticulture, Cherokee Nation of Oklahoma and Professor of Horticulture, resp.

basic growing medium. Osmocote 18N-2.6P-0K (18-6-12) was used at rates of 0, 3.6, 8.3 and 11.8 kg/m^3 (0, 6, 14, 20 lbs/yd^3) 0, 1.1 and 2.2 kg/m^3 (0, 2, 4 lbs/yd^3) of Perk and 0, 1.1 and 2.2 kg/m^3 (0, 2 and 4 lbs/yd^3) dolomite. The 4 x 3 x 3 factorial experiment was replicated 4 times with 4 subsamples in a randomized complete block design.

The bottomless, square containers located on wire benches allowed the root system to grow downward out of the medium and 'air prune.' A border row was provided. All plants were grown in full sun.

Treatments receiving Osmocote had 3.6 kg/m^3 (6 lbs/yd^3) incorporated in the mix. The 2 highest levels of Osmocote were then top-dressed by adding 3 or 6 grams of Osmocote per container after seedling emergence. The highest rates of Osmocote were equal to 8.3 and 11.8 kg/m^3 (14 and 20 lbs/yd^3).

At the termination of the propagation phase, subsamples of each treatment were evaluated in the following manner. The seedling which was most unlike the other 3 in a treatment sub-sample was discarded. Height, bud breaks (flushes) and caliper were measured on the three seedlings remaining. On August 12, 1 seedling was sacrificed to determine top and root weight and foliar nutrient analysis. Entire tops of seedlings were dried and ground for analysis. One seedling was planted into a 11 liter container (#3) and 1 seedling was planted in the field. A Technicon nitrogen analyzer was used for total nitrogen analysis. Potassium, magnesium, calcium, manganese, iron and zinc were analyzed by atomic absorption spectrophotometry.

Seedlings planted in containers had a growth medium of ground pine bark, peat and sand (2:1:1 by volume) with the following amendments per 0.8 m^3 (1 yd^3), 2.2 kg (4 lbs) each of Perk and single superphosphate 0N-8.6P-0K (0-20-0), 4.7 kg (8 lbs of dolomite and 8.3 kg (14 lbs) of Osmocote 17N-3.0P-10.0K (17-7-12).

The randomized complete block design with 4 replications was maintained in containers and the field.

Results and Discussion

Increasing Osmocote in the growth medium from 0 to 3.6 kg/m^3 (6 lbs/yd^3) significantly increased plant height, bud breaks, stem caliper, top weight and root weight (Table 1). Additional Osmocote did not significantly increase seedling growth and the highest rate decreased root weight. However, foliar nitrogen concentrations increased in direct proportion to increased rates of Osmocote (Table 2). Potassium, iron and magnesium increased as Osmocote level increased from 0 to 3.6 kg/m^3 (6 lbs/yd^3), with no response to the higher levels. In contrast, manganese levels did not increase above the control except for the highest level of Osmocote which resulted in a significant increase. Calcium also increased with increasing Osmocote. Total percent nitrogen increased up to the 8.3 kg (14 lbs) rate with no further change with additional Osmocote.

Perk micronutrients increased plant height, top weight and root weight but did not increase branching or stem caliper (Table 1). As the level of Perk increased iron, manganese and zinc increased (Table 2). This was probably due to the increased concentration of micronutrients in the growing medium and as expected, Perk had no effect on percent nitrogen, magnesium or calcium in the plant tissue. However, potassium decreased when Perk was added to the growing medium, thus suggesting a competitive ion effect.

Dolomite restricted plant height and top weight slightly but had no effect on branching, stem caliper or root weight (Table 1). These data show that the levels of dolomite used were detrimental to Japanese black pine seedlings during propagation.

Adding dolomite to the growth medium decreased foliar nitrogen and manganese levels and increased calcium and magnesium (Table 2). Zinc increased as dolomite increased from 0 to 2.4 kg/m^3 or higher (Table 2). This may be due to a more favorable balance of nutrients at this level of dolomite. Iron concentration remained essentially the same, independent of dolomite levels.

As the dolomite was increased, potassium concentration in the foliage increased (Table 2). Other research has produced similar results (12). Kahn and Hanson (9) found an accumulation of potassium promoted by increased calcium and to a lesser extent, magnesium. This effect of calcium on potassium occurred with corn and was reversed with soybeans, i.e., calcium inhibited potassium uptake. Shear and co-workers (14) found a definite relationship between the accumulation of man-

Table 1. Effects of Osmocote, Perk and Dolomite on Height, Branches, Stem, Caliper, Top and Root Dry Weight of 3 Month Old Japanese Black Pine Seedlings.

Treatment	Rate (kg/m^3)	Rate (lbs/yd^3)	Height (cm)	Branches (no)	Stem Caliper (cm)	Top Wt (g)	Root Wt (g)
Osmocote	0.0	0	4.6a[z]	1.0a	0.15 a	1.7 a	1.5 a
	3.6	6	15.9 b	4.0 b	0.51 b	13.6 b	4.8 c
	8.3	14	15.4 b	4.2 b	0.52 b	14.9 b	4.3 bc
	11.8	20	15.7 b	3.9 b	0.52 b	14.3 b	3.9 b
Perk	0.0	0	12.1 a	3.3 a	0.40 a	10.0 a	3.2 a
	1.1	2	13.1 b	3.2 a	0.43 a	11.6 b	3.9 b
	2.2	4	13.6 b	3.4 a	0.44 a	11.8 b	3.8 b
Dolomite	0.0	0	13.6 b	3.3 a	0.44 a	12.5 b	3.8 a
	1.1	2	12.9 a	3.4 a	0.43 a	11.0 ab	3.6 a
	2.2	4	12.2 a	3.2 a	0.41 a	10.0 a	3.5 a

[z]Means in columns followed by the same letter or letters are not significantly different at the 5% level using a protected LSD test.

ganese, zinc, copper and iron in tung trees, with increasing levels of calcium, magnesium and potassium producing a manganese deficiency. Although manganese was also decreased in the Japanese black pines by increasing dolomite, tissue concentrations remained well above what is thought to be a deficiency level.

Post-Propagation Performance. Seedlings transplanted into larger containers remained in the open and were subjected to an unusually adverse winter. Prolonged freezing temperatures resulted in desiccation and injury of some plants. Dieback of shoots was related to a north-south gradient, therefore no further data were taken. However, survival of seedlings suggested a strong relationship to fertility levels during propagation.

Seedlings transplanted into the field showed excellent survival, regardless of propagation treatment. However, subsequent growth was significantly influenced by nutrition treatments during propagation.

Japanese black pines showed a dramatic increase in height due to Osmocote in the propagation medium and continued to respond to the favorable treatments 1 year after field planting (Table 3). Although after 1 year there was a 200 percent increase in height of seedlings propagated without Osmocote, all Osmocote treatments which were much larger when planted were over 130 percent taller 1 year after transplanting and over twice as tall as those receiving no Osmocote during propagation. The root to shoot ratio was not related to survival and growth. The influence of Perk micronutrients 1 year after transplanting in the field was still apparent on height and percent increase in height (Table 3). Dolomite added during propagation continued to be detrimental or of no benefit to Japanese black pine one year after transplanting (Table 3). The inability of a seedling to overcome the influence of poor nutrition during the early stages of growth cannot be over emphasized. Many nurserymen feel they can 'save' stunted seedlings by providing a more desirable nutritional environment following transplanting. This idea is challenged by these data.

As a comparative demonstration, 50 two-year-old bed grown Japanese black pine seedlings were obtained from a commercial grower. The average 3-month-old container grown pine was slightly larger than the 2-year-old bed grown seedlings. However, 1 year after transplanting into identical fertility regimes the container grown seedlings were 400% larger. Similar differences were observed in the field. Loss of roots during harvest and poor fertility practices probably contributed to the stunted growth.

Significance to the Nursery Industry

Osmocote added during propagation significantly influenced tree seedling growth. These studies indicated

Table 2. Effects of Osmocote Perk and Dolomite on Nutrient Concentrations of 3 Month Old Japanese Black Pine Seedlings.

Treatment	Rate (kg/m³)	Rate (lbs/yd³)	N (%)	K (%)	Mg (%)	Ca (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)
Oscomote	0.0	0	0.72 a[z]	0.33 a	0.098 a	0.08 a	48 a	188 a	71 a
	3.6	6	1.92 b	0.63 b	0.153 b	0.10 a	61 b	183 a	80 a
	8.3	14	2.40 c	0.66 b	0.163 b	0.13 ab	56 b	184 a	80 a
	11.8	20	2.70 d	0.68 b	0.165 b	0.16 b	59 b	226 b	82 a
Perk	0.0	0	1.91 a	0.75 b	0.15 a	0.14 a	52 a	146 a	68 a
	1.1	2	1.93 a	0.64 a	0.17 a	0.15 a	59 ab	219 b	84 b
	2.2	4	1.98 a	0.65 a	0.17 a	0.14 a	62 b	250 c	92 c
Dolomite	0.0	0	2.05 b	0.56 a	0.13 a	0.11 a	57 a	289 c	66 a
	1.1	2	1.90 a	0.68 b	0.17 b	0.15 ab	56 a	192 b	93 b
	2.2	4	1.86 a	0.77 c	0.19 c	0.17 b	61 a	134 a	87 b

[z]Means in the same column followed by the same letter or letters are not significantly different at the 5% level using a protected LSD test.

Table 3. Effects of Osmocote, Perk and Dolomite during Propagation on Root:Shoot Ratio and Height of Japanese Black Pine one year after Transplanting.

Treatment	Rate kg/m³	Rate (lbs/yd³)	Height (cm) at transplanting	Height (cm) after 1 yr	Percent increase in height	Root:Shoot Ratio[z]
Osmocote	0.0	0	4.6a[z]	13.4 a	201 a	0.98 b
	3.6	6	15.9 b	38.5 b	145 a	0.37 a
	8.3	14	15.4 b	37.5 b	144 a	0.29 a
	11.8	20	15.6 b	36.7 b	131 a	0.27 a
Perk	0.0	0	12.1 a	25.5 a	114 a	0.48 a
	1.1	2	13.0 b	34.4 b	180 b	0.47 a
	2.2	4	13.6 b	34.8 b	172 b	0.50 a
Dolomite	0.0	0	13.6 b	33.8 b	162 a	0.46 a
	1.1	2	12.9 a	31.8 b	155 a	0.47 a
	2.2	4	12.2 a	29.0 a	151 a	0.53 a

[z]Means in the same column followed by the same letter or letters are not significantly different at the 5% level using a protected LSD test.

that seedlings grown under less desirable nutritional regimes remained inferior to the better treatments 1 year later. A balanced slow-release fertility system combined with the fibrous root system produced by 'air pruning' resulted in significantly larger seedlings in 3 months than 2-year-old seedlings grown in conventional ground beds. In this study, no evidence was found to relate root:shoot ratios to plant height, survival or further growth in the field.

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Influence of Ozone on the Severity of Phytophthora Root Rot of Azalea and Rhododendron Cultivars[1]

Laurence D. Moore, Robert C. Lambe and Wirt H. Wills[2]

Department of Plant Pathology, Physiology and Weed Science,
Virginia Polytechnic Institute and State University,
Blacksburg, VA 24061

Abstract

The susceptibility of 21 azalea and rhododendron cultivars to colonization by *Phytophthora cinnamomi* and to injury caused by ozone was determined. Resistance to *P. cinnamomi* was lacking in most cultivars with only 3 rhododendron cultivars 'Caroline,' 'Chionoides' and 'English Roseum' and 3 azalea cultivars 'Hinodegiri,' 'Sweetheard Supreme' and 'Tradition' having resistance. All of the rhododendron cultivars, except 'Nova Zembla,' were highly resistant to ozone injury. Of the azalea cultivars, only 'Delaware Valley White,' 'Roadrunner' and 'White Water' exhibited injury following fumigation with 0.20 ppm ozone for 6 hours on 3 consecutive days. The fumigation of *P. cinnamomi*-inoculated plants with ozone significantly increased the severity of Phytophthora root rot only in 'Hinodegiri' plants, but a trend towards greater disease severity was evident in many cultivars.

Index words: Air pollution, *Phytophthora cinnamomi*

Introduction

Phytophthora root rot of *Rhododendron* species is destructive worldwide (20). We have found that *Phytophthora cinnamomi* Rands is the most common fungus we have isolated from diseased azalea and rhododendron roots in Virginia. This fungus is also the most important *Phytophthora* species involved in the root rot syndrome of *Rhododendron* species in the United States (8).

Azalea and rhododendron cultivars vary in their susceptibility to ozone, nitrogen dioxide and sulfur dioxide (4, 5, 17, 19). Some azaleas are extremely susceptible while others are very resistant to fumigations with ozone

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[2]Associate professor, associate professor and professor, respectively.