NTC: Current Seedling Nutrition Research

Diane L. Haase, Nursery Technology Cooperative
Forest Science Department, Oregon State University

Abstract

The Nursery Technology Cooperative (NTC) consists of participants from state, federal, and private forestry. It's objective is to improve reforestation success through an integrated program of studies, information sharing, and technical assistance. One area of NTC activity is to evaluate the effect of fertilizer on subsequent seedling nutrition and field performance. This paper reports on the NTC and summarizes fertilization projects currently underway.

NTC Background

The Nursery Technology Cooperative (NTC) is based in the Forest Science Department at Oregon State University (OSU) and has been active since 1982. The NTC is a non-profit group with participants from state, federal, and private forestry including several bareroot and container nurseries and several seedling users. The Cooperative objective is to improve the productivity of the Northwest's forests through the use of advanced seedling technology to achieve optimal regeneration. With an integrated program of coordinated studies, information sharing, and technical assistance, the NTC focuses attention on all aspects of nursery management, especially its consequences for seedling performance. The NTC helps participants meet both immediate and long-range goals to develop techniques and practices which result in improved seedling quality and reforestation success.

Along with projects conducted by its staff, the NTC supports graduate student work aimed at meeting the Cooperative's goals. Graduate student projects focus on a particular aspect of seedling quality and are conducted in the nursery and/or the field. Annual meetings are held to discuss current projects and to set objectives for future work. As a result, cooperators have direct input into the NTC's activities. Regular newsletters, cooperator visits, and an annual report serve to keep cooperators up-to-date on NTC projects and other issues of interest to the forest nursery and reforestation community.

One area of NTC activity is fertilization trials. Seedling nutrition is a crucial component in determining the performance of outplanted seedlings. As a result, fertilizer applications in both the nursery and the field play an important role in the production of quality seedlings and subsequent reforestation sucess. In recent years, field fertilization has increasingly been recognized as a tool to promote healthy, fast-growing seedlings which can reach a "free-to-grow" height in just a few years. Following is a summary of NTC projects currently underway to examine the effect of fertilizer on seedling quality and field performance.

The Use of Controlled-Release Fertilizers in the Field

This study was developed in cooperation with Scotts Company to test the effect of several fertilizer formulations on the growth and survival of outplanted Douglas-fir *(Pseudotsuga menziesii* [Mirb.] Franco) seedlings.

Methods

Table 1. Fertilizer treatments used in the study.

Treatment	Fertilizer	N-P-K	Release rate
1	Forestcote, (in the hole)	14-7-10 plus micros	14-16 months
2	Forestcote, (to the side)	14-7-10 plus micros	14-16 months
3	CB-1-95	19-6-13	8 months
4	KH-4-95	19-6-12	after 12 months
5	CB-2-95	18-6-12	12-14 months
6	KH-5-96	18-6-11	during 2nd and 3rd year
7	Woodace, (3 briquettes)	14-3-3 plus micros	16-24 months
8	Control	0-0-0	N/A

Eight fertilizer treatments (Table 1) were applied March 13, 1996 to 1+1 Douglas-fir seedlings at the time of planting to the field. The outplanting site is located on Willamette Industries land (formerly Cavenham Forest Industries) and is just SE of Seaside, OR. Treatments 1-6 (Scotts Company formulations) were applied at a rate of 10g N/seedling while three briquettes of Woodace (Vigoro Company, Japan) deliver approximately 7.5 g N/seedling. With the exception of treatment 2, fertilizer was placed in the planting hole and covered with a layer of soil before the seedling was placed in the hole. For treatment 2, fertilizer was placed approximately 8 cm from the tree and 15 cm deep.

Two weeks after planting, initial height and stem diameter were recorded. In mid-August, 1996 and 1997, seedlings were measured for first and second season height and stem diameter. Instances of browsing, chlorosis, frost damage, dead tops, and browning were recorded. In addition, foliar samples were collected and dried for 48 h at 68°C and assessed for nutrients using standard laboratory procedures. Nutrient content was calculated by taking the product of nutrient concentration and dry weight of 100 needles per seedling. Relative nutrient concentraiton, content, and dry weight were calculated (relative to the control treatment) and vector diagrams were constructed (Haase and Rose 1995) to facilitate a thorough examination of nutrient responses to the fertilizer treatments. Seasonal growth was calculated by substracting height values. Second-season stem volume was calculated using the formula for a cone: $1/3(1/4 \pi d^2)h$, where d is the basal diameter and h is the height.

Preliminary Results and Discussion

Approximately 20% of seedlings, regardless of treatment, were damaged by a late frost in the first season but most were fully recovered by the end of the second season. Trea·ment 1 had significantly lower survival than any of the other treatments (Table 2). This may be due to fertilizer burn although treatments 3-7 which were applied in the same manner did not exhibit reduced survival. Also, a partial row of treatment 1 seedlings in two of the blocks died during the first season (accounting for half of all dead treatment 1 seedlings). This indicates possible environmental factors contributing to their mortality.

Table 2. Field performance for seedlings planted with each fertilizer treatment. Note: Because of foliar sampling and exclusion of seedlings with dead tops, totals and second-season (1997) means are based on fewer trees. This explains why 1996+1997 growth is unequal to the total.

Treatment	Mean Total Height (cm)	Mean Height Growth 1996 (cm)	Mean Height Growth 1997 (cm)	Mean Total Height Growth (cm)	Mean Total Stem Diameter (mm)	Mean Stem Diameter Growth 1996 (mm)	Mean Stem Diameter Growth 1997 (mm)	Mean Total Stem Diameter Growth (mm)	Mean Total Stem Volume (cm^3)	Mean Survival (%)
1	78.6	5.9	25.6	40.8	16.3	0.91	6.4	9.5	70.2	83.6*
2	77.3	6.9	27.8	40.0	15.1	1.14	6.6	8.6	55.6	97.3
3	73.8	8.0	23.2	35.4	15.4	1.14	6.6	8.7	51.2	96.7
4	83.7	7.9	31.0	44.0	17.2	1.14	8.1	10.2	73.6	96.7
5	76.9	6.8	28.2	39.9	15.8	1.30	7.0	9.4	60.8	96.7
6	77.2	6.7	26.1	36.4	16.5	1.10	7.7	9.7	64.0	98.9
7	73.1	6.2	23.2	33.5	15.2	0.96	6.6	8.4	49.6	97.8
8	70.6	5.8	21.7	31.2	15.2	0.94	6.5	8.3	45.0	98.9

*significantly different from the other treatments

Statistically, there were no treatment differences for seedling morphology in the field. However, unfertilized control seedlings (treatment 8) had the lowest mean height, stem diameter, stem volume, and seasonal growth (Table 2). Control seedlings also had the lowest foliar dry weight and exhibited the greatest number of chlorotic trees during the first season (15%).

The data also indicate a possible difference in nutrient availability to the plant due to fertilizer placement. Treatment 2, which is the same formulation as treatment 1 but was applied adjacent to the tree rather than in the planting hole, had 9% chlorosis in the first season while treatment 1 had only 1%. Furthermore, although treatments 1 and 2 had similar height and diameter growth, treatment 1 tended to have a much higher stem volume. Carlson and Preisig (1981) found that fertilizer placed in the planting hole stimulated more dry weight accumulation in the shoots of Douglas-fir seedlings than did fertilizer placement in an adjacent hole.

The first-season nutrient data was consistent with the observed chlorosis. Treatments 1, 3, 4, and 5 which had the lowest incidence of chlorosis (0-3%) also had the highest foliar N concentrations. Conversely, treatments 2, 6, 7, and 8 (control) had the highest incidence of chlorosis (4-15%) and the

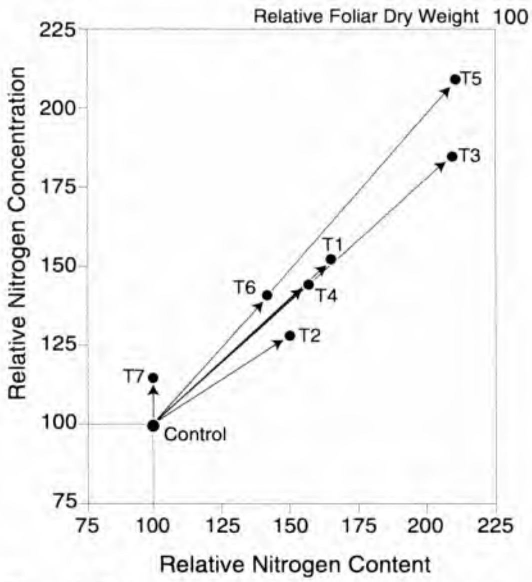


Figure 1. Foliar nitrogen concentrations and contents of fertilized seedlings were higher than the control after one season in the field.

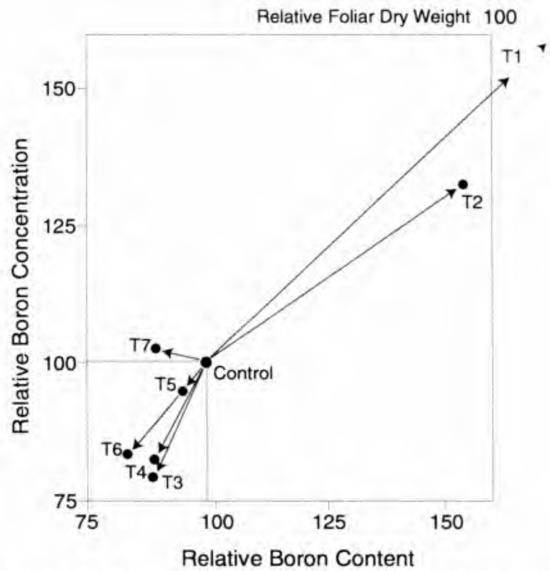


Figure 2. Fertilizer treatments which included micronutrients in their formulations had higher foliar boron than the control. Note: treatment 1 boron concentration was nearly seven times greater than the control and could not fit on the graph.

lowest foliar N concentrations (Figure 1). Second-season nutrient data was not available at the time of this writing.

The inclusion of micronutrients in the Forestcote is evident by the significantly higher levels of B in Treatment 1—nearly seven times as much as the control (Figure 2) at the end of the first season. Although non-significant, Treatment 2 (Forestcote to the side) also had higher foliar B concentrations and Treatment 7 (Woodace) had slightly higher foliar B concentrations. Again, the differences between treatments 1 and 2 may indicate decreased nutrient availability when fertilizer is placed adjacent to the seedling rather than in the planting hole. Treatments 3-6 which did not include micronutrients, showed a trend toward lower B levels than the control indicating a possible dilution due to a trend toward greater growth.

Although data are not statistically significant, the data certainly indicate a favorable fertilizer response. Gleason et al. (1990) found that fertilized ponderosa pine *(Pin us ponderosa* Laws.) seedlings had significantly higher N concentrations after one season in the field but did not show a significant increase in height growth until after the second season. Fertilizer can increase the number of needle primordia formed in the bud at the end of the season in which fertilizer was applied thereby increasing the growth potential for the following year (Carlson and Preisig 1981). We intend to continue monitoring this site and expect that fertilized trees will continue to outperform the unfertilized trees, especially given the long release rates of some of the treatments.

Boron Loading in the Nursery

Boron deficiency is one of the most common micronutrient deficienies in forest plantations (Stone 1990). Grasses and other monocots can grow well at low tissue concentrations of B (Bradford 1966). As a result, conifers may have a competitive disadvantage on sites with deficient soils. Severe deficiency can result in shoot dieback, swelling of the leader, and deformity. Green (1993) found that B fertilization of Douglas-fir seedlings on a deficient site resulted in improved height growth and an abscence of B deficiency symptoms compared to the control trees. Boron fertilization of shortleaf pine *(Pinus echinata* Mill.) has been shown to increase ectomycorrhizal colonization of roots and seedling growth (Mitchell et al. 1987).

Little research has been done to determine deficient and toxic boron levels on conifer seedlings. This study was developed in cooperation with Scotts Company to examine the effect of applying different levels of boron to seedling transplant beds. The objective is to determine if boron applications will result in significant increases in boron uptake and if these increases result in enhanced or diminished seedling quality after outplanting.

Methods

Five fertilizer treatments were applied to 1+1 Douglas-fir seedling beds at the Washington DNR L.T. Webster Nursery (Olympia, WA) as follows:

1) control—nursery's operational treatment
2) boron @ 0 lb/ac
3) boron @ 1 lb/ac
4) boron @ 2 lb/ac
5) boron @ 4 lb/ac

Boron was applied to treatments 3-5 in the form of Solubor (U.S. Borax, Inc., Valencia, CA). N, P, K and minor elements (Scotts Company's 19-9-9 Forestcote) were also applied to treatments 2-5. Applications were made on April 2, 1996, prior to transplant. A soil sample was taken prior to fertilizer applications and again sixteen weeks after applications. Five, ten, and sixteen weeks after treatment, foliar samples were collected and assessed for mineral nutrient content.

Seedlings were lifted in February, 1997. A subsample of seedlings were measured for morphological parameters (height, stem diameter, fresh weight, root volume, and shoot volume) and foliar nutrients. Another subsample from each block/treatment was outplanted to a site near the nursery. One-third of the seedlings were outplanted with no additional fertilizer, one-third were outplanted with Osmocote (16-7-12) @ 10 g N/seedling, and one-third were outplanted with Forestcote (14-7-10) plus minors @ 10 g N/seedling.

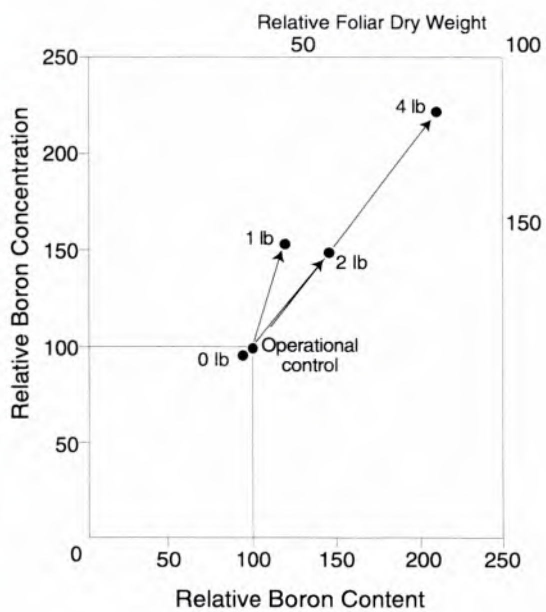
Preliminary Results

Pre-treatment soil analyses revealed that initial boron levels were low (average=0.4ppm). The sixteen-week soil sample showed slightly higher levels of boron in the plots which had been treated with 1, 2, and 4 lb B/ac (0.5, 0.5, and 0.7 ppm, respectively) while the operational plots and the 0 lb plots remained at 0.4 ppm. For other nutrients, the operational plots differed somewhat from those that had been fertilized with Forestcote. The operational plots tended to have higher CEC, Ca, K, Mn, and NO_3, while the Forestcote plots tended to have higher pH, Mg, P, and Cu.

There were no significant treatment differences in foliar dry weights, nutrient concentrations, or nutrient contents five weeks after treatment applications. After ten weeks, significant treatment differences were found for both B and K but not for dry weight or any of the other nutrients. The K concentrations did not follow any meaningful pattern relative to the B treatments although the operational treatment was significantly greater than the 0, 1, and 2 lb/ac applications (treatments 2-4). Foliar B concentration and content doubled from the 0 lb B/ac application (treatment 2) to the 4 lb B/ac application (treatment 5) while the nursery operational fertilizer application (treatment 1) had slightly higher, although non-significant, B levels than the 0 lb B/ac treatment.

After 16 weeks, there were significant differences in foliar concentrations of Al, B, Fe, K, Mo, and N. Similar to the ten week foliar sample, foliar B levels after 16 weeks showed significant increases with applications of B. Furthermore, the increased foliar B between the ten week and sixteen week samples show that B uptake continued to be high. Foliar Al, Fe, and Mo tended to be highest in the 0 and 1 lb B/ac applications (treatments 2 and 3) and lowest in the operational fertilizer (treatment 1). This may be because of a higher concentration of these elements in the Forestcote fertilizer vs. the operational fertilizer. At the 2 and 4 lb B/ac applications (treatments 4 and 5) the increased B uptake may have a slight inhibitory effect on the uptake of Al, Fe, and Mo. Both foliar K and soil K were higher in the operational treatment indicating differences in fertilizer formulations. Foliar N was lowest in B treated plots (treatments 3-5) suggesting a slight inhibitory effect on N uptake.

At lifting, B and N concentrations continued to differ significantly by treatment while all other nutrients were non-significant by treatment. The magnitude of difference in boron concentrations at lifting was less than the 16-week sample. However, seedlings treated with the 4 lb B/ac rate still had an average concentration more than twice that of the operational control and



0 lb/ac treatments (Figure 3). Nitrogen concentration was approximately 0.3% higher and stem diamter was approximately 0.5 mm greater in the operational control treatment than in the other four treatments. Other measures of morphology (height, weight, root volume, and shoot volume) and percent cull at the time of lifting did not differ by treatment.

At the end of the growing season seedlings will be measured again to determine if there are differences in field performance attributable to nursery and/or field fertilizer treatments. At that time, additional foliar samples will be collected.

Figure 3. Foliar B concentrations and contents increased significantly with B applications.

Other NTC Projects Currently Underway

In addition to the above-mentioned fertilizer projects, the following projects were recently established and are expected to yield useful information for management of forest seedling nutrition.

At the end of the growing season, morphology and survival will be measured and recorded for each seedling. In addition, foliar samples will be collected and nutrient concentration will be assessed. Field performance will be assessed again at the end of the second (and possibly third or fourth) field seasons. As data is collected and analyzed, the results will be presented in the NTC's Annual Report.

1) Fertilizer applications to improve seedling performance on a riparian site

The objective of this study is to test the effectiveness of fertilizer applications on the growth and survival of outplanted western redcedar *(Thuja plicata* Donn.) seedlings on a riparian site. Forestcote (Scotts Company) fertilizer (22-4-6 plus micronutrients) was applied to 1+1 western redcedar at the time of outplanting (February 25, 1997) at rates of 12g N and 20g N per seedling. Fertilizer was placed in the planting hole and covered with a layer of soil before the seedling was placed in the hole. In addition, there is an unfertilizer control.

Preliminary results indicate a significant increase in both height and stem diameter growth due to fertilizer.

2) Applications of foliar fertilizer with NuFilm 17®

Foliar fertilizers are seldom used in outplanting. Slow release products are usually preferred since they provide nutrients to the plant over time. Previous projects with herbicides showed that higher rates of NuFilm® may slow the rate of herbicide action. Therefore, we speculated that this could have application to foliar fertilization. The objective of this study is to test the effectiveness of foliar fertilizer applications on the growth and survival of outplanted Douglas-fir seedlings and to determine if NuFilm® can serve to slowly release the fertilizer. Two rates of fertilizer (18-18-18) in combination with two rates of NuFilm® were applied to 1+1 newly-outplanted Douglas-fir seedlings on March 19, 1997. In addition, there is an unfertilized control.

3) Effect of LiquiGroTM on conifer seedling performance in the nursery

This study is being developed in cooperation with Enviro-Ag, Inc. to examine the effect of LiquiGroTM, an organic fish fertilizer, on conifer seedlings. The objective is to determine if LiquiGroTM applications can be used as an alternative fertilizer for producing quality conifer seedlings. Two concentrations of LiquiGroTM are being compared to operational fertilizers at the Hood Canal Nursery (Port Gamble, WA) on transplant beds and container stock and at the Bend Pine Nursery (Bend, OR) on seedbeds.

Literature Cited

Bradford, G.R. 1966. Boron. pp. 33-61 In: Diagnostic Criteria for Plants and Soils. H.D. Chapman, ed. University of California.

Carlson, W.C. and C.L. Preisig. 1981. Effects of controlled-release fertilizers on the shoot and root development of Douglas-fir seedlings. Can. J. For. Res. 11:230-242.

Gleason, J.F., M. Duryea, R. Rose, and M. Atkinson. 1990. Nursery and field fertilization of 2+0 ponderosa pine seedlings: effect on morphology, physiology, and field performance. Can. J. For. Res. 20:1766-1772.

Green, R.N. 1993. Boron and magnesium fertilization of a coastal Douglas-fir plantation. West. J. Appl. For. 8:48-53.

Haase, D.L. and R. Rose. 1995. Vector analysis and its use for interpreting plant nutrient shifts in response to silvicultural treatments. For. Sci. 41:54-66.

Mitchell, R.J., H.E. Garrett, G.S. Cox, A. Atalay, and R.K. Dixon. 1987. Boron fertilization, ectomycorrhizal colonization, and growth of *Pin us echinata* seedlings. Can. J. For. Res. 17:1153-1156.

Stone, E.L. 1990. Boron deficiency and excess in forest trees: A review. For. Ecol. and Mgmt. 37:49-75.