Interaction of Initial Seedling Size, Fertilization, and Vegetation Control

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Introduction

It is not enough any more to plant trees and come back later to see if they are surviving. For all practical purposes on most sites, survival is a "given." The current issue is how to attain the greatest growth out of a seedling within the first few years after outplanting. "Green-up" laws in Oregon and Washington have made it necessary to prove that cleared lands adjacent to land about to be cut must have seedlings at specified sizes or ages before cutting can commence. This urgency is the impetus for seeking new and innovative ways to successfully reforest land.

The probable key to enhancing reforestation success is to successfully apply those combinations of silvicultural treatments that maximize conifer response. There have been several studies over the past few decades which have focused on one or another early silvicultural treatments. For example, studies focusing exclusively on the evaluation of different initial stock size and type (Rose, et al. 1991, Hobbs et al. 1989), or exclusively on the effect of weed control treatments (Tesch and Hobbs 1989, White and Newton 1989, Newton and Preest 1988). There are fewer examples of studies evaluating the interaction of separate silvicultural treatments.

This paper will detail the early results of a study initiated by the Vegetation Management Research Cooperative at Oregon State University. The study was designed to evaluate the interactive effects of initial stock size, weed control, and fertilization on Douglas-fir growth across several sites in Washington State. The objective of the study is to determine those combinations of these three treatments that resulted in the greatest early conifer growth.

Materials and Methods

Treatments. Twelve treatments were tested resulting from a 2 x 2 x 3 factorial treatment design. Two stock sizes, 2 vegetation control treatments, and 3 fertilizer treatments were tested for a total of 12 different treatment combinations (Table 1).

Stock Size. The appropriate nursery beds were randomly sampled to assess the diameter distribution of trees to be planted into the different study areas. A distribution curve was generated from this data for each site. From this data, two diameter groupings of 3 mm were identified (small and large), each separated from the other by at least 1 mm. At lifting the seedlings were sorted and separated into the different size groupings.

Table 1. Stock dimension, vegetation control, and fertilizer application treatments. There is also a zero fertilizer control treatment.

Fertilizer Treatments	none	year 1	year 1 and 2
Vegetation Control	years 1 and 2	years 1, 2, and 3	
Tree Size	small	large	

Vegetation Control. The two vegetation management treatments were complete vegetation control for two years and complete vegetation control for three years. The vegetation control was achieved by using pre-emergent herbicide applications (oust or velpar). The herbicide used varied by site. At sites where there were species resistant to the herbicide used, additional applications of either accord or garlon were used.

Fertilizer Application. Three fertilizer treatments were applied: a no fertilizer treatment, a one-year fertilizer treatment and a two-year fertilizer treatment. The fertilizer treatments consisted of a 70g teabag of Scott's slow release fertilizer, 10-22-6 formulation. The one-year treatment consisted of placing a fertilizer teabag in the hole at planting. The two-year treatment included the first year treatment plus a dibbling of the same fertilizer

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teabag formulation in the winter following the first year of growth. The fertilizer was formulated from Scott's Forestcote fertilizer, with coated MAP and uncoated triple super phosphate. Each tree receives 7g N, 15.4g P_2O_5 and 4 g K_2O_4 from each year of fertilization. The fertilizer used had an eight-month release period.

Plot Size. Each plot contained 36 seedlings planted on an 8 ft by 8 ft spacing. The study has 12 plots per block requiring 432 treatment seedlings for each block. Each plot is surrounded by a buffer row of trees. The number of buffer trees required varied depending on plot layout. Installation of a minimum of four blocks of the 12 treatment plots was required and if possible five blocks was preferred. The installation of five blocks required a minimum of six acres of land and 2,160 treatment seedlings and approximately 1,300 buffer trees.

Replications of the above experimental design were installed on three sites in Washington State, here after referred to as the Belfair, Rainier, and Randle sites. The Belfair and Rainier sites were installed in spring of 1997 and have completed three growing seasons. Randle, the third site, was installed in spring of 1998 and has completed two growing seasons.

The Rainier site is located at an elevation of 1700 ft on the western slope of Mt. Rainier. Site index is 123 ft (base height 50) and the soil is a deep, relatively well drained loam. The site was harvested the spring prior to the study installation and slash was piled and burned. Only enough suitable ground on the site was found to install four complete blocks of the 12 treatments instead of five as on other sites.

The Belfair site is located on a glacial outwash soil near the Puget Sound, east of the Olympic Mountain Range, and has dramatically poorer soil conditions than either of the other Douglas-fir sites. Additionally, the entire site was heavily compacted by machinery during harvest. Fifty-year site index is approximately 107 ft.

The Randle site is located in the western Cascades 15 miles south of Randle, Washington. This study site was installed in 1998 one year later than the other two sites. Fifty-year site index is approximately 120 ft. This site received a deep Mt. St. Helens ash deposit in the early 1980s. The upper horizon of soil contains an ash layer of approximately 6-8 inches. Elevation is 2000 ft.

All three sites receive between 50 and 65 inches of rainfall per year with the majority of this rain falling in the winter months. Long periods of summer drought are common at all three sites.

Height, caliper and deer browse has been assessed in the fall for every tree since the studies were installed. Stem volume was calculated as the volume of a cone using the caliper and height measures. Analysis of variance was used to assess differences among treatments in mortality, caliper, height and deer browse using a factorial modeling scheme.

Results

No significant interactions were found among any of the experimental treatments at the Belfair and Rainier sites. At Randle, a marginally significant interaction between initial seedling size and fertilization was observed ($p=0.06$). Seedling stem volume response to fertilization tended to be greater for large seedlings than small seedlings. This interaction was not evident when diameter, height or mortality were analyzed.

Seedling mortality did not differ between the small and large caliper seedlings at either the Belfair or Rainier sites (Figure 1). At Randle, mortality was significantly greater for small caliper seedlings than large. The larger caliper seedlings continued to have larger caliper, height and stem volume after two and three years of growth at all study sites.

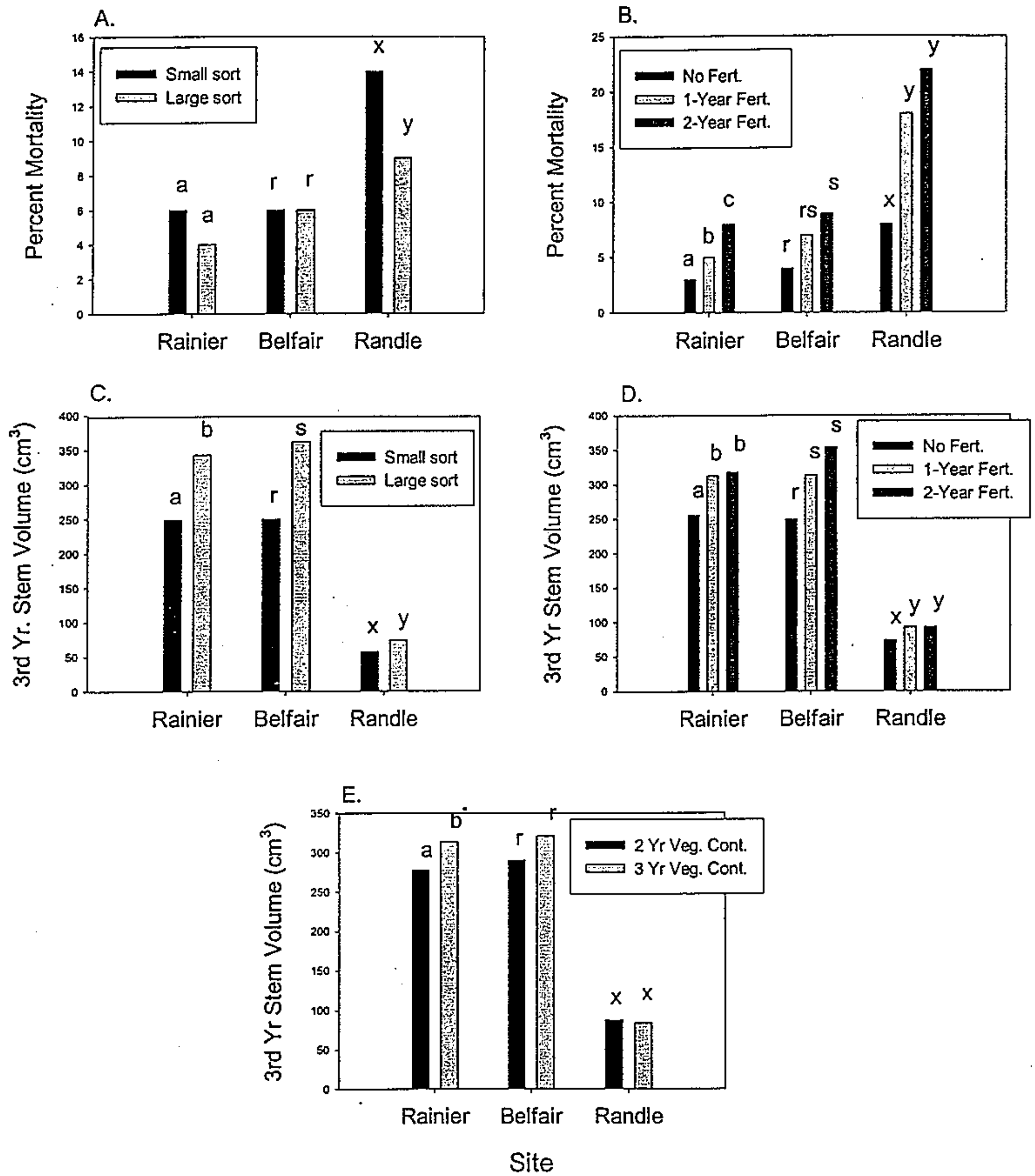

Figure 1. *Differences in third year mortality percentage and mean stem volume by initial caliper sort class, fertilization treatment, and vegetation control treatment for each study site. Bars associated with the same letter (a,b,c; r,s; or x,y) by site are not significantly different ($p \leq 0.05$). If a letter is associated with an * the significance level is $p \leq 0.1$.*

Fertilized plots had greater levels of mortality at all three sites. This was most evident at the Randle site with mortality in fertilized plots being two to three times that of unfertilized sites (Figure 1). At Belfair and Rainier mortality increased but only slightly, 2-5 percentage points. First-year fertilization treatments increased seedling size (caliper, height and stem volume) at all three sites. No growth response was observed for the second-year fertilization treatment at any of the sites.

An additional third year of vegetation control resulted in an increase in third-year stem caliper at the Belfair and Rainier sites. Stem volume and height did not exhibit similar gains. Results at Randle are inconclusive because this site has not received its final year of vegetation control.

Trends in Data

Differences in initial caliper have expanded with time. At the time of planting, differences in caliper between the two size classes was 2.2 mm and 2.1 mm at the Belfair and Rainier sites respectively. By year three, these differences have enlarged to 4.6 mm and 3.2 mm, respectively (Figure 2). Fertilization in year one resulted in an average increase in seedling caliper of 3.1 mm and 1.5 mm in the first year for Belfair and Rainier, respectively. This difference has maintained itself and by year three remains nearly the same. It is still too early to evaluate trends in growth resulting from the weed control treatments.

Planting seedlings with larger calipers has resulted in the largest third year gains in seedling caliper size (35-45% depending on site). First-year fertilization resulted in a 22-35% stem caliper gain, and the third-year weed control treatments a 10-12% gain. The second-year fertilization treatment did not result in any additional seedling growth.

Discussion

Douglas-fir seedlings responded in an additive manner to the three different treatments applied in this study. This suggests that each treatment is affecting growth independently from the others. The greatest gain in growth resulted from planting seedlings of greater caliper. Fertilization was the second most influential treatment followed by the third-year weed control treatment.

The methodology used to sort seedlings into separate caliper classes may have resulted in an additional level of confounding. Sorting could have separated the most genetically superior trees into the large caliper group. The sorting process may also result in seedlings of superior physical and physiological vigor being concentrated in the large sort class. It is unclear from our results if gains measured due to larger caliper class are due to larger caliper or result from enhanced genetics and physical attributes. However, there is abundant scientific literature suggesting larger planting stock generally will outperform smaller stock (Rose et al. 1991, Wagner and Radosevich 1991).

Our results suggest dibbling is not as effective in eliciting a fertilizer response as placing fertilizer in the hole at the time of planting. The lack of any significant increase in seedling growth resulting from the second-year fertilizer treatment supports this statement. The first-year treatment was accomplished by placing the fertilizer in the hole at planting, while fertilizer was dibbled adjacent to the seedling in the second year. Fertilization in the hole at planting puts the nutrients within easy reach of seedling roots. Dibbling may not provide such easy access. For conifers to utilize fertilizer applied as a dibble they need to grow roots into the fertilized zone or nutrients need to flow via soil solution nutrient gradients to the seedlings. Dibbling only increases fertilizer availability in a small slice of the total volume of soil in which roots grow out from the seedling. Consequently, the potential for dibbled nutrients to be utilized by seedlings is low as compared to in-the-hole applications. Foliage nutrient data (not shown) further supports that seedlings did not acquire additional nutrition from the dibbled fertilizer.

Other investigators have evaluated in-the-hole versus dibbling as a methodology of fertilization and results have varied (Ballard 1978,Carlson 1981, Carlson and Presig 1981). Brockely (1988) does a good job of summarizing these studies and suggests that either fertilizing in the hole or dibbling if done very close to the seedling both have potential. However, if in-the-hole fertilization is used, Brockley (1988) suggests using slow-release fertilizers to minimize the potential for toxic salts to build to the point seedlings are killed.

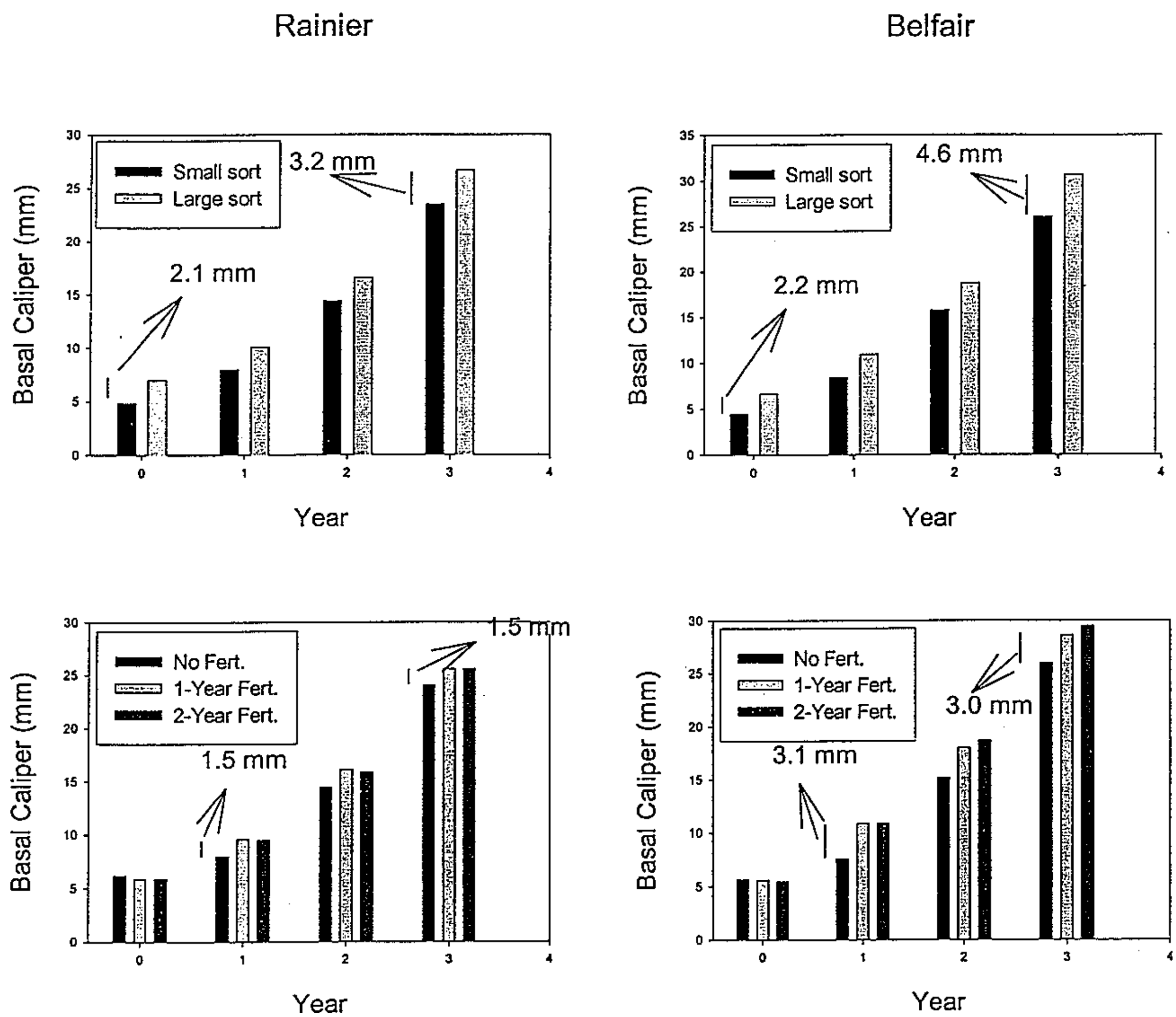

Figure 2. *Mean differences in basal caliper between sort size and among fertilizer treatments at the Rainier and Belfair sites for each year since planting. Note that the original difference in basal caliper at planting between the large and small sort classes has expanded. Conversely, the initial gain in year one from fertilization has remained the same with time.*

First-year fertilization increased seedling mortality across all sites. This increase was slight at the Rainier and Belfair sites, but large enough to be of concern at Randle. Due to a thick volcanic ash layer, accumulated in the early 1980s from eruptions of Mt. St. Helens, soils at Randle are extremely low in cation exchange capacity (CEC). Soils with low CEC have less nutrient buffering ability and consequently toxic levels of fertilizer salts can build more quickly in such soils. We suspect toxic salt concentrations resulted in the higher percentage of mortality observed in fertilized plots at Randle. This suggests that on other similar low CEC sites less fertilizer should be used.

Growth response to an additional third year of weed control was not large at either the Rainier or Belfair sites. Response to weed control treatments tend to increase in magnitude over the first several years after treatment, and the response to the third-year treatment in this study may continue to influence growth into the next year (Newton and Hanson 1999).

One of the more interesting findings in this study is that early gains using larger seedlings have magnified with time. A 2 mm difference in initial caliper has increased up to a 3 to 4.5 mm difference depending on the site. Conversely, gains from first-year fertilization have not increased with time. A 1.5 mm difference in stem caliper after one year is still a 1.5 mm difference after three years in fertilized plots. This suggests that gains from these two different silvicultural treatments will eventually have different long-term impacts on tree growth.

If the above trend continues, it suggests that monetary resources should be first put towards planting large caliper seedlings and then to treatments such as fertilization or unusually aggressive weed control treatments. It should be noted that all the treatment plots received a minimum of two years of weed control. Conclusions about investments of large stock versus one or two years of weed control cannot be made from this study.

Differences in growth from early vegetation control treatments tend to continue to expand for several years after the initial treatments and behave much the same as has been observed for growth gains due to greater initial seedling size. It is not clear why gains from early fertilization do not result in a similar pattern of growth and raises a question for future research. More research evaluating the interactive effects of more than one early silvicultural treatment is needed. Other factors that could be investigated include comparing the effect of genetically enhanced stock, soil tillage, storage time, planting date relation, container versus bareroot stock all in relation to fertilization and weed control. Such studies will provide foresters with information on combinations of silvicultural treatments that could be expected to provide the maximum benefit.

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