Vegetation Management and Seedling Fertilization: Factors Influencing Growth Response

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Introduction

Fertilization is a common silvicultural practice used in young to mature stands to enhance growth. In the past fertilization during regeneration has rarely been done, principally because nutrient deficiencies are generally not obvious in most regeneration settings and the response to broadcast fertilization has not been consistent. It is not surprising that without the assurance that fertilization is going to have a positive effect foresters have been reluctant to aggressively fertilize at the time of planting. Why has past seedling fertilization resulted in such variable results especially since fertilization in mature stands consistently results in growth gains?

In forest nursery operations fertilization has resulted in marked increases in seedling growth and has allowed for the production of larger, more vigorous seedlings in a shorter period of time. Why do we see such large consistent responses of nursery seedlings to fertilization and not see these same responses in young trees in the field? It is apparent that in regeneration environments eliciting a consistent response to fertilization poses a significant challenge. It is the goal of this paper to outline the basic physiology that limits response to fertilization in the field and to help foresters build a mental framework of how field fertilization and other silvicultural treatments interact. With this knowledge foresters can determine if fertilization is a viable option in their respective regeneration decisions. These goals will be accomplished by first describing a VMRC research project and relating the results to other relevant research. Then factors such as fertilizer application and formulation will be discussed relative to the regeneration environment.

Herb II

The VMRC is currently conducting a study in which we have systematically manipulated the area of vegetation control around seedlings; termed the Herb II study. One half of the seedlings in this study have been fertilized and one half have not. The fertilization treatment consisted of 2 fertilizer briquettes placed in the bottom of the planting hole. The combined briquettes are considered an 11-6-4 formulation delivering 4 grams of N, 2 grams of P, and 1.2 grams of K. The briquettes are complete slow release fertilizers delivering nutrients over a period of 2 to 3 years. A layer of dirt was scattered over the briquettes before the seedlings were planted to prevent root burn.

Vegetation control treatments consisted of a no vegetation control check treatment, a 2 ft. radius treatment, and a 3 ft. radius treatment. Initiated the spring of planting, the radius treatments were achieved with spot herbicide applications and maintained for two years. We currently have 5 replications of this experiment on 5 different sites with 4 conifer species. Two of the sites were planted in the spring of '95 and the other three in the spring of '96. Each site is a stand-alone study consisting of 4 replications of 6 treatments (24 treatment plots in total per site) applied in a fully randomized design at operational spacing. The five replications of this study design have been installed over a wide range of conifer habitats (Table 1). The sites in Table 1 have been arranged from the best site to the worst in terms of the site characteristics relative to the specific species planted on them. For example, redwood requires moist sites in the fog belt to grow best. The Korbel

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site is on a southern exposure on the eastern edge of the fog belt. This site would be considered good Douglas-fir ground but only marginal redwood ground, thus it is considered a dry site in terms of redwood growth.

Table 1. Site and Description of Herb II Replications.[1]

Replicate Name	**Tree Species**	**Site Description**	**Growing seasons since planting**
Seaside	Western Hemlock	**Excellent:** Very Moist Coastal Site, NW OR	2
Vernonia	Douglas-fir	**Good:** Typical Coast Range site, NW OR	3
Klickitat	Ponderosa Pine	**Good:** Good Pine Site Poor Douglas-fir, Eastern WA	3
Drain	Douglas-fir	**Dry:** Southern Exposure Coast Range Site, Central OR Coast Range	2
Korbel	Coastal Redwood	**Dry:** Southern exposure poor Redwood but Good Douglas-fir site, N. CA.	2

[1]*Site quality (excellent, good, and dry) are relative to the site index and species planted. For instance, a dry redwood site would be considered a good Douglas-fir site and possibly an excellent pine site.*

All the sites were planted with transplant 1+1 or p+1 seedlings. Stem volume was calculated from height and caliper measurements and is considered our best measure to illustrate treatment differences.

Results and Discussion

Soil Moisture and Fertilizer Response: Our results suggest that if seedlings are to respond positively to fertilization good vegetation control is a must. When the data from all five Herb II sites is combined, increased volume growth is observed with increased radius of vegetation control for both the fertilized and unfertilized treatments (Figure 1.f.). With no vegetation control (check), there is no additional growth response to fertilization. A 2 ft. radius of control and fertilization increased stem volume by 25 % over the same radius of control with no fertilization. In the 3 ft. radius treatments stem volume was enhanced even more, being 42 % greater in the fertilized versus unfertilized. Over all, 3 ft. radius of vegetation control and fertilization resulted in an 177 % increase in stem volume over the untreated check. These results support those of Power and Ferrel (1996) who observed increased ponderosa pine growth when sites had been fertilized and received weed control but variable response to fertilization in the absence of weed control. However, it should be noted that these Herb II results are generalizations made from pooled data across all 5 sites which consists of 4 different conifer species, results at each individual site are not as statistically distinct (Figure 1. a., b., c., d.).

Fertilization and weeding increased growth over that of weeding alone on all 5 sites suggesting that nutrients are limiting on all of the sites. Seedlings absorb nutrients in solution with soil moisture. For this reason plants that are facing moisture stress are also facing nutrient stress (Powers and Ferrel 1996, Nambiar and Sands 1993). Moisture is often the most limiting factor in regeneration environments in the Pacific Northwest due to regionally dry summers, and competition from quickly invading vegetation. Vegetation control increases the level of available moisture to planted conifers and, subsequently, seedling growth (Stewart et al. 1984). Because there is an interaction between soil moisture and nutrient absorption, it is difficult to separate the relative influence of competition for moisture and competition for nutrients on most PNW sites. Regardless, fertilizing weeded sites insures that planted seedlings can exploit fully the advantage that more readily available soil moisture gives them.

Powers and Ferrel (1996) observed that on their best 3 of 8 sites (highest site index) fertilization resulted in a ponderosa pine growth response even in the absence of vegetation control. They concluded that as an operational treatment fertilization would have the greatest success on highest site indexes. Herb II results loosely support this conclusion with fertilizer response being slightly more apparent on the best sites. Herb II was installed using 4 different conifer species over a variety of sites. For the sake of discussion each site, relative to average rainfall and the conifer species

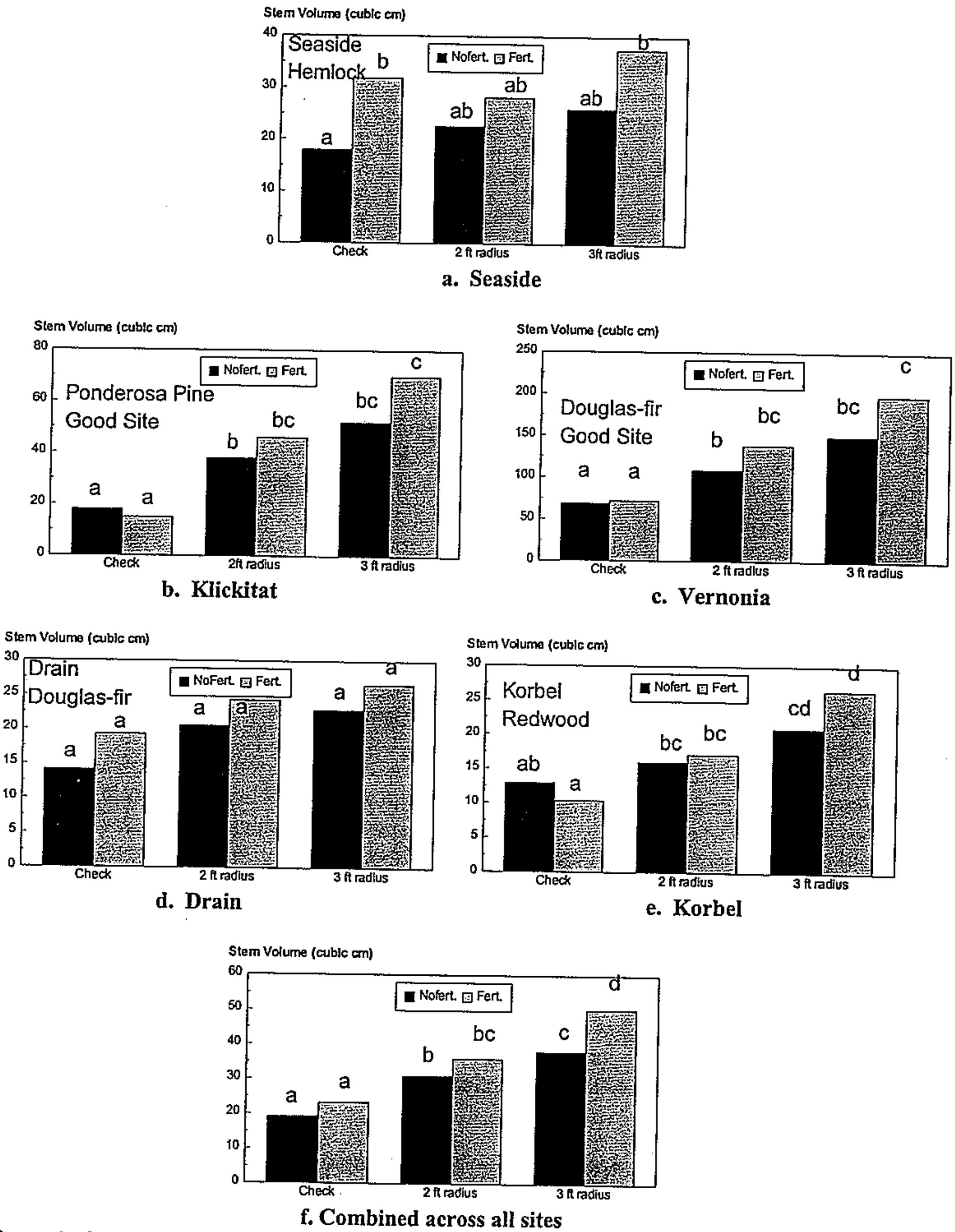

Figure 1. Stem volume means for all 5 sites across all six treatments. Bars associated with similar letters within a graph are not significantly different ($p \leq .05$).

planted, has been classified as either "dry," "good" or "excellent" (Table 1). The fertilized 3 ft. radius treatments resulted in significantly greater stem volume than the untreated check at all 5 sites regardless of site classification (Figure 1). Only on the "excellent" site (Seaside) did the fertilized check treatment not differ significantly from the fertilized 3 ft. treatment. Additionally at the "excellent" site, mean stem volume in the fertilized check treatments was nearly double that of the unfertilized check, suggesting that on "excellent" sites fertilization may result in volume gains. However, the difference between the check treatments was not significant with variability being unusually high across this site. Additionally, the Seaside results are somewhat confounded because vegetation was slow to invade and the radius control treatments had less influence on this site than on the others. Consequently, it is difficult to determine if fertilization in the absence of vegetation control resulted in a growth response or not. On the other four sites, differences in the stem volume means for the check fertilized and unfertilized treatments differed little. This suggests that even on relatively "good" sites a certain level of vegetation control will be necessary to illicit a positive growth response from fertilization in the year of planting.

Other Factors Influencing Fertilization Success: Too often we, as foresters, talk about fertilizer and fertilization in a very general sense. We discuss a fertilizer treatment without really discussing what we are going to fertilize with and how we are going to apply it. Fertilizers come in a variety of formulations, plant availabilities, and are applied in a variety of ways, all of which can have a profound effect on the success of a treatment. Probably the most commonly used fertilizer in the PNW is urea. This is a soluble fertilizer which supplies only nitrogen to the plant. Urea's advantage over others is that it is cheap and historically has produced positive results, at least in older stands. Because it is soluble, thus very mobile in the soil, the period of increased nitrogen availability is short lived especially in high rainfall areas. This is not a big issue in mature stands because trees dominate most of the rooting zone and are in position to exploit the majority of urea applied. In regeneration settings, trees occupy a very small proportion of the rooting zone and can take advantage of only a fraction of any fertilizer broadcast. It is especially unlikely that newly planted seedlings will derive much benefit from broadcast urea applications, because much of the nitrogen supplied will be leached past the rooting zone through the next rainy season.

Another problem with broadcast applications of fertilizer in regeneration settings is that they are not target specific. Herbaceous weeds and grasses often can take quicker advantage of fertilizer broadcast than planted conifers. Herb and grass root systems are generally closer to the soil surface and often occupy a greater soil volume than newly panted trees. In some instances broadcast applications can actually enhance competition by fertilizing the weeds (White and Newton 1990, Roth and Newton 1996). The end result is a decrease in growth versus the desired increase.

Broadcast fertilizer applications can also potentially reduce herbicide efficacy. In a recent VMRC study, we performed a broadcast application of urea to test whether hexazinone efficacy could be enhanced. The theory being, faster growing weeds would absorb more herbicide resulting in greater herbicide effect at lower rates. Our results indicated that broadcast applications of 200 lb./acre of urea resulted in less control efficacy at low to moderate rates of hexazinone (1 to 1.5 lb. ai/acre) than in the absence of urea. At higher rates of herbicide (2 to 3 lb. ai/acre) urea had no influence on herbicide phytotoxicity. Thus, the application of fertilizer, in this case urea, actually reduced the effectiveness of moderate rates of hexazinone and subsequently increased competition faced by planted conifers.

Applying fertilizers directly to conifers either in the planting hole or by dibbling into the rooting zone is recommended to insure that fertilizer gets to its target. However, adding fertilizer directly to the planting hole brings up the issue of the type of fertilizer to be used. Readily soluble fertilizers can kill conifers if they are in direct root contact. This is especially the case under dry conditions. Most of these fertilizers consist of soluble salts and at low soil moisture these salts can be at lethal levels. A layer of dirt should always be put between roots and any added fertilizer. A better option has become available in recent years, especially for dryer climates. A number of new slow release fertilizers have come on the market which have less potential to burn roots because they slowly release nutrients such that toxic concentrations do not build up. The first generation of these used slowly soluble forms of urea which released nitrogen in the presence of moisture. More recently, polymer or resin coated products have come on the market which are available in a variety of release timings for 3 months to two years. These new products are heat activated. After warming to a certain temperature, they begin to release nutrients through cracks and pores in the coating. Although they don't directly require high levels of moisture, they will be ineffective unless soil moisture is high enough for released nutrients to go into solution. In addition, if applied on the soil surface they require rain to move nutrients down to the rooting zone.

Timing and placement of slow release fertilizers is important. The cost of these fertilizers generally makes it prohibitive to broadcast apply them plus we have already mentioned the potential problems with broadcast application. Those fertilizers which require water to release should be applied in late fall or at a time in which plentiful moisture is available. This is especially the case if they are applied at the soil surface near the base of the seedling. We recommend either putting the fertilizer in the planting hole or dibbling into the rooting zone. This keeps the fertilizers in a moist environment close to the rooting zone maximizing the potential for the fertilizer to be released. When released, nutrients will be in close proximity to the target conifer.

The final fertilizer consideration is what formulation to use. There have been entire text books written on this subject and I doubt we have all the answers yet. What is readily apparent in the PNW is that of the macro nutrients, nitrogen most consistently results in a growth response. However, the growth response to one nutrient is often influenced by the availability of others. For example, fertilizing with nitrogen on sites where phosphorus is unavailable may result in little growth benefits; phosphorus would be considered limiting in this case. Complete fertilizers reduce the likelihood of such an occurrence. Complete fertilizers contain all the macro and micro nutrients essential for plant growth. They come in a myriad of different nutrient combinations with some potentially working better on some locals than others. One formulation that will achieve good results for all sites likely does not exist. In using complete fertilizers, make sure they contain both macro and micro nutrients. The amount of fertilizer used per seedling, of course, is another important factor. In the Herb II study a fertilizer delivering 4 grams of nitrogen and 1.2 grams of phosphorus plus potassium and micros was used. We suspect that the amount of nitrogen and phosphorus delivered to our seedlings was on the low side. In a more recent experiment we have doubled the amount of nitrogen per tree and added approximately 15 grams of phosphorus. Thus far, results have been very encouraging. However, there is a great deal of research that needs to be done to appropriately match different sites with the most appropriate fertilizer formulation. Foresters interested in fertilization should spend some effort testing different formulations before jumping in with both feet.

Conclusions

Some basic guidelines for early fertilization of regeneration sites are:

1. Without good vegetation control a response to fertilization is unlikely except on the best sites.
2. Avoid broadcast applications because they are not target specific and may result in growth losses versus gains.
3. When possible, apply fertilizer directly to the target seedling by either adding to the planting hole or dibbling into the root zone. Be sure to always keep a layer of soil between fertilizers and newly planted seedlings.
4. Use complete fertilizers making sure that all the macro and micro nutrients essential for growth are included.

5. Fertilizers should be applied in late fall or winter to capitalize on abundant soil moisture.
6. Experiment with fertilizer formulation and amount delivered to seedlings before adopting large-scale fertilization projects. A minimum of 4 grams of nitrogen per seedling will likely be necessary on most soils to illicit a response.

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