INTEGRATING STOCKTYPE, FERTILIZATION AND COMPETING VEGETATION CONTROL IN REFORESTATION DECISIONS.

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ABSTRACT

The primary focus of this paper is to discuss the integration of stocktype, fertilization, and vegetation management. To achieve successful results it is vital to understand the scientific links all along the path. It is not possible to expect even the best seedlings to over come heavy weed competition any more than it is valid to assume fertilizers will make up for poorly executed herbicide treatments. Achieving environmentally sound and excellent results the first time every time is going to become a major reforestation objective in forestry in the next century.

An Overview of Forestry in the Pacifc Northwest
Well over a decade ago I worked in the South for Westvaco Corporation in Summerville, South Carolina where Jack Gnegy was doing some inovative research in the area of vegetation management. Getting seedlings to grow as quickly was just as important then as I am sure it is now. Having been all over the South and visited many nurseries I was intimately aware of how important loblolly pine was. But, then I went West to Oregon to take over the Nursery Technology Cooperative at Oregon State University. I quickly discovered that the concepts (i.e. plant moisture stress, photosynthesis, and depth of A horizon) I'd studied and learned in the South were very applicable to western forestry, be it in the coast range, Cascades, or the high desert.

Since few of you are likely to have dealt with the "culture shock" of going from sweetgum and loblolly pine to Douglas-fir and ponderosa pine, I thought it best to ever so briefty explain the major differences between here and there. Aside from a general lack of humidity in many parts of the west, the near absence of "bugs" in most places, big timber, and snow capped volcanoes, there are considerable differences in reforestation practices between (what I'll call) Southern pine reforestion and Pacific Northwest reforestation.

Here is a synopsis of some major differences* in reforestation:

South	PNW
Small 1+0 planting stock	Large 1+1 planting stock is common, but there are a myriad of other stocktypes
Ground slopes a bit in places , wet to dry ground, soil variation goes from sands to clays	Flat to very steep slopes, highly variable terrain from dry to wet, soils vary greatly due to past volcanic eruptions and mudflows
Few social negatives associated with herbicides and fire	Major social negatives associated with herbicides, fire, and roads

*please forgive the gross generalizations!

What about vegetative competition? Having worked in both areas for extended periods of time it would be objectionable to me to suggest one area is more severe than the other. A severe blackberry thicket in the Coast Range of Oregon on a steep slope with fertile soils can be just as problematic as a wet heavy clay site filled with thickets of sweetgum, sedges and palmetto on the coast of South Carolina.

We are unified as foresters by the fact that while our specific reforestation concerns may be different there are a great many commonalities. We certainly share the same objective of trying to get seedlings to grow successfully and quickly toward rotation age.

Purpose
The primary focus of my talk today is to discuss the integration of stocktype, fertilization, and vegetation management in a way that maybe some of you have not thought of lately. We as a profession pay a lot of attention to these three factors, but we do not push hard enough toward their integration. Even in our research I am surprised to see vegetation management studies done where the purpose is to test different herbicides to control vegetation, but little or no regard is given to the quality of seedlings planted. In such studies the seedlings almost seemed ancillary to the purpose, yet it was the seedlings which were the primary factor by which the hypotheses were to be tested. We have tried to take the mathematical route to reforestation success by attempting to build models to explain seedling and vegetation response. This, too, has not been terribly successful because we are dealing with very complex biological systems where so many factors are confounded with one another and too often the modeling equations are used far beyond their capabilities. I can not tell you how many times I have heard silviculturalists complain about the short comings of this or that model. This talk is about integrating as best we can while keeping a sense of rationality about what is possible and what is not.

The Issue
A good deal of research has been done on improving the quality of seedlings in the Pacific Northwest in the past 10 years. We have seen a movement away from the traditional 2+0 seedling into much better stocktypes such as the 1+1 and the plug+1. Over the past two decades we have seen an interest in fertilization go up and down with the economy.

If money is tight, plant the seedlings and move on. If profits are up, fertilize. For the past three decades researchers such as Dr. Michael Newton at Oregon State University and others have contributed a wealth of information to our library of knowledge about controlling competing vegetation to establish and grow trees on a myriad of sites.

Over the years we have learned a great deal. Through study, observation, and experience we have learned a number of concepts about how to successfully establish tree seedlings on cut over ground. (1) Larger seedlings do better than smaller seedlings (Newton et al. 1993). (2) Reducing competing vegetation increases the amount of light and water available to the seedling (Stewart et al. 1984). (3) Fertilization seems to work...some times. Certainly, we have learned a lot more than these simple statements, but we have also learned two major notions about successfully planting trees. These are:

1) Reforestation environments are very complex. In the beginning they did not seem very complex because we mass herbicided them or raked, chopped, slashed, wind-rowed, and burned them. The advent of stricter environmental laws has meant a reduction in the use of herbicides in many areas and often the near elimination of fire due to smoke management rules. The reforestation working environment is currently more complex than ever before because we must navigate both environmental and legal "thunderheads" of opportunity.

2) Integration and innovation are our only real hope for continued reforestation decision making. It is becoming ever more common for us to improvise and invent ways to mediate our reforestation difficulties whether it be trying to reforest an area over looking a scenic highway, getting trees to survive on dry steep slopes, or planting 4 foot seedlings in dense brush where herbicides are not allowed. More and more a sense of timing and professional knowledge of the situation play an important role in success.

Stocktype

As we all know a stocktype designation tells us very little about the growth potential of a seedling. The designation 1+1 tells us it was bareroot, grown for two years, and transplanted at the beginning of its second growing season. We know nothing about either its morphological quality much less its physiological quality.

Over the years it has been very surprising to me that foresters have had such difficulty coming to grips with standards for seedlings. A seedling is a commodity like any other product such as logs or plywood. Seedlings are graded primarily to meet certain minimums. We would do well to put more of what our research tells us about seedling quality into contracts. In fact, the Phipps and Stone nurseries in Oregon will soon have computerized grading machines which can grade seedlings for height and caliper. This is the Target Seedling Concept in action.

Morphological Quality

Height and caliper have been the mainstays of the reforestation business for about 70 years. We have learned over the years that height at planting per se is not all that reliable in predicting future success (Mexel and Landis 1990). Some have valid disagreements with this point, but overall height is not that useful. Caliper on the other hand has been quite useful largely because it is related to both height and root mass. We do know that the larger the root volume the better seedlings will perform (Rose, et al. 1991). In the South in the 1980s Bill Carlson at Weyerhaeuser and Burdett in Canada did some very nice work with root volume. Here in the west reforestation supervisors began to figure out empirically that the larger 1+1 seedlings simply did better under even the harshest conditions. The container industry has never been as large in the PNW because bareroot seedlings can have such massive root volumes, going far beyond what can be developed in a container. However, even now there are Canadian container operations that have caught on to the need to grow larger root masses and have gone to huge cavity sizes.

There is not enough space here to go into all of the morphological parameters of tree seedlings. Consider that a seedling grower and a planter should train their eye to look at height, caliper, color, root volume, shoot volume, number of branches, number of first order laterals (roots), branch distribution, mycorrhizae, root suberization, stem form, root form, root length, needle length, needle density (needles per unit length), and stem lignification (stiffness) (Duryea 1985). The point is that all of these factors need to be integrated into programs aimed at improving seedling growth performance where fertilization and vegetation management are concerned.

Physiological Quality

Most foresters know next to nothing about plant physiology even though Phil Wakeley had a lot to say about it as far back as 1949! By the time foresters head for a job they've largely forgotten much of what they learned about plant physiology from freshman botany. Unfortunately, undergraduate forestry training focuses very heavily on silviculture and many-a-forester got only marginal mention of reforestation in a silviculture course.

Physiology is where the pay off is and I can not stress this enough. We have disciplines like physiological ecology, physiological genetics, hormone and carbohydrate chemistry because these are the gateways to our understanding of the how and why of growth responses. The mode of action of herbicides and seedling responses are explained by physiological principles. The vegetation response models and other attempts at explaining competition are too often frustrated because they have no way of accounting for physiology.

In the Pacific Northwest Drs. Hermann and Lavender of Oregon State University did some wonderful work years ago on cold hardiness. This work turned out to be a turning point for all of us in that we could better understand how to handle seedlings after lifting. In many areas it is vital to have seedlings with LT50s (lethal temperature 50%) of at least -15C. This is the temperature at which 50% of the seedlings die at -15C. When seedlings are cold hardy they are at rest and then they move into a stress resistance phase. In fact, we plant trees in this stress resistance phase of the dormancy cycle. When seedlings are not physiologically prepared they too often succumb to "mysterious" mortality leading to speculations as to sensitivity to herbicides sprayed after planting, frost pockets, bad planting, and many other unsubstantiated rationales. It is important at this point to pay homage to Phil Wakeley who first brought the importance of physiogical quality to our attention in 1949!

A critical aspect of seedling survival soon after planting is the production of new roots. The production of new roots can take anywhere from 5 to 35 days depending on conditions. Bareroot seedlings will not take water until they have produced new white root tips. Suberized container seedling roots do not take up water until they produce new white root tips. This production of new roots is all driven by physiological quality factors like dormancy, carbohydrates, auxins, water, and nutrients (Duryea 1985). Off-cycle phenology is a common problem in containers and can be the reason some lots will just "sit there" and do nothing after planting. The point is that all of these factors need to be integrated into programs aimed at improving seedling growth performance where fertilization and vegetation management are concerned.

Fertilization

Fertilization has a long history in forestry going back two decades at least. Many studies have been done using different agricultural formulations of fertilizer. Fertilizer has been broadcast around the seedlings at the drip line and pellets have been stuck in the ground next to the seedlings or in the hole at the time of planting. Results have been mixed.

Forest fertilization has always been one of those promising techniques waiting for our scientific knowledge of plant physiology and the technology of fertilizer manufacture to catch up. Some foresters have generally felt it was not worth the time and especially the cost to fertilize trees because the responses were poor, it was an added cost, and soil fertility did not seem to be a major problem. Some also have questioned if the long term effect could be justified since the growth advantage seems to wear off in time.

All too often the effects of early fertilization have been confounded with the response of competing vegetation. Broadcast application can actually make a bad competition situation worse by fertilizing weeds and putting seedlings at an even greater disadvantage. From a research perspective we are faced with trying to determine the direct influence of the fertilizer on the target seedlings and the indirect influence of fertilized competing vegetation on those same seedlings. Such indirect effects can be extremely complex and difficult to impossible to assess.

In reviewing forest fertilization research I have always wondered why more work was not done to analyze the trees for actual uptake. Many foresters seem to think that growth is the only parameter needed to be measured to determine if the fertilizer is working or not. In my own work I have seen very nice fertilizer uptake, yet gotten poor statistical results for height. The fertilizer effect may be statistically significant, but the growth is hardly biologically note worthy much less economically worth the trouble. Without nutrient analysis of the trees the forester is never actually sure what is happening physiologically. Did the tree take up the fertilizer? If not, why not? If it did, what is the explanation for the poor growth? Sometimes there is a delay in response and the growth comes later.

I have even heard that Douglas-fir as an example does not seem to need fertilizer after planting. Some have suggested that the soils seem to mask the effect of fertilization. If this is the case then why are we putting on so much fertilizer in our nurseries to produce those massive root systems and that dense green luxuriant foliage? Does anyone know of a grower of any species who produces top quality trees without fertilizers? If our plants respond so well to fertilizers in the nursery, why are we so hesitant to fertilize them in the field?

One of the much over looked and poorly understood aspects of seedling fertilization and growth is what happens to seedling nutrition between that final year in the nursery and months after outplanting. In most cases there is a drop in seedling nutrition across the board. The field equilibrium for nutrients in the plant drops from that in the nursery where soil nutrient and moisture levels are high. Even in the presence of fertilizer the nutrition can drop off. Why? Largely it is due to a lack of water. No water. No uptake. To give you an idea of how crazy this can be, I once over fertilized some loblolly pine seedlings with urea and triple superphosphate. The trees turned yellow - a very bright yellow! However, something went right because by the next year they were out growing everything around them by a wide margin! What may have happened was they suffered toxicity due to a lack of water, recovered from the toxicity along with a positive mineralization of the fertilizer in the soil, and eventually corrected their internal balance. The result was some unknown optimum internal balance of nutrients that accelerated growth the following spring.

There is also the problem of how much and what kind of fertilizer to use. There are exciting new slow release fertilizers on the market which offer an endless array of choices. If the summer environment cooperates and water is made available there is no doubt in my mind that the matching of quality fertilizers will greatly enhance tree growth just as it does in the nursery. My sense is that we need to figure out how to keep the seedlings near their optimum nutrition after outplanting and attempt to modify the drop to a new nutrient equilibrium. It is interesting that after one growing season many trees will actually recover to nutrient levels comparable to the nursery, but by then a lot of growth has been compromised and the weeds are starting to have an impact.

Vegetation Control

There is no need for me to lecture anyone in this room on the need for vegetation control whether it be by fire, herbicides, or some other way. Everyone here knows that reducing competition from weeds can sometimes exponentially increase seedling growth (Wagner et al. 1989). Some of the more interesting recent facts have been that controlling early herbaceous weeds may be much more critical than previously thought in some areas (Rose and Ketchum unpublished data). Up to certain limits actively trying to control shrubs may be a waste of effort since in some cases the shrubs constitute a small threat to growth and yield.

One of the more interesting statements I have heard is that maybe we do not need to control quite as much as we think. The theory goes that as vegetation control goes down growth goes up. The relationship is inverse. When plotted on a graph the lines cross. Somewhere down on the growth line, say 75% competition control, tree growth as judged by some still seems acceptable. The question arises that maybe we should just leave more weeds and take the lesser growth. It all depends on your objectives. A 40 year rotation forester thinks a whole lot differently from a 300 year rotation forester.

It is interesting to me that with all of the theories there are surrounding vegetation management we do not seem to want to fully accept the empirical evidence that controlling around 95% of the vegetation around a seedling really gives the best results. Whether it has been published studies or in-house corporate data it never surprises me when the best practice is to keep the ground free of weeds for the first two years. A sun tolerant species like Douglas-fir will grow exponentially under these conditions as will other conifers such as loblolly and radiata pine which have exhibited amazing growth. Haywood et al (1997) found through five growing seasons that fertilization and weed control resulted in the greatest loblolly pine productivity.

Integration

Why not just integrate all of the best practices and science that we know into operational procedures to attain the best growth we can? In the Vegetation Management Research Cooperative (VMRC) we are researching this question exactly. However, to achieve successful results it is vital to understand the scientific links all along the path. It is not possible to expect even the best seedlings to over come heavy weed competition any more than it is valid to assume fertilizers will make up for poorly executed herbicide treatments. Haywood et al (1997) definitely confirm this for loblolly.

In the PNW attempts to model seedling growth and vegetation responses have not met high expectations. Part of the problem is not the models or the modelers, but the simple fact that integrating high quality seedlings with technically sound vegetation management practices can make the models obsolete. Add in fertilizers with good rain fall and the equations change again. Add in superior genetics and the equation shifts again. Improve the timing of the whole operation to coincide with the weather (and luck) and all of that old data to try to explain seedling performance becomes instantly obsolete. In the South they have lowered the rotation age to 20 from 28 years on some sites in just ten years of research. In New Zealand they are getting 25 ft in four years with radiata pine. In Brazil they can get 12 foot loblollys in the first growing season. Of course, all this modeling has led to the marvelous result that by improving seedling quality and planting, making effective use of specific fertilizers and herbicides it is possible to redefine for the first time the whole notion of site index! We see trees reaching larger volumes years earlier than expected.

CONCLUSION

The integration of a host of disciplines is going to become more and more of an issue in the future as the environmental laws get more stringent and the need to attain free to grow seedlings in less than five years. More and more we see that planting failure will also carry the cost of not being allowed to timely harvest the adjacent unit. Achieving environmentally sound and excellent results the first time every time is going to become a major objective in forestry in the next century. Ironically past research, which seldom integrated more than one factor and instead focused on individual facets of reforestation, has not led to operational treatments which optimize growth over a range of site qualities.

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INTERACTION OF GENETIC IMPROVEMENT AND FOREST VEGETATION MANAGEMENT. B.D. Shiver and W.M. Harrison. D.B. Warnell School of Forest Resources, University of Georgia, Athens, GA 30602.

ABSTRACT

Effects of genetic tree improvement on growth and disease resistance have been acknowledged and widely accepted over the last thirty years. Similarly, the dramatic effects of vegetation management, particularly on growth, have been documented in many studies over the past decade. In 1986-87 a study was established to evaluate effects of the two treatments when applied together on loblolly pine (*Pinus taeda* L.) in the coastal plan and Piedmont regions of Alabama, Georgia, Florida and South Carolina.

The study consisted of four treatments at each location: (1) no genetic improvement, no competing vegetation control, (2) no genetic improvement, complete competing vegetation control, (3) genetic improvement, no competing vegetation control, and (4) genetic improvement, complete competing vegetation control.

Results after nine years indicated that competing vegetation control and genetic improvement both increased merchantable volume significantly. In the costal plain the average increase from competition control was 123% and in the Piedmont the average increase from vegetation control was 88%. The increases in merchantable volume from