Nutrient Management in Pine Plantations in the Southeastern United States

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ABSTRACT. Nutrient management of pine plantations by fertilization has been a continuous practice in the southeastern United States for well over 20 years. Through 1990, phosphorus and nitrogen had been applied to nearly 1.2 million hectares in varying amounts. Diagnostic tools for prescribing fertilizer application include soil group descriptions, soil nutrient analysis, foliar analysis, and field indicators such as competing vegetation and site index. Fertilization must be integrated into normal management activities to become an effective management tool, and this has occurred on much of the southeastern industrial forest lands. Nutrient management has historically been synonymous with fertilization, but the concept has grown to include vegetation management and other accepted silvicultural activities. Future research will focus on more basic physiological responses, rather than simple field trials. The challenge will be to stay ahead of nutrient deficiencies, other than phosphorus, and develop true nutritional recommendations for management.

Since the early trials of the 1940s and 1950s (Walker and Tisdale 1959), forest fertilization has become a common practice for much of the southeastern United States. The region from Virginia to Florida and west to Texas encompasses over 17 million hectares of loblolly and slash pine lands (Allen et al. 1990). A summary completed by the North Carolina State Forest Nutrition Cooperative staff in 1991 shows that 697,000 hectares of loblolly pine (*Pinus taeda*) and 494,000 of slash pine (*Pinus elliottii*) had been fertilized by the end of 1990. Fertilization closely follows the general breakdown of the Southeast into physiographic regions. Most often fertilized are the Atlantic and Gulf coastal plains, especially the nearly flat, poorly drained lower coastal plains, which in Georgia and Florida are collectively called "flatwoods." In general, these lower coastal plain regions have had priority for fertilization (Fisher 1981), but recently upper coastal plain fertilization has been growing in importance because responses suggest it to be economically justified (NCSFNC 1990).

Loblolly and slash pines are the most common species used in intensively managed plantations, and show similarities in response. In the southern pine region, slash pine is more limited in range, occurring along a strip running from Texas east to southern Georgia and northern Florida. With few exceptions, fertilization research has dealt with these two species. As early as the 1940s (Walker and Tisdale 1959), research demonstrated the potential of fertilizing stands of pines in the coastal flatwoods of the Southeast. These coastal areas in Georgia and Florida are often broken into two broad soil categories: (1) wet savannas, of poorly and very poorly drained ultisols, and (2) sandy flatwoods, of very poorly to moderately well drained spodosols.

Other coastal landforms and soils, such as pocosins, occur in parts of the coastal plains, but are not represented in the Georgia-Florida area. They are, however, similar to the flatwoods soils in their response to phosphorus (P) and nitrogen (N) fertilization (Allen et al. 1990). Early work in the flatwoods identified phosphorus as a limiting factor, and in many cases a small addition of fertilizer to wet savanna soils provided a dramatic response (Pritchett and Comerford 1982).

The apparent scope of the flatwoods fertility problem led to the formation of the Cooperative Research in Forest Fertilization (CRIFF) program at the University of Florida and the Forest Nutrition Cooperative (NCSFNC) at North Carolina State University in 1969. Both programs continue today.

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Operational Fertilization

Between 1965 and 1970, some industrial forest companies began fertilization programs in the southeastern lower coastal plains. These early programs sought mainly to correct phosphorus deficiencies. Additions of nitrogen became more common in the late 1970s as areas previously fertilized with phosphorus became older, and as fertilization of the predominantly sandy spodosols in Georgia and Florida became common. It is noteworthy that most of these companies, having begun fertilization programs in the early 1970s, remain active in forest fertilization 20 years later. It is equally noteworthy that some companies have never initiated a program.

Nitrogen and phosphorus have received a great deal of study, and both elements are prescribed. In general, phosphorus is applied early in the stand; as the stand gets older, nitrogen plays a more prominent role. Good general prescriptions have been available for some time (Fisher 1981). Young pines usually receive 40-60 kg P/ha, and occasionally an equal amount of nitrogen. A midrotation (10-15 yr) pine stand receives about 200-300 kg N/ha if previously fertilized with phosphorus. If a stand reaches midrotation with no prior fertilization, a mix of N and P is generally added.

Several techniques are used in prescribing fertilizer application (Jokela et al. 1988), including descriptions of soil groups, soil analysis, foliar analysis, and field indicators such as competing vegetation and site index. The most prevalent approach is a combination of techniques. For example, simple soil groups may be used as an initial screening. Stand conditions such as stocking and site index might be used next. Finally, if deemed appropriate, a chemical analysis of soil and/or foliage might be employed. Individual companies, in turn, continue to develop methodology to prescribe, apply, and monitor operational fertilization programs. Applications are made in a variety of ways. Large landholdings are fertilized by tractor, rubber-tired skidder, helicopter, or fixed-wing aircraft. Some small private landholders apply fertilizer manually. Materials commonly utilized are ground rock phosphate, triple superphosphate, diammonium phosphate, and urea.

Operational Fertilization at ITT Rayonier

The earliest fertilization on ITT Rayonier lands was done in 1971, when a relatively large area of wet savanna was determined to be substandard in growth. Since the area had been cut and regenerated in 1959, the lack of growth was evident 12 years later. Twenty-five year site indexes were predicted to be 15 to 17 m, while expectations based on the previous natural stands were 20 m or more.

Fertilization was prescribed through the CRIFF program, and treatments of 50 kg P/ha were applied as triple superphosphate by helicopter. Response was so dramatic that measured heights at age 25 were up to 24 m. It became obvious that the extent of that type of soil was somewhat limited, and that the real opportunity for fertilization was on the company's sandy flatwoods spodosols that made up about 80% of the plantable pine lands.

From 1971 to 1978 a few more very P deficient wet savanna sites were fertilized, but little was done to reach into the larger area of spodosols. In 1978 the data from CRIFF were carefully reviewed, and it was felt that there was a high probability of response to midrotation applications of 50 kg P and 150-250 kg N per hectare. Application rates were selected based on CRIFF soil groups (Fisher 1981). At that time, rotation lengths were 25 to 28 years, and we anticipated fertilization at ages 12 to 17.

Approval was obtained with a stipulation to "PROVE IT." This was the beginning of ITT Rayonier's fertilizer monitoring plots as well as the start of a more consistent fertilization program. Monitoring plots have been installed periodically since that time, and have become important to continuation of the fertilization program.

The monitoring plots are designed to provide information about specific treatments and their effects on stand-level parameters, while traditional research trials do the job of screening and refining materials and rates. In order to accomplish this, a large number of 0.02 ha plots are installed in fertilized and unfertilized areas in an operationally fertilized plantation. This plot size was chosen so that a minimum sample of 30 trees would be available per plot. Data from up to 12 plots per treatment per location can then be used to study effects of treatments on stand-level variables. In addition to normal evaluations of height and diameter, we will look at other effects such as changes in diameter distributions, or volume response by crown class. An example of where monitoring plots can be helpful is in the development and evaluation of growth and yield models. These monitoring plots would generally be installed only once during a fertilizer season. No specific monitoring of individual stands is done. Each time a site is selected, it represents a specific combination of soil and stand conditions.

In 1981—based on research plots, our acquired knowledge of basic soil groups, early monitoring plot results, and our ability to summarize age classes with our computerized inventory—a plan was developed to create a routine fertilization program that would eventually lead to fertilizing all stands that required nutrient additions. At this time, a great deal of "selling" was done to promote confidence in the program. Comparisons with other traditional silviculture activities in terms of expense, gain, and risk showed fertilization to be a good program.

As ITT Rayonier's Southeast Forest Resources program moves into the 1990s, there is a very positive shift to the concept of management regimes to make it possible to consider all treatments that will be made throughout a rotation rather than individual treatments determined on a case-by-case basis. Nutrient management crosses all lines, since other factors such as water control and windrowing affect the quality, quantity, and availability of nutrients. Most silvicultural treatments will directly or indirectly influence the availability of nutrients (Allen et al. 1990).

Vegetation Management and Nutrient Implications

Since 1980, research has shown consistent tree growth responses to mechanical site preparation and to control of competing vegetation (Shiver et al. 1990). The emerging trend is toward more intensive management, with growth showing a strong positive relation to mechanical site preparation, fertilization, and competition control (Figure 1). In flatwoods areas the competing vegetation is more often grasses than woody species, and there has been an increase in herbaceous weed control programs. Research continues at both the North Carolina State and University of Florida research cooperatives as well as the Auburn University Silvicultural Herbicide Cooperative. Many companies have large-scale operational programs that now include herbaceous weed control and fertilization.

Questions continually arise as to the relative value of vegetation control and fertilization. But when considered in the context of nutrient management, both may be required for the long-term high yields that intensive management is targeting. It appears that herbaceous weed control offers large benefits in establishment and early growth, but nutrient additions may still be required for long-term productivity gains.

Integration with Other Management Activities

On further review, it becomes apparent that all silvicultural activities must be coordinated. Each piece or practice is dependent on another, with nutrients being

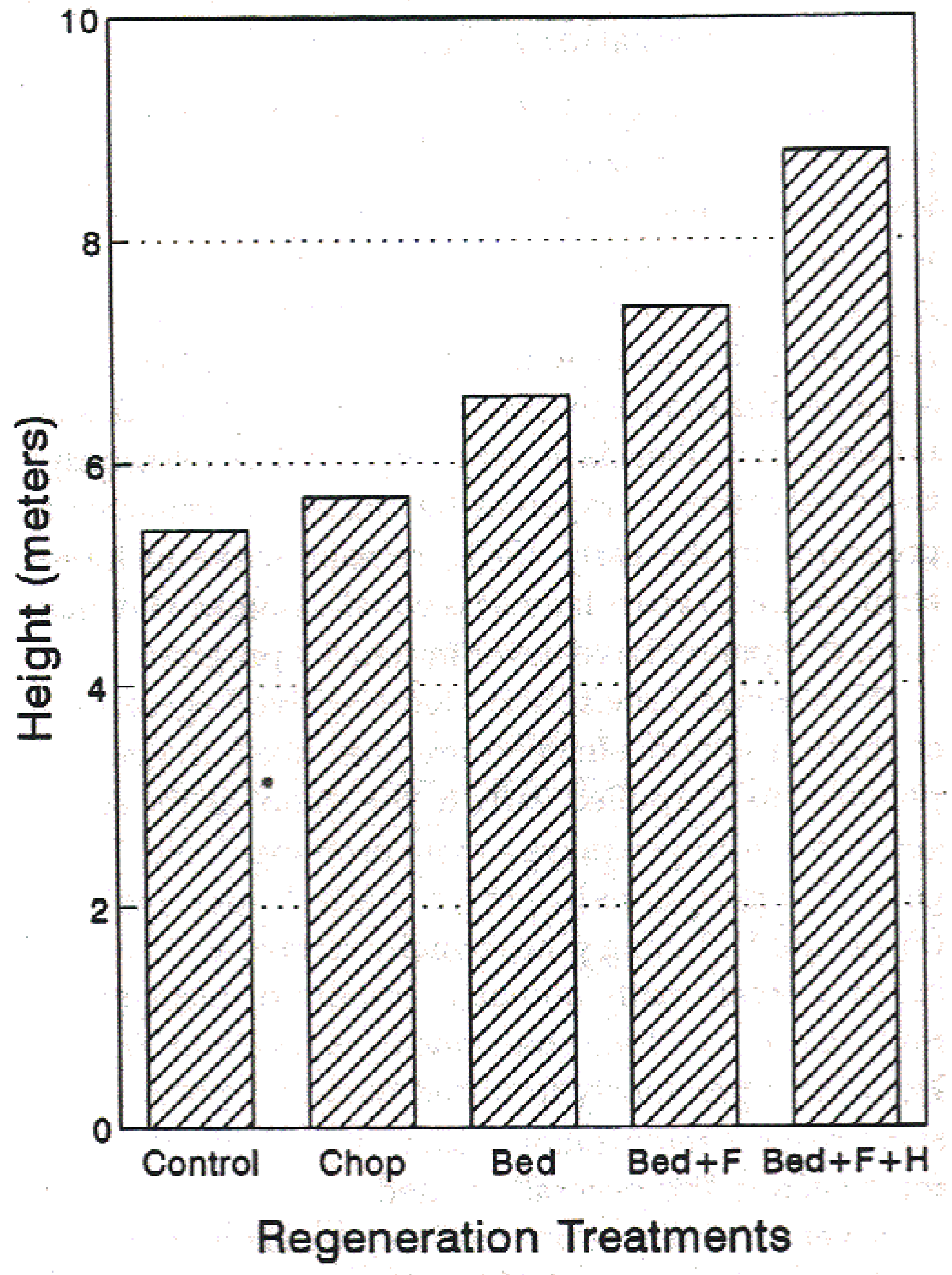

Figure 1. Effect of intensive management on tree height eight years after planting. Regeneration regimes include control (no treatment), drum chopping, bedding, bedding plus fertilization, and bedding plus fertilizer and herbicide. From Shiver et al. (1990).

the primary limiting factor. The effectiveness of other activities may be in question without nutrient additions. It may be possible to select and breed tree species for better nutrient utilization, but that is a future choice, while correction of nutrient deficiencies can be done now. Excellent site preparation technology may be ineffective if competing grasses occupy the site prior to stand establishment. An added benefit of utilizing the technologies together is that the targeted trees will have a higher uptake of the applied fertilizer.

Future Research

The technology of basic fertilization prescriptions is generally in place in the southeastern United States. Nutrient management technology is not. The treatments and basic prescriptions have not changed a great deal in the last ten years. The biggest change has been in confidence, thus resulting in wider use of fertilization in the region. For the future, these technologies will not be enough. We need to move from fertilization technology to true nutrient management technology. We need to be prepared to deal with major interactions with other treatments as well as the development of deficiencies in nutrients other than nitrogen and phosphorus. We need to understand the physiology of tree growth in terms of nutrient requirement, uptake, and response. We must be able to predict not only yield but modifications in yield from nutrient management.

True nutrient management implies that we know what deficiencies exist and then take the necessary steps to provide what is needed. This is not currently the case. We do know that for an application of specific material an economic benefit will be obtained. The challenge that we face is to do research to answer future needs and not research that applies to current technologies.

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Questions and Answers

First, how are your repeat applications timed on a single rotation? Second, how have your short rotation lengths and longer growing seasons affected your fertilization scheduling?

A good general overview is that phosphorus is applied early in the life of the stand, probably before age 8. The more deficient the site is, the earlier the application. Phosphorus will be applied at establishment in very deficient areas. Nitrogen generally is applied at least 5 to 8 years, and as early as 10 to 12 years, prior to harvest. The effects of shorter rotation ages are interesting, and they vary a great deal from company to company. One aspect is that we can show a real effect on a rotation length. If you manage for a fixed volume per hectare, it is possible to reduce a 25-year rotation by as much as 5 years. If you manage to maximize net present value, the effects are generally higher returns per hectare. The direct effects of short rotations on fertilizer scheduling are simply expressed as a priority system. In some situations it may be possible to fertilize in a 5-year window, while other situations such as acute phosphorus deficiencies require fertilization at establishment. In the later case, failure to do so can increase a rotation age or result in dramatically reduced volumes.

Have you considered the economics of growing some of your plantations to 30-50 year rotations?

Yes. In some areas of the Southeast, longer rotations are used, and fertilizer remains a part of the general management scheme. In our particular case, using economic considerations as a guide, we prefer to manage for shorter rotations that produce a high proportion of pulpwood at rotation age. During the meeting, we heard discussions about mean annual increments of Douglas-fir culminating in the 50 to 70 year range. In the coastal plains of Florida and Georgia, this occurs in the 20 to 30 year range, and growth may drop dramatically after that time.

You have stated that more litter accumulated on the forest floor of fertilized versus unfertilized areas. This implies that litterfall exceeds decomposition. Do you have any indication that the rate of decomposition is affected by fertilization?

I recognize that this question comes from a much colder climate than we have in the Southeast, and that humus accumulation can be quite high in these areas. In the Southeast, the only areas of real accumulation are in swamps, ponds, or bottomlands. When a stand is regenerated in the Southeast, there is generally very little and often no organic material on the surface of the soil. This is the result of high moisture and temperature that provide rapid decomposition, prescribed burning in the life of the stand as well as during regeneration, and mechanical site preparation techniques that are designed to incorporate any surface organic matter into the mineral soil. Having said that, I will repeat that fertilized stands produce more litterfall and subsequently more forest floor. This is likely to be short-lived, however, as an equilibrium will develop between litterfall and decomposition. In our case of shorter rotations, and prescribed burning, we may never see that equilibrium. An answer that I would like, and am unaware of any work on, is if the midrotation nitrogen fertilization accelerates decomposition enough to provide more rapid release of phosphorus, potassium, and micronutrients.

What have groundwater monitoring results revealed concerning the fate of nitrogen, phosphorus, and herbicides in the poorly and very poorly drained sites?

The work that I am familiar with is from the USFS Intensive Management Practices Assessment Center in Gainesville, Florida, and a Weyerhaeuser study in North Carolina. The answer is that no problems have turned up with materials used at operational rates, and any detection at all has been after unusual rain events, artificially high rates of application, or annual applications for a number of years.

Do you have any concern about changed physical properties of soil over time when you remove the entire tree? You are removing a lot of potential humus, and that can affect soil texture.

Yes, that has to be a concern with the type of management that we are using. The truth is that we do not have definitive data, but research is proceeding on more than one front. Of particular interest to us is the organic matter content of the surface soils.

Since you have undoubtedly harvested some of the stands you have fertilized; have you noted any manufacturing problems associated with these stands?

Speaking in general, there have been no problems associated strictly with fertilization. Problems do exist with using younger, faster growing material, but this is being dealt with at the manufacturing end. Markets for wood are strong in all categories. A good deal of work has been done on wood properties and fertilization, and in general no problems exist. One good source for information and further literature is a 1989 article in *Forest Science* by Jokela et al. on slash pine.