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A Loblolly Pine Management Guide

Preparing Atlantic Coastal Plain Sites for Loblolly Pine Plantations

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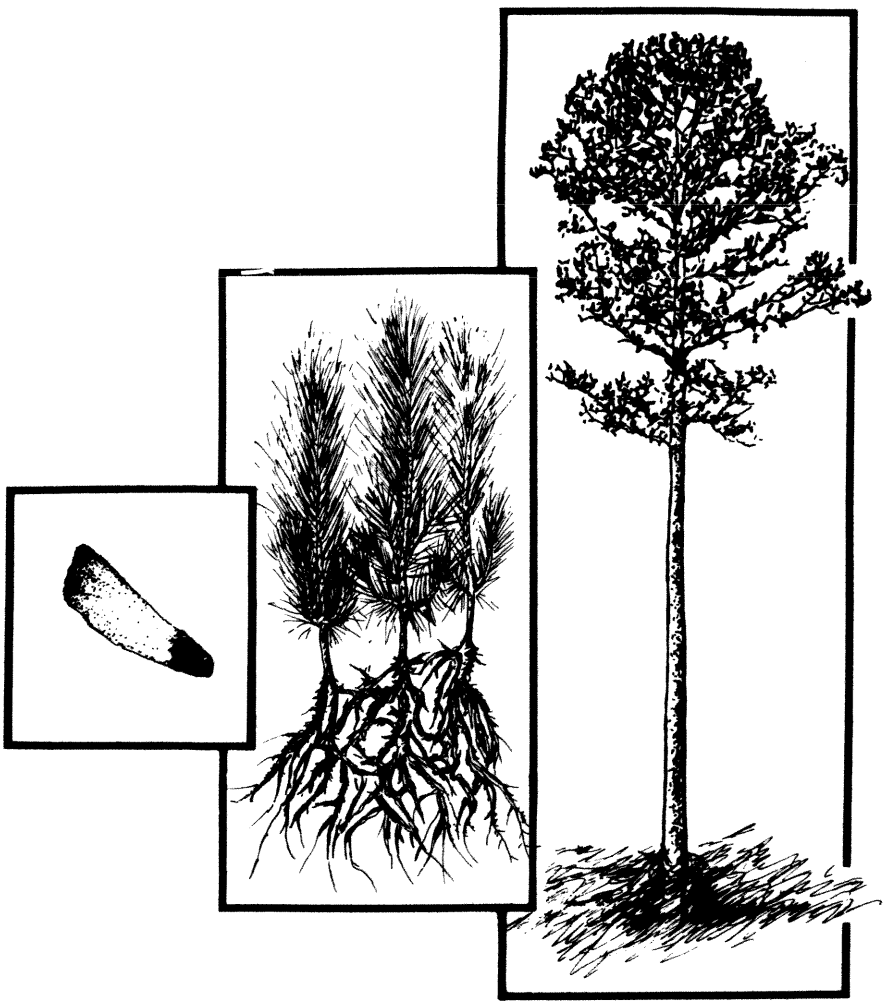

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ABSTRACT

Site preparation is essential for establishment of loblolly pine plantations on the Coastal Plain of the Southeast. Purposes of site preparation include control of competing vegetation, improving drainage, and increasing soil fertility. The choice of an appropriate treatment depends heavily upon the type of soil that is present and on the amount of hardwood control that has been exercised in the previous timber rotation.

KEYWORDS: *Pinus taeda*, drainage, forest fertilization, herbicide use, bedding, forest soil.

Site preparation is absolutely essential for the establishment of successful loblolly pine (*Pinus taeda* L.) plantations on the Atlantic Coastal Plain of the Southeastern United States. In the absence of major disturbances, loblolly pine is not a climax species there. It grows rapidly in full sunlight after it has been established, but many of its hardwood associates are far more aggressive in establishing themselves and in competing for light and nutrients.

The widespread occurrence of loblolly pine in the region is attributable to natural and manmade disturbances—primarily fire and agriculture. A hot fire in heavy fuels kills hardwood competitors and provides an excellent seedbed for loblolly pine. What is more, pole-size and larger loblolly pines are highly resistant to fire damage. Recently abandoned agricultural fields are also excellent sites for loblolly seeding or planting because repeated plowing has eliminated hardwood rootstocks, whose fast-growing sprouts are devastating competitors.

Ideal site preparation for loblolly pine planting creates conditions similar to those after an intense fire or those in a recently abandoned field, but cost is an important consideration. One overall objective, therefore, is to kill as many hardwood rootstocks as possible and to minimize competition from grasses and annuals at a reasonable cost. Definitions of reasonable cost vary widely, so this guide describes relatively cheap as well as relatively expensive treatments.

Site preparation costs can be reduced considerably by tending stands carefully before they are harvested, and by clean harvesting. As a general rule, the cleaner the harvest and the greater the effort put into suppressing hardwood competition prior to harvest, the less costly and less intensive the site preparation requirement

will be at the time of regeneration. A prescribed burn can be conducted for $1 to $5 per acre, while intensive mechanical treatment costs $100 to $400 per acre.

In addition to control of competing vegetation, a frequent purpose of site preparation on the southern Coastal Plain is improvement of soil drainage. Loblolly pine growth is severely retarded by flooding for more than 15 days during the growing season. Many Coastal Plain sites are flooded for extended periods each year, particularly when there are no trees present removing water by transpiration. Fertilization, drainage, and bedding treatments discussed in this guide can make many of these sites highly satisfactory for loblolly pine culture.

Characteristics of the Region

The most obvious characteristic of Atlantic Coastal Plain topography is that it is flat, or nearly so. The region is also well watered. From the standpoint of site preparation, flat topography means relatively low risk of stream siltation or soil erosion after treatment. Since Coastal Plain soils are primarily deep unconsolidated sediments, problems with rocks are seldom encountered.

Flat terrain, however, leads to imperfect surface drainage. Some of the Nation's largest swamps are found on the Atlantic Coastal Plain, and many areas are flooded for some portion of the year. Flooding is especially common on forest land, which often is in forest primarily because it cannot be farmed profitably. Artificial drainage structures are often needed to make such sites productive for loblolly pine.

The deep moist soils of the Coastal Plain support lush hardwood vegetation. If that vegetation is not controlled as a pine stand matures, it precludes establishment of a new pine stand, and treatments to control it are not cheap. Thus, control of hardwood competition is the never-ending job of the loblolly pine manager on the Coastal Plain.

Discriminating Factors

In choosing appropriate preparation measures for a specific site on the Coastal Plain, four factors must be considered: (1) soil texture, (2) soil fertility, (3) drainage, and (4) competing vegetation.

Soil Texture—The percentage distribution of sand, silt, and clay in a soil affects its ability to hold moisture and nutrients and to transfer them to plants on demand. As sand content increases, moisture and nutrient holding ability and fertility decline. On the other hand, soils with a high sand content have rapid internal drainage, so they are seldom flooded for extended periods.

Coastal Plain soils with a high clay content drain very slowly. And when they are wet, they are difficult to traverse and easily damaged by heavy equipment. These effects are described in a another Loblolly Pine Management Guide by McKee and others (1985).

Loblolly pine grows best on soils with sufficient sand to promote good internal drainage but with sufficient silt, clay, and organic matter to retain large amounts of nutrients and moisture. Of course, the same is true for most competing tree species and for most crop plants. Loblolly pine is a very common tree species, in part because of its ability to grow moderately well on soils ranging from sandy to pure clay.

Soil Fertility—A fertile soil is one that is rich in materials necessary to sustain plants. Plants vary somewhat in fertility requirements, depending on texture and drainage. It is not always easy to tell how well a species will do on a site where it is now absent. This is particularly true for trees, for which nutrient supplies must be estimated for an entire timber rotation. To a limited extent, fertility can be judged by analyzing soil samples and samples of current-year foliage of loblolly pine growing on the site. The phosphorus requirement increases as the drainage deteriorates and is of particular concern on very poorly drained sites. Phosphorus can replace the need for drainage to a limited extent. Nitrogen fertilizer is seldom added during site preparation because it stimulates growth of competing vegetation (Wells and Allen 1986).

Drainage—The need to drain a site can be anticipated by referring to soil survey maps, which identify soils with poor and very poor drainage. Sites should also be inspected to substantiate the mapping designations. Thick, dark-colored surface layers, mottling near the soil surface, and the presence of organic layers in the soil profile are indications of poor drainage. It also must be recognized that sites with a mature, well-stocked stand of trees often appear to be better drained than they really are. These sites may become exceedingly wet after transpiration losses are eliminated by harvesting the trees. As the new stand develops,

moisture loss through transpiration will supplement drainage through the soil, drying the site. On poorly drained sites, bedding is often required, and, on very poorly drained soils, a system of surface drainage is usually needed to grow loblolly pine. The design of surface drainage systems is beyond the scope of this paper; technical engineering assistance is therefore recommended before such an option is installed. Areas that require extensive surface drainage usually are classified as "wetlands," and State and Federal regulations may limit treatments that can be applied.

Where water does not stand above the soil surface, bedding will generally furnish sufficient drainage for tree establishment. Beds should be 8 to 12 inches above the residual soil surface after settling. Some settling is necessary for sufficient compaction around the roots of planted seedlings to assure survival. Settling time depends on the extent of root mat involved, the soil texture, and the soil structure. Sandy soils compact faster than clayey soils, and organic matter retards settling of the beds. The amount of settling needed for establishment also depends on soil moisture conditions and method of planting.

Competing vegetation – Reduction of competition from hardwoods and herbaceous vegetation is probably the main reason for preparing a site for pine planting. The need for mechanical vegetation control can be greatly reduced by discouraging growth of competing hardwoods throughout the timber rotation, especially in the years just before final harvest (Crutchfield and Martin 1983).

The most economical method of vegetation control is a combination of prescribed burning annually for 3 to 4 years prior to harvest plus whatever additional treatment that may be needed after harvest. Preharvest burning usually includes a winter burn followed by three or four annual summer fires. Fire should also be used at periodic intervals throughout the life of the stand. The major disadvantages of winter burning are: (1) Scheduling is difficult because proper burning conditions are dependent on weather, (2) hardwood stems over 1 inch d.b.h. are hard to kill, and (3) 3 or 4 years may be needed to fully implement the treatment. Summer burning can be difficult to manage, and the potential of damage to the residual stand is high. Hence, if summer burning is contemplated, plans should also be made to harvest the stand on short notice. Rewards from summer burning are reduced site preparation costs and more complete control of hardwood vegetation than from winter burning (Waldrop and others 1987).

Herbicides can control competing vegetation in a single treatment, but that treatment is more expensive than several burns. Herbicides are available for specific site conditions, target species, and times of application (Nelson and others 1981). Herbicides are applied in one of three ways: foliar sprays, soil treatment, or injection into the stems. Foliar contact sprays work on a wide range of species. Pines may be affected, but ground spraying can be done on almost all sites. Since aircraft are required, aerial spraying often is not practical on small tracts. Also, aerial application carries the risk of herbicide spray drifting onto nontarget areas. Herbicides for soil treatment are not expensive and can be applied from the ground, but they can be used only on certain soils and species. Injection of individual stems has the advantage of controlling most species over a wide range of sites, but injection costs are high, especially where large numbers of target trees are present.

Particularly in plantations managed on short rotations, hardwoods are usually controlled through some form of mechanical site preparation, often in conjunction with prescribed fire or herbicides. Hardwood brush is either crushed by repeated passes with a rolling drum chopper or sheared at groundline and raked with a root rake into piles or windrows (Jorgensen and Wells 1986).

Recent research indicates that brush removal with topsoil displacement lowers site quality over a broad range of conditions and such treatment, therefore, is not generally recommended (Neary and others 1984). A preferred alternative is roller drum chopping or shearing of the brush and allowing it to rot sufficiently for bedding or planting. On many lower Coastal Plain sites, chopping does not cut hardwood stems sufficiently because the forest floor soil surface is too soft. Raking of brush is difficult to justify because of its high cost and the likelihood of significant reduction in site quality. Raking debris into windrows also sacrifices about 10 percent of the production area. The area loss can be remedied in part by burning windrows, but the remaining residue can still cause problems for planting.

Recommendations for Specific Soil Groups

Since the selection of a site preparation treatment depends heavily on soil properties, recommendations are presented here for six separate soil drainage and texture groups. A photo of a typical soil profile is presented on pages 10-11 for each group. The

recommendations are designed to sustain reasonably rapid growth through the first 10 to 20 years after loblolly pines are planted (pages 16-17, table 1).

Site 1. Organic Soils With Very Poor Drainage

These sites are characterized by very poor drainage and large accumulations of organic matter, sometimes in layers several feet thick. The pocosins in eastern North Carolina are representative of this type of site. Historically, these sites have been vegetated with white-cedar, pond pine, waxmyrtle, gallberry, and pine-grass savannahs. Surface drainage is often needed to lower the water table sufficiently to allow use of equipment for logging, site preparation, and planting.

Drainage—Surface drainage structures should include provisions for partial blockage as the new stand develops and the transpiration demand increases. The water table should be lowered to 12 to 18 inches below the surface (24 inches in ditches) until trees have grown back to a basal area of about 40 square feet per acre. Then, the water table should be raised to within 6 to 12 inches of the surface.

Competition control—If brush and hardwoods are present, they must be controlled to obtain a well-stocked pine stand. Unfortunately, there are special problems associated with burning and herbicide use on these sites. Peat soils will burn when they are sufficiently dry, and peat fires are very difficult to extinguish. Hence, soil moisture conditions must be ideal, with the water table near the soil surface, if such areas are to be burned. High soil-organic-matter content renders soil-applied herbicides inactive. Herbicide treatment on these sites, therefore, is largely restricted to a foliar spraying during the growing season or stem injection.

Brush removal from these sites is usually a problem because of the poor drainage. Double or triple chopping with a rolling drum chopper usually removes brush sufficiently for bedding if 6 to 9 months are allowed for the slash and hardwood brush to rot. If brush is raked and piled, nutrients removed during treatment must be replaced. This treatment therefore represents a last resort for control of competition.

Bedding and cultivation – Although bedding helps to control competition on these sites, drainage of the rooting zone is the main benefit. Over 90 percent of the time, pines on these sites respond to bedding with a onefold to twofold increase in height growth through age 10. Beds should be about 12 to 15 inches above the original soil surface after settling. Individual soils in this group may not support bedding or other heavy equipment, and survival may be poor when they are dry. Seedlings can frequently be planted 2 to 3 months after bedding. When there are long dry periods in summer, more time should be allowed for beds to settle.

Fertilization – With or without bedding, phosphorus fertilization is recommended on these sites. Application of 50 pounds of phosphorus per acre as triple super phosphate at planting has yielded 50- to 300-percent increases in height by age 10 on more than 90 percent of the sites tested. Responses to nitrogen have been less consistent, and nitrogen application is recommended only if competition is closely controlled.

Phosphorus application can reduce the need for drainage on poorly to very poorly drained peaty and clayey soils. Application of 50 pounds of phosphorus (250 pounds of triple superphosphate) per acre appears to allow loblolly pine to compete with hardwoods. Phosphorus application is an attractive alternative to drainage and bedding for long rotations, and increasingly strict regulation of wetland drainage is making it desirable for shorter rotations. Phosphorus can be applied during bedding and incorporated into the bed, or it can be broadcast on the soil surface.

Site 2. Wet Soils With Sandy or Sandy-Loam Subsoil

These sites are characterized by very poor drainage and a sandy texture. Little or no organic matter is present at the soil surface. Grass savannahs and pond pine stands often occupy this soil group. Most soils in the group are sandy throughout the profile; some are groundwater spodosols (Aquods) and have an accumulation of organic matter, forming a pan, 12 to 24 inches below the surface. Vegetation on these sites includes waxmyrtle, pitcher plants, greenbriar, bitter gallberry, fetterbush, sweetbay, and pond pine. Vegetation is normally less dense than on soils with the thick organic layers. Response to drainage of these sites is uncertain, partly because the water table often drops below the normal root depth for 3 to 6 months a year. In general, these sites

are only moderately productive and show only small responses to site preparation treatments.

Drainage—Drainage may be needed on these sites to facilitate mechanical operations, but it can cause excessive drying during droughts.

Competition control—Competition frequently must be controlled to establish plantations. When these sites are dry, they can be prescribed burned with little damage to the soil, but some of the vegetation can burn intensely, destroying established pine stands. Mechanical site preparation is also limited by extended periods of wetness. Drum chopping followed by fire is effective in removing hardwood competition if the soil is firm enough that a good job of chopping can be obtained. Because of the wet conditions, soil herbicides cannot be used but foliar sprays and injection are often practical.

Root raking and piling reduce growth more on this type of site than on most others because fertility is inherently low and because organic matter in the surface layer is scarce. On these sites, responses to applied phosphorus have been inconsistent.

Bedding and cultivation—Loblolly pines do not respond as well to bedding on sandy soils as on organic soils, even under very poor drainage conditions. If beds are constructed, they should be 12 to 15 inches high after settling. Disking on this site group is effective in reducing competition.

Fertilization—Response to applied phosphorus has ranged from a 200-percent increase in height at age 10 to none, even when levels of phosphorus in the soil and foliage samples are low. Precise reasons for this varied response are not known, but deficiencies or imbalances of other nutrients may be involved. As with site group 1, young pine plantations on this type site do not respond to nitrogen application.

Site 3. Wet Soils With Loam or Clay Subsoil

These sites include the flatwoods and areas surrounding pocosins with less than 2 percent slope. Water stands at or near the soil surface for 2 to 5 months a year and in some cases can be a problem in stand establishment. These sites support a dense

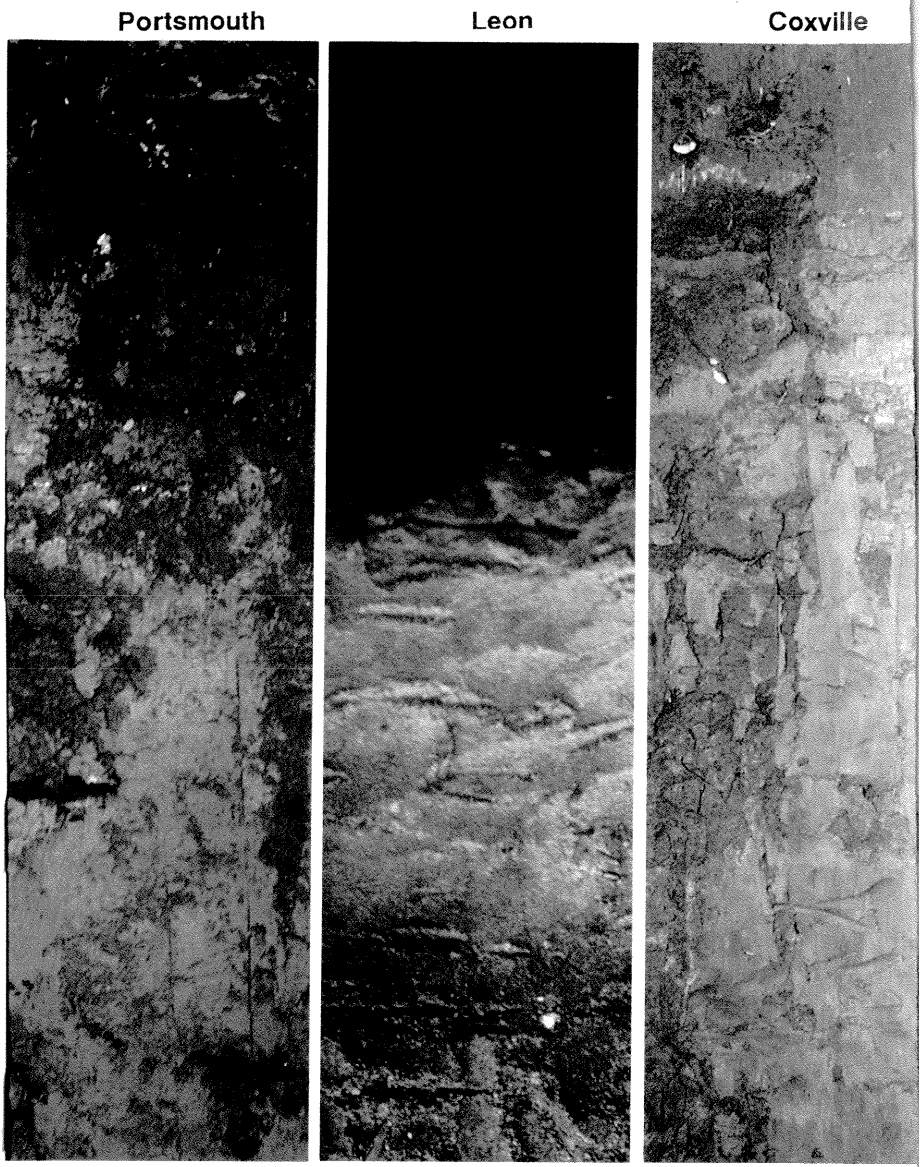
hardwood understory consisting of sweetgum, red maple, several oak species, and waxmyrtle which presents a major problem in site preparation. The absence of presence of a species generally depends on fire history.

Drainage—These soils are normally easier to drain than organic soils, and locally poor drainage can impede harvest, site preparation, planting, and early growth of the stand. Care should be exercised in assessing drainage because water tables can rise several feet after clearcutting, complicating the regeneration process. Where drainage ditches are built, the water table should be lowered to 12 to 18 inches below the soil surface for maximum benefit. Soils in this group are slowly permeable, and water movement is primarily lateral. A large number of shallow ditches may be needed on a site to remove surface water within 1 or 2 days after heavy rains. The number of ditches will depend on the size of the area and soil permeability.

Competition control—These sites revert slowly to hardwood if competition is controlled throughout a pine rotation with prescribed burning. Many of the problems of site preparation on these sites can be eliminated by burning prior to harvest. The soils and sites in this group offer few restrictions to use of fire. As on the other sites, shearing and root raking can degrade these sites. Roller drum chopping and burning under dry conditions is a preferable site preparation treatment. These sites should be prepared when dry because they are very susceptible to compaction, and drum choppers are ineffective in destroying brush when soils are wet.

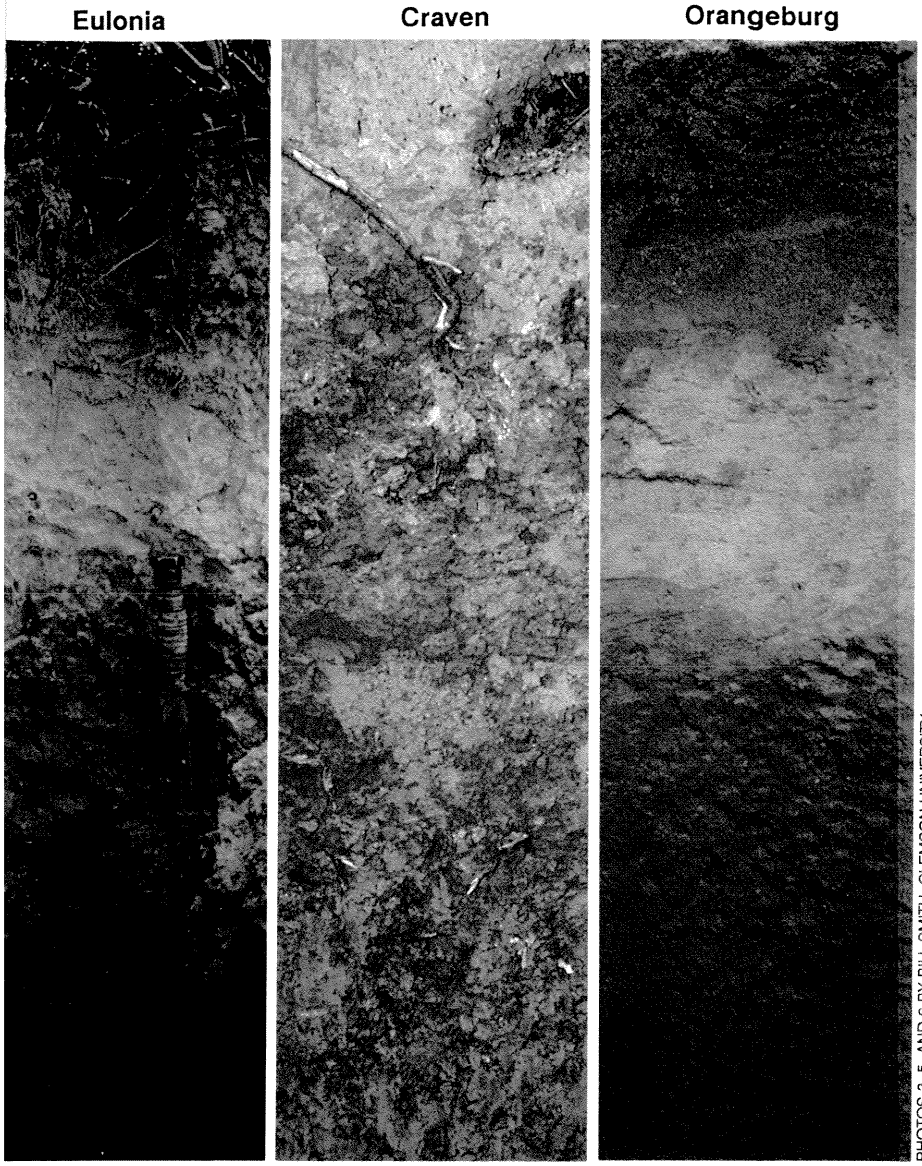
Foliar-applied or stem-injected herbicides work well on these sites. Response to soil-applied herbicide is somewhat erratic, and these chemicals should be used only if the manager is familiar with the particular herbicide on similar soils.

Bedding and cultivation—The need for bedding will depend, in part, on the drainage of the site and the manager's expectations about percentage of survival and length of rotation. On wetter sites in this group, bedding is essential for short rotations to ensure high survival and rapid early growth. On a long saw-log rotation, bedding may not be economical. Sites in this group tend to be quite responsive to bedding at an early age, but, as the stand develops and draws the water table down through transpiration, the response will probably diminish. Generally, pine will respond to bedding over 90 percent of the time with a 25- to 100-percent



Group 1	Group 2	Group 3
Very poorly drained	Poorly drained	Poorly drained

Typical soil profiles of the six groups of sites found in the Atlantic
for soils with poor drainage and lack organic matter and bright so



PHOTOS 3, 5, AND 6 BY BILL SMITH, CLEMSON UNIVERSITY

oup 4

mewhat
orly drained

Group 5

Moderately
well drained

Group 6

Well
drained

lain. Note the appearance of dark organic horizons and mottling without mottling on the better drained soils.

increase in height at age 10. The relative response is expected to diminish after this age. As with site groups 1 and 2, beds should be 12 to 15 inches high after settling.

Fertilization – Soils in this site group are generally low in phosphorus, and pine will respond over 90 percent of the time if the soil has less than three to five parts per million of available phosphorus, or if pine foliage has less than 0.10 percent total phosphorus. On highly fertile soils in this group (Alfisols), pine does not respond to fertilizer application. If phosphorus is deficient, the response will be a 50- to 300-percent increase in height growth at age 10, with or without bedding. For long rotations, the application of phosphorus may be more effective than bedding, and its cost is only about one-fourth that of bedding. Phosphorus can reduce the drainage requirement in the same manner as with group 1 sites. One application of 50 pounds of phosphorus (200 pounds of triple super phosphate) is usually sufficient for a full rotation.

Site 4. Moderately Wet Soils With Sand or Sandy-Loam Subsoils

These soils have sand profiles and a depth to mottling of 18 inches to 30 inches. They are found on low ridges in the lower Coastal Plain and on flat areas of the upper Coastal Plain. Soils frequently have slopes of 5 to 10 percent, but erosion is seldom serious. Competing vegetation consists of oaks, sweetgum, and dogwood. As with group 3 sites, hardwood species present will depend on the fire history.

Drainage – Drainage is not needed on these sites. The soils normally have sufficient internal drainage to allow mechancial equipment to operate most of the year. Compaction is generally not a problem.

Competition control – Hardwoods are a problem on these sites, and an effort is needed throughout the life of the stand to control them. Prescribed burning during the rotation can eliminate much of the competition problem at regeneration time. The sites create few inherent limitations on herbicide use, if any. Mechanical equipment can normally be used on this site group much of the year. Since the soils are sandy they resist compaction, but they do not hold large quantities of nutrients. As a a result, shearing and windrowing can reduce stand growth 30 to 40 percent through age 10. These treatments are recommended only if other methods

of control are not possible. Topsoil and slash residue should be moved as little as possible.

Bedding and cultivation—Bedding for drainage will have little positive effect on tree growth. Although bedding of these sites may provide short-term benefits through competition control and concentration of nutrients in the planting row, this treatment is not needed for drainage and is not recommended. The possible benefits can be gained in a more cost-effective manner through control of hardwoods and fertilization. In the long run, bedding may increase moisture stresses, reducing growth.

Fertilization—Trees growing on these soils are not especially responsive to phosphorus, and soil or foliage should be analyzed before fertilizer is applied.

There is a 50- to 60-percent chance of a 15- to 30-percent increase in height at age 10 through application of 50 pounds of phosphorus per acre. However, if competition is closely controlled, a 50- to 75-percent increase in height can be obtained at about age 5 from a combination of nitrogen and phosphorus on most sites. The amount of nitrogen needed will depend on methods of application.

Site 5. Moderately Wet Soils With Loam to Clay Subsoil

This site type is found on rolling topography and short slopes of as much as 5 percent. Such sites are representative of the middle Coastal Plain. These soils frequently have sandy surfaces, but the B horizon contains 18 percent or more clay at a depth of 30 inches. This site type supports dense stands of brush. The density and size of the competition depend largely on burning history.

Drainage—Artificial drainage is not needed on these sites. Soils normally have sufficient internal drainage to allow mechanical equipment to operate a large portion of the year. Compaction on some sites can be a problem if equipment is operated under wet conditions.

Competition control—Hardwoods are aggressive on these sites, and periodic prescribed fires are required to suppress them. The

sites themselves offer few restrictions to burning. Annual burning prior to harvest will reduce the need for site preparation.

Except where high clay content restricts use of soil herbicide, all techniques for application of herbicides work on these sites. Roller drum chopping followed by burning is effective, as is shearing. Mechanical treatments are generally more expensive than fire or herbicides for competition control. Root raking and piling should be avoided.

Bedding and cultivation—Bedding is not needed for drainage of these sites. Cultivation in the form of disking or bedding may improve survival and early growth on heavy soils that have been highly compacted. Disking is also effective for initial control of hardwood sprouts, but it is a relatively expensive way to achieve this goal.

Fertilization—On these sites, loblolly pine does not respond strongly to phosphorus applied alone. If extractable levels of phosphorus are below three parts per million, a 0- to 20-percent increase in height growth may be expected at age 10 on 50 percent of the sites from an application of 50 pounds of phosphorus per acre at planting. The growth is much larger if 100 to 200 pounds of nitrogen plus 50 pounds of phosphorus fertilizer are applied after planting, but herbicide application is required to control competition. This type of treatment may triple aboveground biomass of seedlings at age 3. Responses are erratic, however, with a marked growth response expected about 50 percent of the time.

Site 6. Dry Soils

Dry sites are found on the middle to upper Coastal Plain on rolling topography. Slopes may be as steep as 20 percent and sufficiently long for erosion problems if the soil is unprotected. Drought is especially important on the sandy soils, where special measures may be needed to conserve moisture. Hardwood understory species consist of turkey oak, dogwood, black cherry, persimmon, and hickories.

On deep sandy soils in this group, sand pine or longleaf pine should be favored over loblolly pine, which often performs poorly on deep sands such as Lakeland.

Drainage—Drainage is not needed on these sites.

Competition control—Hardwood competition is a problem. Hardwoods are not as aggressive as on moister sites, but they compete for a smaller supply of available moisture and nutrients.

A primary limitation on burning is that fuel may be too sparse to carry fires as frequently as desired. Maintaining a well-stocked stand permits an increase in the frequency of burning because of heavier litterfall. Herbicides can be used on these sites with few limitations other than that the herbicide should be selected to be effective against the target species and that rates should reflect the low clay and organic content of the soil.

A preemergence herbicide that will not injure pine seedlings on deep sandy soils should be selected. Mechanical chopping is effective, but care should be exercised to work across slopes to prevent erosion. Root raking and piling are especially destructive because the exposed soil may be subject to erosion and loss of nutrients when the forest floor and slash are moved into piles. Surface soils are thin, and the organic matter content is usually low.

Bedding and cultivation—Bedding is not needed on this site group to improve drainage. Trees often respond slightly to bedding—probably through concentration of nutrients in beds and from the additional weed control—but this response probably is short lived. These benefits can be obtained cheaper through fertilizer or herbicide application. Disking may be effective as a cultivation treatment, but care should be taken to prevent erosion. Disking strips for planting rows may be an attractive alternative.

Fertilization—These sites are not responsive to phosphorus alone. Frequently, they will respond to small applications of a mixed fertilizer such as diammonium phosphate (18-46-0) at 100 to 200 pounds per acre, but only if moisture supply is adequate. In general, a small increase in height can be expected about 40 to 60 percent of the time.

Table 1 — Key to management of site preparation for Atlantic Coastal Plain sites

Site group	Representative soil classes	Typical series	Drainage class
1. Organic soils (pocosins)	Humaquepts Umbraquults	Portsmouth Pantego Bayboro Pamlico	Very poorly to poorly drained
2. Wet soils with sand or sandy loam subsoil (pond pine flats)	Aquults Aquods	Lynn Haven Rutlege Leon	Very poorly to poorly drained
3. Wet soils with loam to clay subsoil (wet flats)	Albaquults Paleaquults Albaqualfs	Bladen Bethera Coxville Meggett Yonges	Poorly drained
4. Moderately wet soil with sand or sandy loam subsoil (sand ridges)	Paleaquults Paleudults Psamments	Lynchburg Seewee Chipley Goldsboro Eulonia	Somewhat poorly to moderately well drained
5. Moderately wet soils with loam to clay subsoils (middle Coastal Plain)	Ochraquults Ochraquafs Hapludults	Okeetee Wahee Nemours Duplin Dunbar Craven	Somewhat poorly to moderately well drained
6. Dry soils (upper Coastal Plain)	Paleudults Psamments Entisols	Orangeburg Lucy Eustis Norfolk Lakeland Caroline	Well to excessively drained

Response to drainage	Limitations on chemical use to control hardwoods	Response to bedding	Response to fertilizer at planting
Positive. Excess water severe problem	Severe because of high organic and clay content of soil. Weed species are difficult to control	50 to 100% increase in growth to age 10	P: 200 to 300% increase in growth. N: small response
Erratic. Sites respond to drainage 40 to 50% of the time	Seasonal limitations because of wetness	30 to 50% increase in growth to age 10	P or N+P: erratic response. Other nutrients may be deficient
Small response in localized conditions	Some wet soil species are difficult to control	30 to 50% increase in growth through age 10	P: 100 to 200% increase where deficient. N+P: small response, even with competition control
None	No limitations	0 to 30% increase in growth. Generally not recommended	P: 10 to 15%. N+P: modest response
None	No limitations	0 to 30% increase in growth. Only recommended to block compaction	P: 0 to 10%. N+P: 10 to 30% response with competition control
None	On sandy soil with low organic matter, pine may be more susceptible to herbicide damage	No response	P: 0%. N+P: small response with competition control

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The choice of an appropriate site preparation treatment depends heavily on the type of soil, its drainage, and the amount of hardwood control that has been exercised in the previous timber rotation.

KEYWORDS: *Pinus taeda*, site preparation, site classification, fertilizer, soil drainage.

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NOTES

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