THE FOREST NURSERY AND ITS SOILS

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Forest tree nurseries are located on a variety of soils ranging in texture from sand to silt loam in the top soil and from sand to clay in the subsoil. The organic matter content and the mineral level of soils vary widely within nurseries and among nurseries (table 1).

Soil management is a complicated process involving use of commercial fertilizer, organic material, and biocides. Other factors contributing to the complexity of the process are (1) variations in climatic conditions from year to year; (2) reaction of physical, chemical, and mineralogical characteristics of the soil to cultivation, fertilization, irrigation, etc.; (3) variations in nutritional requirements of different species; (4) biological factors associated with warm, humid climates and variety of soil treatments; and (5) personal and economic factors that include the tendency to apply the same soil treatment to all nurseries regardless of species or differences in soil characteristics.

Specific soil characteristics of interest to nursery managers include:

I. Physical properties

- A. Texture
- B. Soil structure
- C. Bulk density and porosity
- D. Critical moisture values

II. Mineralogical properties

- A. Silt fraction
- B. Clay fraction

III. Chemical properties

- A. pH
- B. Organic matter
- C. Cation exchange
- D. Available nutrients
- E. Reserve or fixed nutrients

Many of these characteristics are highly correlated. For example, soil structure and cation exchange capacity are closely correlated with organic matter content and the silt and clay fractions.

Texture

Texture within the nursery is relatively stable. Some clay or fine material from the B horizon can be mixed with the top soil by deep plowing.

Structure

In general, the structure of the surface soil ranges from single grain to weak crumb or moderate fine granular. Subsoils will have a single grained to sub-angular blocky structure.

Looseness, friability, good aeration, drainage, and easy tillage are characteristic of sandy soils. However, such soils are often too loose and open, and lack the capacity to absorb and hold sufficient moisture and nutrients. They need granulation. The only practical measure of improving the structure of such soil is the addition of organic matter.

The heavier textured or more plastic soils are prone to become hard and cloddy when dry. If plowed too wet, the aggregation of particles is broken down, the soil is likely to puddle, and an unfavorable structure is sure to result. Lifting operations coincide with wet seasons and consequently tend to promote unfavorable structure. As already emphasized, organic matter is a major asset.

Organic matter

Sandy soils should have from 1.5 to 2.0 percent, and heavier soils from 2.0 to 3.0 percent organic matter in the upper 6-inch layer.

Sources of organic matter will be sod and green manure crops, sawdust, ground bark, peat, pine straw, composts, and animal residues. Most sources of organic material carry large amounts of carbon and relatively small amounts of total nitrogen, with C/N ratios ranging from 500 to 1 for sawdust, 150 to 1 for straw, to 20 to 1 for some legumes.

Competition for available nitrogen is high when sawdust or other high C/N ratio residues are added to the soil. The heterotrophic flora -- bacteria, fungi, and actinomycetes -- becomes active and multiplies rapidly, yielding CO_2 in large quantities. Nearly all of the inorganic nitrogen that is available in the soil is quickly converted to organic forms in microbial tissue.

After the carbonaceous matter has been partially decomposed so that energizing material is no longer abundant, nitrogen assimilation slows down and by-product ammonium compounds appear in the soil. For the time being, the soil is somewhat richer, both in nitrogen and humus.

Soil-water relationships

Large quantities of water are needed to satisfy the evapotranspiration requirements of growing seedlings. Nurserymen are concerned with soil properties as they affect (1) movement of water into and within the soil, (2) the moisture storing capacity of the soil, and (3) the availability of soil moisture to seedlings. Each of these factors is directly or indirectly related to soil texture, soil structure, organic matter content, salt content, type of clay mineral, etc.

Critical conditions develop during periods of excessive rainfall or excessive droughts. Superfluous water results in poor aeration, retards favorable bacterial activities, and leaches nutrients from the soil.

The available moisture zone is between field capacity and wilting coefficient. A study at the Herty Nursery in 195') indicates that soil moisture tensions approaching the wilting point for periods of several days have no detrimental effect on 5- or 6-month-old slash pine seedlings. Apparently, root spread is an important factor in this regard. Seedlings with an extended system of lateral roots are able to draw on a greater amount of water and withstand a drought period; whereas seedlings without extensive laterals may succumb.

Chemical considerations

A knowledge of both chemical and physical properties of the plow layer and the upper sub-soil is a prerequisite to good soil management. Annual soil tsts provides a balance sheet whereby individual nurserymen can detect changes that result from current practices or modifications of these practices. For example, the soil reaction in one nursery decreased from about 7.0 to 5.0 during 6 years of operation. In another nursery, organic matter content decreased from about 5.0 to 2.0 percent in a 5-year period.

Major and minor fluctuations in H-ion concentration occur frequently. For instance, the drying of soils above field temperatures will often cause a noticeable increase in acidity. Two major groups of factors which bring about large changes in soil pH are (1) those which result in increased absorbed hydrogen; and (2) those which increase the content of absorbed bases.

Carbonic, nitric, and sulfuric acids are formed in the process of organic matter decomposition or from microbial action on certain fertilizer. These and other acids are suppliers of hydrogen ions and account for the development of moderately and strongly acid conditions. Bases which are dissolved by percolating acids or which are replaced from the colloidal complex are removed in the drainage waters, thereby increasing soil acidity.

pH ranges of 5.5 to 6.5 appear to be about optimum for pine seedlings production. Nitrification and nitrogen fixation take place vigorously in mineral soils only at pH values well above 5.5 Calcium, magnesium, potassium, phosphorus, and sulphur availability are favorable without being extreme.

Cookbook procedures for fertilizing seedling crops are not available. Many nurseries located on sandy or sandy loams in the Coastal Plain are inherently low in fertility. A few nurseries are located on fine-textured loess or alluvial soils of high productive capacity, and with high potassium and calcium contents. Fertilization and cultivation techniques are quite different for these groups of soils. For example, average mineral levels recommended for good seedling production are as follows:

	Coastal Plain sandy loams (lbs. per acre)	Alluvial silt loams (lbs. per acre)
Available P	50	75
Exchangeable K	160	200
Exchangeable Ca	600	1000

Nutrient removal varies for species and seedling size. Longleaf pine seedlings produce almost double the dry weight of other southern pines. The mineral requirements for white pine, yellow poplar, cottonwood, and sycamore are usually higher than for southern pines. The amount of nutrient removed by a crop of shortleaf, loblolly, or slash pine is as follows:

Nutrient	Range-pounds per acre
Nitrogen	141 - 215
Phosphorus	16 - 24
Potassium	50 - 78
Calcium	30 - 45
Magnesium	13 - 20

In determining the amount of fertilizer to be applied for production of a seedling crop, consideration must be given to (1) the nutrient requirements of the plant; (2) the available and non-available nutrients in the soil; (3) the fixation of minerals by clay or organic fractions; and (4) mineral losses due to leaching and erosion. The recovery rates of nitrogen and potassium vary according to the type of soil, fertilizer material and method of application, averaging about 50 to 70 percent.

The recovery rate for phosphorus is much lower, ranging from 15 to 3U percent in many of the acrd sandy soils.

The adjustment of soil fertility to a desirable optimum level can not be accomplished by single applications of fertilizing materials but by the systematic annual analyses of the soil and gradual adjustments of fertilizer factors.

Excess application of mineral fertilizer may result in serious problems. Added fertilizer salts are almost invariably localized and in higher concentrations than one would expect. On some soils adverse effects may result from compounds such as urea which supplies NH4 ions in the soil by hydrolysis. Occasionally, nitrite accumulations may occur in toxic quantities when ammonium containing compounds are added to the soil.

Inorganic phosphorus reacts with soluble irons, aluminum, and manganese at low pH levels and with calcium at high pH levels, rendering the phosphorus insoluble and unavailable for plants. Frequent and heavy applications of inorganic phosphorus may satisfy the fixing power of a soil and result in phosphorus toxicity. However, this reverted phosphorus is not lost from the soil and through the years undoubtedly is slowly available to growing plants.

Nutrient balance is essential among macro-nutrients and trace elements; otherwise, antagonistic effects result in toxicities to seedlings. Examples of known antagonistic effects of elements are:

1. Iron deficiency is encouraged by an excess of phosphorus, zinc, manganese, and copper.

2. Heavy nitrogen fertilization decreases phosphorus uptake.

3. Excess phosphate may encourage a deficiency of zinc, iron, copper, and nitrogen.

4. Excess calcium may adversely affect potassium, magnesium, and boron uptake.

5. Excess sodium or potassium may adversely affect manganese and magnesium uptake.

Other major factors contributing to the complexity of soil management are the uses of biocides for pest control. These chemicals may affect soil micro-organisms and subsequently nutrient availability. Observations of southern nurseries indicate that there is no one optimum nutrient ratio that is applicable to <u>all</u> soils and <u>ail</u> species. Each soil and each species will require individual treatment.

Table 1.--Soil characteristics of three forest nurseries in the southern pine region

Characteristic	Nursery A	Nursery B	Nursery C Block A	Nursery C Block B
Mechanical analysis				
Sand percent	93.0	43.0	66.0	85.0
Silt percent	5.0	41.0	22.0	9.0
Clay percent	2.0	16.0	12.0	6.0
Organic matter, content percent	--	4.0	3.3	2.4
Exchange capacity, m.e./100 gm.	0.0	13.1	5.8	5.5
pH	5.5	5.4	4.0	4.8
Total nitrogen, ppm	T 1/	1638.0	765.0	1245.0
Replaceable calcium, lb./acre $CaCO_3$	252.0	6125.0	1190.0	280.0
Exchangeable magnesium, lb./acre, $MgCO_3$	T	1414.0	336.0	32.0
Available phosphorus, lb./acre P_2O_5	183.0	28.0	18.0	367.0
Reserve phosphorus, lb./acre P_2O_5	--	308.0	225.0	70.0
Available potassium, lb./acre K_2O	40.0	136.0	252.0	64.0
Potassium supply power, lb./acre, K_2O	--	2263.0	115.0	85.0

1/ Trace

Table 2.--Height growth of slash pine seedlings growing in different media (stem length in inches)

Nutrient treatments	Growth media		
	Sand in greenhouse 1/	Magnolia sandy loam 1/ in greenhouse	Magnolia sandy loam 2/ in nursery
		NITROGEN SERIES	
$N_0P_1K_1$	3.1	6.2	--
$N_1P_1K_1$	8.9	8.1	6.3
$N_2P_1K_1$	8.7	5.8	4.3
		PHOSPHORUS SERIES	
$N_1P_0K_1$	3.8	7.8	5.8
$N_1P_1K_1$	8.9	8.1	6.3
$N_1P_2K_1$	7.5	7.7	4.8
		POTASSIUM SERIES	
$N_1P_1K_0$	6.6	7.0	4.5
$N_1P_1K_1$	8.9	8.1	6.3
$N_1P_1K_2$	7.4	8.4	5.5

1/ Greenhouse seedlings were sown May 15, 1961, and measured September 21, 1961.

2/ Nursery seedlings were sown April 5, 1961, and measured September 11, 1961.