THE SOUTHERN FOREST NURSERY SOIL TESTING PROGRAM

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Abstract.--In 1980, a committee was established to address the problem of soil testing and interpretation for southern forest nurseries. Subsequently, a program has been developed primarily for the nurseries in the southern coastal plain and involves (1) soil testing from a single lab; (2) soil fertility interpretation and suggestions for amendments; and (3) computer storage and retrieval of data. In 1982, 25 southern nurseries used the services of the Southern Forest Nursery Soil Testing Program.

At the 1980 Southern Nurseryman's Conference, the Nursery Technical Committee discussed the problems of soil testing and interpretation for forest nurseries in the South. Dr. John Mexal was appointed chairman of a committee to address this problem. The committee met at Raleigh, N.C. on June 23, 1981 and as a result, the Southern Forest Nursery Soil Testing Program was formed.

This program consists of three seperate but integrated parts:

(1) Soil testing performed by - A&L Agricultural Labs in Memphis, TN.

(2) Soil fertility suggestions by - Dr. Chuck Davey.

(3) Soil data storage by - the Auburn University Southern Forest Nursery Management Cooperative.

The program works as follows.

(A) The nurseryman takes soil samples from his nursery by block or unit. It is very important that the acreage and sampling code should remain the same from one sampling period until the next. This means that in 1990 the analysis from sample 1A will be comparable to the analysis from sample 1A in 1982. This is essential if balance sheets are to be made for each sampled area.

(B) The samples should be taken during the "cold" season (October to January) prior to the crop being sown. Taking samples after January increases the risk of late recommendations which may cause problems in ordering the correct fertilizers. To ensure sampling consistency, the same person should take and handle all soil samples.

(C) Each sample should be a composite of 25-30 cores taken at random. If there are visible differences in soils or nursery stock growth in a block, a separate sample should be taken from each uniform soil area.

(D) The cores should be taken with a soil probe tube and to a consistent depth of 15 cm (6 inches). Collect the cores forming a single sample in a clean plastic pail. Mix the cores thoroughly and remove a half-liter (pint) sample.

(E) The soil samples should be air dried and sent to A & L Labs in Memphis, Tennessee. The results of the analysis are usually returned within two weeks. Copies of the analysis should be sent to Dr. Davey and one copy should be sent to the Auburn Coop. Figure 1 illustrates an example of the soil report from A&L.

(F) For each soil sample, the nursery should fill out a History Data Form (Figure 2). This form should include all the amendments (organic, fertilizer,

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lime etc. that have been applied since the previous soil test. The crop species grown for each year should be recorded in addition to the next crop which will be grown on the area. The soil texture of the area should also be included. One copy of this form should be sent to Dr. Davey and one copy sent to the Auburn Cooperative.

(G) Dr. Davey will review the soil analysis, history forms, balance sheets and will make suggestions for amendments. These suggestions are sent directly to the nursery.

(H) The Auburn Cooperative will place the data from the soil analysis and history forms into the computer. This data bank will be utilized for two functions.

(1)For each nursery, balance sheets will be prepared for each soil sampling unit (Figure 3). This information will aid the nurseryman in determining how his soil management practices have affected soil fertility. The balance sheet should help avoid large fluctuations in soil factors which may result in reduced productivity. For example, Figure 4 indicates the change in calcium over a 13-year period from one block in a forest nursery. This type of fluctuation is undesirable and could have been avoided with the use of a balance sheet.

(2)The data bank will be used to combine analysis from nurseries with similar soil textures. By comparing data among nurseries with similar textures, it can be more readily determined what is "normal" and what is "out of line". This method of analysis has already benefited several nurseries by defining soil fertility problems which were causing decreases in seedling productivity. The remainder of this paper will present some preliminary data which will illustrate how southern forest nurseries will benefit from having their soil analyzed at one lab.

MATERIALS AND METHODS

Soil samples were collected by the Auburn Cooperative between 1977 and 1980. Most of the samples were collected in conjunction with pre- and postemergence herbicide experiments and therefore they were usually collected from April until June (after the preplant fertilizer application). Samples were not representative of the entire nursery but were only representative of an area of two acres or less. Four soil samples were collected from each herbicide test area. Soil texture was determined by the hydrometer method at the Auburn Forestry Department. Chemical analysis was performed by A & L Laboratories in Memphis, Tennessee on a composite sample from each nursery. Phosphorus was extracted with the Weak Bray and Strong Bray methods. Calcium, magnesium, potassium, sodium, and sulfur were extracted with 1M ammonium acetate. Zinc, manganese, iron, and copper were extracted with 0.1N hydrochloric acid. Boron was extracted with boiling water. Organic matter was determined with a modified Walkley-Black method. Soil pH was determined using a 1:1 ratio of water to soil. Correlations between soil texture and chemical analysis were determined with the aid of the Statistical Analysis System (Table 1). When significant correlations occurred, nurseries were separated into three soil texture groups. Twenty-five nurseries were in Group A (>75% sand); twelve nurseries were in Group B (between 75% and 50% sand); and eight nurseries were in Group C (<50% sand).. Median, minimum, and maximum values for each soil group were determined for each variable (Table 2).

RESULTS AND DISCUSSION

Of the nurseries sampled, 38 were located in the Coastal Plain (Figure 5). Nurseries in this geographic province tended to have soil textures that were sands, loamy sands, and sandy loams. The three nurseries in the Mississippi Alluvial Valley had silt loam textures and were among the finest textures sampled. The remaining nurseries were located in the Ridge and Valley, Lower Plateau, and Piedmont provinces and were normally located on alluvial terrace soils. One nursery in the Valley and Ridge province in Alabama was not located on a river terrace. However, in 1980 and 1981, the entire nursery was covered with approximately 25 cm (10 inches) of river terrace soil which was moved to the nursery site. The original soil contained 54% sand and the new soil has 77% sand.

A coarse textured soil is desirable for pine nurseries because it allows seedbed preparation, lifting, and other work to be carried out sooner under wetter condition than fine-textured soils. For pine nurseries, many authors suggest soil texture having no less than 75% sand (Aldhous 1972, Armson and Sadreike 1979, Stoeckler and Jones 1957, Wakeley 1954, Wilde 1958). Only 25 of the nurseries had textures which met this requirement.

It is apparent that many nurseries established before 1960 had finer soil texture than those established later (Figure 6). This trend is in part due to the increased usage of mechanical harvesting after 1960. With hand lifting, soil texture was of little importance; however, mechanical harvesters perform better on loamy sands or sands. Of the 18 nurseries established after 1960, 14 had textures greater than 75% sands. This fact has implications to soil management in that the coarser textured soils will have a lower nutrient holding capacity and therefore monitoring essential elements is of more importance on these soils.

SOIL ACIDITY

The hydrogen ion activity of the soil, expressed as the pH value, is perhaps the most important chemical property. Soil acidity not only influences the availability of elements but also has a direct influence on the microbial population of the soil. The forest nurseryman is well aware of the influences of the soil acidity on seedling growth and has the ability to change the pH value with either liming, acid-forming fertilizers, or sulfur applications.

Figure 7 indicates that many of the nurserymen have kept soil acidity in pine nurseries in the South between pH 5.0 and 6.0, and this range is optimum for most tree species (Wilde 1958, May 1982). However, because conditions for growth of some pathogens are more favorable at a higher pH value, the senior author recommends a level between pH 5.0 and 5.5 for loblolly pine. Nutrients may become less available in soils with soil acidity levels below 5.0. The three hardwood nurseries were more alkaline, with pH levels between pH 6.2 and 6.4. However, some hardwood species can grow well at pH levels as low as 4.5 (Stone 1980, Kormanic 1980). The assumption that pH 6.2 is the optimum acidity level for hardwood growth is based on natural bottomland hardwood stands and not on studies from the nursery (Stone 1980).

Figure 8 indicates the history of one compartment at a nursery in the South which has alkaline irrigation water that is well buffered with calcium.

Between 1955 and 1965 the primary source of fertilizer nitrogen was ammonium nitrate. Because of the calcium level in irrigation water, the pH steadily rose until it reached a maximum of 6.6 in 1966. In 1967 the nursery began using ammonium sulfate and sulfur in order to lower soil pH. This practice was continued and eventually the pH was lowered to the desired range of 5.5 in 1975.

Because the cation exchange capacity (CEC) of this nursery was high (12 meq/100g), the change in pH took place gradually. The amount of sulfur required to lower the soil pH varies with the cation exchange capacity of the soil. The higher the cation exchange capacity the greater the amount of sulfur required. The cation exchange capacity for most of the nurseries in the south is below 5 meq/100g (Figure 9). In Florida nurseries, 448 kg/ha (400 lb/a) of sulfur have been used in March before planting loblolly and up to 224 lg/ha (200 lb/a) have been directly applied to the seedlings (Mizell 1980). Sulfur applications of more than 1,600 kg/ha has reduced survival of red pine in Ontario (Mullen 1969) but rates this high are not needed in southern pine nurseries.

Organic Matter

A&L Labs normally determines the percent organic matter content by the Walkley-Black method. However, the results from A&L are consistently higher than from other labs (Peter 1982). Table 3 indicates the organic matter values reported by A&L labs are about 25% higher than those from Auburn (Auburn uses a Leco Carbon Analyzer). This difference is attributable to the extra heating of the sample by A&L in their variation of the basic method.

Incorporation of organic matter in the soil usually improves physical and chemical properties (Armson & Sadredika 1979). Organic levels are often correlated with soil texture. The more clay and silt in the soil the higher the organic matter. This is a result of less macropores in a fine textured soil which favor slower decomposition of organic matter.

Organic matter maintenance is considered basic to good soil management programs. In the 50s and early 60s organic matter amendments were routine practice in most forest nurseries in the South with sawdust being one of the primary sources. However, today less than 2/3 of the southern nurseries routinely add organic amendments. With the A&L analysis, two percent organic matter is considered to be the minimum desired level for southern nurseries. However, over 2/3 of the nurseries sampled had organic levels below 2.0% (Figure 10). In the Pacific Northwest 19 of 20 Douglas-fir nurseries routinely apply organic amendments for each rotation (van den Driessche 1979).

It seems ironic that in the Northwest (where the decomposition rates are much lower than the South) such emphasis is placed on organic amendments. Whereas in Florida (where decomposition rates are extremely high) until recently, none of the six forest nurseries were routinely adding organic amendments. One nursery in Georgia with 87% sand had an organic matter content of 2.8% (A&L) in 1981. This supports the observations by May (1958) that "organic matter content of 1.5 to 2.5 percent can be developed and maintained in sands and loamy sands..."

Organic matter provides numerous benefits to soil management, including increased water-holding capacity; improved soil physical properties; increased cation exchange capacity; a source for nutrients such as nitrogen and phosphorus; a regulator of micronutrients such as manganese, boron, copper, zinc, and iron; reduces toxicity of certain herbicides; favors mycorrhizal development; and may suppress certain pathogens. It is possible for a nurseryman to grow good seedlings with soil having a low organic matter content, however, he cannot afford to make mistakes in fertilizer application, irrigation, pesticide application, management of microbial populations, or management of soil physical properties. The benefit of organic matter is that it provides a buffer against such mistakes. Some nurserymen say they can't afford to grow seedlings without this buffer. Other nurserymen say they can't afford to spend money for it.

It is doubtful that the use of cover crop will substantially increase soil organic matter levels. This is supported by several experts in forest soils. In 1948 Dr. Earl Stone (1948) stated that, "It is now appreciated that organic matter content will not be built up by green manures as is commonly employed unless the initial level is very low. Even their frequent inclusion will not prevent a decline in organic matter under most circumstances." Dr. Allison (1973) stated that "it is now well established that green manures have a negligible effect on total soil organic matter levels if cultivation is continued. Although they do replenish the supply of active, rapidly decomposing organic matter." Davey and Krause (1980) stated that "cover crops, catch crops and green manures are very benefical in nursery management, but current wisdom indicated that they will not suffice for the total needed soil organic matter... The realistic nurseryman will not depend on cover crops to substain his soil organic matter content." Dr. May (1982) stated that "in many soils the organic matter content cannot be maintained or increased much above the irreducible minimum 0.3 to 0.8 % using a 1 to 1 rotation without the addition of large quantities of organic matter."

A recent study by Sumner and Bouton (1981) has indicated that growing cover crops for two years only increased soil organic matter levels at the Morgan Nursery in Georgia by 0.23 to 0.34%. Recent soil analysis from these plots have indicated that one year of seedling production reduced the level by 0.21 to 0.37%, therefore negating the benefit of the cover crops. The production of the cover crop was approximately 12.1 to 13.2 metric tons per hectare (5.4 to 5.9 short tons per acre) per year. The addition of 45 metric tons per hectare (20 short tons per acre) of sawdust can easily increase soil organic matter levels by 1.5%. The amount of lignin contained in sawdust and/or pine bark greatly exceeds that contained in cover crops such as corn or sorghum. Pine bark is reported to have between 31 and 50% lignin and sawdust is reported to have 27 to 30% lignin. Corn can contain 15% lignin and sorghum-sudangrass can contain between 5 and 14% lignin depending on the stage of development. Therefore the maximum amount of lignin added in a two year cover crop of sorghum-sudangrass would be 3.8 metric tons/hectare. The minimum amount of lignin added in a 2.5-cm addition of sawdust or bark would be 12 metric tons/hectare. Lignin is a desirable organic amendment because of its slow decomposition rate. It degrades much slower than starch or carbohydrates and degrades slower than cellulose and hemicellulose. In addition, lignin is the source of the substances that provide for the increase in cation exchange capacity.

SOIL NUTRIENTS

Figure 11 indicates a generalized response of seedling growth as affected by nutrient level. The forest nurseryman should not wait until he sees a deficiency symptom before deciding to fertilize nor should he keep his seedlings in the hidden hunger area of the curve. Although no distinct deficiency will be noted, productivity will be reduced. However, the nurseryman should not over fertilize to the degree where other nutrients become unavailable or toxic symptoms occur. It is the goal of our program to help keep the nurseryman's soil fertility in the area where maximum productivity will be achieved at the most economical cost.

NITROGEN

Nitrogen is the nutrient which is most frequently limiting to plant growth and is needed in greatest quantities for production of tree seedlings. Scientists have been unable to develop a reliable test to determine the nitrogen supplying capacity of soils. There are several reasons for this; first, a majority of the nitrogen is stored in soil organic matter. The rate of nitrogen release is affected by the amount of soil organic matter, the carbon/nitrogen ratio of the organic matter, the soil temperature, soil moisture, and length of growing season. These and other factors make it impractical to predict the amount of nitrogen that will be supplied by the soil in one growing season. Second, most forest nurseries are low in organic matter content and do not vary much in their capacity to supply nitrogen. Therefore nitrogen recommendations are based primarily on the crop to be grown.

The estimated nitrogen return (ENR) as reported by A&L Laboratories is an attempt to estimate the amount of nitrogen available from decomposition of organic matter. This figure is computed directly from the soil organic matter. The assumption is the higher the organic matter in the soil, the higher the carbon/nitrogen ratio. For soils having 3% organic matter, 116 kg/ha (104 lb/A) of nitrogen is estimated to be released through the growing season. However, soils with 1% organic matter would be calculated to release only 72 kg/ha (64 lb/A) of nitrogen. On fields where the organic matter level is lower than 1%, some preplant nitrogen is suggested. Otherwise, it is more efficient to apply all the nitrogen as summer top dressings. Where preplant nitrogen is used, 56 kg/ha (50 lb/A) of nitrogen should be applied preplant, with additional top dressings during the summer totaling 140 kg/ha (125 lb/A). Where no preplant nitrogen is applied, a total of 170 kg/ha (150 lb/A) of nitrogen during the growing season should be sufficient. In some instances, (i.e., Hauss nursery, 1981) loblolly and longleaf seedlings have been grown with no preplant or top dressed nitrogen.

If the pH is high, or the soil sulfur test is low, or concentrated fertilizers are used, then some or all of the nitrogen should be applied as ammonium sulfate. Otherwise ammonium nitrate can be used. Light applications of nitrogen during the growing season are recommended to prevent summer chlorosis in loblolly pine (Carter 1964). The application rate should range from 22 to 33 kg/ha (20 to 30 lb/A) of nitrogen per application. Therefore five to seven applications of nitrogen would be required when applying 170

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PHOSPHORUS

The level of available phosphorus (Weak Bray) is not strongly correlated with soil texture. For loblolly, the minimum desired level of phosphorus using Weak Bray extraction is 40 ppm (25 ppm if a Double-Acid extraction is used). For hardwood seedlings, Paul Kormanic (1980) has recommended soil phosphorus levels of 75 to 100 ppm using weak Bray. Too high a level of phosphorus can be undesirable. Our analysis indicated that four nurseries had phosphorus levels greater than 120 ppm (Weak Bray)(Figure 12). By using our previous records at Auburn University, we found that these nurseries were high in phosphorus because of management practices. In the late 1950s, these nurseries had lower phosphorus levels. However the practices in those days were to apply 1,100 kg/ha (1000 lb/A) of superphosphate.

Phosphorus does not leach through the soil but forms compounds with calcium, iron, and aluminum in the soil which release it slowly. It is doubtful whether much of the phosphorus in a top dressing of superphosphate ever becomes available to the current seasons crop due to phosphorus immobility and fixation in the soil. Where needed, phosphorus should be applied preplant. If a top dressing of phosphorus is needed, ammonium phosphate should be used. Crops require much smaller quantities of phosphorus than nitrogen and potassium. One crop of pine seedlings would usually remove less than 8 kg/ha of phosphorus. Therefore, under continuous fertilization, soil content of phosphorus has increased at some forest nurseries to high levels. High phosphrous levels are undesirable because of potential decreases in the availability of iron, zinc, and copper.

In addition, Youngberg(1980) suggests that when the ratio between phosphorus and potassium becomes out-of-line, seedlings may have problems in hardening-off in the fall. Figure 13 indicates the phosphorus/potassium ratio of the sampled nurseries. According to Youngberg, nurseries with twice as much phosphorus as potassium may have hardening-off problems. This helps explain why some nurseries have had trouble hardening seedlings off in the fall. This may also explain some of the responses observed after late applications of phosphorus. In 1982, two nurseries reported that seedlings fertilized with diammonium phosphate were delayed in hardening-off and also broke bud earlier in the spring. At one nursery, seedlings that were fertilized with 140 kg/ha (125 lb/a) of diammonium phosphate on September 24 broke bud early the following spring and had produced 15 cm of growth by March 9. Research needs to be conducted to confirm the role phosphorus plays in the dormancy of loblolly.

POTASSIUM

Potassium levels were also significantly correlated with soil textures. The junior author suggests a minimum of 90 ppm of potassium. Of the 45 nurseries in our sample, 26 nurseries had less than this minimum level (Figure 14). This suggests that of the major nutrients, potassium may be the one which is most often neglected. The ratio of potassium to other cations may indicate whether potassium may be deficient. The % base saturation for potassium should be greater than 5% (Figure 15). A crop of loblolly seedlings can remove up to 100 kg/ha of potassium. Leaching of potassium in sandy soils is usually a common occurrence and potassium top dressings may be required even during the growing seasons at some nurseries where leaching is great. Use of more potassium than is needed may cause magnesium deficiencies especially on sandy soils.

CALCIUM

Calcium is positively correlated with the silt and clay content and therefore the absolute amounts will vary with texture (Figure 16). For sands and loamy sands, at least 200 ppm of calcium is recommended. However, the absolute amount of exchangeable calcium present is frequently not so important to plant nutrition as the amount present in relation to the quantities and kinds of other cations present. Figure 17 shows the % base saturation of calcium for the 45 nurseries sampled. This distribution suggests that nurseries with less than 40% base saturation of calcium are either too low in pH, or too low in calcium.

When an increase in pH is desired, dolomitic or calcitic limestone can be used. When an increase in pH value is not desired, calcium sulfate (gypsum) can be applied. Low calcium levels are undesirable in a conifer nursery since deficiencies can result in serious injury to meristematic regions (Davis 1949; Lyle 1969; Sucoff 1961).

MAGNESIUM

Magnesium is also correlated with silt and clay content (Figure 18). For nursery soils with more than 75% sand, we recommend at least 25 ppm. For those with sandy loams, we recommend at least 35 ppm. Loams and silt loams should have at least 40 ppm. The % base saturation for Magnesium should be between 10 and 25% (Figure 19). As a general rule, if the soil test indicates that the ppm of exchangeable potassium to exchangeable magnesium ratio is more than 3 to 1, then a magnesium deficiency could occur. Magnesium is important in chlorophyll formation. Magnesium deficiency yields a needle color similar to nitrogen deficiency (Lyle 1969).

SODIUM

Sodium is not usually regarded as an essential element. However, the sodium level in the soil can greatly affect the production of quality seedlings. Problems may arise if the exchangeable sodium in the soil exceeds 10%. By testing irrigation water, the Auburn Cooperative identified three nurseries that had high sodium absorption ratios (Figure 20). Irrigation water with a sodium absorpion ratio of 3 to 5 indicates slight to medium hazard. Values above 5 indicate that problems with permeability are likely to occur, especially for fine textured soils. One of these nurseries was having difficulty producing loblolly seedlings. When the soil was tested, up to 21% exchangable sodium was reported. This was causing problems with soil structure and was probably causing a nutrient imbalance. Now that the problem has been identified, steps have been taken to remedy the situation. Calcium sulfate additions helped in reducing the sodium absorption ratio in the soil. Up to

780 kg/ha of gypsum was applied directly to the seedlings. Sodium usually does not need to be monitored except at those nurseries that have a high sodium absorption ratio in their irrigation water.

SULFUR

Sulfur is essential for efficient nitrogen utilization by the plant. In the past, when sulfur "contaminated" fertilizers were used, sulfur was normally added in sufficient amounts to avoid deficiencies. However, today with the use of highly concentrated fertilizers and leaching losses from irrigation, sulfur deficiencies can and have occurred in forest nurseries. Sulfur deficiencies have been documented for at least three southern nurseries (Lyle and Pearce 1968, Morris 1980, Stone 1980). Response of loblolly seedlings at the Ft. Towson nursery in Oklahoma was dramatic (Morris 1980). For the present, the junior author recommends maintaining at least 10 ppm of sulfur (Figure 21). The ratio of nitrogen to sulfur in the plant tissue may be a better indicator of sulfur requirement. On the average, loblolly seedlings require approximately 1 kg of available sulfur for each 15 kg of available nitrogen. Because most sulfur-containing fertilizers are highly soluble and the sulfate portion is subject to leaching, the best way of building sulfur reserves in soils is by maintaining an adequate organic matter content. Where organic sulfur reserves are not maintained, ammonium sulfate or other sulfur containing fertilizers will need to be applied.

IRON

Deficiency of iron is one of the most common and conspicuous micronutrient deficiencies of trees and occurs chiefly on alkaline and calcareous soils where absorption is inhibited. This is the main reason why loblolly does not grow well above pH 6. Iron chlorosis occurring after heavy applications of nitrogen or during hot weather are known as nitrate-induced chlorosis or heat-induced chlorosis. High levels of phosphorus can tie up iron by forming insoluble iron-phosphate compounds. Soil analysis for iron is probably only useful if a low level is indicated (Figure 22). A soil test with medium or high levels of iron is almost meaningless since the iron may not be in an available form. Much of the iron in the leaves occurs in the chloroplasts where it plays a role in the synthesis of chloroplast proteins. Iron is relatively immobile and therefore chlorosis develops first at the terminal needles. Iron chlorosis is usually corrected by either acidifying the soil with sulfur, or with the application of iron-chelates. The iron-chelates produce favorable results more quickly.

MANGANESE

Plants can use manganese over and over; therefore, only small amounts are required. The junior author suggest a minimum level of 5 ppm. None of the nurseries sampled had less than 7 ppm of Manganese (Figure 23). This element is also essential for the synthesis of chlorophyll and also probably affects the avaliability of iron. For this reason, the symptoms of manganese deficiency are easily confused with iron chlorosis.

ZINC

Zinc is essential for the transformation of carbohydrates and for regulation of the consumption of sugar. The junir author suggests a minimum level of 1 ppm for zinc. The lowest level of zinc for the nurseries sampled was 1.1 ppm (Figure 24). However, in 1981 three nurseries had levels as low as 0.7 ppm. Those nuseries with sandy, easily leached soils and high in phosphorus are subject to zinc deficiency. Heavy applications of phosphate to the soil or soils with high levels of phosphates are often low in available zinc. It has been found that fumigation of soils low in zinc can result in increased plant uptake of zinc (Thorne 1957).

COPPER

Copper plays an important role in plant growth as an enzyme activator. The junior author suggests a minimum level of 0.8 ppm. Of the 45 nurseries sampled, 19 had less than this level (Figure 25). On sandy soils containing little organic matter, copper generally becomes less available to plants as the pH value increases. High levels of phosphorus in the soil can reduce the uptake of copper by the seedling. The nursery with 4 ppm of copper in figure 25 is high because of the frequent use of bordeaux mixture as a fungicide.

BORON

A recent paper in the Southern Journal of applied Forestry by Stone et al.(1982) has pointed out the importance of monitoring the boron level in sandy nurseries. In a sandy soil, organic matter is the sole means or boron retention. This points out the importance of maintaining an adequate level of organic matter. In addition, soil acidity above pH 6 in conjunction with high calcium level resulted in less available boron. The lowest level of boron reported by A&L Labs for the St. Regis nursery in Florida was 0.2 PPM. (Figure 26). Several other nurseries had soils with this low level in 1981. The junior author suggests maintaining the level of boron above 0.3 ppm. Boron deficiency causes serious injury and death of the apical meristem and is well illustrated in the paper by Stone et al, (1981).

CONCLUSION

Thus far, 25 southern nurseries have used the services of the Southern Forest Soil Testing Program. Although we have only just begun, several nurseries have already improved their seedling production as a result of this program. The primary goal of this soil testing program is to provide the nurseryman with help so that he can avoid imbalances in soil nutrients as well as avoid dramatic fluctuations in nutrient levels. We hope that with this Program, nursery soil productivity will be maximized throughout the South.

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Table 1. A&L CORRELATION COEFFICIENTS AND PROBABILITIES OF A GREATER r VALUE1/

	OM	PH	CEC	SAND	SILT	CLAY
OM	1.00000 0.0000	0.01033 0.9476	0.30024 0.0504	-0.28438 0.0583	0.23548 0.1194	0.33392 0.0250
pH	0.01033 0.9476	1.00000 0.0000	0.23727 0.1255	0.05741 0.7146	-0.07246 0.6442	-0.00130 0.9934
CEC	0.30024 0.0504	0.23727 0.1255	1.00000 0.0000	-0.86540 0.0001	0.83231 0.0001	0.71183 0.0001
P1	0.10734 0.4933	-0.03572 0.8201	-0.25102 0.1044	0.26579 0.0850	-0.32230 0.0350	-0.02036 0.8969
P2	0.18884 0.2252	0.01310 0.9336	-0.16841 0.2803	0.19638 0.2069	-0.26954 0.0805	0.07793 0.6194
K	0.49984 0.0006	0.06338 0.6864	0.59714 0.0001	-0.58231 0.0001	0.46514 0.0015	0.74002 0.0001
Mg	0.26241 0.0853	0.41512 0.0056	0.90644 0.0001	-0.63875 0.0001	0.57178 0.0001	0.62557 0.0001
Ca	0.28687 0.0590	0.45628 0.0021	0.95673 0.0001	-0.76855 0.0001	0.75126 0.0001	0.56787 0.0001
SO4	0.23049 0.1277	-0.23377 0.1314	0.26704 0.0834	-0.38207 0.00096	-0.41512 0.0046	0.15955 0.2951
Zn	0.09941 0.5159	0.05338 0.7339	0.11572 0.4599	-0.09373 0.5403	0.08294 0.5880	0.09622 0.5295
Mn	0.21060 0.1659	0.06587 0.6747	0.45290 0.0023	-0.54081 0.0001	0.44549 0.0022	0.63822 0.0001
Fe	0.17975 0.2374	0.03123 0.8424	0.40074 0.0077	-0.41553 0.0045	0.48765 0.0007	0.07949 0.6037
Cu	0.01151 0.9402	-0.00212 0.9892	0.15335 0.3262	-0.25148 0.0956	0.25747 0.0877	0.15051 0.3237
B	0.34443 0.0205	-0.10497 0.5029	0.52361 0.0003	-0.65993 0.0001	0.62467 0.0001	0.55740 0.0001
% BASE SAT. K	0.22594 0.1452	-0.18127 0.2247	-0.37186 0.0141	0.28649 0.0625	-0.33783 0.0267	-0.05445 0.7288
% BASE SAT Mg.	0.08858 0.5722	0.39372 0.0090	-0.07555 0.6301	0.26844 0.0818	-0.32492 0.0335	-0.03400 0.8286
% BASE SAT. Ca	-0.09059 0.5635	0.84911 0.0001	0.29692 0.0532	-0.08882 0.5711	0.11157 0.4763	-0.00402 0.9796
% OF CEC H	-0.03017 0.8477	-0.97419 0.0001	-0.14431 0.3559	-0.12947 0.4080	0.15536 0.3198	0.02163 0.8905
H meq/100g	0.19112 0.2196	-0.57571 0.0001	0.55013 0.0001	-0.71499 0.0001	0.72185 0.0001	0.49259 0.0008

1/ the top value is the linear correlation coefficent and the bottom value is the probability of a greater correlation coefficent.

Table 2. Median, minimum, and maximum values for soil characteristics from 45 southern forest nurseries.

Variable	Group A Sands + loamy sands (25 nurseries)			Group B Sandy loams + sandy clay loams (12 nurseries)			Group C Loams + silt loams (8 nurseries)		
	Median	Min.	Max.	Median	Min.	Max.	Median	Min.	Max.
p.H.	5.7	5.2	6.0	5.6	4.5	6.1	5.7	4.6	6.4
C.E.C.	1.7	1.1	2.8	2.8	1.9	3.5	4.8	4.0	9.2
% O.M.	1.6	0.7	2.8	1.6	0.9	3.4	1.9	1.3	3.0
% Sand	83	76	95	66	55	71	38	15	49
% Slit	8	2	15	21	23	28	46	37	67
% Clay	7	1	12	14	11	25	17	7	23
	---------------------------p.p.m.---------------------------								
P1	76	27	167	67	40	136	48	28	114
P2	92	36	186	87	46	166	79	38	138
K	58	20	126	103	47	136	111	68	138
Mg	40	15	85	55	25	90	82	35	250
Ca	200	100	300	300	100	400	550	300	1200
Mn	25	4	144	132	26	278	108	63	260
S-	14	5	60	16.5	5.0	50.0	33	13	100
Fe	47	13	102	45	24	105	84	43	217
Cu	0.7	0.4	2.3	0.8	0.5	4.3	0.9	0.5	2.4
Zn	2.2	1.1	11.4	4.4	1.9	29.4	3.4	1.6	4.7
B	0.4	0.3	1.4	1.2	0.9	1.8	1.2	0.9	2.5
Base saturation	--								
%K	8.3	3.3	17.0	8.8	6.3	12.9	5.0	3.2	8.8
%Mg	19.8	8.9	27.2	17.6	11.0	21.4	15.4	10.6	22.6
%Ca	53.6	35.7	62.5	48.1	26.3	62.5	58.5	31.3	65.2
%H	21.4	12.5	35.3	23.3	14.3	57.9	20.0	8.7	54.2

Table 3. Regressions of Auburn Soil Lab Analysis on A&L Soil Analysis of 45 Nursery Soils

Auburn soil test		Intercept		A&L soil test	R^2
Organic matter	=	NS*	+	.8(O.M)	.56
pH	=	1.35	+	.745(pH)	.56
C.E.C.	=	1.18	+	1.283(C.E.C)	.75
P**	=	NS	+	.62(p weak Bray)	.44
P	=	NS	+	.58(p-$NaHCO_3$-p)	.45
K	=	NS	+	.71(K)	.63
Mg	=	NS	+	.94(Mg)	.75
Ca	=	NS	+	1.13(Ca)	.83
Fe	=	9.6	+	.356(Fe)	.72
Mn	=	NS	+	.80(Mn)	.93
S-SO_4	=	9.3	+	.25(S-SO_4)	.40
Cu	=	NS	+	.88(Cu)	.59
Zn	=	1.24	+	.23(Zn)	.26
B	=	NS	+	.165(B)	.49

* NS = intercept not significantly different from zero.

** Auburn soils lab uses Double Acid Extraction.

FIGURE 1

REPORT NUMBER 169-9

A & L AGRICULTURAL LABORATORIES, INC.
411 N. THIRD ST., MEMPHIS, TN 38105 * (901) 527-2780

SEND TO:
AUBURN U. (D.SOUTH)
DEPT. OF FORESTRY
AUBURN UNIVERSITY,
ALABAMA 36849

GROWER:

SAMPLES SUBMITTED BY: DAVID SOUTH

DATE OF REPORT 06/21/82 PAGE 1

SOIL ANALYSIS REPORT

SAMPLE NUMBER	LAB NUMBER	ORGANIC MATTER % * RATE	ORGANIC MATTER ** ENR lbs./A	PHOSPHORUS P1 (Weak Bray) * **** ppm-P RATE	PHOSPHORUS P2 NaHCO3-P * **** ppm-P RATE	POTASSIUM K * ***** ppm-K RATE	MAGNESIUM Mg * *** ppm-Mg RATE	CALCIUM Ca * *** ppm-Ca RATE	SODIUM Na * *** ppm-Na RATE	pH SOIL pH	pH BUFFER pH	HYDROGEN H meq/100g	Cation Exchange Capacity C.E.C. meq/100g	PERCENT BASE SATURATION (COMPUTED) % K	% Mg	% Ca	% H	% Na
1L	4094	2.2	88 M	49VH	52 H	102 VH	39 L	250 L	35 M	5.2	6.90	1.0	3.0	8.7	10.8	41.7	33.3	5.1
2U	4095	1.5	74 L	60VH	61VH	96 VH	38 L	250 L	35 M	5.3	6.90	0.9	2.9	8.5	10.9	43.1	31.0	5.2
3	4096	1.3	70 L	36VH	39 M	100 VH	19VL	200 L	84VH	5.0	6.80	1.2	3.0	8.5	5.3	33.3	40.0	12.2
4	4097	1.5	74 L	37VH	38 M	108 VH	28 L	250 L	101VH	5.1	6.80	1.3	3.5	7.9	6.7	35.7	37.1	12.5

(SEE EXPLANATION ON BACK)

SAMPLE NUMBER	NITRATE NO3 ppm-NO3-N RATE	SULFUR S ppm-S RATE	ZINC Zn ppm-Zn RATE	MANGANESE Mn ppm-Mn RATE	IRON Fe ppm-Fe RATE	COPPER Cu ppm-Cu RATE	BORON B ppm-B RATE	EXCESS LIME RATE	SOLUBLE SALTS mmhos/cm RATE	CHLORIDE Cl ppm-Cl RATE	MOLYBDENUM Mo ppm-Mo RATE	PARTICAL SIZE ANALYSIS % SAND	% SILT	% CLAY	SOIL TEXTURE
1L		8 M	1.3 L	20 M	50VH	1.9 H	.4 L	N	.4 L						
2U		12 M	1.2 L	12 M	26 H	2.4 H	.3VL	N	.4 L						
3		10 M	4.2 H	118VH	62VH	6.1VH	.8 M	N	.7 M						
4		21VH	3.7 H	108VH	74VH	6.1VH	1.0 M	L	.8 M						

A & L AGRICULTURAL LABORATORIES, INC.

RL Large
R.L. LARGE 8JL

BY

* CODE TO RATING: VERY LOW (VL), LOW (L), MEDIUM (M), HIGH (H), VERY HIGH (VH), AND NONE (N).
** ENR - ESTIMATED NITROGEN RELEASE
*** MULTIPLY THE RESULTS IN ppm BY 2 TO CONVERT TO LBS. PER ACRE OF THE ELEMENTAL FORM
**** MULTIPLY THE RESULTS IN ppm BY 4.6 TO CONVERT TO LBS. PER ACRE P_2O_5
***** MULTIPLY THE RESULTS IN ppm BY 2.4 TO CONVERT TO LBS. PER ACRE K_2O
MOST SOILS WEIGH TWO (2) MILLION POUNDS (DRY WEIGHT) FOR AN ACRE OF SOIL 6-2/3 INCHES DEEP.

Figure 2. SOUTHERN NURSERY SOIL MANAGEMENT HISTORY FORM

NURSERY:____________________________________ PHONE:________________________

SUPERINTENDENT:____________________________

ADDRESS:___________________________________

COMPARTMENT (BLOCK):___________________ UNIT (S):____________________________

SOIL TEXTURE:__________ % SAND:_____ % SILT:______ % CLAY:____

NEXT CROP TO BE GROWN:____

CONDITION OF LAST CROP OF PINE SEEDLINGS
Chlorotic ☐ Stunted ☐ Below average ☐ Average ☐ Above average ☐

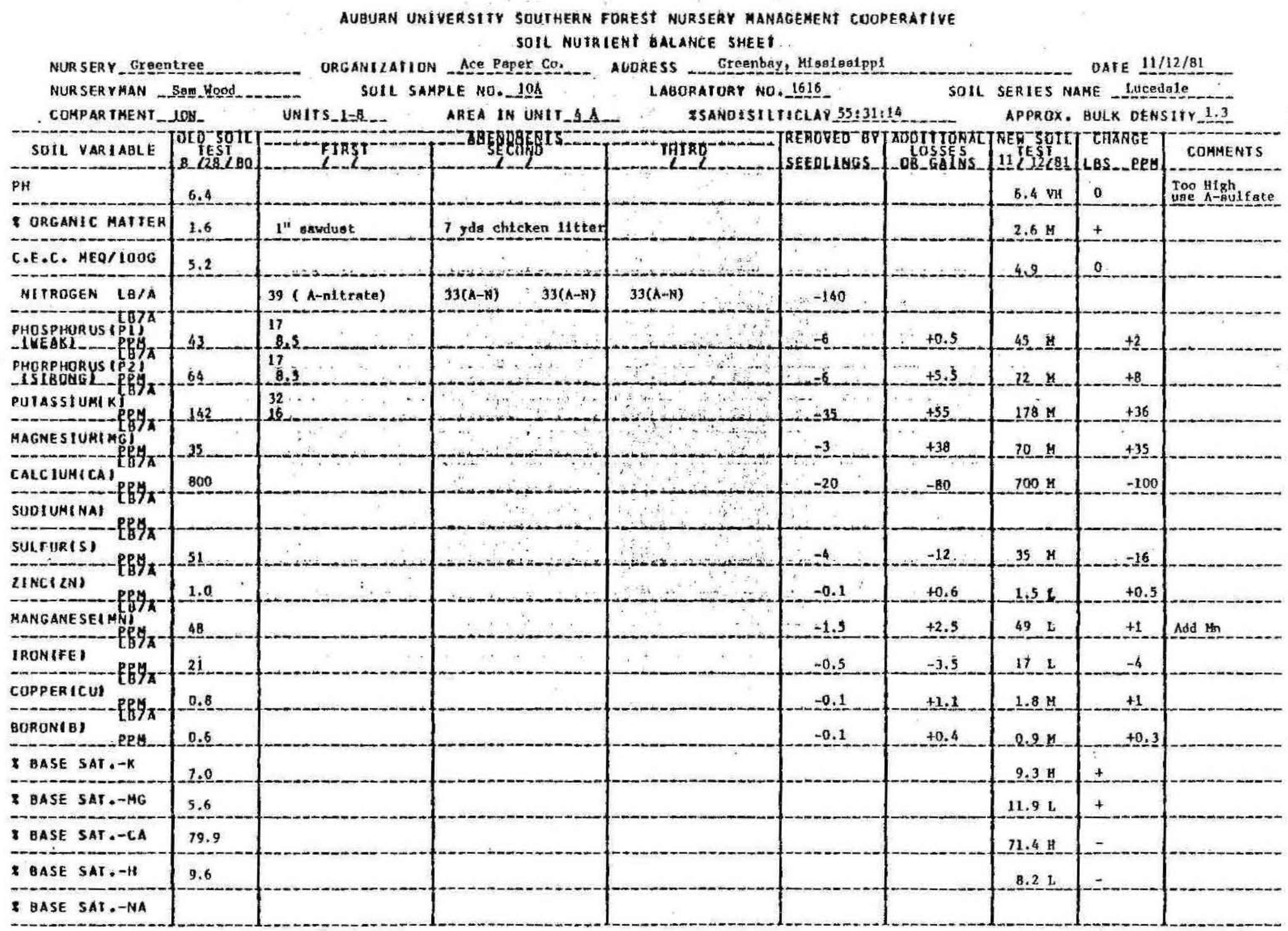
Other____

	DATE APPLIED	RATE APPLIED	DATE APPLIED	RATE APPLIED
Crop Grown[1]				
FERTILIZERS APPLIED				
Ammonium nitrate				
Ammonium sulfate				
Calcium nitrate				
Calcium sulfate (Gypsum)				
Magnesium sulfate (Epsom salt)				
Diammonium phosphate				
Nitrate of Soda-potash				
Potassium chloride (Muriate)				
Potassium nitrate				
Potassium sulfate				
Sulfate of Potash Magnesia				
Sulfur				
Superphosphate, normal				
Superphosphate, double				
Superphosphate, triple				
Urea				
Other				
MICRONUTRIENTS (list form)				
Boron				
Copper				
Manganese				
Zinc				
Iron				
LIME				
Calcite				
Dolomite				
ORGANIC MATTER				
Pine bark				
Hardwood bark				
Pine sawdust				
Hardwood sawdust				
Pine chips				
Hardwood chips				
Other				

[1] If cover crop, include both winter and summer covercrop.

Is irrigation water high in calcium? No ☐ Yes ☐

Is irrigation water high in sodium? No ☐ Yes ☐



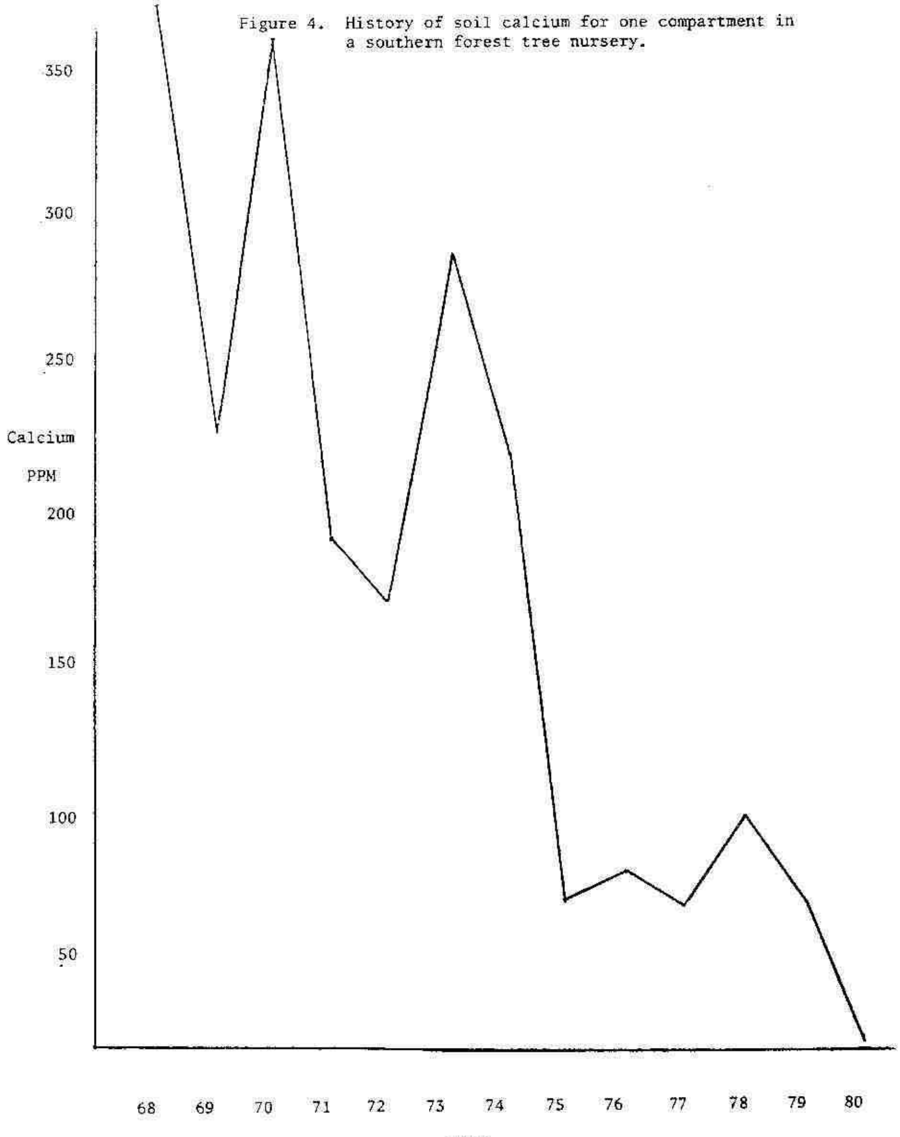
AUBURN UNIVERSITY SOUTHERN FOREST NURSERY MANAGEMENT COOPERATIVE
SOIL NUTRIENT BALANCE SHEET

NURSERY Greentree ORGANIZATION Ace Paper Co. ADDRESS Greenbay, Mississippi DATE 11/12/81
NURSERYMAN Sam Wood SOIL SAMPLE NO. 10A LABORATORY NO. 1616 SOIL SERIES NAME Lucedale
COMPARTMENT 10N UNITS 1-8 AREA IN UNIT 6 A %SAND:SILT:CLAY 55:31:14 APPROX. BULK DENSITY 1.3

SOIL VARIABLE	OLD SOIL TEST 8/28/80	AMENDMENTS FIRST / /	SECOND / /	THIRD / /	REMOVED BY SEEDLINGS	ADDITIONAL LOSSES OR GAINS	NEW SOIL TEST 11/12/81	CHANGE LBS	PPM	COMMENTS
PH	6.4						6.4 VH	0		Too High use A-sulfate
% ORGANIC MATTER	1.6	1" sawdust	7 yds chicken litter				2.6 M	+		
C.E.C. MEQ/100G	5.2						4.9	0		
NITROGEN LB/A		39 (A-nitrate)	33(A-N) 33(A-N)	33(A-N)	-140					
PHOSPHORUS(P1) (WEAK) LB/A PPM	43	17 8.5			-6	+0.5	45 M		+2	
PHORPHORUS(P2) (STRONG) LB/A PPM	64	17 8.5			-6	+5.5	72 M		+8	
POTASSIUM(K) LB/A PPM	142	32 16			-35	+55	178 M		+36	
MAGNESIUM(MG) LB/A PPM	35				-3	+38	70 M		+35	
CALCIUM(CA) LB/A PPM	800				-20	-80	700 M		-100	
SODIUM(NA) LB/A PPM										
SULFUR(S) LB/A PPM	51				-4	-12	35 M		-16	
ZINC(ZN) LB/A PPM	1.0				-0.1	+0.6	1.5 L		+0.5	
MANGANESE(MN) LB/A PPM	48				-1.5	+2.5	49 L		+1	Add Mn
IRON(FE) LB/A PPM	21				-0.5	-3.5	17 L		-4	
COPPER(CU) LB/A PPM	0.8				-0.1	+1.1	1.8 M		+1	
BORON(B) LB/A PPM	0.6				-0.1	+0.4	0.9 M		+0.3	
% BASE SAT.-K	7.0						9.3 H	+		
% BASE SAT.-MG	5.6						11.9 L	+		
% BASE SAT.-CA	79.9						71.4 H	-		
% BASE SAT.-H	9.6						8.2 L	-		
% BASE SAT.-NA										

FIGURE 3

Figure 4. History of soil calcium for one compartment in a southern forest tree nursery.



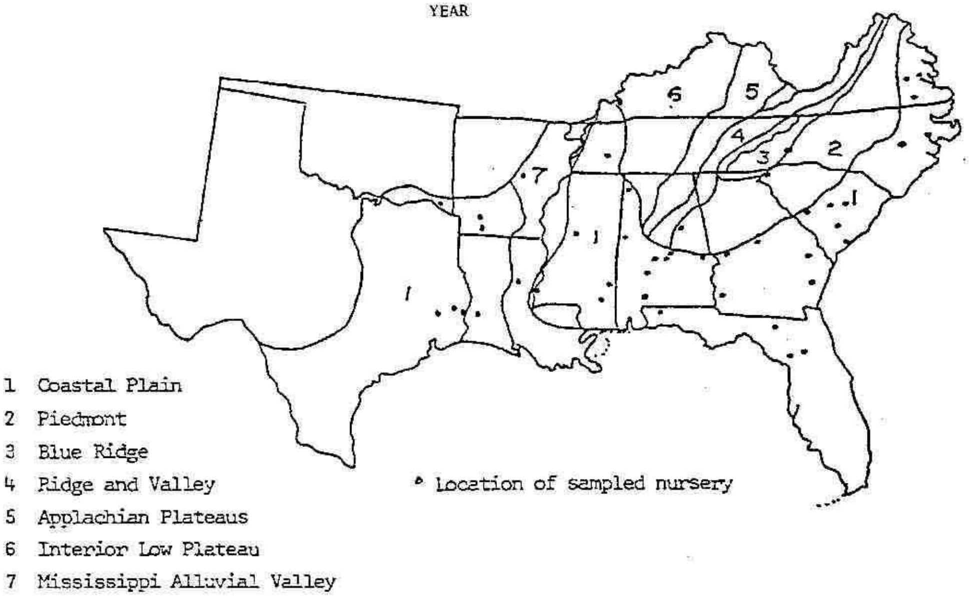


Figure 5. Physiographic Division of the Southeastern States.

FIGURE 6

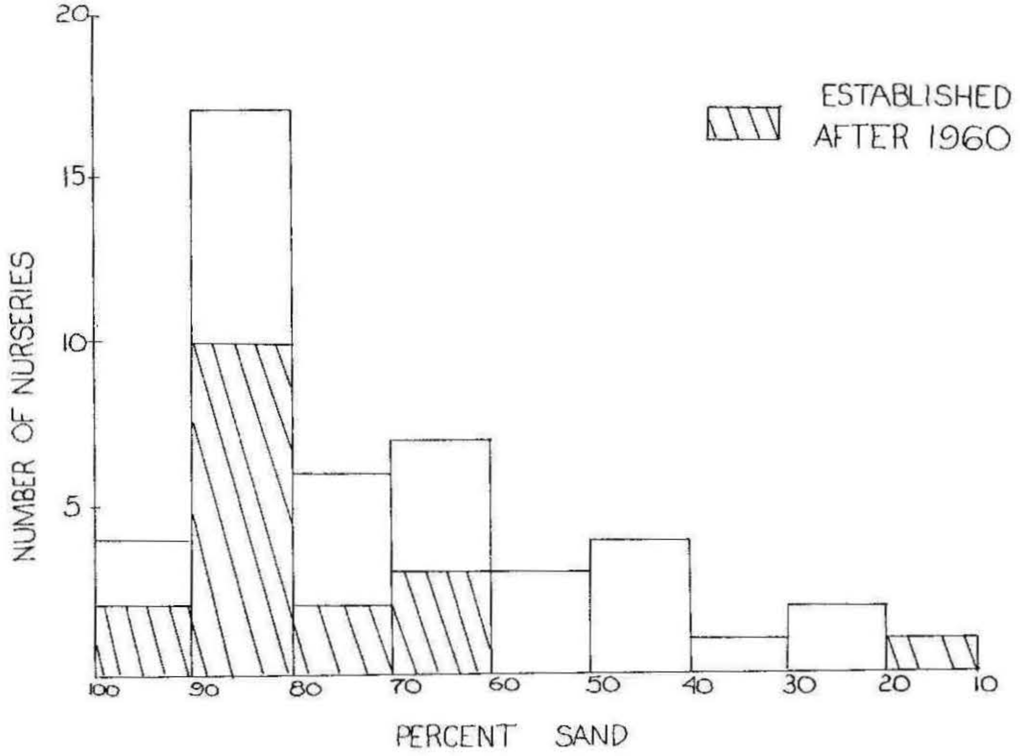


FIGURE 7

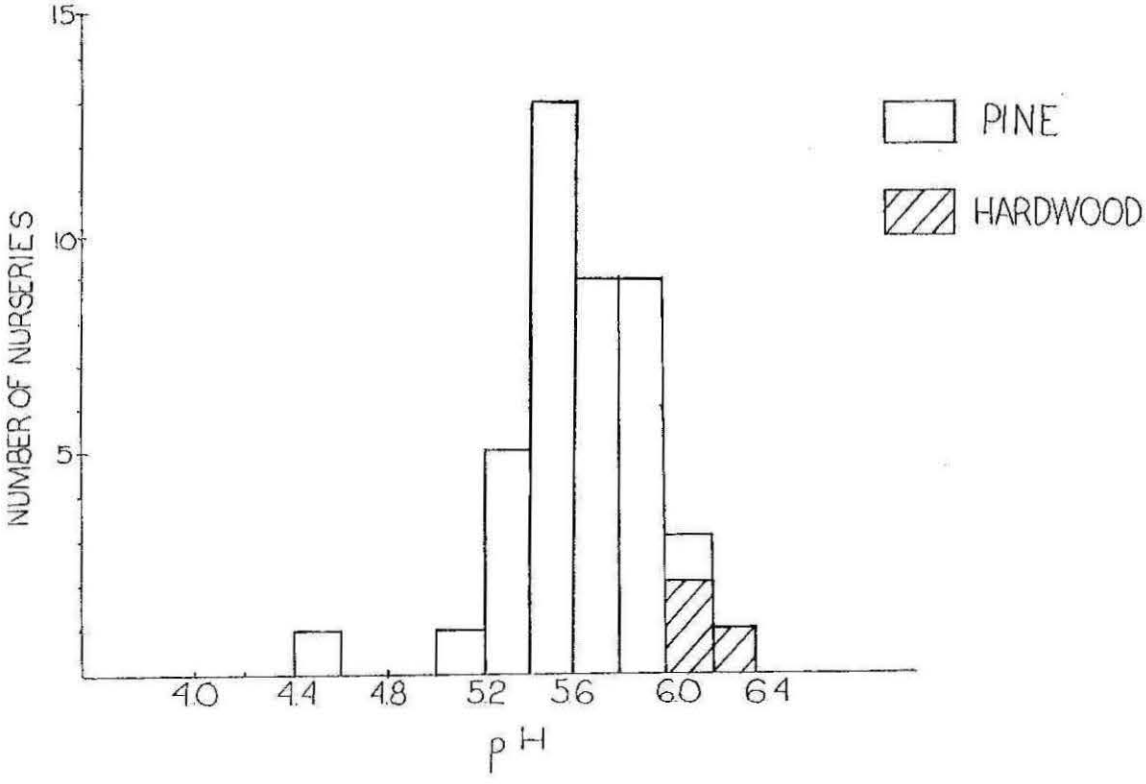


Figure 8. History of soil acidity for one compartment in a southern forest tree nursery.

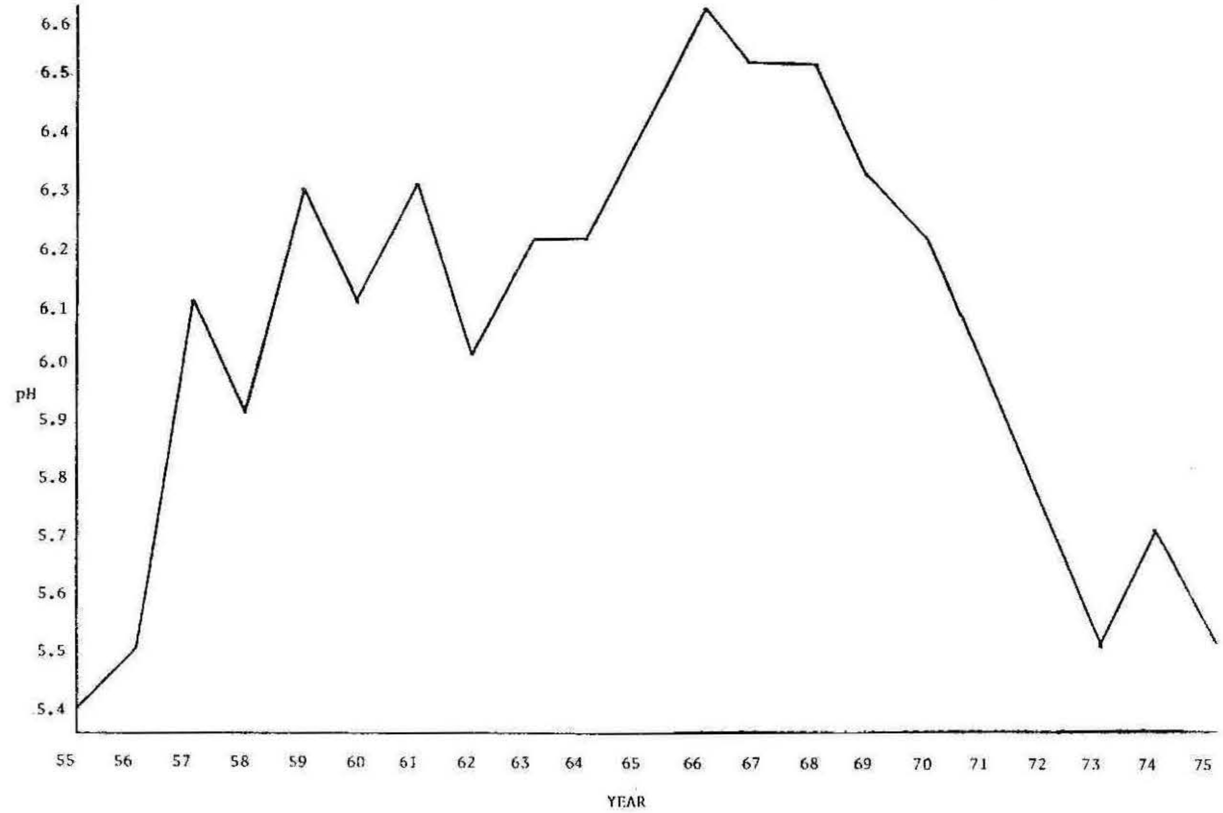


FIGURE 9

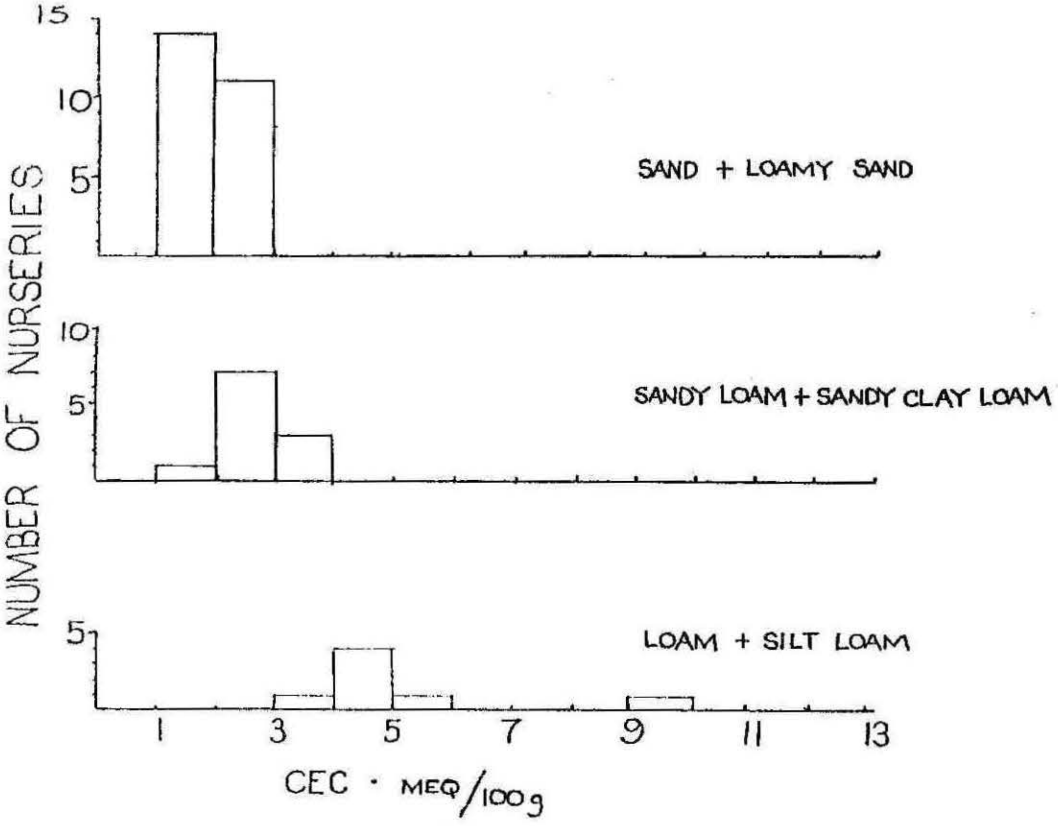
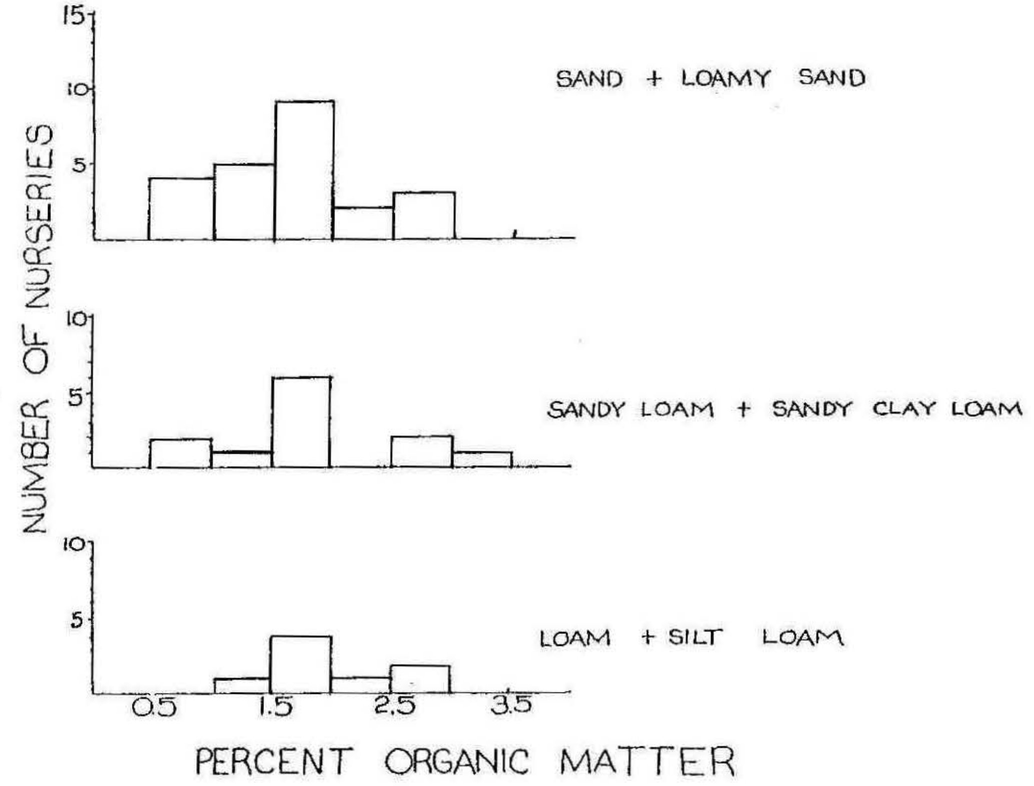
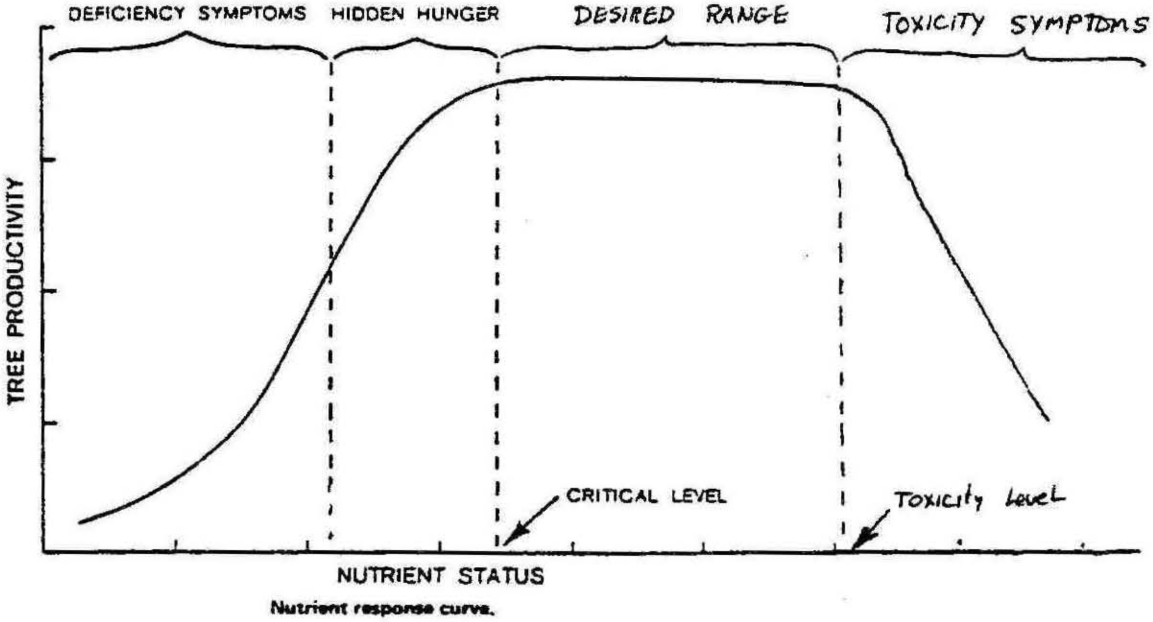


FIGURE 10





Nutrient response curve.

Figure 11 Relationship between tree productivity and nutrient status.

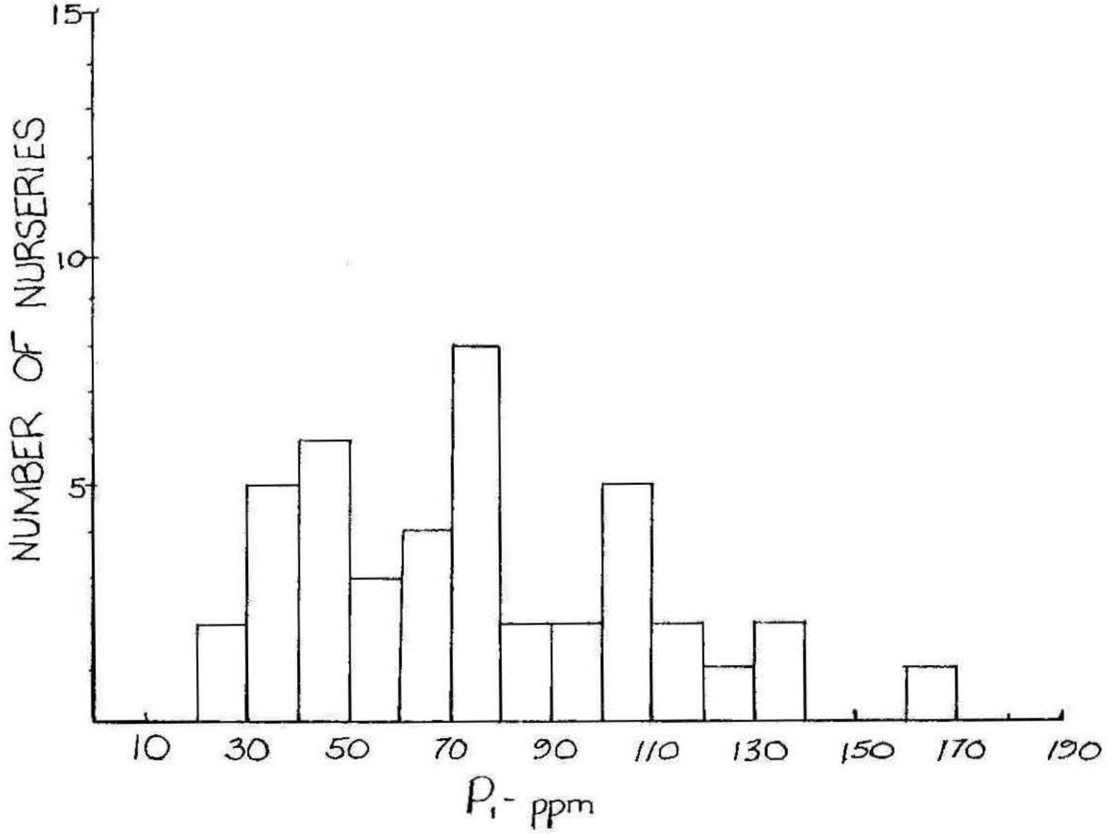

NUMBER OF NURSERIES
15
10
5
10
30
50
70
90
110
130
150
170
190
P_1 - ppm

FIGURE 13

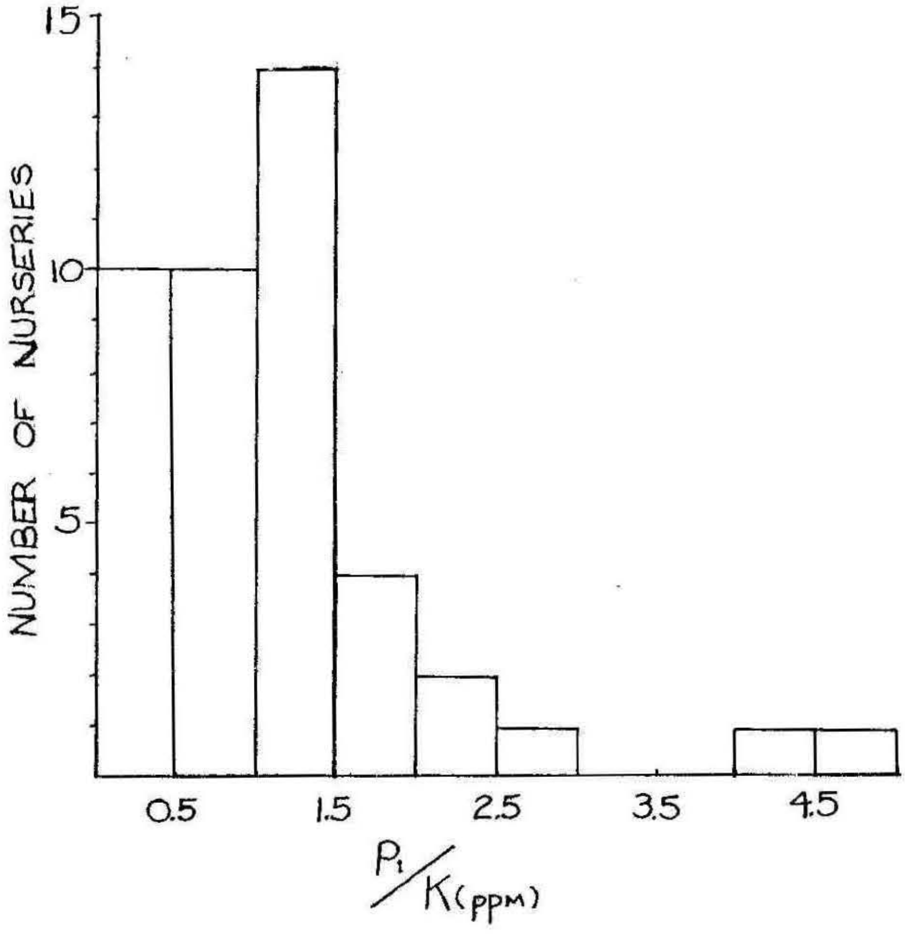

NUMBER OF NURSERIES
15
10
5
0.5
1.5
2.5
3.5
4.5
P_1/K(ppm)

Figure 14

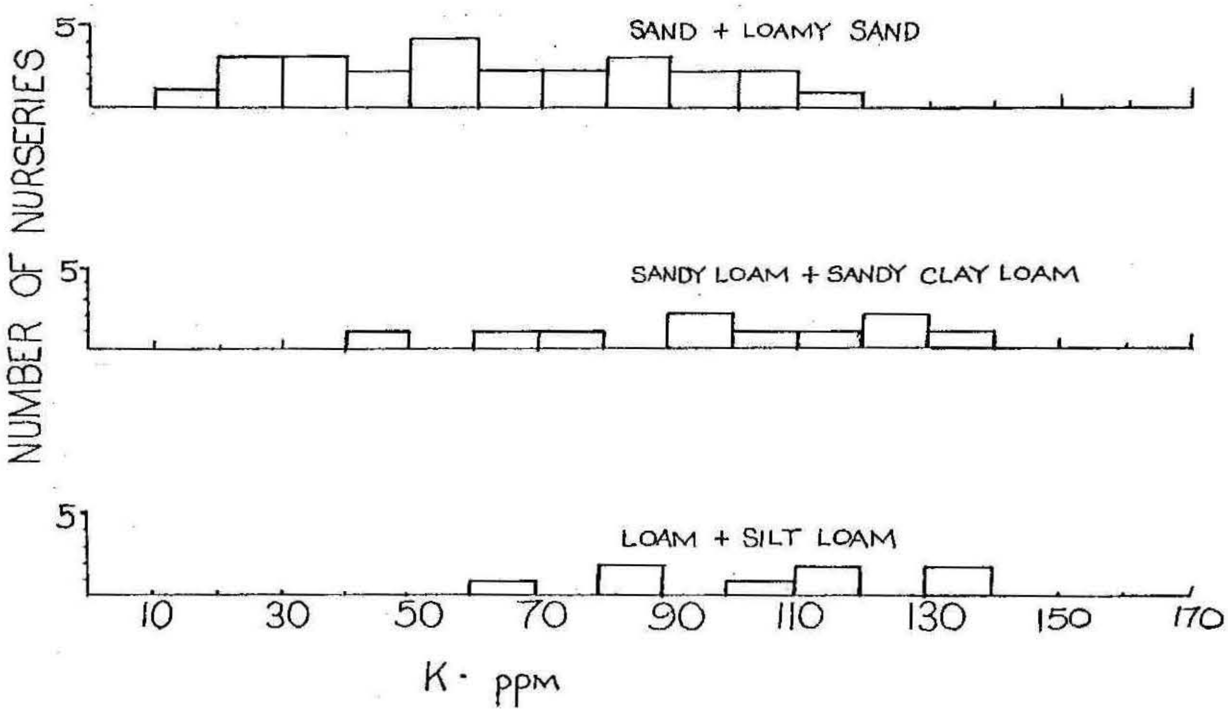


FIGURE 15

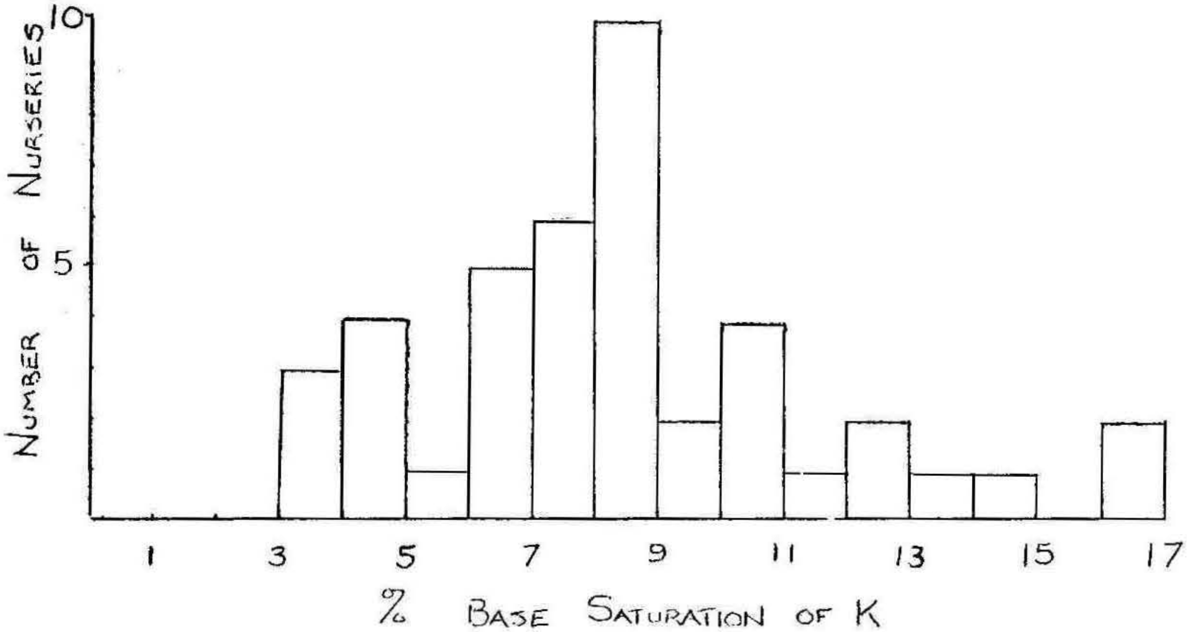


FIGURE 16

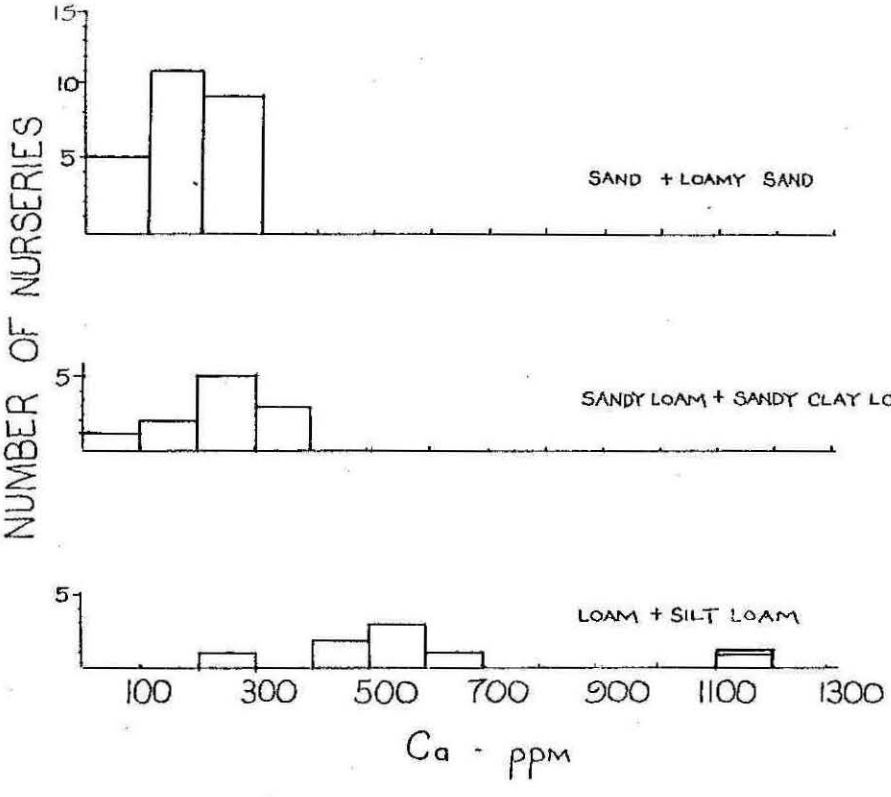


FIGURE 17

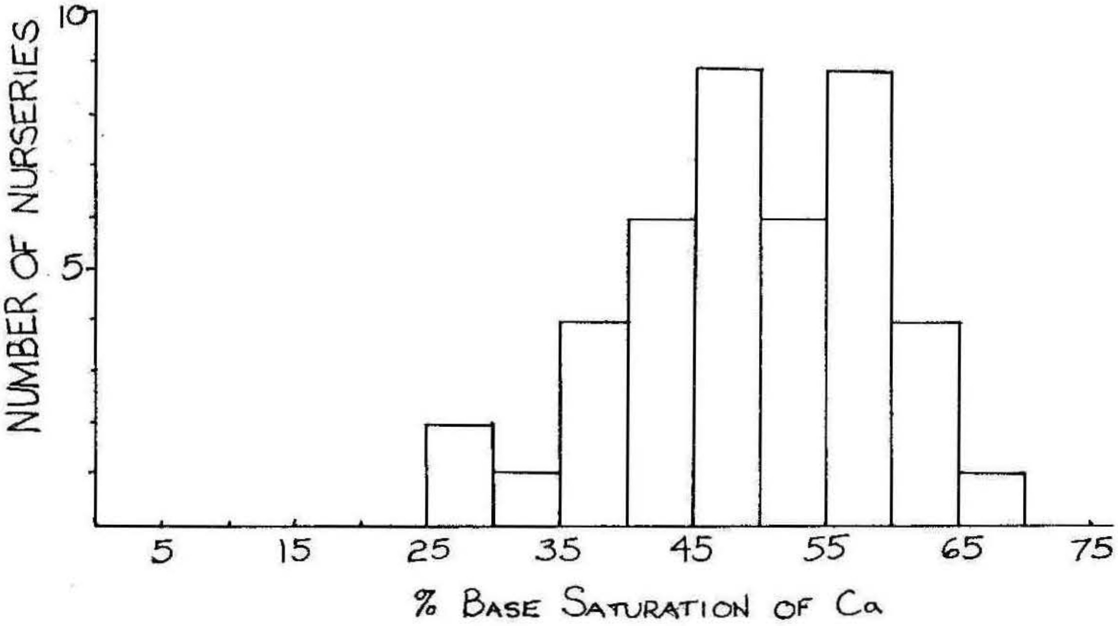


FIGURE 18

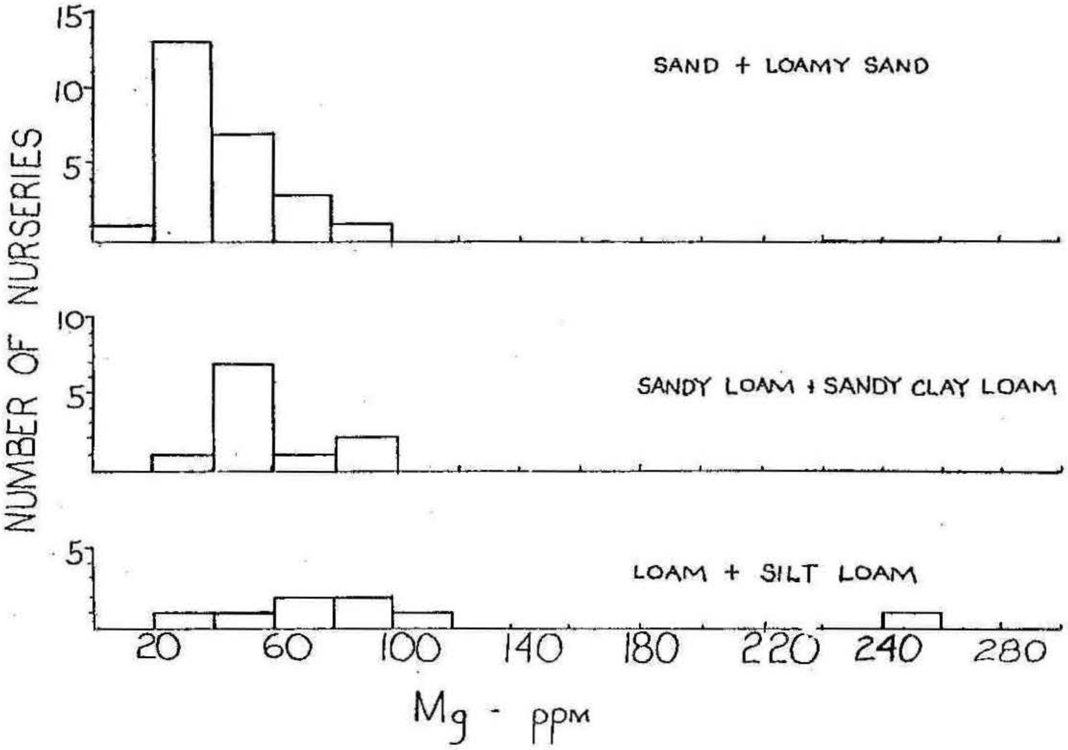


FIGURE 19

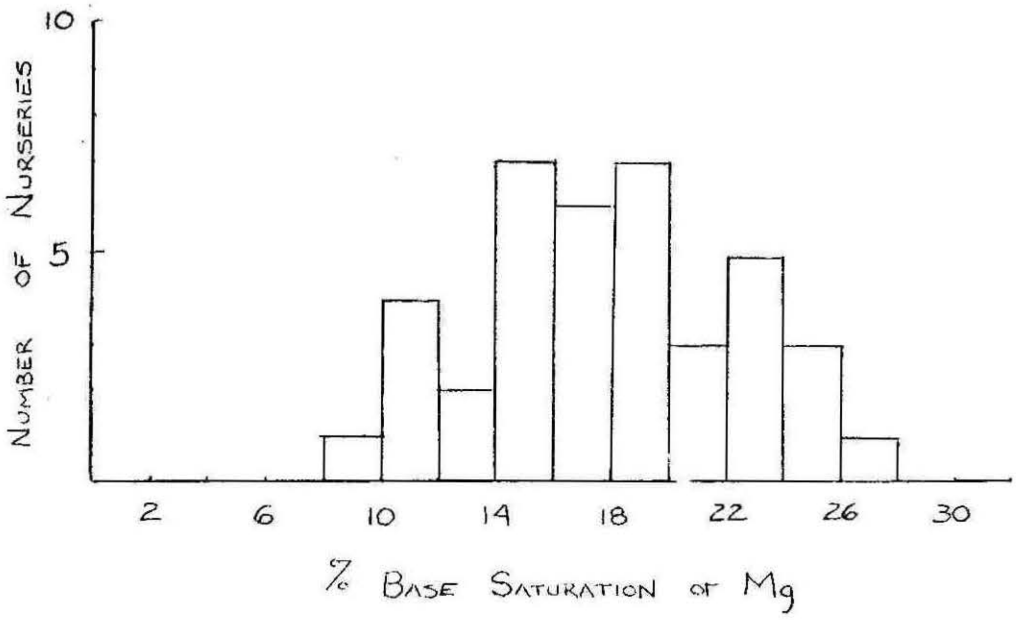


FIGURE 20

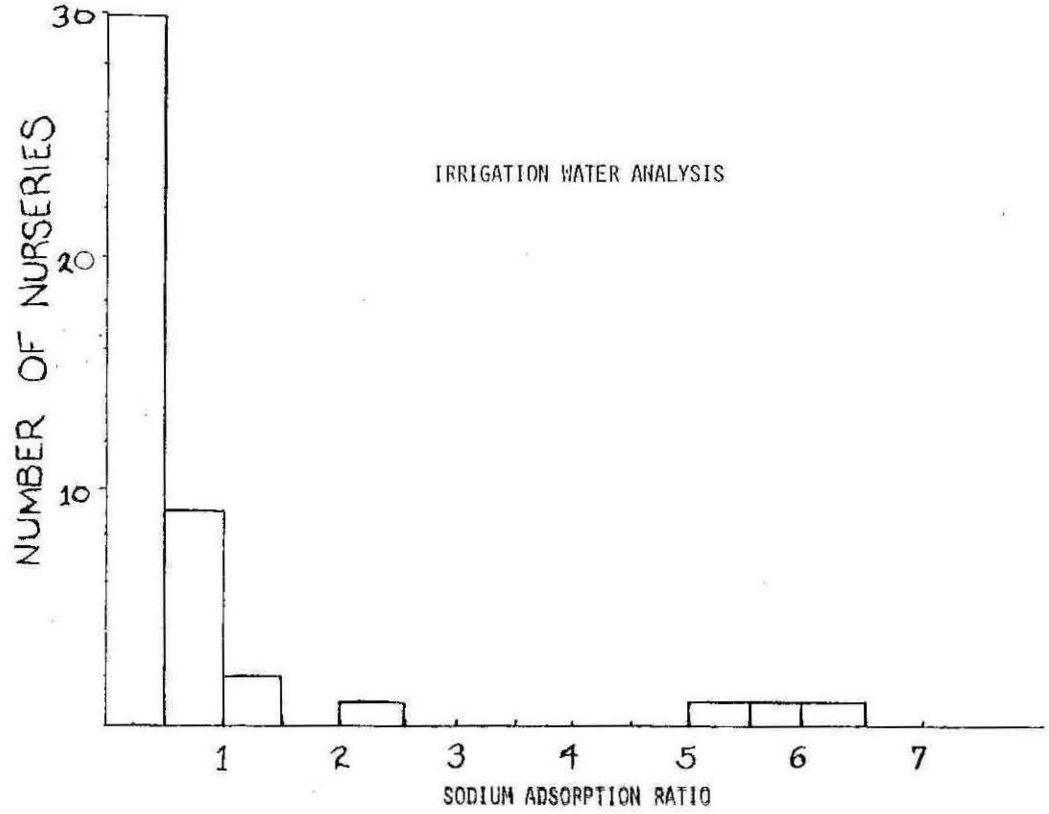


FIGURE 21

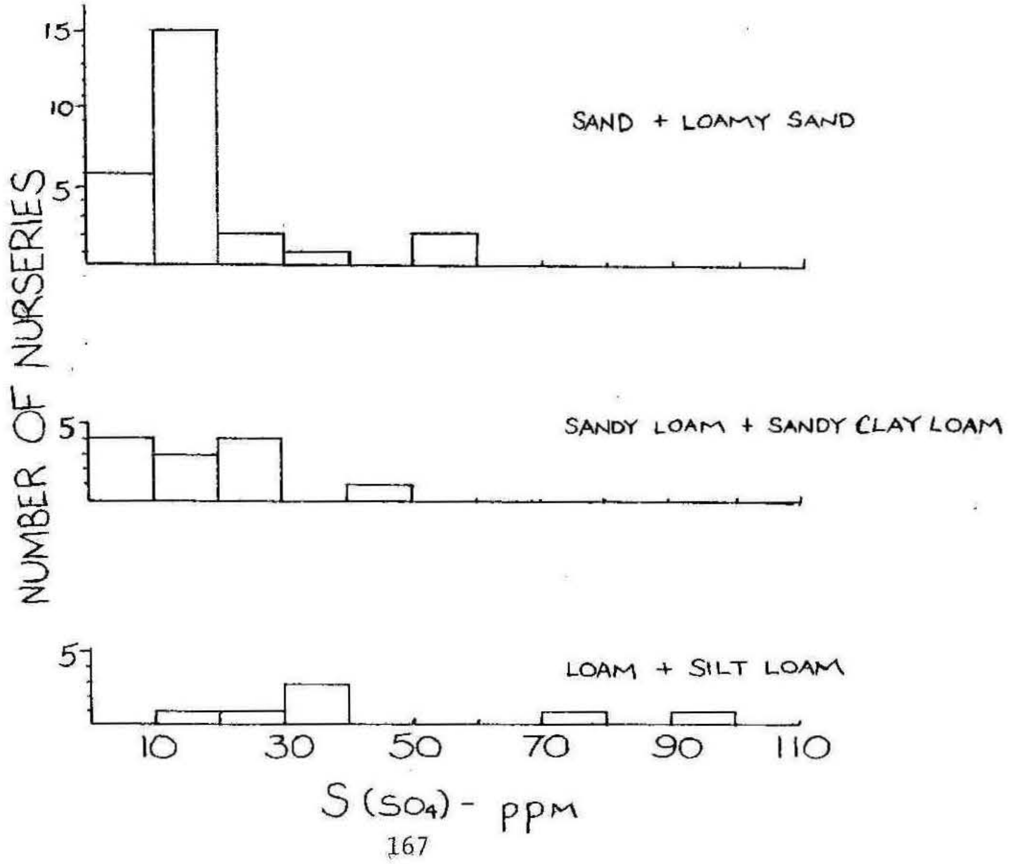


FIGURE 22

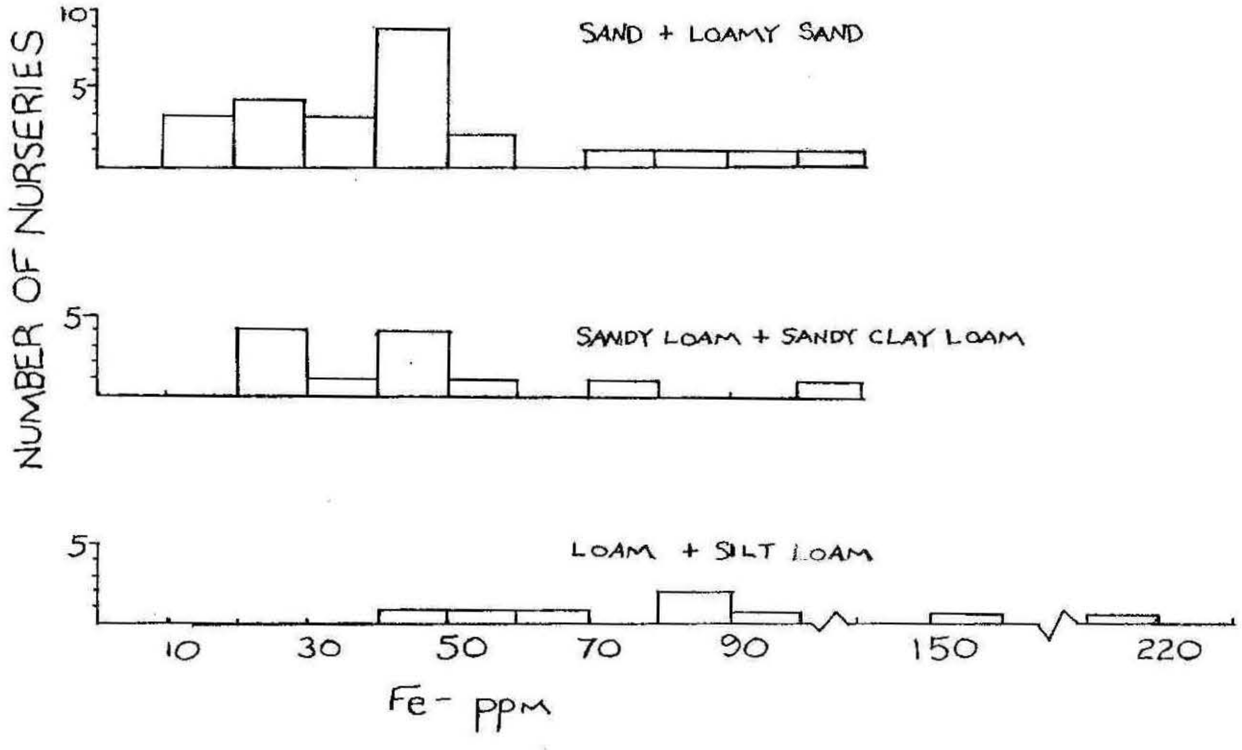


FIGURE 23

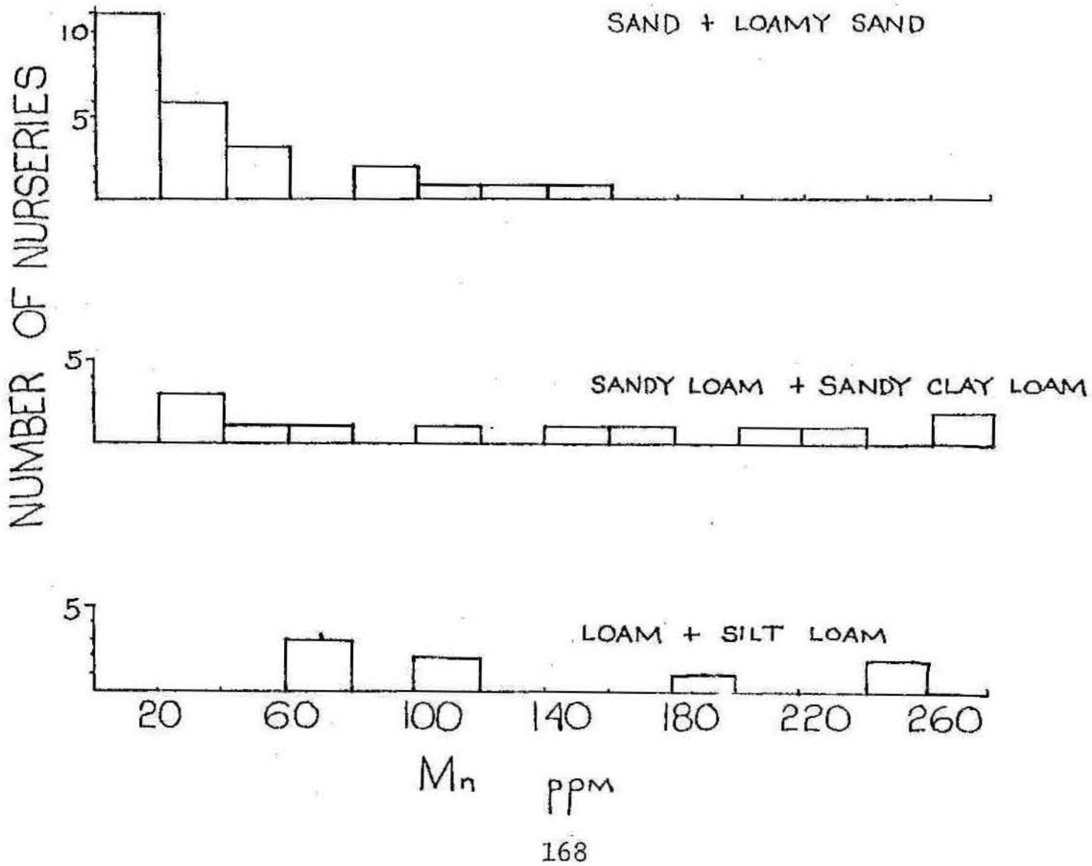


FIGURE 24

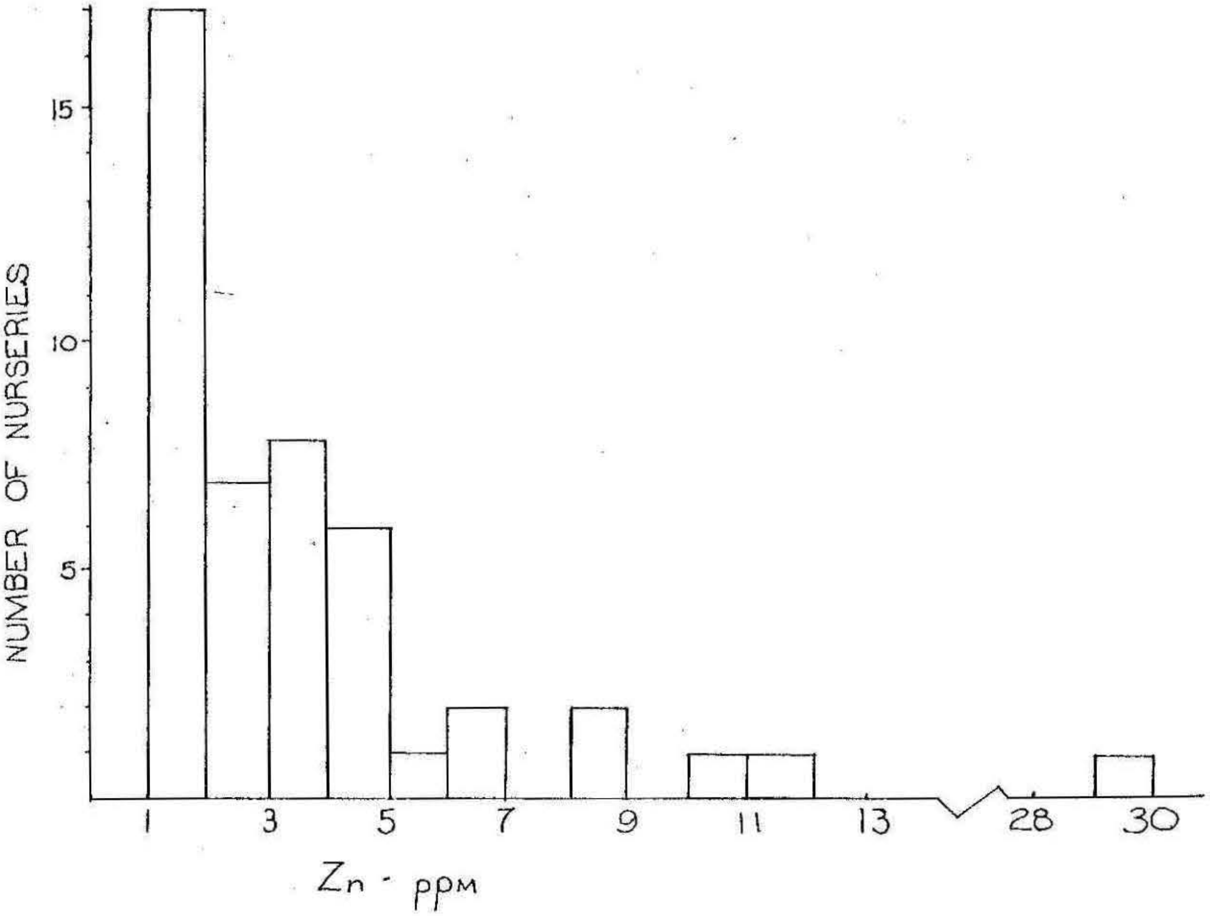


FIGURE 25

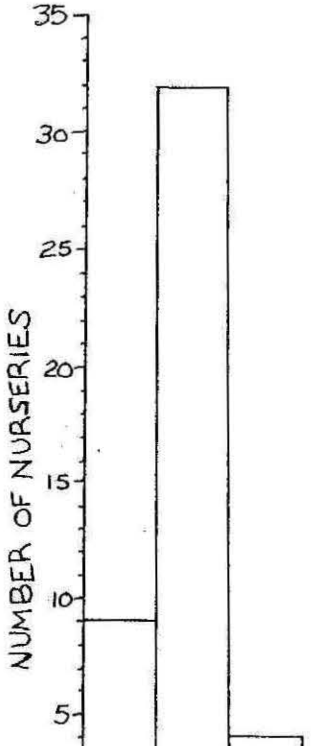
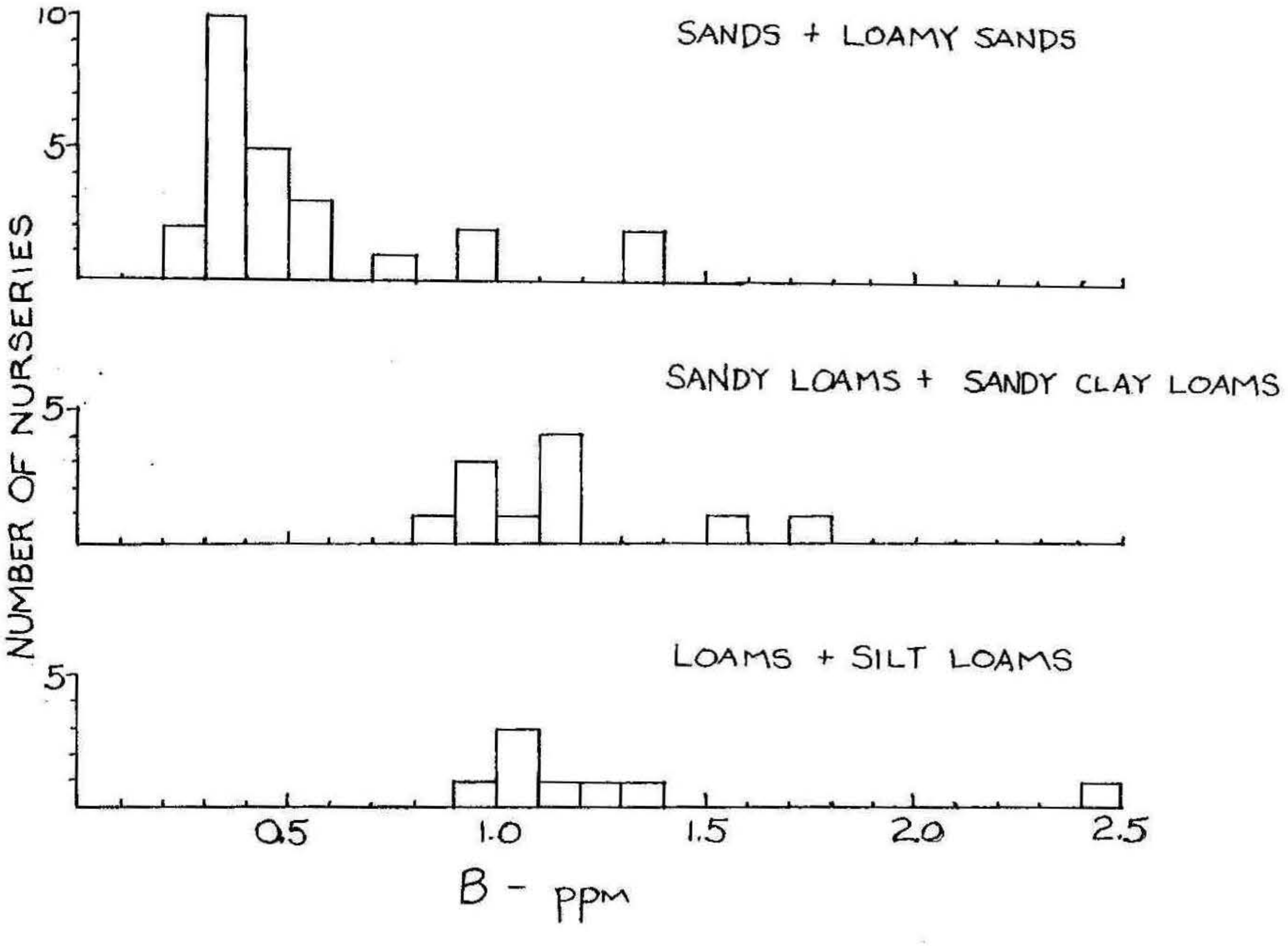


FIGURE 26


SANDS + LOAMY SANDS
SANDY LOAMS + SANDY CLAY LOAMS
LOAMS + SILT LOAMS
NUMBER OF NURSERIES
10
5
5
5
0.5
1.0
1.5
2.0
2.5
B - ppm