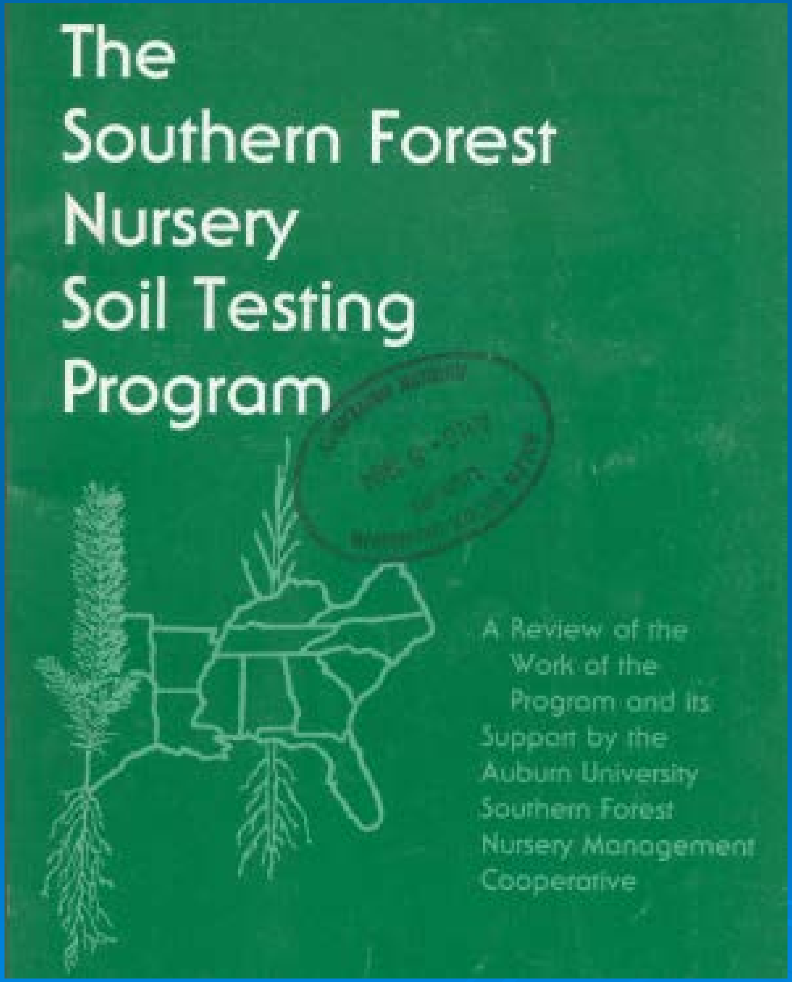
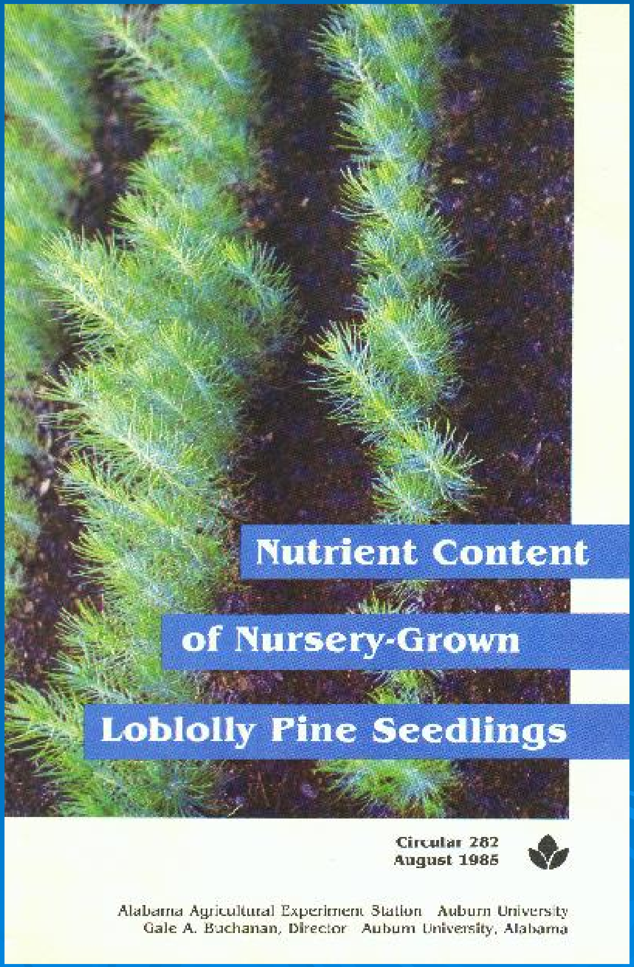
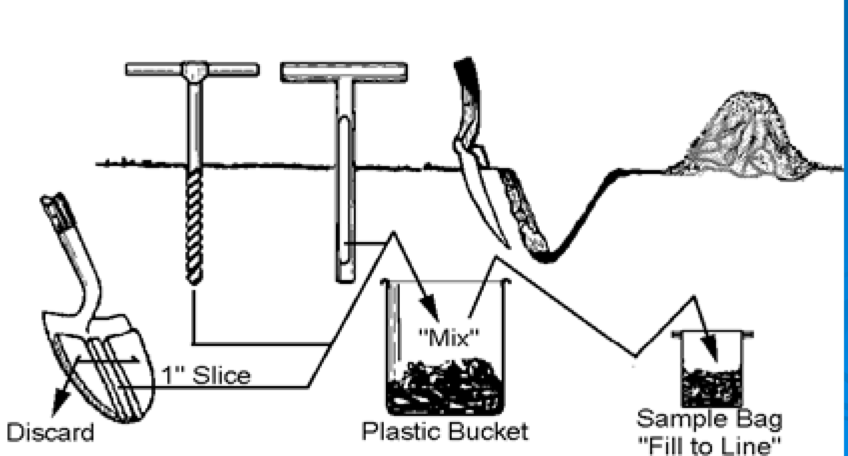
Soil and Tissue Analysis





Introduction

A systematic sampling program must be the base upon which a sound soil-management program is developed. Benefits will accrue only if the data generated are accurate, interpreted correctly, and put to use and if the results are then evaluated. However, data are only as good as the samples analyzed. Consistent quality control in the sampling program, analytical procedures, and recordkeeping is essential so that valid trends may be distinguished from anomalies. [C. T. Youngberg]



Soil Analysis - sampling

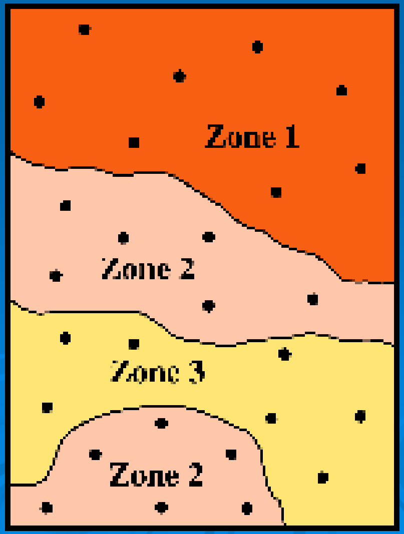
Soils should be routinely sampled at the end of the seedling crop rotation so that changes in nutrient levels can be monitored and fertilizer and lime added before establishment of a cover crop or new seedling crop. This is especially important in the case of the macronutrients P, K, Ca, and Mg, which do not readily move into the soil when surface applied.

[C. T. Youngberg]

▲ Dr. Jack May pioneered Forest Nursery Research in the South.

Soil Analysis - sampling

The first step in the sampling procedure is to stratify the area on the basis of obvious soil differences, e.g., wet areas, areas having striking textural differences, or areas where topsoil has been removed as a result of land leveling. Most nurseries already have sampling patterns (e.g., predetermined lines or zigzag patterns) established within compartments or seedling blocks. [C. T. Youngberg]



Soil Analysis - sampling

See detailed instructions on pages 81-86.

Soil Analysis - testing

Ammonium N (NH4-N) and nitrate N (NO3-N) tests are not common in nursery soil analysis. The N fertilization is typically not based on soil sample results.

Soil tests are useful within limits. Perhaps the most serious limitation is the arbitrariness of extraction procedures. Stick with using one soil lab.

Soil Analysis - testing

A MAJOR problem associated with soil testing is the lack of data correlating seedling growth response, quality, and performance after outplanting with soil-test values and fertilizer additions.

Comparisons must be made for each species produced at a given nursery. Thus, soil-test values are, at best, only a starting point and must be related to overall soil-management practices and seedling performance.

Furthermore, it cannot be overemphasized that the benefits derived from a soil-testing program depend on meticulous recordkeeping for soil-test data, soil-management practices, and seedling performance. [C. T. Youngberg]

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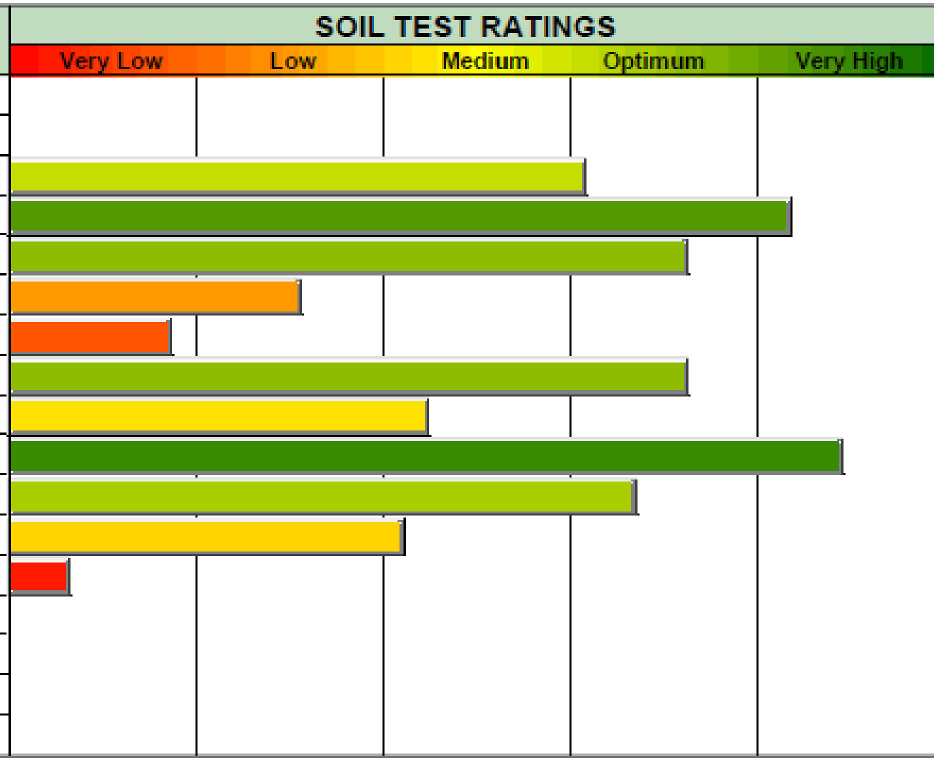
How To Interpret A Soil Test Report

(Report Explanation and Definitions)

Soil Analysis

Lab Number : 98999 **Sample Id :** SAMPLE 1 **Signature :**

Test	Results
Soil pH	6.4
Buffer pH	7.81
Phosphorus (P)	62 LB/ACRE
Potassium (K)	434 LB/ACRE
Calcium (Ca)	3672 LB/ACRE
Magnesium (Mg)	104 LB/ACRE
Sulphur (S)	8 LB/ACRE
Boron (B)	2.4 LB/ACRE
Copper (Cu)	2.8 LB/ACRE
Iron (Fe)	592 LB/ACRE
Manganese (Mn)	368 LB/ACRE
Zinc (Zn)	3.6 LB/ACRE
Sodium (Na)	46 LB/ACRE
Soluble Salts	
Organic Matter	2.4 % ENR 92
NO3-N	



Calculated Cation Exchange Capacity

11.8 meq/100g

Calculated Cation Saturation

%K	4.7
%Ca	77.8
%Mg	3.7
%H	12.9
%Na	0.8

Note: Nitrogen tests not conducted

SOIL FERTILITY GUIDELINES

Crop : CORN				Yield Goal : 150 BU			Rec Units: LB/ACRE		
LIME	N	P2O5	K2O	Mg	S	B	Cu	Mn	Zn
0	183	68	40	15	15	0	0	0	2.7
Crop : COOL GRASS PASTURE				Yield Goal : 3 TONS			Rec Units: LB/ACRE		
0	120	58	40	15	15	0	0	0	0

Comments :

CORN

· Greater N efficiency for corn may be achieved by splitting the N application. Apply 1/4 to 1/3 of the N prior to or at planting and the remainder as sidedress when corn is 8-24 inches high.
· For early planted corn or no till corn, apply a starter fertilizer at least 2 inches from the seed at a rate of 10-20 lbs N/Acre and 30-60 lbs P2O5/Acre.

COOL GRASS PASTURE

· On light soils with high grass hay yields, soil test annually to maintain soil pH and nutrient level.
· For soils low in sulphur, apply 20-40 lbs of sulphur as a sulfate in the spring with the nitrogen.
· For grass hay or pasture needing high rates split the P and K application. Apply 1/2 in the spring and 1/2 in late summer.
· For cool season grass topdress with nitrogen: Feb 15 - March 15 60 to 100 lbs N/Acre.
May 1-15 0 to 50 lbs N/Acre. Aug 1 - Sept 15 60 to 80 lbs N/Acre.

Soil Fertility Analyses

Soil Fertility Testing Packages

S3M	(*S1M* ***plus*** *all of the following:* B, Cu, Fe, Mn, Na, S, and Zn)	$ 16.50
S2M	(*S1M* ***plus*** *two* of: B, Cu, Fe, Mn, Na, S or Zn)	$ 12.00
S1M	(Soil pH, Buffer pH, Ca, Mg, K, P and OM, calculated CEC, Base Sat.%)	$ 8.00

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2 crop recommendations! **Easyread® Graphical report!**

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Individual Analysis	With Package	Without Package
Na, S, B, Zn, Mn, Fe or Cu (per element)	$ 2.50	$ 4.00
Soluble Salts (Cond.) 1:2	$ 3.50	$ 6.00
Nitrate Nitrogen	$ 3.50	$ 6.00
Ammoniacal Nitrogen	$ 14.00	$ 20.00
Chloride	$ 15.00	$ 15.00
Phosphorus (Bray-P1, P2 or Olsen)	$ 6.00	$ 10.00
Exchangeable Aluminum	$ 12.00	$ 15.00

Results maybe listed in ppm (parts per million) or Kg/ha.

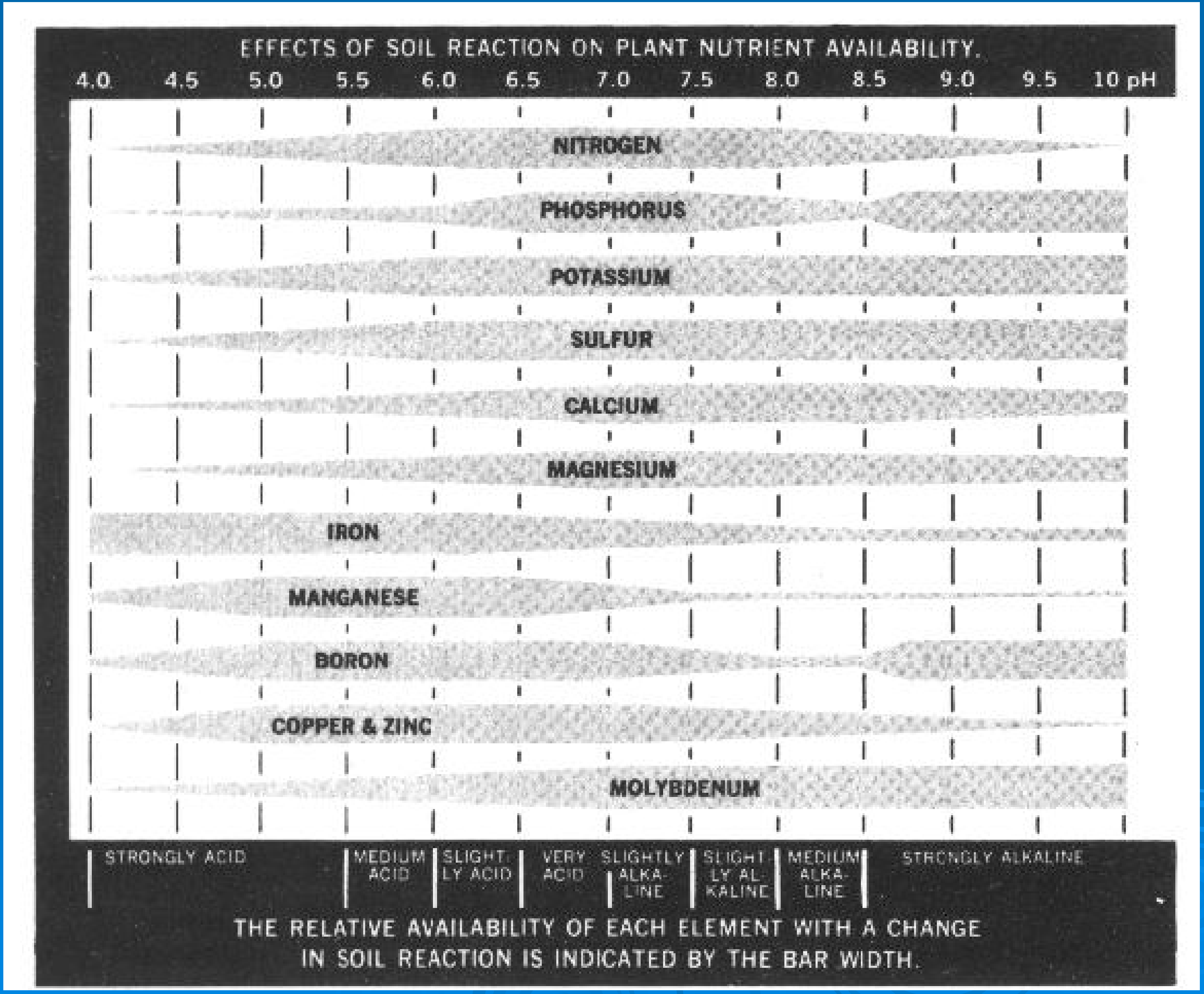
To convert from ppm to Kg/ha multiply by 2

Soil pH

The soil pH measures active soil acidity or alkalinity. A pH of 7.0 is neutral. Values lower than 7.0 are acid; values higher are alkaline. The soil pH is the value that should be maintained in the

pH range most desirable for the crop to be grown

Soil pH


EFFECTS OF SOIL REACTION ON PLANT NUTRIENT AVAILABILITY.
4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10 pH
NITROGEN
PHOSPHORUS
POTASSIUM
SULFUR
CALCIUM
MAGNESIUM
IRON
MANGANESE
BORON
COPPER & ZINC
MOLYBDENUM
STRONGLY ACID
MEDIUM ACID
SLIGHTLY ACID
VERY ACID
SLIGHTLY ALKALINE
SLIGHTLY ALKALINE
MEDIUM ALKALINE
STRONGLY ALKALINE
THE RELATIVE AVAILABILITY OF EACH ELEMENT WITH A CHANGE IN SOIL REACTION IS INDICATED BY THE BAR WIDTH.

Soil pH

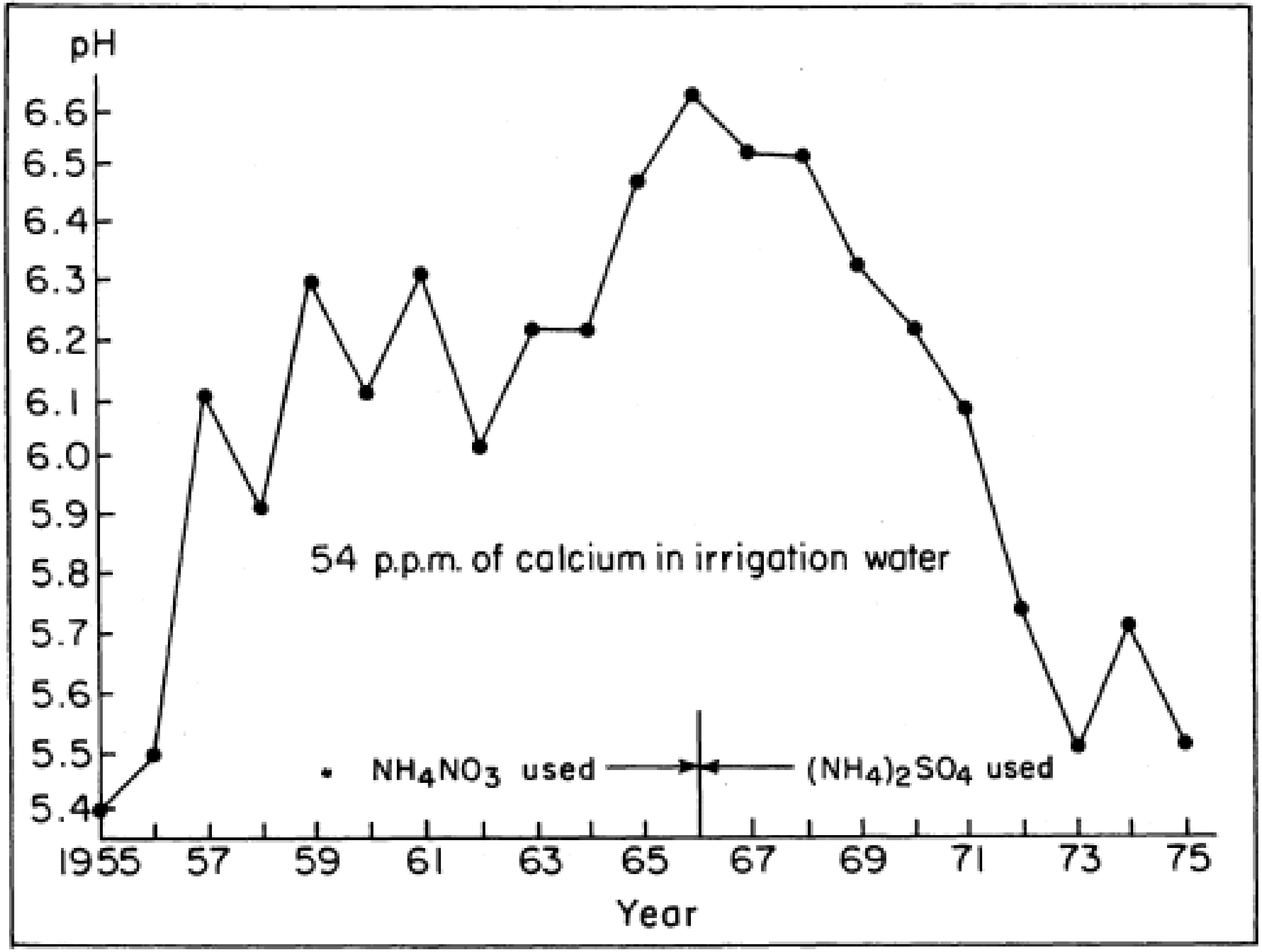


Fig. 8. History of soil acidity for one compartment in a southern forest tree nursery as affected by nitrogen source.

Buffer pH

This is an index value used for determining the amount of lime to apply on acid soils to bring the pH to the desired pH for the crop to be grown. The lower the buffer pH reading the higher the lime requirement.

Phosphorus

The phosphorus test measures that phosphorus that should be available to the plant. It is important for the production of ATP. P deficiency can occur in soils that lack mycorrhiza.

For soils with pH above 7.3 the sodium bicarbonate test will determine the available P. These pH levels are rarely measured in existing tree nurseries in the South.

Potassium

K is the second most common nutrient in the seedling (if we ignore C and O). K does not have a structural role in the seedling. It does serve in various regulatory functions. The K^+ ion is highly mobile in the seedling.

Calcium

Primarily soil type, drainage, liming and cropping practices affect the levels of calcium found in the soil.
Calcium is closely related to soil pH.
Calcium deficiencies are rare when soil pH is adequate. The level for calcium will vary with soil type, but optimum ranges are normally in the 50% to 65% cation saturation range.

Calcium

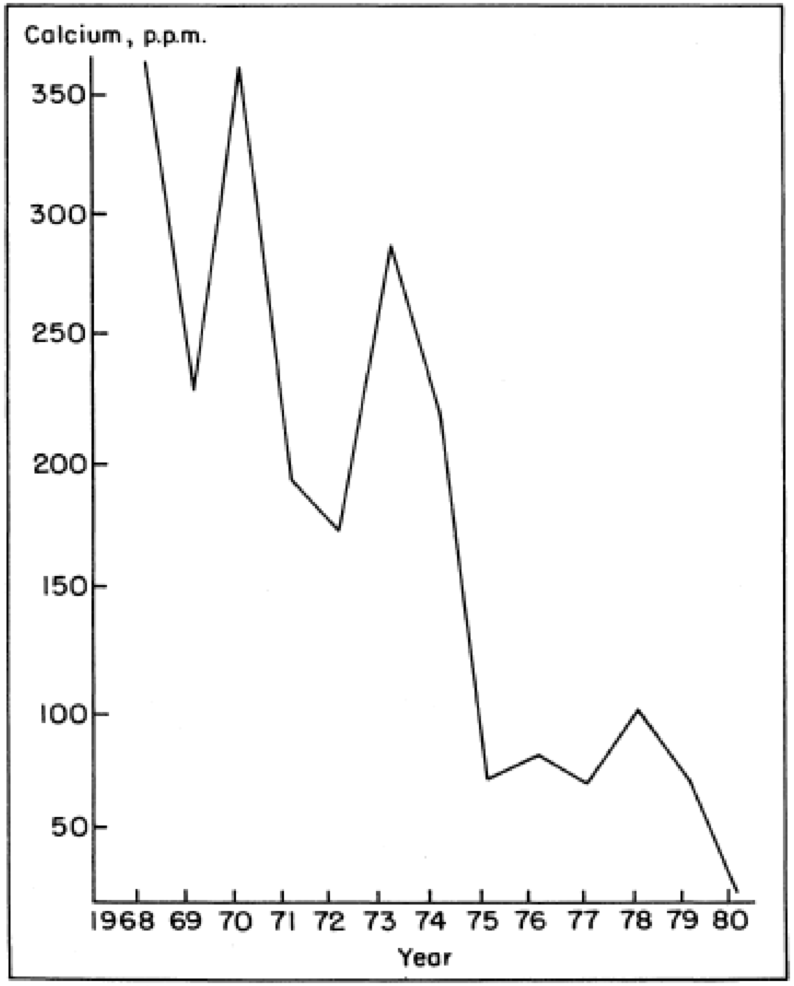


Fig. 4. History of soil calcium for one compartment in a southern forest tree nursery.

Magnesium

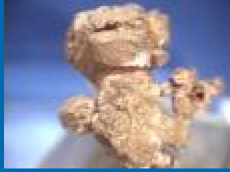
The same factors, which affect calcium levels in the soil, also influence magnesium levels except magnesium deficiencies are more common. The cation saturation for magnesium should be 10 to 20%.

Sulphur

The soil test measures sulfate-sulfur. This is a readily available form preferred by most plants. Soil test levels should be maintained in the optimum range. It’s important that other soil factors, including organic matter content, soil texture and drainage be taken into consideration when interpreting sulfur soil test and predicting crop response.

Boron

The readily soluble boron is extracted from the soil. Boron may become deficient in sandy soils that are low in organic matter with adequate rainfall. Soil pH, organic matter level and texture should be considered in interpreting the boron test, as well as the crop to be grown.



Copper

Copper is most likely to be deficient on low organic matter sandy soils, or in organic soils. The crop to be grown, soil texture, and organic matter should be considered when interpreting copper tests.

Iron

Crops vary a great deal in sensitivity to iron deficiency. Normally a medium level would be adequate for most soils. If iron is needed it would be best applied foliar.

Zinc

Other factors, which should be considered in interpreting the zinc test, include available phosphorus, pH, and crop and yield level.

Sodium

Sodium is not an essential plant nutrient but is usually considered in light of its effect on the physical condition of the soil. Soils high in exchangeable sodium may cause adverse physical and chemical conditions to develop in the soil. These conditions may prevent the growth of plants. Reclamation of these soils involves the replacement of the exchangeable sodium by calcium and the removal by leaching. One nursery in Aliceville, AL was closed, in part, due to high sodium in the irrigation water.

Soluble Salts

Excessive concentration of various salts may develop in soils. This may be a natural occurrence or it may result from irrigation, excessive fertilization or contamination from various chemicals or industrial wastes. One effect of high soil salt concentration is to produce water stress in a crop to where plants may wilt or even die. The effect of salinity is negligible if the reading is less than 1.0 mmhos/cm. Readings greater than 1.0 mmhos/cm may affect salt sensitive plants and readings greater than 2.0 mmhos/cm may require the planting of salt tolerant plants.

Organic Matter and ENR (Estimated Nitrogen Release)

The organic matter serves as a reserve for many essential nutrients, especially nitrogen. During the growing season, a part of this reserve nitrogen is made available to the plant through bacterial activity. The ENR is an estimate of the amount of nitrogen (kg/ha) that will be released over the season. In addition to organic matter level, this figure may be influenced by seasonal variation in weather conditions as well as soil physical conditions.

N03-N (Nitrate Nitrogen)

Nitrate nitrogen is a measure of the nitrogen available to the plant in nitrate form. In high rainfall areas, sandy soil types and areas with warm winters, this measurement may be of limited value.

Cation Exchange Capacity (CEC)

Cation exchange capacity measures the soil's ability to hold nutrients such as calcium, magnesium, and potassium, as well as other positively charged ions such as sodium and hydrogen. The CEC of a soil is dependent upon the amounts and types of clay minerals and organic matter present. The common expression for CEC is in terms of milliequivalents per 100 grams (meq/100g) of soil. The CEC of soil can range from less than 5 to 35 meq/100g for agricultural type soils. Soils with high CEC will generally have higher levels of clay and organic matter. For example, one would expect soil with a silty clay loam texture to have a considerably higher CEC than a sandy loam soil. Although high CEC soils can hold more nutrients, it doesn't necessarily mean that they are more productive. Much depends on good soil management.

Cation Saturation

Cation saturation refers to the proportion of the CEC occupied by a given cation (an ion with a positive charge such as calcium, magnesium or potassium). The percentage saturation for each of the cations will usually be within the following ranges:
Calcium 40 to 80 percent Potassium 1 to 5 percent
Magnesium 10 to 40 percent

Potassium:Magnesium Ratio

On some crops high magnesium levels may reduce potassium uptake by the plant. The ratio should be between 0.2 to 0.3 for best uptake. Ratios below 0.2 could cause reduced potassium uptake.

A West –Coast example

Year	pH range	Available P	Available K	Exchangeable Ca	Exchangeable Mg	Total N	Organic matter
		~ ~ ppm ~ ~		~ meq/100g ~		~ ~ ~ % ~ ~ ~	
			Humboldt Nursery				
1961	5.1-5.3	5	100	1.5	0.65	0.31	8.0
1971	5.4-5.7	17	60	1.8	0.46	0.26	7.1
1982	5.4-6.2	13	120	3.2	1.4	0.22[1]	6.3

Over 20 years, pH values and P levels have increased slightly at the Humboldt Nursery. The increase in P has probably resulted from residual buildup from phosphate fertilizer applications. Potassium levels decreased during the first 10 years but are now at or above initial levels. The increases in exchangeable Ca and Mg, as well as pH, are the result of adding dolomitic limestone. Organic matter and total N have decreased over the 20-year period as a result of frequent cultivation.

[C. T. Youngberg]

Good practice to look at trends over time

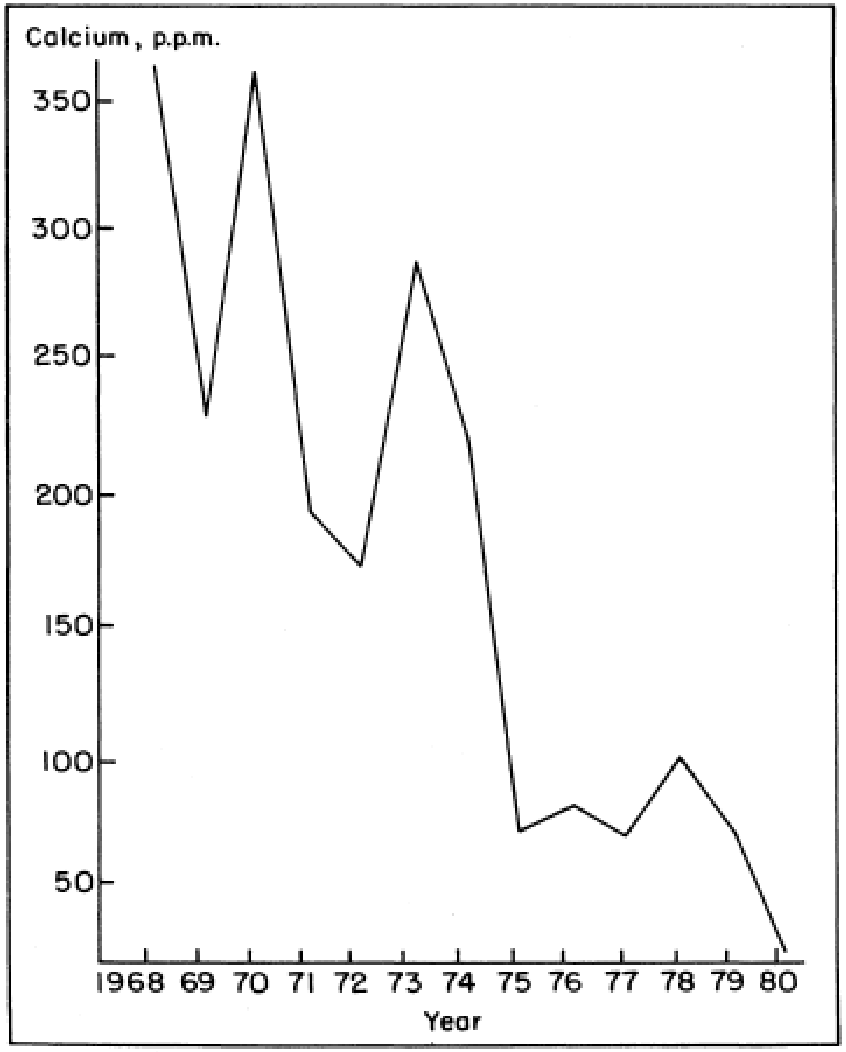
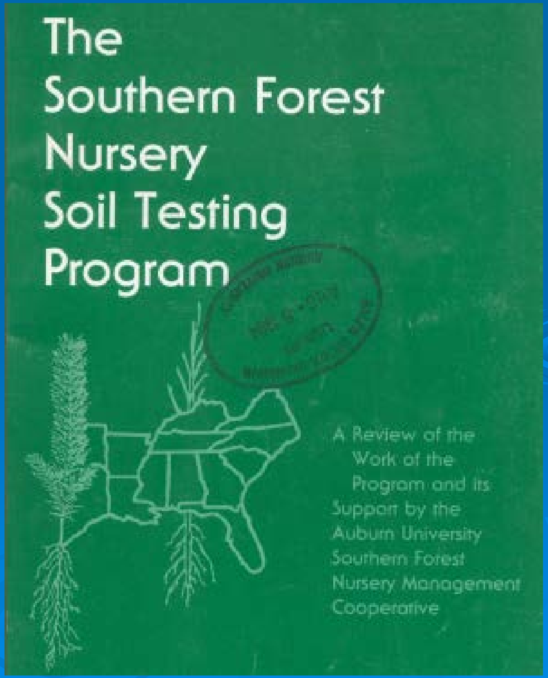


Fig. 4. History of soil calcium for one compartment in a southern forest tree nursery.

Suggested levels for
loblolly pine nurseries:

pH of 5.0 to 5.5
Minimum P of 25 ppm (double-acid extraction)
Minimum K of 90 ppm
Minimum Ca of 200 ppm
Minimum Mg of 25 ppm
Minimum S of 10 ppm
Minimum Mn of 5 ppm
Minimum Zn of 1 ppm
Minimum CU of 0.8 ppm
Minimum B of 0.3 ppm



Tissue Sampling

1980 methods used for tissue analysis

ELEMENT	METHOD
N.......................................	Kjeldahl digestion with H_2SO_4 K_2SO_2-Hg catalyst, distillation into standard acid and titration.
P.......................................	Dry ashed at 500EC and dissolved in 1:1 HCl. Phosphorus in extract determined colorimetrically.
Ca, Mg, K, Na, Zn, Mn,Fe, Cu, Al................	Dry ashed at 500EC and dissolved in 1:1 HCl. Metals in extract determined by atomic absorption.
S.......................................	Sample ashed with Mg $(NO_3)_2$. Sulfate in ash determined by $BaSO_4$ precipitation.
B.......................................	Dry ashed at 500EC and dissolved in 1:1 HCl. Boron in extract determined by Azomethine-H colorimetric method.

[1]Analyses performed by A&L Laboratories, Memphis, Tennessee.

2000 methods used for tissue analysis

Extracting Solution (Mehlich 1, 0.05N HCl in 0.025N H2SO4):

Determination of P, K, Ca, Mg, Zn, Mn, Cu, Fe, B, and Al

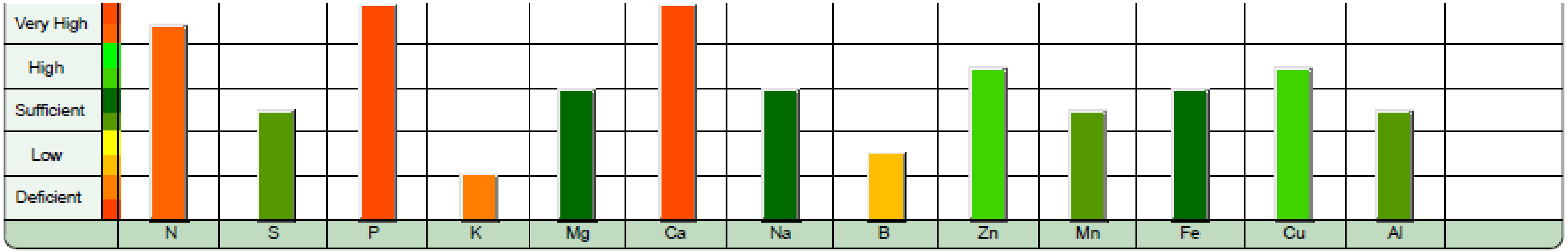
All elements are analyzed in the same extract by an ICP (inductively coupled plasma atomic emission spectrometer).

Plant analysis

Report Date :02/27/2001 Page 1 of 1 Sample Id :1 Crop : RYEGRASS

	Nitrogen %	Sulfur %	Phosphorus %	Potassium %	Magnesium %	Calcium %	Sodium %	Boron ppm	Zinc ppm	Manganese ppm	Iron ppm	Copper ppm	Aluminum ppm	
Analysis	5.09	0.47	0.80	2.19	0.28	0.95	0.12	5	73	85	142	21	48	
Normal Range	3.00 4.20	0.20 0.80	0.35 0.50	3.00 4.00	0.15 0.30	0.30 0.60	0.00 0.20	7 25	20 50	30 150	75 200	8 20	0 200	

	N/S	N/K	P/S	P/Zn	K/Mg	K/Mn	Ca/B	Fe/Mn						
Actual Ratio	10.8	2.3	1.7	109.6	7.8	257.6	1,900.0	1.7						
Expected Ratio	7.2	1.0	0.9	121.4	15.6	388.9	281.3	1.5						



Comments :

POUNDS OF NITROGEN REMOVED PER TON OF DRY MATTER=100

02018) THESE PLANTS ARE LOW OR DEFICIENT IN POTASSIUM. POSSIBLE CAUSES INCLUDE LOW SOIL POTASSIUM LEVEL, POOR DRAINAGE, DROUGHTY SOIL CONDITIONS OR COMPACTION.

02024) THESE PLANTS ARE LOW OR DEFICIENT IN BORON. THIS MAY BE THE RESULT OF LOW SOIL BORON OR DROUGHTY CONDITIONS.

Plant Nutrient, Diagnostic and Golf Course Analyses

Plant Nutrient Analyses	Price/Sample
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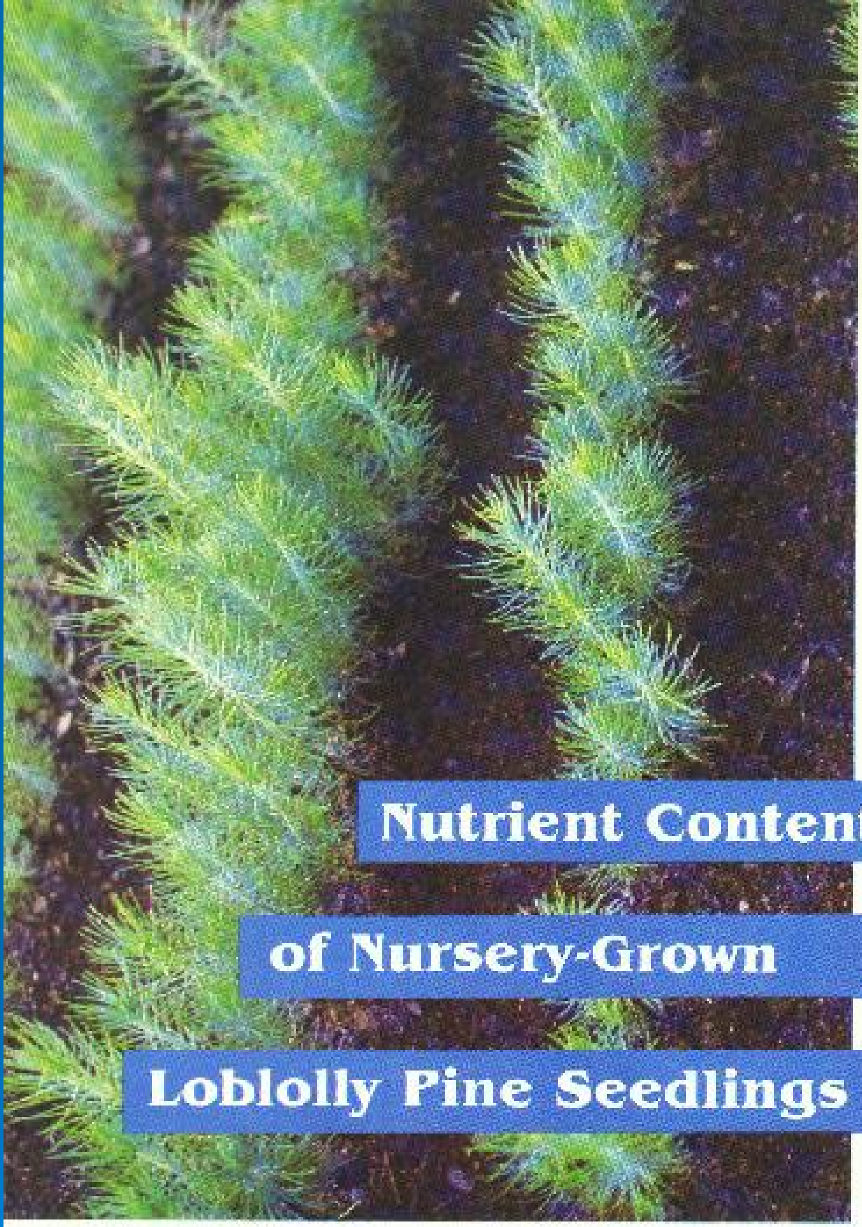
Sampling and Handling

For analyzing 2-month old seedlings, the whole shoot may be sampled. For analyzing 9-month old seedlings only the needles are sampled.

Tissue samples should be washed to remove soil and dust, especially if Fe analysis is desired, and sent as quickly as possible to the laboratory. if a drying oven is available, samples can be dried at 65 to 70°C for 24 hours; 10 g of dry plant tissue is adequate for lab analysis. If fresh seedlings cannot be sent to the lab soon after sampling, they should be stored in a refrigerator until ready for shipping; upon receipt, they are dried, if necessary, and ground in a Wiley mill to pass a 20-mesh screen in preparation for analysis. [C. T. Youngberg]



Nutrient Content of Nursery-Grown Loblolly Pine Seedlings

Circular 282
August 1985

Alabama Agricultural Experiment Station   Auburn University
Gale A. Buchanan, Director   Auburn University, Alabama

A combination of both soil and tissue analyses can be much more useful than either one alone. Because tissue analysis does not rely so heavily on arbitrary extraction procedures, it can be useful for calibrating soil test values. One problem with the use of plant analysis as a management tool is the lack of suitable reference standards. The objective of the research on which this publication is based was to provide ranges of nutrient levels which seedling producers may use to compare the nutritional status of their loblolly pine (*Pinus taeda* L.) Seedlings with that of seedlings sampled during 2 years at a large number of nurseries.

- Plant analysis is playing an increasingly important role in the expanding technology of economic plant production. The chemical composition of foliage and other plant parts indicates the amounts of minerals removed from the soil and is a tool for diagnosing nutritional deficiencies. While nutrient removal data have certain limitations, they do serve as estimates of the magnitude of the soil nutrient loss.

From late November 1981 to late January 1982, 21 forest nurseries in 10 Southern States were visited to sample loblolly pine seedlings in production at that time. In December 1982, 20 nurseries in six states were visited, including eight which had been sampled the previous season, figure 1. Random nurseries were visited the first year and samples representing many seed sources were chosen from an average area in the nursery. The second year, only nurseries which sowed Livingston Parish (Louisiana) seed were visited, and an average area within that seed source was sampled.

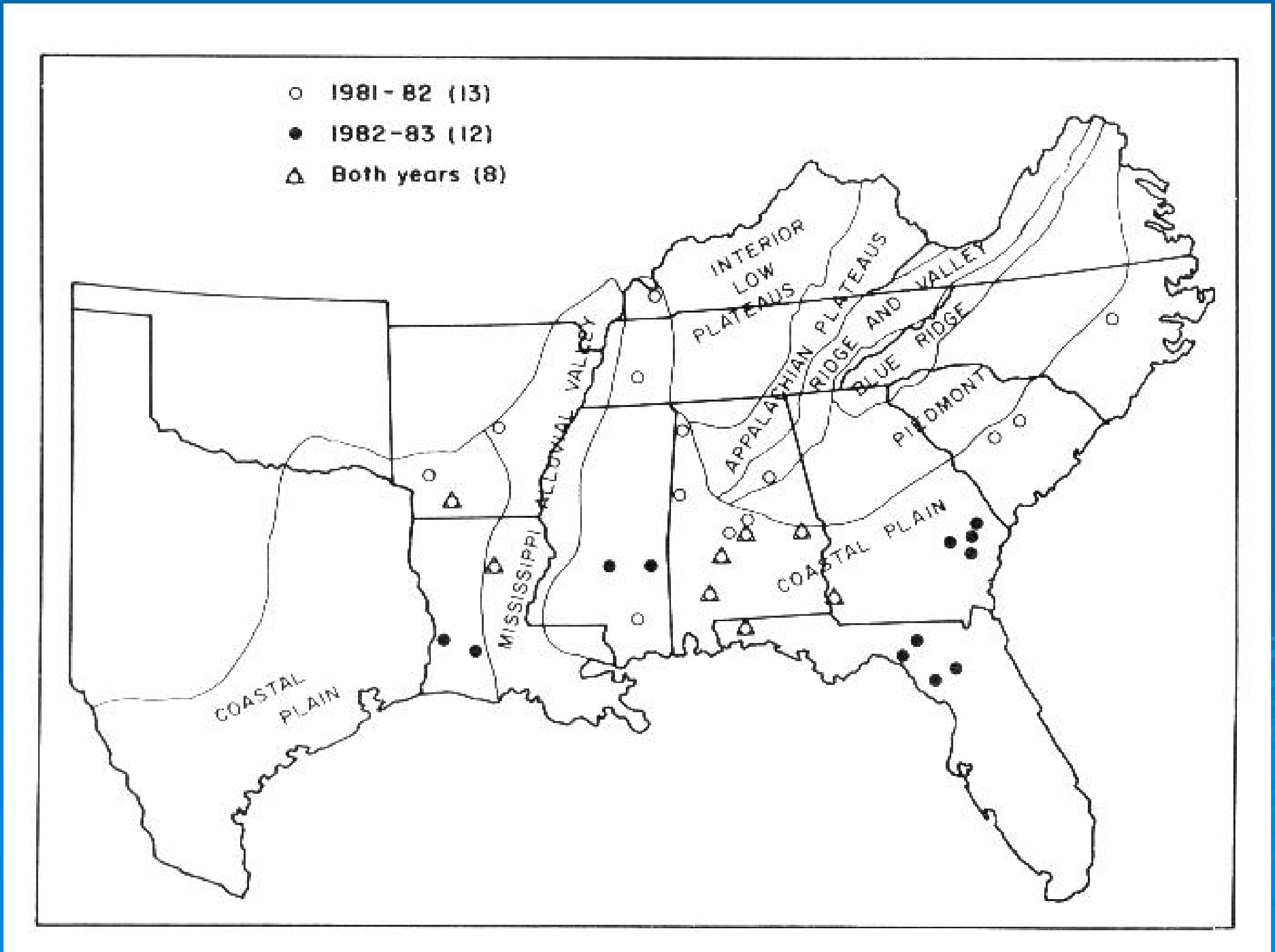


TABLE 2. MACRO- AND MICRONUTRIENT CONCENTRATIONS IN SAMPLE COMPONENTS OF LOBLOLLY PINE SEEDLIN

Tissue	Concentration											
	N	P	K	Mg	Ca	S	Na	Fe*	Al*	Mn*	B	Cu
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
Foliage												
Minimum	0.92	0.12	0.82	0.03	0.22	0.05	0.01	107	340	85	10	2
Median	1.64	.21	1.12	.10	.30	.08	.02	412	650	518	17	6
Maximum	2.24	.30	1.47	.23	.66	.16	.12	2,150	6,380	1,350	65	10
Stems												
Minimum	.45	.10	.82	.05	.14	.02	.01	85	130	65	8	2
Median	.95	.20	1.12	.11	.22	.06	.02	274	460	329	16	8
Maximum	1.79	.37	1.46	.16	.33	.19	.13	880	2,770	1,020	33	24
Roots												
Minimum	.52	.12	.87	.03	.10	.04	.01	395	780	63	13	3
Median	.85	.20	1.14	.10	.20	.08	.03	1,470	3,460	304	23	9
Maximum	1.66	.39	1.53	.16	.31	.49	.22	3,410	15,270	733	47	26

*Contamination from soil makes these results of doubtful value.

TABLE 3. MACRO- AND MICRONUTRIENTS REMOVED FROM A NURSERY BY LOBLOLLY PINE SEEDLINGS (ONLY 66 PERCENT OF AREA IN SEEDLINGS)

Tissue	Removal per acre											
	N	P	K	Mg	Ca	S	Na	Fe*	Al*	Mn*	B	Cu
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
Foliage												
Minimum	16.3	2.0	12.5	0.5	3.3	0.8	0.2	0.2	0.5	0.2	0.02	0.00
Median	42.8	5.2	30.5	2.5	8.6	2.1	.4	1.1	1.7	1.4	.06	.02
Maximum	62.1	8.4	48.7	4.7	13.5	4.0	2.6	6.2	18.7	3.2	.17	.04
Stems												
Minimum	3.5	.7	4.2	.4	.9	.2	.1	.1	.1	.1	.01	.00
Median	12.9	2.5	14.3	1.4	2.7	.8	.3	.4	.5	.4	.02	.01
Maximum	24.2	4.6	23.9	2.4	5.6	2.3	1.5	1.4	3.3	1.0	.06	.04
Roots												
Minimum	2.4	.8	3.1	.3	.5	.2	.1	.1	.3	.0	.01	.00
Median	8.6	2.0	11.2	.8	1.8	.8	.3	1.5	4.0	.3	.02	.01
Maximum	16.8	4.5	24.6	3.6	4.9	4.4	1.9	5.2	20.0	.9	.08	.04
Total												
Minimum	23.7	3.6	21.4	1.3	5.5	1.3	.4	.5	.8	.4	.01	.01
Median	66.0	9.7	56.3	4.7	13.3	4.0	.9	3.2	6.7	2.0	.10	.04
Maximum	97.5	16.8	91.3	9.8	22.3	8.2	5.8	11.0	41.6	4.5	.25	.12

*Contamination from soil makes these results of doubtful value.

TABLE 4. MACRO- AND MICRONUTRIENT CONTENT OF LOBLOLLY PINE SEEDLINGS

Tissue	Amount per seedling											
	N	P	K	Mg	Ca	S	Na	Fe*	Al*	Mn*	B	Cu
	mg	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
Foliage												
Minimum	12.0	1.3	6.6	0.3	2.3	0.5	0.1	0.1	0.3	0.1	0.01	0.00
Median	21.6	2.7	14.5	1.2	4.3	1.0	.2	.6	.9	.7	.03	.01
Maximum	30.7	4.5	26.2	3.1	7.3	2.4	1.5	3.9	11.4	1.5	.08	.02
Stems												
Minimum	1.7	.5	2.0	.2	.6	.1	.0	.0	.0	.0	.00	.00
Median	6.4	1.2	7.3	.6	1.4	.4	.1	.2	.3	.2	.01	.01
Maximum	12.5	2.5	12.2	1.4	3.0	1.2	.9	.7	2.0	.5	.03	.02
Roots												
Minimum	1.2	.3	1.5	.1	.3	.1	.0	.1	.1	.0	.00	.00
Median	4.5	.9	5.4	.5	1.0	.4	.2	.8	1.7	.1	.01	.00
Maximum	7.9	2.4	11.6	1.7	2.6	2.3	1.2	2.8	12.5	.5	.03	.02
Total												
Minimum	16.2	2.6	10.1	.7	3.7	.7	.2	.2	.4	.2	.02	.00
Median	32.5	4.9	27.1	2.3	6.7	1.9	.5	1.7	3.4	1.1	.05	.02
Maximum	50.4	9.2	49.2	5.2	12.0	4.4	3.4	6.8	26.0	2.3	.14	.06

*Contamination from soil makes these results of doubtful value.

Weight of nutrient per seedling depends on the size of the seedling and what time of year the sample is taken.

Pine plantation values for "action"

Fertilization recommended if values are below the ones listed in this table.

FOLIAR NUTRIENT CONCENTRATIONS AND RATIOS

Target Values

	Loblolly Pine		Sweetgum		Sycamore	
	%	100x:N	%	100x:N	%	100x:N
N	1.20	100	1.80	100	2.20	100
P	0.12	10	0.14	8	0.16	8
K	0.40	35	0.60	35	0.70	35
Ca	0.15	12	0.70	40	0.80	40
Mg	0.08	6	0.20	12	0.25	12
S	0.12	10	-	-	-	-
B	0.0012	0.1	-	-	-	-

NCSFNC

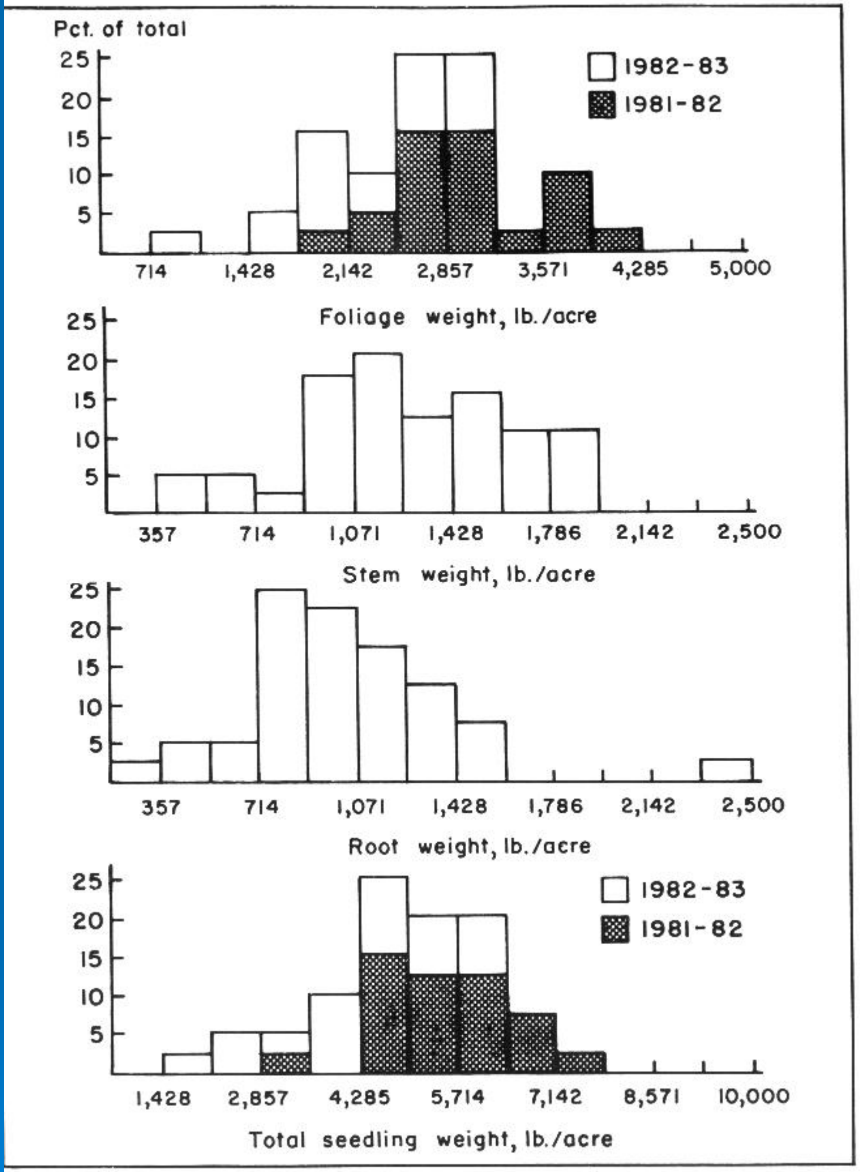


FIG. 2. Distributions of foliage, stem, root, and total weight of seedling crops sampled for nutrient content over 2 years (only 66 percent of area in seedlings). Where means for the 2 years are significantly different (0.05 level), the portion of the distribution representing the first year of sampling is shaded.

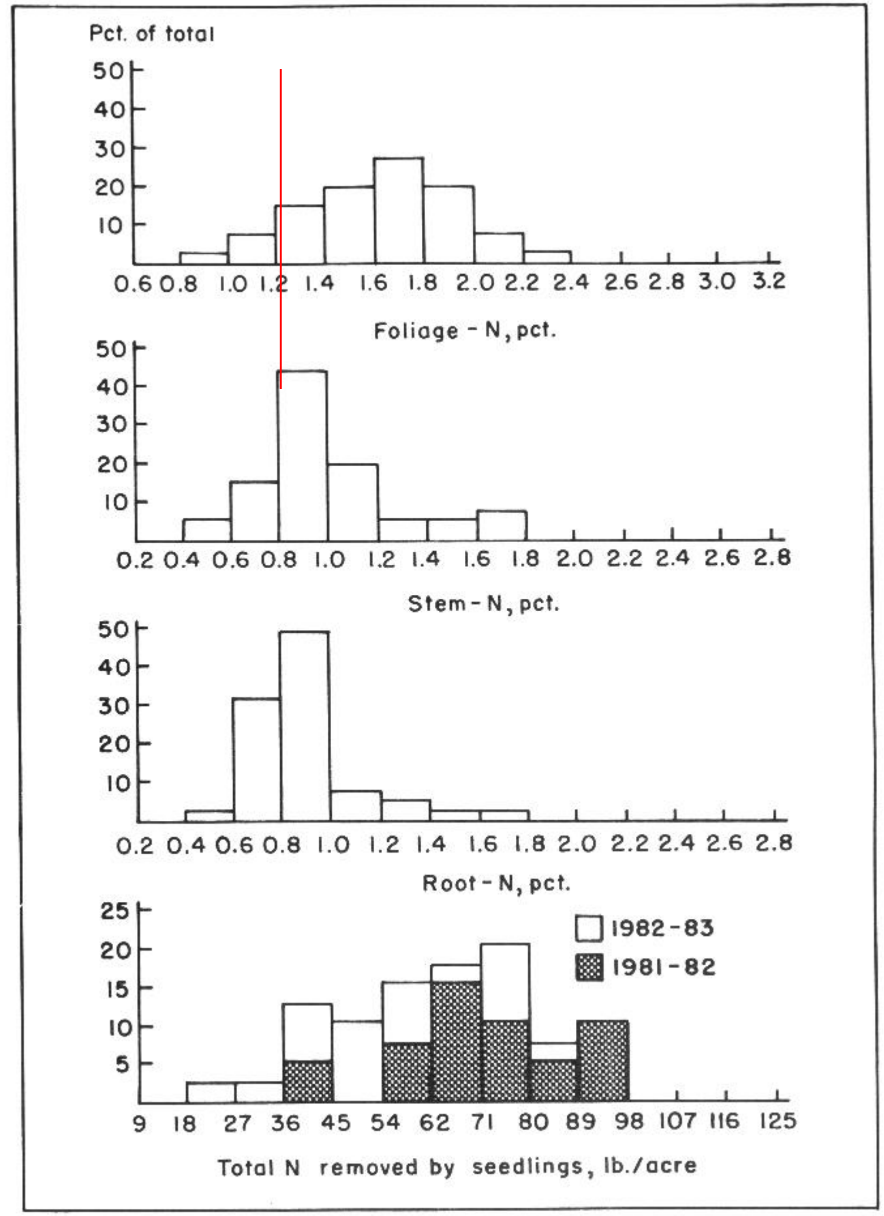


FIG. 3. Distributions of nitrogen (N) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of N by crop from data collected over 2 years. Where means for the 2 years are significantly different (0.05 level), the portion of the distribution representing the first year of sampling is shaded.

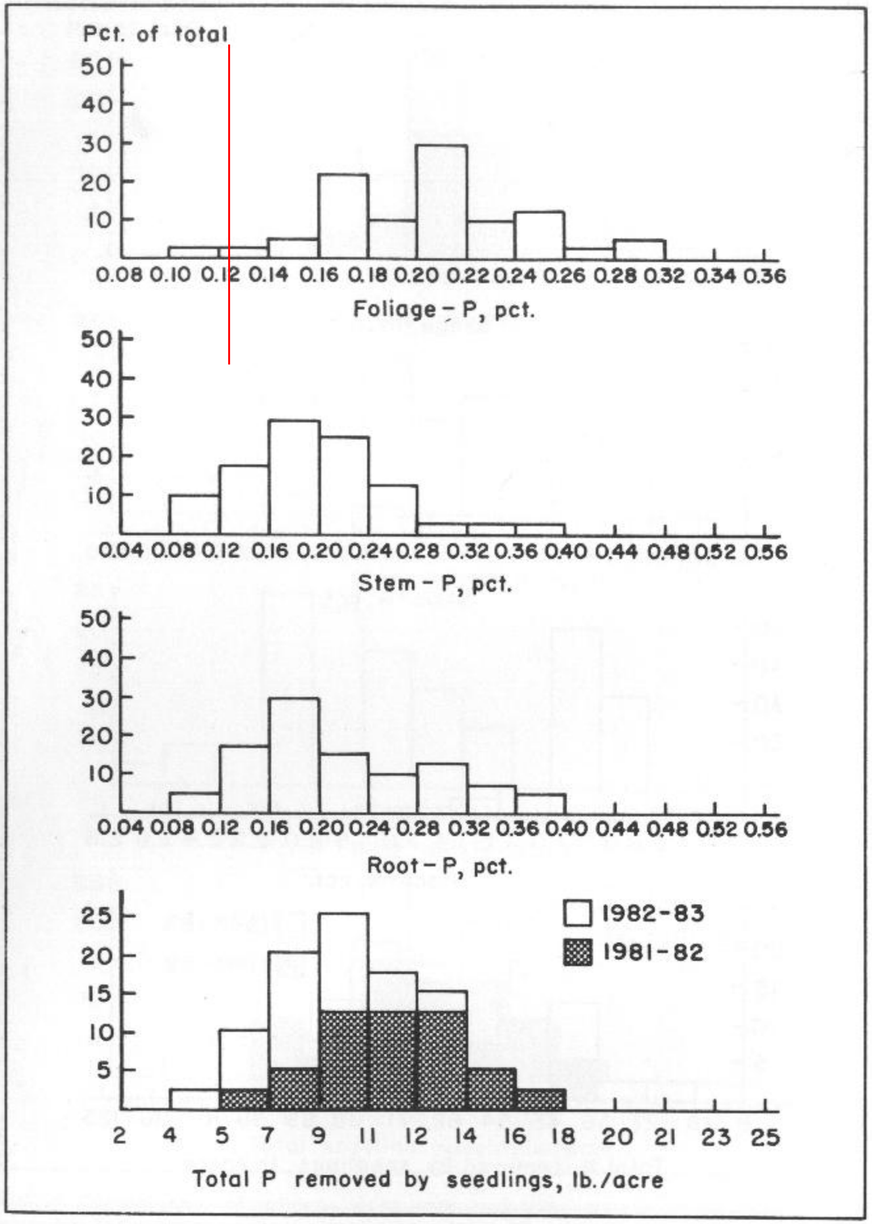


FIG. 4. Distributions of phosphorus (P) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of P by crop from data collected over 2 years. Where means for the 2 years are significantly different (0.05 level), the portion of the distribution representing the first year of sampling is shaded.

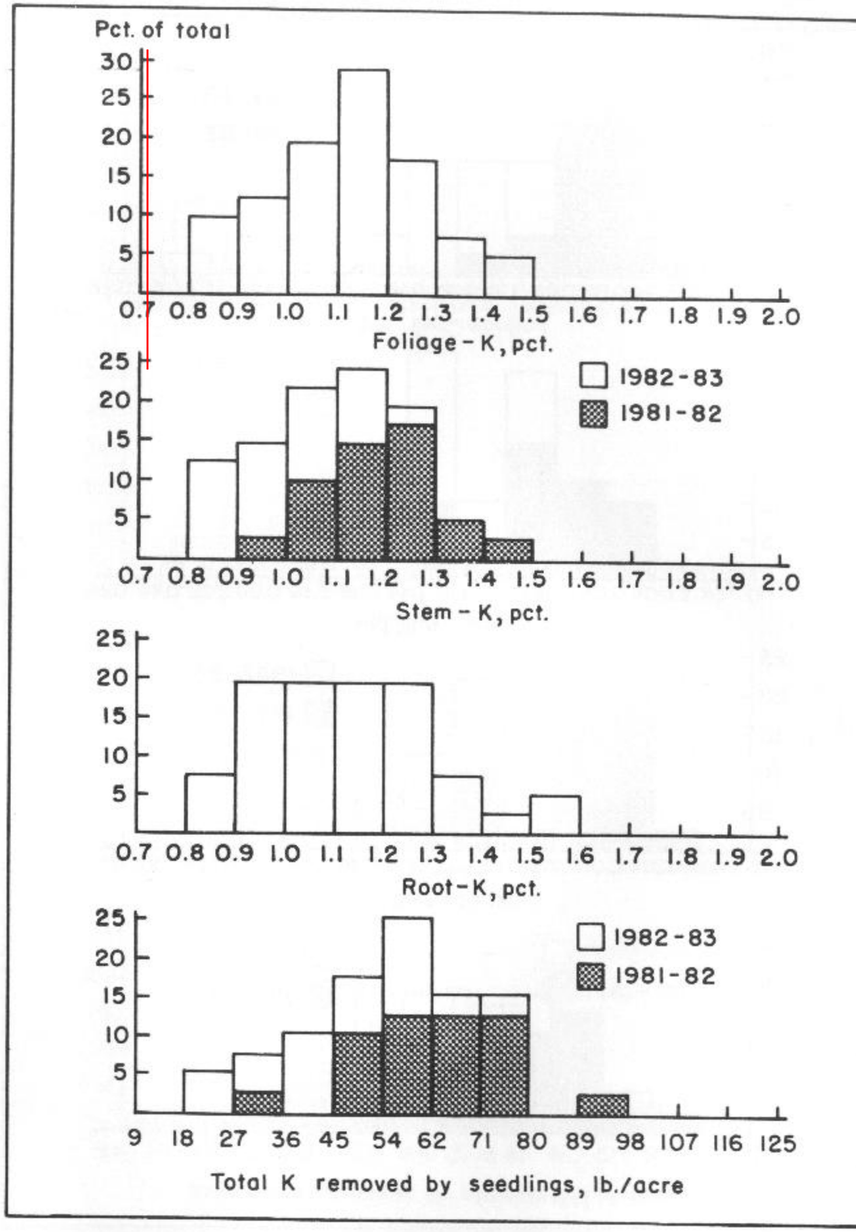


FIG. 5. Distributions of potassium (K) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of K by crop from data collected over 2 years. Where means for the 2 years are significantly different (0.05 level), the portion of the distribution representing the first year of sampling is shaded.

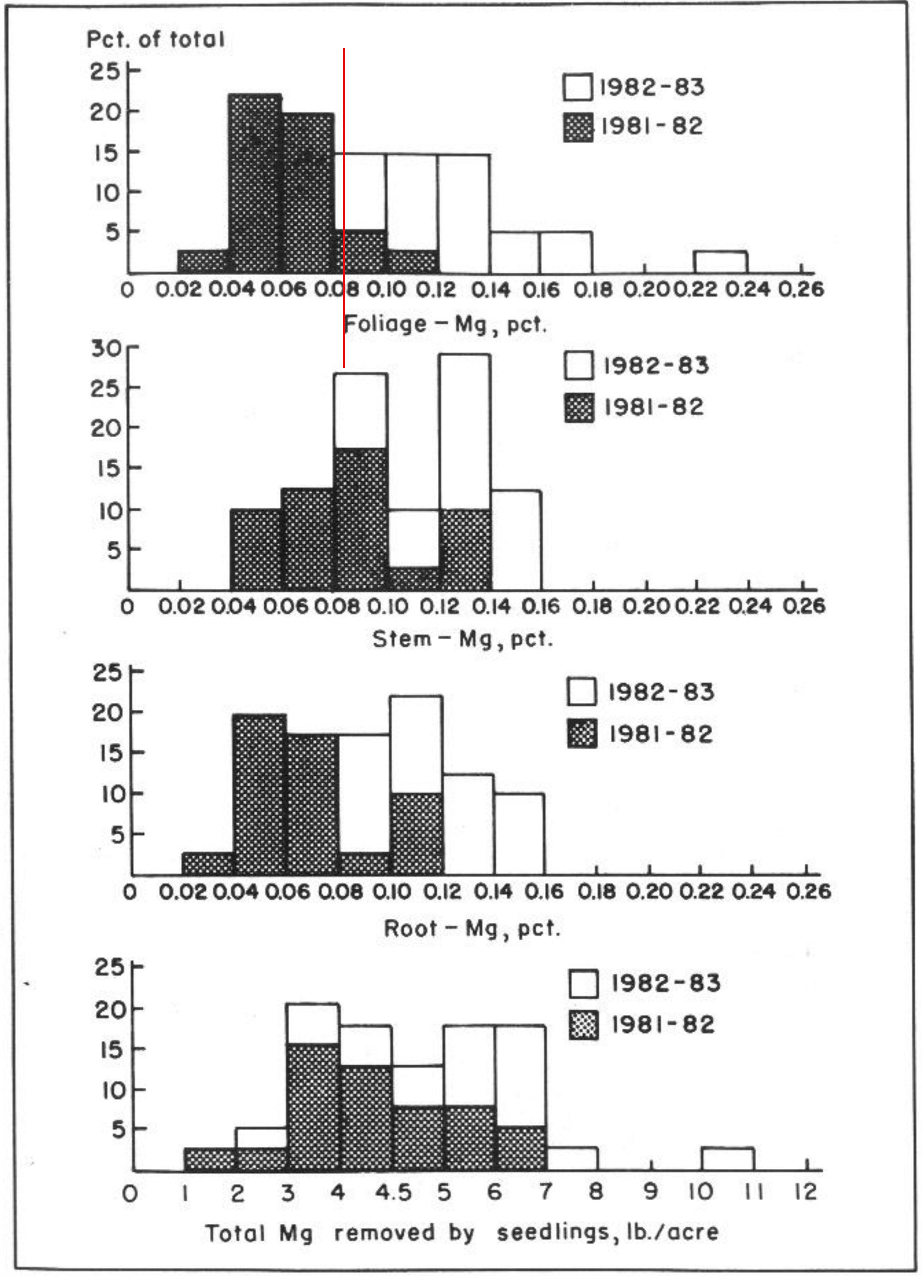


FIG. 6. Distributions of magnesium (Mg) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of Mg by crop from data collected over 2 years. Means for the 2 years are significantly different (0.05 level) and the portion of each distribution representing the first year of sampling is shaded.

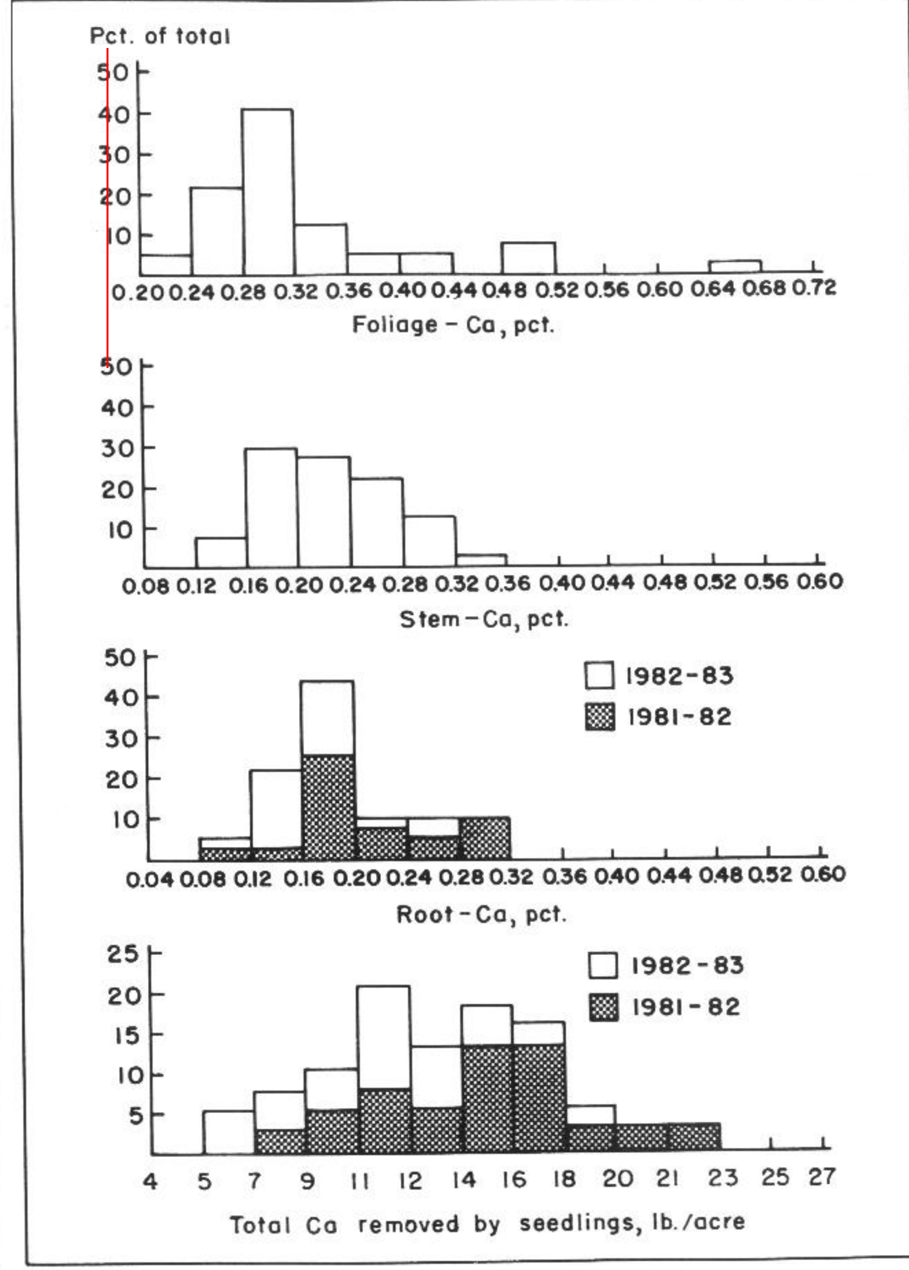


FIG. 7. Distributions of calcium (Ca) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of Ca by crop from data collected over 2 years. Where means for the 2 years are significantly different (0.05 level), the portion of the distribution representing the first year of sampling is shaded.

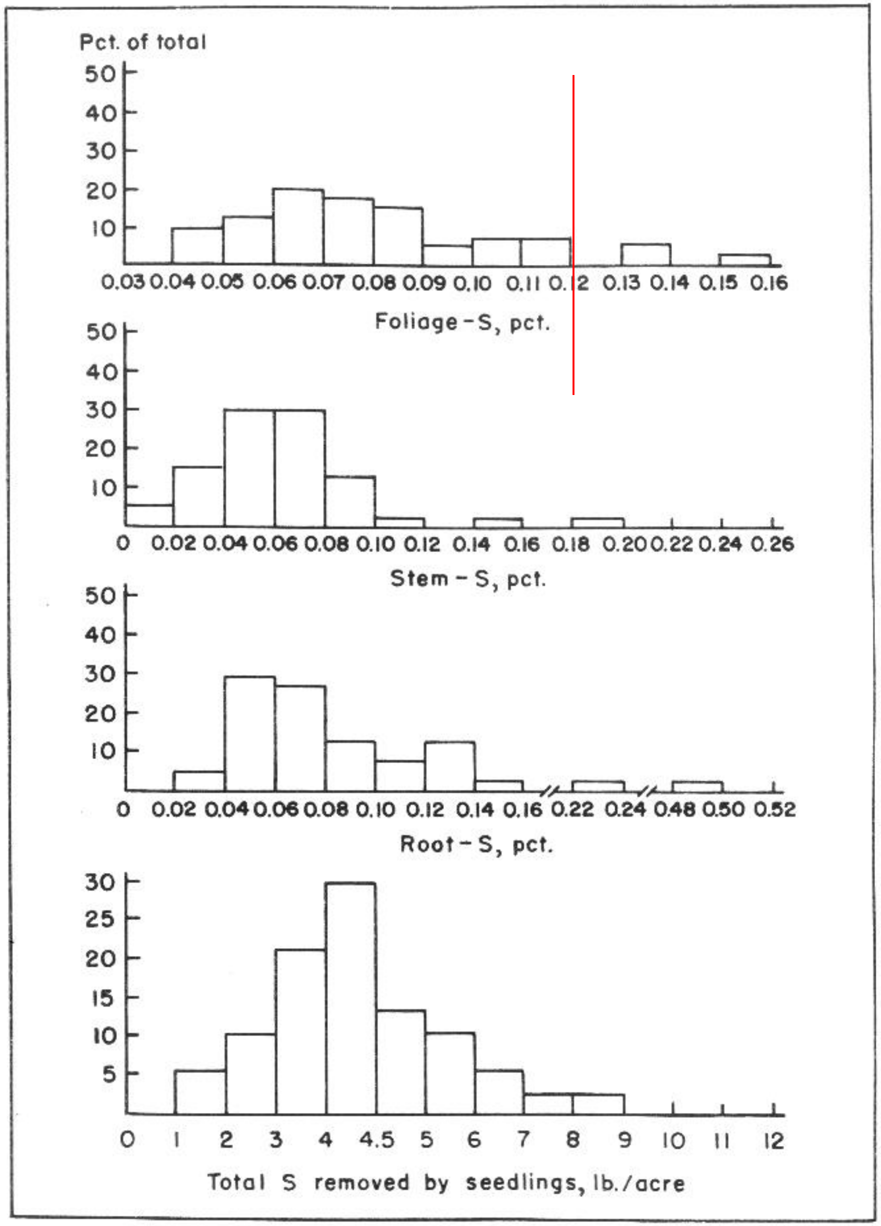


FIG. 8. Distributions of sulfur (S) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of S by crop from data collected over 2 years.

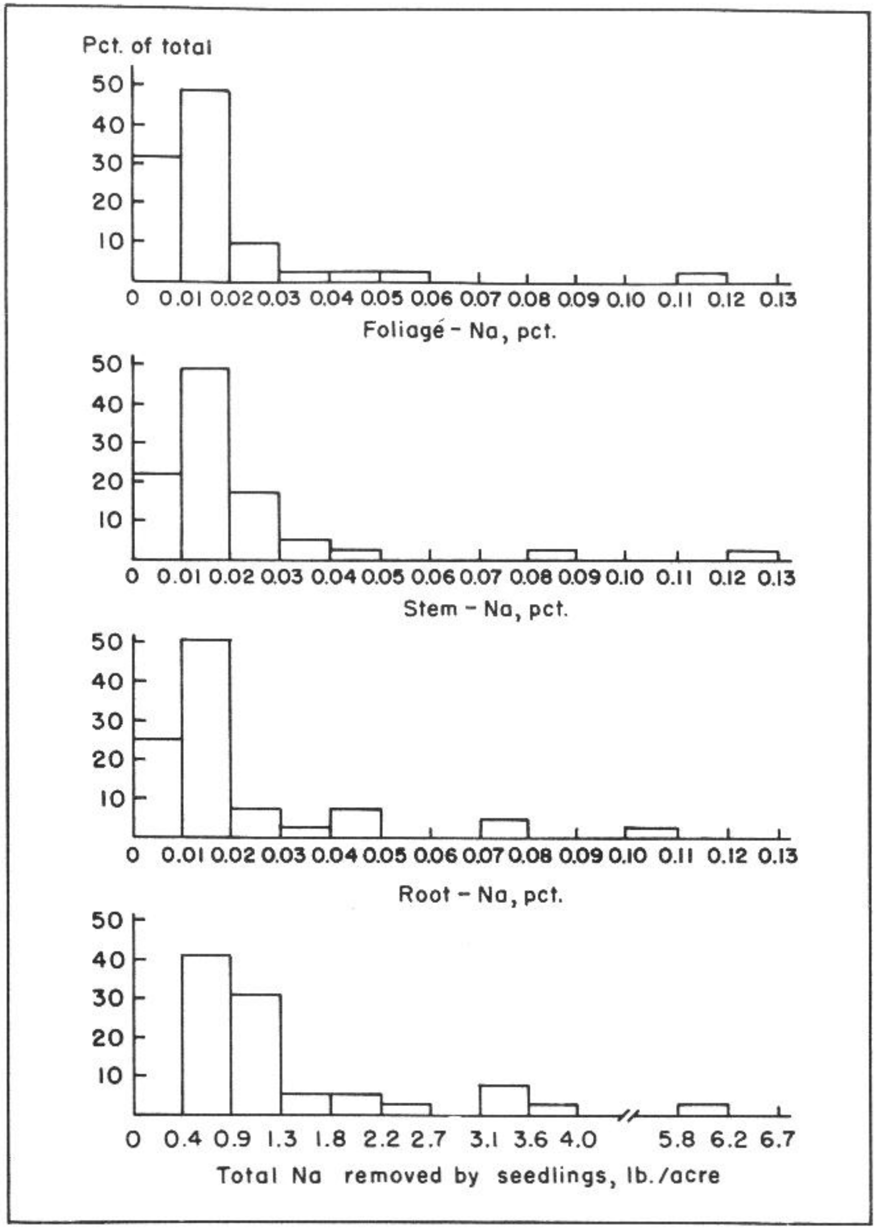


FIG. 9. Distributions of sodium (Na) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of Na by crop from data collected over 2 years.

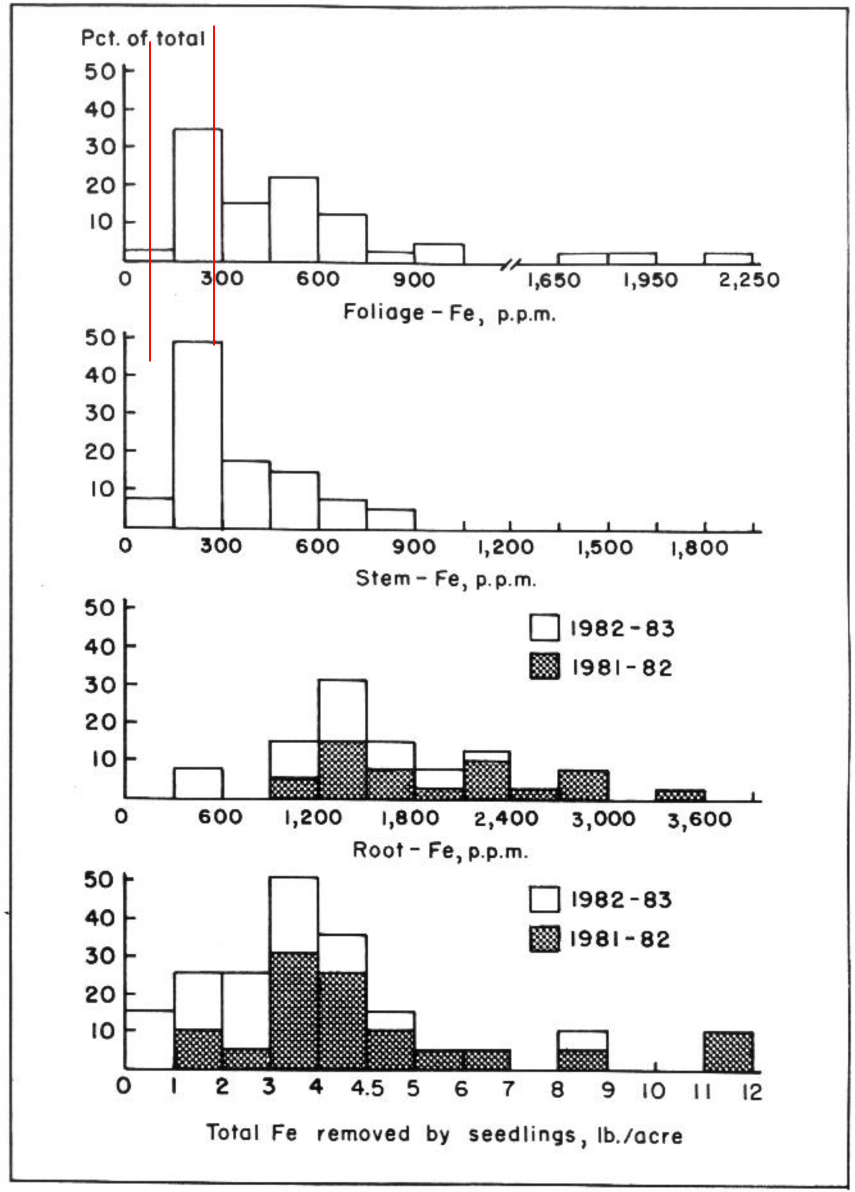


FIG. 10. Distributions of iron (Fe) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of Fe by crop from data collected over 2 years. Where means for the 2 years are significantly different (0.05 level), the portion of the distribution representing the first year of sampling is shaded.

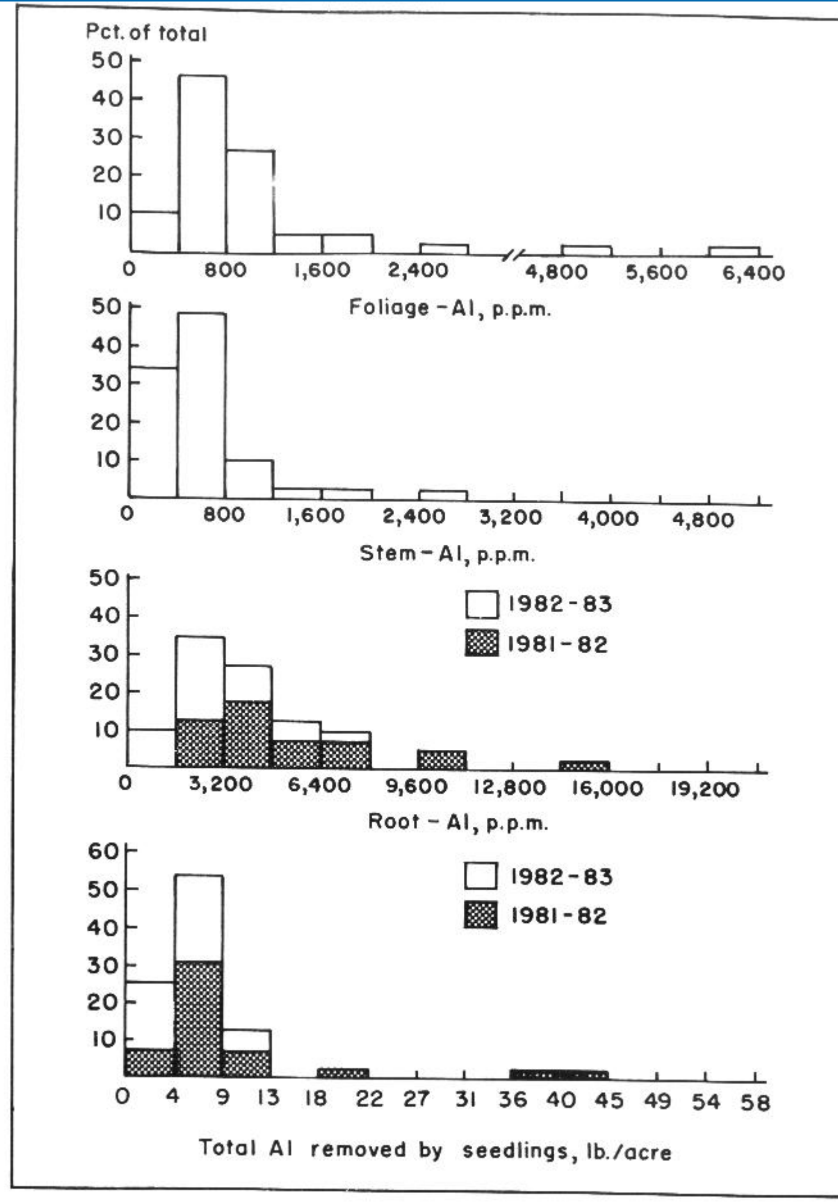


FIG. 11. Distributions of aluminum (Al) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of Al by crop from data collected over 2 years. Where means for the 2 years are significantly different (0.05 level), the portion of the distribution representing the first year of sampling is shaded.

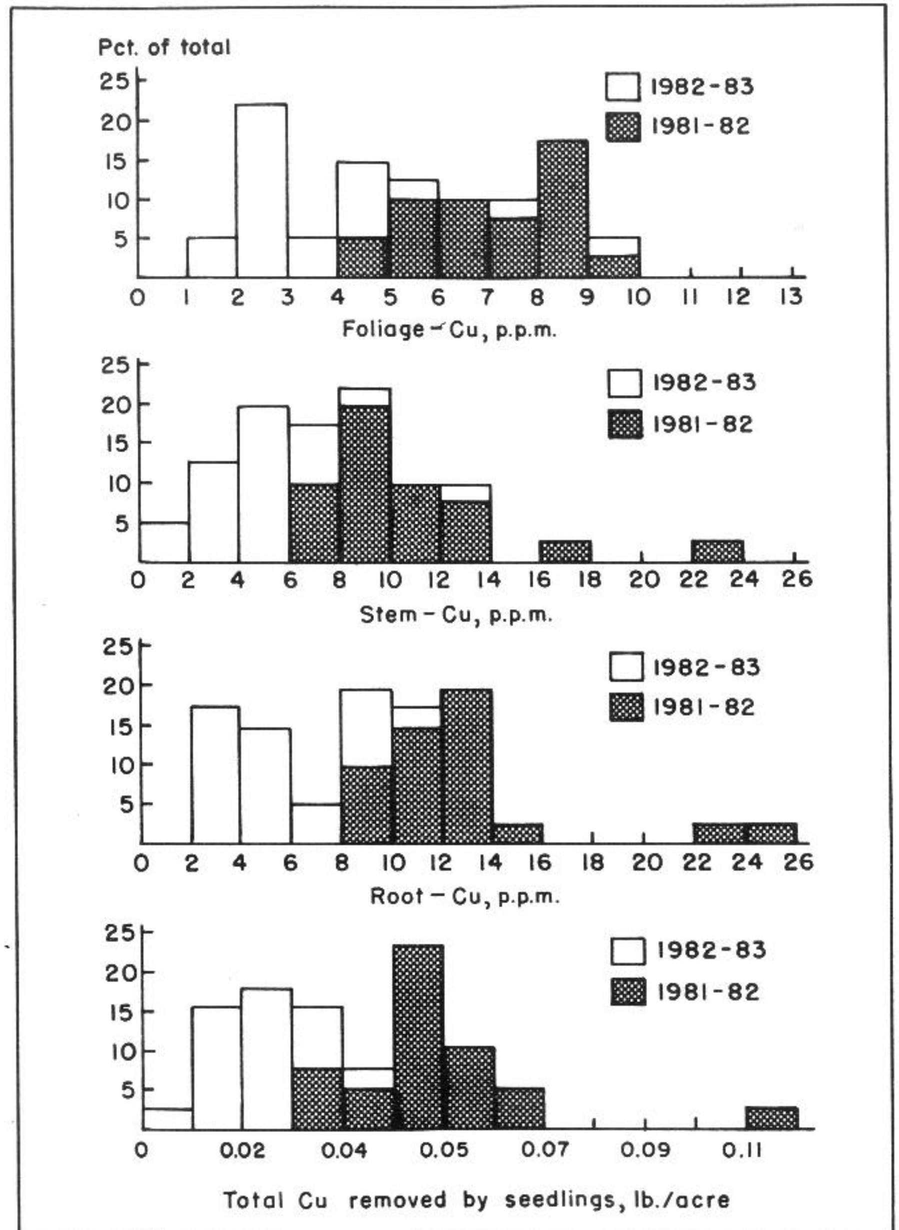


FIG. 12. Distributions of copper (Cu) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of Cu by crop from data collected over 2 years. Means for the 2 years are significantly different (0.05 level) and the portion of each distribution representing the first year of sampling is shaded.

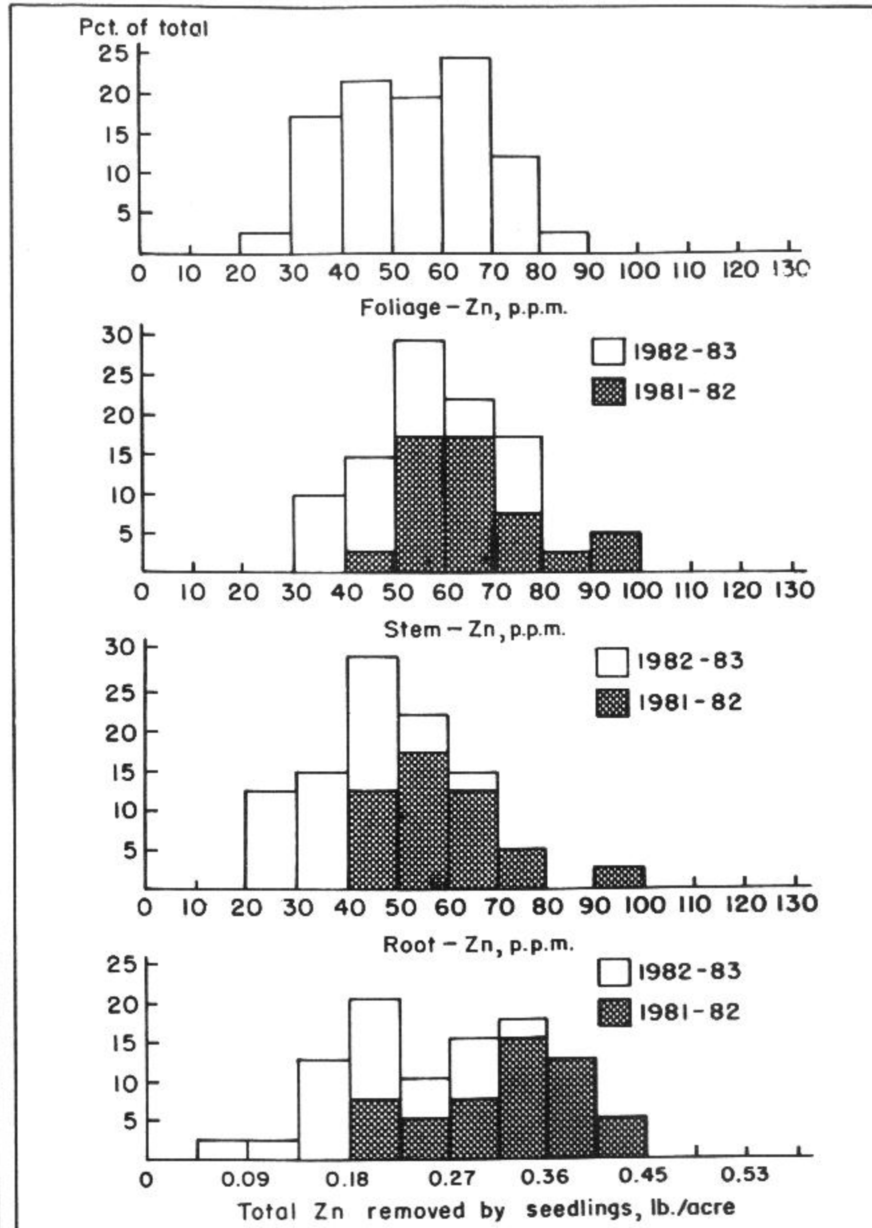


FIG. 13. Distributions of zinc (Zn) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of Zn by crop from data collected over 2 years. Where means for the 2 years are significantly different (0.05 level), the portion of the distribution representing the first year of sampling is shaded.

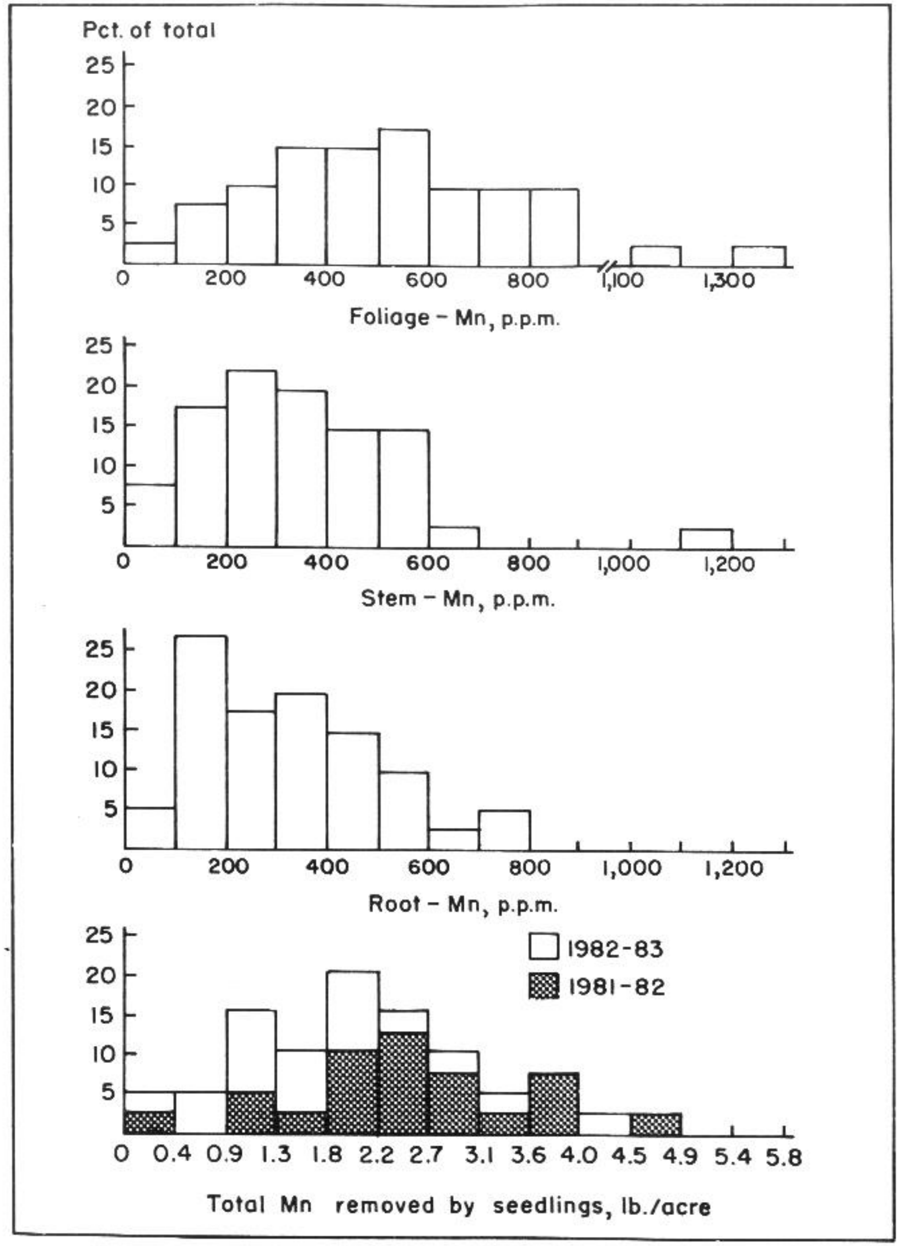


FIG. 14. Distributions of manganese (Mn) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of Mn by crop from data collected over 2 years. Where means for the 2 years are significantly different (0.05 level), the portion of the distribution representing the first year of sampling is shaded.

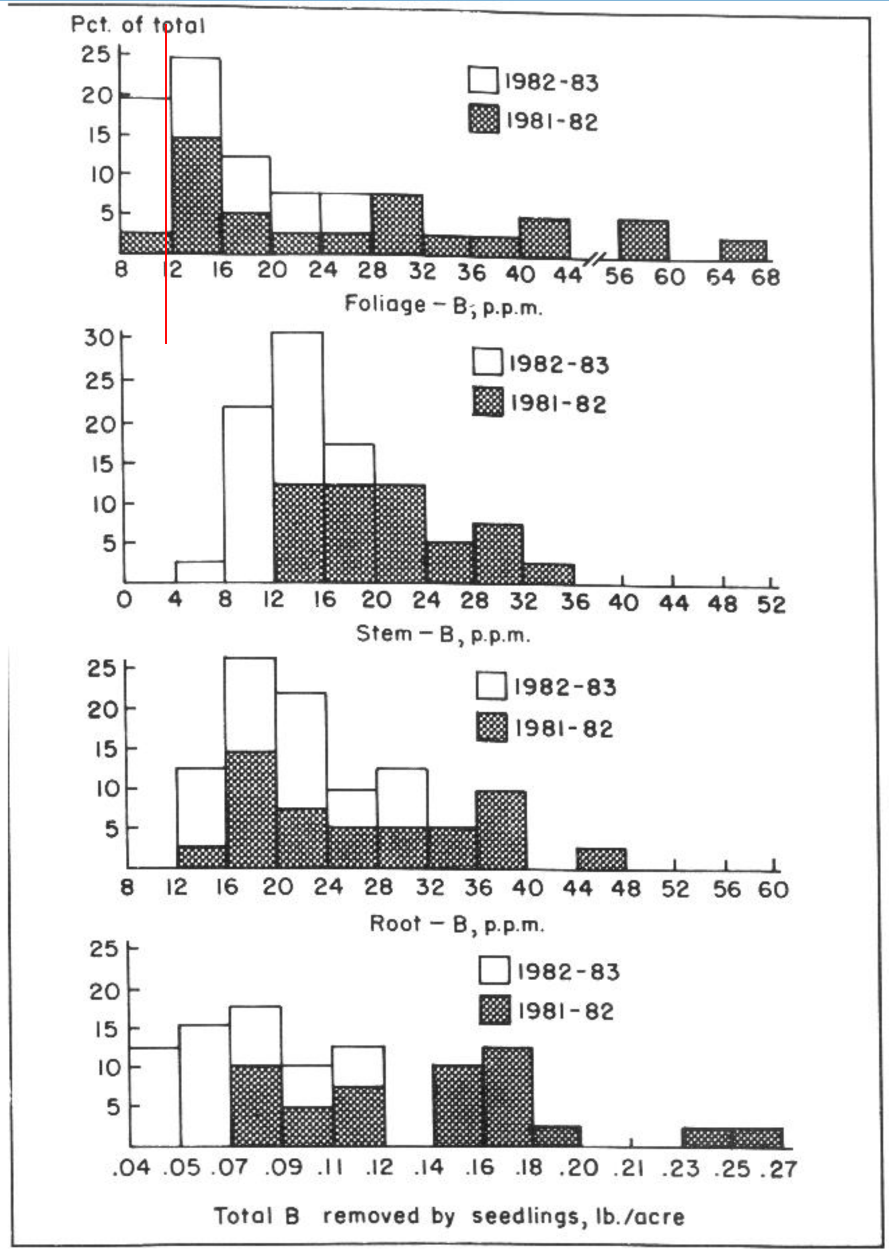


FIG. 15. Distributions of boron (B) concentrations in foliage, stems, and roots of loblolly pine seedlings plus total removal of B by crop from data collected over 2 years. Means for the 2 years are significantly different (0.05 level) and the portion of each distribution representing the first year of sampling is shaded.

These ranges are for hardwoods.

Table 1. Elemental ranges for uppermost mature leaves of woody ornamentals.	
Element	Percent*
Nitrogen	2.0 - 2.5
Phosphorus	0.2 - 0.4
Potassium	1.5 - 2.0
Calcium	0.5 - 1.0
Magnesium	0.3 - 0.8
	Parts Per Million
Iron	100 - 200
Manganese	50 - 100
Zinc	20 - 75
Copper	5 - 10
Boron	20 - 30
Molybdenum	0.1 - 1.0
* Percent of leaf dry weight	

Some value for minor elements (these are not TARGETS).

Table 2. The seven essential micronutrients and their typical concentrations in seedling tissue.

Element	Symbol	Average Concentration in Plant Tissue (%)	Adequate Range in Seedling Tissue (ppm)	
			Bareroot	Container
Iron	Fe	0.01	50 to 100	40 to 200
Manganese	Mn	0.005	100 to 5,000	100 to 250
Zinc	Zn	0.002	10 to 125	30 to 150
Copper	Cu	0.0006	4 to 12	4 to 20
Molybdenum	Mo	0.00001	0.05 to 0.25	0.25 to 5.0
Boron	B	0.002	10 to 100	20 to 100
Chloride	Cl	0.01	10 to 3,000	-

Combined Soil and Tissue Analysis

Sulfur is important in conifer seedling nutrition. Some say there should be 1 part of S for every 20 parts of N added as fertilizer. Foliar analysis for total N and total S is a valuable way of assessing this aspect of fertility management.

Ratios

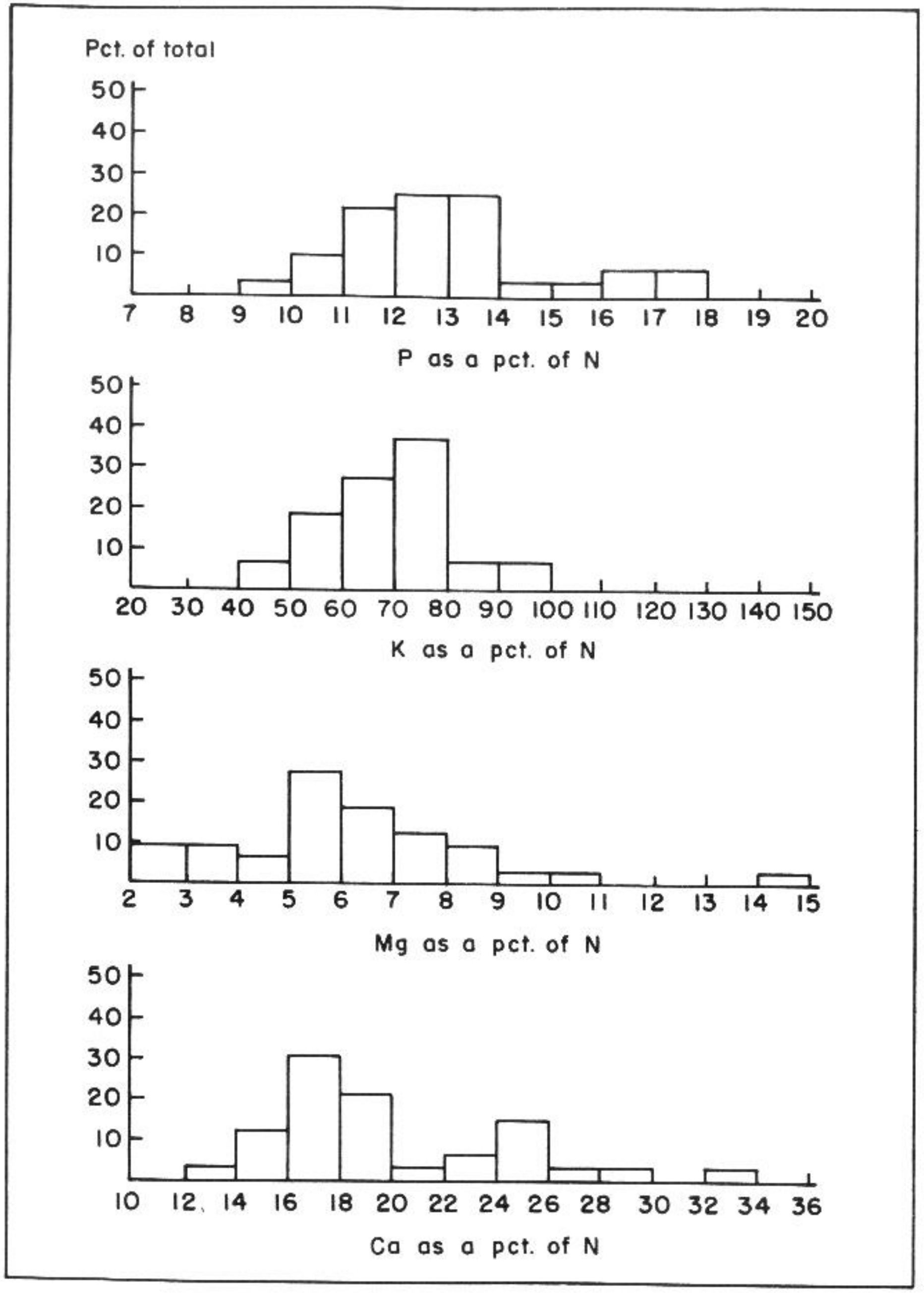


FIG. 16. Distributions of phosphorus (P), potassium (K), magnesium (Mg), and calcium (Ca) concentrations in foliage as a percent of foliar nitrogen concentration.

Combined Soil and Tissue Analysis

Typically soil analysis data is used as the basis for fertilizer recommendations. From time to time it is advantageous to have **both** types of analysis, especially when diagnosing nutritional problems that result in abnormal growth or color.

As might be expected, the correlations between foliar and total soil N were not consistent. [C. T. Youngberg]

Table 8. Mean soft and follar levels of four macronutrients for 2+0 Douglas-fir seedlings in four Northwest nurseries.

	P		K		Ca		Mg	
Nursery	Soil	Foliar	Soil	Foliar	Soil	Foliar	Soil	Foliar
	ppm	%	ppm	%	ppm	%	ppm	%
1	79	0.17	93	0.70	1.5	0.33	0.61	0.19
2	13	0.21	120	0.60	3.2	0.46	1.4	0.30
3	....	0.23	....	0.78	.....	.....	.....	.....
4	18	0.15	79	0.50	7.3	0.55	1.8	0.19

Conclusions

Soil and plant analysis are readily available tools that enable nursery managers to monitor the fertility status of their soils. The success of the monitoring program depends on careful sampling which requires sampling the same area each time, careful handling of samples, and consistency in laboratory services.

Seedling nutrient status is assumed to influence performance after planting. Researchers and nursery personnel should seek to uncover the relationships between nutrient status and outplanting performance. [C. T. Youngberg]

- In many cases, “target levels” in the USA for both soil and tissue have NOT been determined by field outplanting trials.

As a result, there are two schools of thought regarding N fertilization of conifers:

A: fertilize so N in needles is > 2%

B: fertilize so N in needles is < 1.5 %