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Soil Properties, Use of Fertilizers, and Nutrient Uptake as Related to the Growth of Loblolly Pine (Pinus Taeda L.).

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SOIL PROPERTIES, USE OF FERTILIZERS, AND NUTRIENT UPTAKE AS RELATED TO THE GROWTH OF LOBLOLLY PINE (*Pinus taeda* L.)

A Dissertation

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by
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ABSTRACT

Three loblolly pine (*Pinus taeda* L.) plantations were established in 1959 and fertilized with granular urea, treble superphosphate, and muriate of potash to determine the optimum level of soil fertility required for maximum early growth of this tree species. The plantations were established at three different locations in Louisiana in order to test the effects of the food elements under varied soil and climatic conditions. One plantation was located on Shubuta sandy loam to loamy sand at Homer in the northern part of the state. Another was established on a complex of Bowie fine sandy loam, Ruston loam, and Beauregard loam near Alexandria in central Louisiana. The third plantation was located in the southeastern part of the state on Ruston sandy loam to loamy sand in Washington Parish.

The fertilizers were applied by hand to individual trees at rates equivalent to 0, 100, and 200 pounds per acre of N, P_2O_5, and K_2O. The three nutrient elements were applied singly and in all combinations in randomized blocks to 0.1-acre plots, each containing 121 trees. Heights of the trees were measured before treatment and after each growing season. Samples of the topsoil and subsoil from each plot were collected before and after fertilization and analyzed. Foliar samples were collected at the end of each growing season and analyzed to determine the content of

nutrient elements in the needles.

The native fertility level of the soils was lower than the level required for normal crop production. After fertilization, the available phosphorus and potassium in the soil increased in proportion to the amounts of P_2O_5 and K_2O applied. Two years after the application of fertilizers, the available phosphorus and potassium content of the soil had diminished measurably from the level at the end of the first year.

The statistical analysis of annual and total growth revealed that nitrogen and phosphorus significantly influenced growth in two plantations and that only nitrogen influenced growth in the third plantation. Nitrogen alone had a depressing effect on first-year and total growth of the loblolly pine on the Shubuta soil in northern Louisiana, but phosphorus alone increased growth. The best treatment was superphosphate applied at 100 pounds of P_2O_5 per acre. In central Louisiana nitrogen alone depressed growth, phosphorus alone increased growth, but the combination of nitrogen and phosphorus provided the maximum growth. The best growth was obtained from the application of 100 pounds N plus 100 pounds P_2O_5 per acre. Only applications of nitrogen alone significantly increased growth in the southeastern Louisiana plantation. The 100-pound level of N produced the greatest amount of growth. Nitrogen treatments significantly reduced first-year survival in all plantations.

Probably due to the lack of complete control in sampling, the percentage composition of foliage samples did not show significant relationships between nutrient uptake and amount of fertilizers applied. The increase in dry weight production of foliage from some of the fertilizer treatments may have caused the percentage composition of nutrients to tend to be similar.

Additional research with lower levels of nitrogen and phosphorus is needed. Better control of variables in the collection, handling, and analysis of foliar samples should provide worthwhile data on nutrient uptake.

INTRODUCTION

In recent years, foresters have expressed an increasing interest in the use of soil amendments for forest stands. The practical aspects of applying nutrients to forest soils have been verified by both European and Australian foresters. Many of their practices, however, cannot be directly applied in this country at the present time since our economy will not justify such intensive cultural treatments except in forest nurseries, seed orchards, or in other specialized uses.

However, as management of pine timberlands becomes more intensive and the value of forest products increases, the need for adequate nutrition of the tree crop on poorer sites leads directly to the hypothesis that fertilization may become an economically essential part of future forest management. In numerous instances, fertilizing forest stands may be needed on eroded or inherently infertile soils in order to shorten the rotation and enable the economic production of a forest crop.

Lacking basic research data, many forest owners in the South have instituted their own fertilizer trials on a limited scale and for a multiplicity of purposes. In order to provide a sound economic basis for fertilizing forest trees, research should include the development of a method for determining the optimum level of soil fertility for each

tree species, establishing a means for detecting nutrient deficiencies in trees, and determining the amount of fertilizer necessary to meet the nutrient requirements of a species for each soil type in each forest region.

In view of the growing interest in fertilizing forest stands, the Louisiana Agricultural Experiment Station initiated a forest fertilization study in 1959 to satisfy, at least in part, the demand for basic research data. The study necessarily had to be restricted within relatively narrow limits at the start, but it can be progressively expanded in the future to supply data on tree and wood quality, volume growth and yields, seed production, and other factors as influenced by fertilizers.

The primary objective of the study was to determine the level of fertilization needed to supply the proper amounts of nutrient elements required for maximum initial growth by young loblolly pine (*Pinus taeda* L.) at selected locations. An important secondary objective was to determine the minimum nutritional requirements for this southern pine species for satisfactory growth on the soil types involved. The possibility was considered that forest fertilization in the future may be based on the nutrient level present in the proposed planting site as determined by a chemical analysis of the soil.

No particular economic significance should be attached to this study. An attempt was made to control or eliminate as many growth-affecting variables as possible to allow the

pine seedlings to receive the maximum effect of the fertilizers. Fertilizer applications, insecticide and herbicide applications, weed control, and other cultural treatments were accomplished largely by manual labor, which is always an expensive item. The costs of such intensive cultural treatments may be prohibitive for normal forest production.

REVIEW OF LITERATURE

It is noteworthy to mention in the beginning the excellent bibliography with abstracts which has been compiled by Donald P. White and Albert L. Leaf and published in 1957 by the State University College of Forestry, Syracuse, New York, as the World Forestry Series Bulletin Number Two (75)[1]. Entitled Forest Fertilization, this bibliography gathers under one cover most publications through the fall of 1956 relating to all of the various phases of forest fertilization. Included are 700 references on the use of fertilizers and soil amendments in forestry from 237 different journals throughout the world.

In addition, a rather extensive review of the literature on fertilizing forest trees as well as forest nursery fertilization has been accomplished by Stoeckeler and Arneman (62) in Volume 12 of Advances in Agronomy. A comprehensive review of literature restricted to fertilization and nutrition of southern forest trees is included in Forest Fertilization Research in the South by Walker and Tisdale (72).

In view of the numerous references cited in the above works, this chapter will be restricted in the main to a coverage of the principal references dealing with the

[1]Numbers in parentheses refer to literature cited.

history and current status of forest fertilization, some general problems involved in fertilizing forests, and the use of fertilizers in the growth of the four principal southern pines. A few outstanding results with other tree species in the United States will also be covered to illustrate the broad usage of fertilizers in forestry. References on the use of fertilizers and other soil amendments in the specialized fields of forest nurseries, seed orchards, and Christmas tree production are excluded so that this chapter may be confined within practical limits.

History and Current Status of Forest Fertilization

According to Wilde (76), work in forest fertilization was first started over 100 years ago in Europe by Biermann. Most of the old work showed positive results with green manure crops such as lupine and with organic remains, humus, forest litter, and slash. Effects of mineral fertilizers were irregular and short-lasting. Some trials gave especially good results on stands injured by drought, fire, insects or diseases and on worn-out soils. On the other hand, in many cases mineral fertilizers failed to improve and often depressed tree growth. As would be expected, the effects of applied fertilizers were most pronounced on soils of low general fertility or soils deficient in a specific nutrient.

In many European countries, the use of commercial

fertilizers and especially lime has become an important part of the silvicultural treatments (64); the objective of adding lime has been as a soil conditioner rather than as an essential nutrient element.

Since World War II, many of these countries, particularly Great Britain, Sweden, Denmark, Holland and Germany, have expanded their research programs aimed at speeding up the re-establishment and production of timber resources depleted during the war. The use of fertilizers is emphasized in this European research work (83).

In Australia, the use of fertilizers in forestry has been standard practice for 25 years. Fertilizing with zinc and superphosphate has often spelled the difference between non-commercial and commercial forests (86). Australian plantations of southern pines are extensively fertilized, particularly with phosphatic fertilizers, and much research has been done to determine the kinds and amounts of fertilizers required under the soil and climatic conditions prevailing in the areas of forestation (85).

American experience with soil amendments in forestry largely is restricted to the past twenty years. Prior to that time, the use of fertilizers as a general practice in forest management was considered ineffectual in terms of yield increases and impractical from the standpoint of difficult accessibility and lack of suitable application techniques. As a result, there was very little research effort directed toward the use of fertilizers in forestry

practice (74).

Within recent years, however, the improved economic picture for forest lands and forest products has stimulated interest in the possibility of increasing forest tree production or quality by means of soil amendments. Major activity is still in the investigative and developmental stages. Research in several important forest regions already has demonstrated the possibility of achieving some increased production with all the major and some of the minor elements. However, except for specialized use, forest nursery management, plantation establishment, or local problem areas, the economy of forest fertilization remains to be proved (31).

Walker (68) has stated: "While the economics of fertilizing southern pines may be questionable today, the situation is expected to be otherwise in 1967.... We must know the effectiveness beforehand; ... we can forecast that the cost of application will fall into line."

Numerous forest industries in the South, lacking basic tree nutrition information from experiment stations and other research institutions, are engaged in forest fertilization trials, studies and experiments. The broad general objectives of all these forest industries is to determine the effects of fertilization on the growth, development and production of tree crops, to evaluate these effects and, in turn, to determine the practicability of fertilization as an economically feasible silvicultural technique for increasing

the production of desired products from forest lands (34).

Because of the interest in fertilization exhibited by the forest industry, the National Plant Food Institute, on behalf of its member companies, approximately two years ago formed the Southeastern Forest Fertilization Task Force under the direction of Dr. Laurence C. Walker of the University of Georgia. As the result of their study of forest fertilization and tree nutrition research in the South, the NPFI established a clearing house through which synopses of the various research projects in forest fertilization are distributed to all institutions, agencies and forest industries engaged in this field. A summary of forest fertilization research was published in 1959 by the NPFI in _Forest Fertilization Research in the South_ by L. C. Walker and S. L. Tisdale (72).

General Problems in Forest Fertilization

As stated by Willis (78), "even a casual examination of the literature on the response of forests to fertilization will reveal a variety of conflicting results." The diverse soil, topographic and climatic conditions, inherent variations both among and within tree species, and the very nature of the growth habit of trees should help to explain some of the variation in fertilizer responses. Add to this list the variable physical and chemical nature of the fertilizer itself, difficulties of terrain and tree growth

in its application, the lack of adequate knowledge in basic tree nutritional requirements and the general problems of forest fertilization are clearly outlined.

Among the many factors which affect the over-all field of forest fertilization are: the chemical and physical nature of the soil and the general topography of the land; the chemical and physical nature, rate and time of application, and placement of the fertilizers used; competition from grass and other plants; species of tree fertilized; age and density of stand; and perhaps of most importance -- the nutrient requirements of the various forest tree species.

Wilde (76, 77) has attributed the failure of early fertilizer trials to insufficient knowledge of soil chemistry, fertilizers and tree nutrient requirements; to competition from grass which the fertilizer stimulated and deprived trees of moisture; and to drought periods which offset fertilizer treatments and caused either burning by mineral fertilizers or a lack of adequate moisture on peat soils or with the use of organic fertilizers. Forest soils are often deficient in only one or two elements and rarely is a complete fertilizer needed, according to Wilde.

The importance of the soil itself is stressed by Wilde (77) in these words: "The concept of <u>fertilizer responsiveness of soils</u> should be placed in the foreground of all forestry fertilization work...". Such factors as water-holding capacity, internal drainage and aeration, and inherent nutrient status certainly affect the response of

soils to fertilizer additions.

Soils of good water-holding capacity have shown more consistent responses to fertilizer applications than coarse sandy soils (76). However, nitrogen responses with Douglas-fir (Pseudotsuga menziesii [Mirb.] Franco) on droughty soils in the Puget Sound region and phosphate responses with slash pine (Pinus elliottii Engelm.) on deep sands in Florida suggest that even where moisture may be limiting supplemental additions of nutrient elements may well be beneficial (86).

Many soil properties have a distinct effect on nutrient availability. The amount of nitrogen, for example, is largely determined by the amount and kind of organic matter present in the soils of humid climates and nitrogen availability from this organic matter depends in turn on soil reaction and other factors which influence biological activity (42). The availability of other nutrient elements depends on the pH of the soil (65). The majority of the elements are not highly available at pH below 5.5; many forest soils have a pH below this point. The same factors which affect inherent nutrient availability will also affect the availability of any nutrients applied as fertilizers.

The physical problems involved in forest fertilization were adequately stated by White and other members of the Committee on Fertilizer Application in Forestry (74):

> Only the ancient hand broadcasting method applied from buckets between rows or around individual trees was employed [in early fertilizer applications]. In dense stands where visibility is often limited to a few feet, crews had to be kept

> oriented by string lines at 20- to 50-foot intervals. As little as one man-hour and as many as 10 man-hours per acre were required in plantations depending on the density and irregularity of the rows. Roughness of topography, inaccessibility, density of stands, interlocking of branches, brush and debris, all combine to preclude the use of any conventional type of applicating machinery. Even if it should prove desirable to fertilize tree crops before or within a few years after planting..., the general topography in many forest areas is unsuitable to wheeled or tracked machines moving in a regular pattern. The use of liquid sprays, although technically possible, is not at all promising because of the excessive quantities of water which would have to be transported and the expense of operating pumper equipment.

Solubility, physical form, and certainly the chemical composition of fertilizer materials are just as important in fertilizing forests as in agricultural crops. The Japanese worker Shibamoto (60) has listed the following properties desirable in a fertilizer for use in forestry:

(1) Minimum leaching out by rain water and percolating waters and minimum loss of fertilizer constituents by fixation by iron and alumina in the soil, by dispersion, etc.;

(2) Long continuance of fertilizing action;

(3) Absence of fertilizer burn;

(4) Intense fertilization action;

(5) Effectiveness in increasing productivity of the soil and absence of ill effects even after repeated use;

(6) Low cost with respect to both fertilizing action and effectiveness in increasing soil productivity;

(7) Ease of application; and

(8) Ease of transportation and storage.

Pritchett and Perry (53) have pointed out that the

placement of fertilizer, as well as the rate, must be considered when fertilizing young pine. Fertilizer placed too far from the trees may be lost by leaching and when placed too close it may burn young trees. Even a very small amount of soluble fertilizer placed in the planting slit may cause damage if it is placed in contact with the roots. However, deep placement of fertilizer, below or to one side of the roots at planting, has been suggested as one means of promoting early tree growth and reducing competition from weeds.

York (82) has drawn an analogy between fertilizer placement in forestry and in agricultural practice. He stated that although problems of fertilizer placement are undoubtedly more complex with forest species than with most agricultural crops, many of the principles involved are the same. Fertilizers should be placed to afford: (1) maximum utilization by the plant by making the applied nutrients easily accessible to the roots with minimum losses from leaching and fixation; (2) minimum burning or other injurious effects; and (3) minimum stimulation of weeds or other competitive plants. York pointed out that "proper fertilizer placement is particularly important with young plants having limited root systems and where competition is a major problem".

The response to fertilization varies between tree species. Hardwoods generally have shown a greater response than conifers (76). Conifers (pine, spruce, fir) apparently

have somewhat lower nutrient requirements than hardwoods (maple, ash, poplar). However, the conifers have been used almost exclusively for large-scale reforestation, often on the poorer soils, so that most instances of nutrient deficiency have been reported with these species (31).

Before methods of application of fertilizers in forest areas become of too great concern, many other questions need to be answered. For example, Fowells (22), Youngberg (86), and others have stated that the first task in the field of forest fertilization is to establish the nutrient requirements of the major commercial species and ultimately the response of each species on a multitude of forest soils. In addition, the kinds of fertilizer materials (slowly soluble versus readily soluble materials), rates of application, time of application (both in regards to season of year and age of stand), and the fertilizer responsiveness of the soils need to be thoroughly explored.

Work in the Fertilization of Southern Pines

Loblolly Pine (Pinus taeda L.):

Probably the most outstanding responses from fertilizer applications to loblolly pine plantations have been reported from Australia (13, 37, 44, 45, 55, 84, 85). Both loblolly and slash pine have been planted extensively in regions very similar to the southeastern United States with respect to climate. Much of the soil, however, is deficient in

phosphorus so that these pines often exhibit a "fused needle" condition associated with a stunting of the tree and a twisting and adhesion of the needles in each fascicle (84). Application of phosphatic fertilizers has been used since 1939 to correct this condition as well as economically increase volume growth. Application of 250 pounds of superphosphate per acre resulted in an 18.1 percent increase in tree volume of loblolly pine in New South Wales the third year after treatment compared with 9.4 percent for non-fertilized trees. This increase was nearly enough to repay the cost of fertilizing (37). Young (85) has reported that rock phosphate applied at rates of 146 to 986 pounds per acre was as effective as superphosphate applied at rates of 190 to 1580 pounds per acre.

Perhaps the oldest study on fertilization of loblolly pine plantations in the United States was undertaken in 1950 by the North Carolina State College School of Forestry (38). The four plantations used in the study were 6, 9, 12, and 16 years old when the first application of fertilizer was made. Measurable responses to nitrogen applied at rates of 80 and 160 pounds per acre, alone and in combination with P and K, occurred in each of three consecutive years. This response amounted to a 40-percent increase in wood production on plots receiving 160 pounds per acre of N over the control plots.

A fertilizer study at the University of Georgia involving loblolly pine seedlings from the same parent tree

produced better growth and higher survival rates in check plots than in fertilized plots (68). Decreased growth and survival were apparently caused by the stimulation of weed growth which, in turn, reduced moisture to a critical level for the first-year pine seedlings. Auten (6), working on North Carolina coastal organic soils, found no significant height growth response of loblolly to phosphorus and minor elements.

While most responses to fertilizer have occurred on soils of low fertility, a study in southern Arkansas measured the growth response and mineral uptake of fertilized loblolly pine in established plantations on average and above-average sites (87). Six fertilizer treatments were broadcast by hand in March, 1954, to plots in three plantations, aged 4, 5, and 8 years. The fertilizer treatments included nitrogen at 100 and 300 pounds per acre; 300 pounds of N plus 200 pounds of P_2O_5 and 120 pounds of K_2O per acre; 300 pounds of N plus 200 pounds per acre of minor-element fertilizer containing Fe, Zn, Cu, Mn, Bo, and Mg; a combination of N, P, K, and minor elements; and a non-fertilized control. Height growth was not affected by any fertilizer treatment tested but diameter growth was stimulated for two years by nitrogen fertilizer (ammonium nitrate) with no increase shown by the addition of phosphorus, potassium or minor elements. Three hundred pounds of N per acre gave better growth than 100 pounds the second year, but not the first. Foliar analysis showed that N was

absorbed in proportion to the amount applied, but after three years the nitrogen content of fertilized needles diminished to the level in the control trees. The total five-year diameter growth increase amounted to 10 percent for a single application of 100 pounds of N per acre.

A small pilot study of the effect of soil moisture and soil fertility on the growth of newly-planted loblolly pine on Grenada silt loam soil is being conducted by the Crossett (Arkansas) Research Center. The soil has been kept at approximately 80 percent of field capacity by applying two inches of water per week during the growing season. Each year 250 pounds of 10-20-10 fertilizer per acre have been applied in April followed by an additional 250 pounds of ammonium nitrate in June. After five growing seasons, height growth has been significantly increased due to watering but not by the fertilizer treatments. However, both fertilizer and water have significantly increased diameter growth, with the fertilizer having the greater effect. Five years after planting the control trees averaged 25.0 feet in height and 4.4 inches in diameter, watered trees 29.0 feet and 5.0 inches, fertilized trees 26.0 feet and 5.5 inches, but the watered plus fertilized trees were 29.5 feet and 5.8 inches in height and diameter, respectively (17).

Work at Mississippi State College on fertilization of outplanted loblolly pine showed height growth response to 150 and 300 pounds per acre of nitrogen after three years in the field (68). In a pole-size stand on poor sandy soil,

growth of 124 cubic feet per acre is reported and on another area 80 pounds of N per acre gave a response in height growth (70).

In 1957, the Tennessee Valley Authority applied several combinations of N, P, and K in the bottom of the closing slit made by bars in planting one-year-old loblolly pine in Alabama. Survival at the end of one year was highest for the unfertilized trees and ranged down to only four percent for some of the more heavily fertilized trees. The Southern Forest Experiment Station has three studies designed to determine the effect of treatment level and frequency of application of various fertilizers, especially nitrogen, on the growth rate of young loblolly pine -- two in Arkansas and one in Alabama (21).

Many of the forest industries in the South are also conducting fertilizer trials with loblolly pine. Although results are yet too meager and inconclusive, several of these studies indicate a response in height and/or diameter growth (34).

Symptoms and correction of nutrient deficiencies and nutritional requirements of loblolly pine have also been studied. As early as 1937, Addoms (1) found that loblolly pine seedlings grown in sand cultures could utilize N in either the nitrate or ammonium forms. The nitrate form was better under acid conditions while the ammonium form was better in soil reactions around pH 6. Addoms stated that loblolly pine probably gets its nitrogen in the ammonium

form since little nitrification occurs in forest soils.

Fused needle disease in Australia has been corrected by application of phosphate (45, 55, 84, 85). According to Richards (55), a minimum total P_2O_5 content of 135 ppm. in the surface soil is required for healthy growth of loblolly pine in Australia and the optimum phosphate content appears to be about 210 ppm. These values have been accepted as the basis for fertilizing loblolly pine and, where the soil analysis shows the total P_2O_5 content to be deficient, sufficient superphosphate or rock phosphate is added to bring the total P_2O_5 figure in the top four inches of soil to 150 ppm. (45).

In greenhouse studies, Fowells and Krauss (24) found that loblolly pine growth was best at levels of one ppm. of P and 25 to 100 ppm. of N. Woodwell (80), on the other hand, found the P and N requirements to be higher. He proposed that the optimum range of the six macroelements for loblolly pine were, in ppm.: 75-600 N, 40-600 P, 25-300 K, 12-100 S, 20-100 Ca, and 25-100 Mg.

Davis (19) has reported calcium deficiency symptoms of loblolly pine and Wilson (79) described zinc deficiency symptoms at less than 0.1 ppm. of Zn, but nitrogen, phosphorus and potassium deficiencies or requirements have not been adequately explored. However, some work has been done on the absorption and translocation of these nutrients, particularly with radioactive phosphorus (36, 43, 54, 69).

Walker (69) fertilized three-year-old loblolly pine

trees in early June with phosphoric acid tagged with P^{32} at an equivalent rate of 100 pounds of P_2O_5 per acre. He found that two days after application to the soil surface more P was found in low-positioned needles than at any other time, indicating the rapid uptake of phosphorus by the trees. One-year-old needles contained slightly more radioactive phosphorus than the current year's needles.

Greenhouse studies have indicated satisfactory nutrition of loblolly pine having foliar concentrations of 0.14 to 0.16 percent P and 1.7 to 2.3 percent N (24). Fowells (23) has also reported a significant correlation between site index and phosphorus concentration in the foliage of loblolly pine growing along the coast from Maryland to Florida. This would suggest that the supply of phosphorus in the soil may be limiting to growth of loblolly pine in some locations.

Seasonal changes in foliar nitrogen of 8-year-old loblolly pine following several levels of nitrogen fertilization are being studied in Arkansas (21).

Other current research with fertilizers and loblolly pine are briefly mentioned by Doolittle (21) and by Johnson (34).

Slash Pine (*Pinus elliottii* Engelm.)

In Australia, slash pine has responded to applications of phosphates with increased growth and correction of the "fused needle" disease in the same manner that loblolly pine

has. Richards (55) has reported that the minimum total P_2O_5 content in the surface soil is about 110 ppm. for healthy growth of slash pine in Australia and the optimum phosphate content appears to be 150 ppm. As a general practice, the total P_2O_5 figure in the top four inches of soil is brought up to 120 ppm. by the addition of phosphatic fertilizers (45). Results of work conducted in the same country by Young (85) revealed increased growth and disappearance of the deficiency symptoms from hand-broadcasted applications of 336 pounds per acre of rock phosphate and 772 pounds per acre of superphosphate. Ammonium phosphate, on the other hand, produced less favorable and even unfavorable results. The value of the increased wood production was considered more than necessary to pay for the fertilizing costs.

One of the earliest experiments on fertilizing slash pine in the United States was reported by Boggess and Stahelin (12) from Alabama. Fertilized and cultivated 8-year-old trees produced one and one-half times the volume of the untreated trees. Each fertilized tree received 0.3 pound of 1-5-4 fertilizer plus a side dressing of 0.1 pound of sodium nitrate for three years after the trees were planted. A third series of plots were intercropped with cotton receiving 325 pounds of 6-8-4 fertilizer per acre in addition to the fertilizer applied to the individual trees. The fertilizer and cultivation also produced a detrimental effect since twice as many treated trees were infected with fusiform rust (Cronartium fusiforme) than unfertilized trees.

The same study was remeasured after the 19th growing season and the results reported by Gilmore and Livingston (27). They found no significant differences in diameter or height growth between treatments, but they did find a significant difference of about 21 percent between the volume of the control plots and the volume of the highest fertilized plots.

Barnes and Ralston (7) reported improved height growth of two slash pine plantations in Florida seven years after application of colloidal phosphate. Trees receiving one-half ton per acre broadcast averaged 26 percent taller than control trees. The same rate of colloidal phosphate disked into the soil increased height by 30 percent and, when applied in four-foot strips and disked, resulted in an increase in height of 48 percent. However, four teaspoonfuls of the material in the planting hole gave no significant increase.

The same plots were remeasured in March, 1960, and the results reported by Pritchett (52). Trees in plots receiving one-half ton of colloidal phosphate per acre, broadcast over the entire surface and disked or applied in alternate four-foot strips and disked, were significantly taller than trees in control plots. The fertilized trees continued to grow at a slightly faster rate than the trees in the control plots although the differences were not as great as previously.

In a 12-year-old open stand of slash pine in Florida,

fertilizer was applied in March, June, and August each year for four years with a total annual rate of 500 pounds per acre of N and varying amounts of P_2O_5, K_2O, and minor elements. Seven years after the first application, fertilizers had increased growth by 37 percent while gum yields rose 23 percent (39).

In Georgia, surface applications of ammonium nitrate in March produced an appreciable increase in stem growth of slash pine during the first growing season after treatment (32). Better growth resulted from 50 pounds per acre than from a 200-pound rate.

In another study in Florida, a response to nitrogen, phosphorus and calcium from fertilizing slash pine at the time of planting on a poorly-drained "flatwoods" soil in the Leon series was notable a year later. On the well- to excessively-drained Lakeland series, nitrogen and potash burned the seedlings but a response to phosphorus was apparent. The equivalent of 100 pounds per acre of N-P-K was applied in a six-inch band around the seedling, six inches from its base. No response to minor elements, including Mn, Zn, Cu, Mo, B, and Fe, was evident a year after treatment (68).

Other research on fertilizing a young slash pine plantation in South Georgia has shown a highly significant response in height growth a year after application. Trees in unfertilized check plots averaged 22.5 inches while fertilized trees exceeded 30 inches for the high N-P-K

application. Fifty pounds per acre of P_2O_5 applied in two-foot bands around the young trees gave the greatest single response. Nitrogen, when used alone, gave highly significant depressing effects (68).

In a similar experiment in South Georgia, a nine-year-old slash pine plantation was treated with broadcast applications of 600 pounds per acre of ammonium nitrate (200 pounds per acre N) and 500 pounds per acre of 20 percent superphosphate (100 pounds per acre P_2O_5). After one year, diameter growth on the nitrogen-treated plots was better than on the check and phosphorus-treated plots and the second year showed a highly significant difference in favor of the nitrogen treatment. Height growth differences, however, were not significant (71).

Pritchett and Perry (53) have reported that the growth response of slash pine in Florida to phosphorus fertilizers was related to the soil type and the soil phosphorus reserves. They found few increases in growth resulting from nitrogen and potassium fertilizers, due perhaps to the use of improper rates and methods of application. They reported that young trees were "burned" or growth suppressed where the concentration of either N or K_2O was 150 ppm., the equivalent of 300 pounds per acre broadcast. No response was obtained from any minor elements tested, but lime produced better growth in young trees on poorly-drained soils, probably related to increased nitrate production caused by the raise in pH.

Growth measurements taken five years after fertilizer had been applied to a 22-year-old slash pine plantation in Florida showed substantial increases in diameter and height growth that were correlated with fertilizer applications. A 7-7-7 mixture applied at rates of 20 and 40 pounds per tree (broadcast under the crown projection of each tree) caused increases in basal area growth of 27 and 32 percent, respectively, over the control plots. A mixture of 3-18-6 applied at 20 and 40 pounds per tree caused increases of 17 and 27 percent, respectively (40).

Preliminary growth responses to phosphorus, applied as ordinary superphosphate, in three slash pine seed orchards in Florida were reported by Pritchett (52). The fertilizer materials were applied annually in early spring in a three-foot radius around the base of grafted trees one year after being transplanted. Three rates of phosphorus -- 0, 2, and 4 ounces of P_2O_5 per tree -- were applied in combination with nitrogen and potash on Norfolk fine sandy loam with an extractable P_2O_5 content of 5-7 ppm. There was no significant effect of added phosphorus on height growth of these trees from October, 1957, to February, 1960.

In the second seed orchard on Norfolk and Ruston loamy fine sands, with extractable P_2O_5 contents of 1-3 ppm., N, P_2O_5, and K_2O at 0, 2, and 4 ounces per tree were applied annually from 1957. Significant growth responses associated with phosphorus and nitrogen fertilizers resulted two years after treatment. In the third experiment, a significant

increase in height was obtained from the use of three ounces of P_2O_5 per tree over that obtained from the one-ounce application. This was on Lynchburg sandy loam with an original extractable P_2O_5 content of 4-8 ppm.

The response of potassium and nitrogen fertilizer on the same soils was also determined. In the case of potassium, only on the Lynchburg soil, containing 35-40 ppm. K_2O, was growth significantly increased by the addition of three ounces of K_2O per tree. On a Plummer sandy loam, significant growth increases resulted from the application of one ounce of K_2O in combination with 0, 1, and 2 ounces of nitrogen per tree. Again the initial extractable K_2O content was very low, being only 30 ppm. Significant growth responses to additions of nitrogen were obtained on the Norfolk and Ruston loamy fine sand and on Plummer sandy loam. Pritchett also reported reduced survival and growth of young slash pines when fertilized with high rates of N and K_2O.

Other current research in fertilizing slash pine has been reported by Doolittle (21), Johnson (34), Walker (68), Walker and Tisdale (72), and others.

Longleaf Pine (<u>Pinus palustris</u> Mill.)

Some of the earliest work on longleaf pine fertilization was reported by Paul and Marts (48) from Florida. Up to 270 pounds of sodium nitrate and ammonium sulphate per tree, plus 245 pounds of superphosphate and 189 pounds of

potassium sulphate per tree, were applied over a three-year period to trees ranging from 100 to 250 years old and growing on deep sands. Summerwood was increased with nitrate fertilizer, while springwood growth was increased by the complete N-P-K fertilizer treatment. Needles were also longer, darker, and more persistent when trees received a complete fertilizer.

In 1937, Pessin (50) studied the effects of the deficiency of seven essential mineral nutrients on the growth and development of longleaf pine seedlings, using nutrient solutions. The lowest dry weight of seedlings were grown in solutions lacking potassium and iron, but symptoms of nitrogen, phosphorus, and potassium deficiencies were also noted.

As early as 1939, fertilizer was applied to longleaf pine in south Mississippi in an effort to stimulate its early height growth and thereby shorten or avoid the period of extremely slow early growth characteristic of the species under usual field conditions (51). Ammonium sulphate at 400 pounds per acre produced no response other than to decrease survival due to a stimulation of grasses. At that time, it was theorized that longleaf nutrient requirements are low and it can obtain optimum nutrient requirements from the soil without the need for fertilizers.

Derr (20) also found that fertilizers reduced survival of longleaf significantly and failed to improve growth except where competition was most effectively removed. The

6-18-5 fertilizer, at a rate equivalent to about 100 pounds per acre, was poured into the closing slit made with the tree planting bar. There was some evidence of fertilizer injury; however, the detrimental effects of the fertilizer were mostly indirect through the stimulation of competing grasses and weeds.

Other fertilizer studies have shown a response in growth. Longleaf pine seedlings grown in a sandy soil, an eroded soil, and a topsoil responded to a complete N-P-K fertilizer in their first year, but not to the addition of nitrogen alone (2). In southwestern Louisiana, Bateman and Roark (8, 9, 10) obtained increased longleaf growth with 60 pounds per acre N, 60 pounds per acre P_2O_5, and 60 pounds per acre K_2O, but this increase was later masked.

Shortleaf Pine (Pinus echinata Mill.)

Most of the research on fertilizing shortleaf pine was done in attempts to correct littleleaf disease prevalent in this species on many soils. According to Roth, *et al.* (56), shortleaf pines with littleleaf disease show a marked deficiency of nitrogen and calcium in the foliage and a somewhat lower Mn, Al, and Cu content than healthy trees. In extensive fertilizer experiments, only soil amendments with large amounts of inorganic N were effective against the disease. Nitrate or ammoniacal N, at rates exceeding 200 pounds of available N per acre, prevented the onset of littleleaf to a notable degree and either checked the

disease or induced noticeable improvement in diseased trees. Salts or combinations of salts of 14 other elements had no beneficial effect when applied to the soil or as foliage sprays, or both. The disease seems to be associated with a failure to assimilate an adequate amount of nitrogen from the soil, for there was no nitrogen deficiency in many of the soils involved. It is highly probable that the failure to absorb enough nitrogen is due to insufficient mycorrhizae and the killing of fine roots by soil fungi.

An appraisal of the effects of the fertilizer treatments on the diameter growth of the apparently healthy trees failed to reveal important wood volume increases in trees under 12 inches in diameter. However, trees fertilized with 3-9-6 at 2,000-pound rates in combination with enough nitrate of soda to bring the available nitrogen up to 220 pounds per acre did grow significantly faster in annual diameter increment than before fertilization (58).

In another study (57), applications of nitrogen and calcium allowed shortleaf pine to overcome littleleaf disease. After a year, the foliage had normal amounts of nitrogen and calcium whereas the needles from the same trees before fertilization were unusually low in these elements. Growth increases in healthy 30-year-old trees receiving nitrogenous fertilizers were also reported.

Boggess and Gilmore (11) obtained a significant increase in diameter growth of shortleaf pine by a March broadcast application of 100 pounds per acre of nitrogen on

a silt loam loess soil of southern Illinois. The addition of 100 pounds per acre of P_2O_5 to the nitrogen treatment produced a smaller increase.

Cummings (18) applied 27 different mixtures of fertilizer supplying ¼, ½, or 3/4 gram each of N, P_2O_5, and K_2O per tree to shortleaf pine in Ohio without marked growth increase through the first two years. He suggested fertilizers with low nitrogen, high phosphorus, and very low potassium for further tests on shortleaf pine.

In a greenhouse study, Hobbs (30) obtained a highly significant reduction in growth of shortleaf seedlings in sand cultures lacking N, P, or K. Distinctive deficiency symptoms, based on three years of observations, were noted. Wilson (79) found that 0.1 ppm. zinc is necessary for normal shortleaf pine growth; seedlings with less zinc had abnormally small needles.

Work with Species Other than Southern Pines

Responses from fertilizer applications to commercially-important tree species in two other regions of the United States are worthy of mention. The first deals with pine and spruce plantations growing on potassium-deficient soils of New York and the second with Douglas-fir in the Pacific Northwest.

Experiments in the application of potash fertilizers to stagnated pine and spruce plantations on coarse sandy

outwash soils in New York were started over 25 years ago by S. O. Heiberg and have continued to the present. A single application of 200 pounds of potash fertilizer per acre produced a very rapid increase in height growth that lasted for many years (73).

Extreme deficiency symptoms developed in stands of eastern white pine (Pinus strobus L.), red pine (P. resinosa Ait.), white spruce (Picea glauca [Moench] Voss), and Norway spruce (P. abies [L.] Karst.) only 5 to 6 years after planting on soils cultivated for more than a century before 1927. In the first trials, soil mulches of logging debris and forest humus and applications of a complete commercial fertilizer produced a strong growth response. Applications of CaO, $NaNO_3$, $(NH_4)_2SO_4$, $Ca_3(PO_4)_2$, and KCl in 1943 and 1946 on red pine plots resulted in a strong growth response to the KCl only. Subsequent fertilization of deficient eastern white pine, white spruce, and Norway spruce resulted in a pronounced response of all to potash fertilizers even at the end of one growing season. Two-hundred pounds per acre of KCl applied in 1943 increased annual height growth over control plots by from 46 to 104 percent. The effect of this potash application was still continuing in 1949 growth. Chemical analyses of needle tissue revealed extremely low potassium contents where deficiency symptoms existed (28, 29).

Recently, fertilization of Douglas-fir in the Pacific

Northwest has produced some outstanding responses on soils of generally low fertility. Gessel and Walker (26) reported very marked response in height growth of 15- to 20-year-old natural Douglas-fir stands to nitrogen fertilization on poor sites in western Washington. Larger, more vigorous trees responded more than smaller trees. In a later report (25), the growth response of a 30-year-old Douglas-fir stand was measured in terms of diameter increment. Nitrogen was applied initially in 1950 at the rate of 100 pounds per acre; subsequent yearly additions brought the five-year total to 350 pounds. Initially 150 pounds of P_2O_5, 30 pounds of K_2O, and 50 pounds of lime per acre were also applied. The fertilizer treatment resulted in accelerated diameter growth, particularly in the larger diameter classes, and in accelerated volume growth on both a tree and a stand basis.

General Observations from Review of Literature

From the preceding review of the literature dealing with the fertilization of southern pines, several important features should be noted.

(1) With the exception of a few nutritional studies in greenhouses, most of the research on the use of fertilizers has been accomplished since 1950.

(2) Much of the research was more of an "applied" than a "basic" nature, since it was concerned primarily with

growth responses and neglected the more basic matters such as nutrient uptake. It is encouraging to note, however, that about 45 percent of the current research being conducted by colleges and universities, at least, is primarily basic in nature (4). The same trend is noticeable in reviewing the projects listed by Walker and Tisdale (72). Private forest industries, on the other hand, are concentrating on field experiments dealing with growth responses, kinds and rates of fertilizer, and other more practical aspects (34).

(3) Relatively little of the research reported in the literature included both foliar analysis and soil analysis, although most included one or the other. Again, the trend appears to be in the right direction. Applequist (4) has reported that all current studies engaged in by colleges and universities include foliar analysis as an essential part of the research although only about 75 percent include both foliar and soil analysis. The diversity of the soils in forest regions would seem to command more attention to soil chemistry in order to fully gauge the worth of fertilizers in the production of forests.

(4) Minimum and optimum nutritional requirements, deficiency symptoms, and nutrient absorption by the trees have been explored only sketchily. These probably remain as the major points in which basic research should be accomplished.

EXPERIMENTAL MATERIALS AND METHODS

Design of Experiment

In this study, a 3x3x3 factorial experiment in a randomized block design was used in order to test the main and interaction effects of nitrogen, phosphorus, and potassium fertilizers, each applied at rates equivalent to 0, 100, and 200 pounds per acre of available N, P_2O_5, and K_2O. The 27 fertilizer combinations used are given in Table 1. Granular urea containing 45 percent available N was used as the nitrogen source, while the P_2O_5 was supplied by superphosphate containing 54.9 percent total and 53.4 percent available P_2O_5. Standard muriate of potash containing 60 percent K_2O was the potassium source.

At each of the three locations described below, the fertilizer treatments were applied at random to individual plots in each of three blocks or replications. In so far as possible, the blocks at each location were chosen so that variations in slope within each block were minimized. Each block consisted of 27 one-tenth-acre square plots, or a total of 8.1 acres in each plantation.

One-year-old nursery-grown loblolly pine seedlings supplied by the Louisiana Forestry Commission from the Columbia Nursery were planted in each plot on a 6' x 6' spacing. This spacing gave a total of 121 trees per plot

Table 1.--Fertilizer treatments.

Treatment Number	Nutrients,* pounds per acre		
	N	P_2O_5	K_2O
1	0	0	0
2	0	0	100
3	0	0	200
4	0	100	0
5	0	100	100
6	0	100	200
7	0	200	0
8	0	200	100
9	0	200	200
10	100	0	0
11	100	0	100
12	100	0	200
13	100	100	0
14	100	100	100
15	100	100	200
16	100	200	0
17	100	200	100
18	100	200	200
19	200	0	0
20	200	0	100
21	200	0	200
22	200	100	0
23	200	100	100
24	200	100	200
25	200	200	0
26	200	200	100
27	200	200	200

*Fertilizer materials used were granular urea (45 percent N), superphosphate (53.4 percent available P_2O_5), and muriate of potash (60 percent available K_2O).

with the central 81 trees constituting the measurement plot.

The experimental layout at each of the three locations is shown in Figures 1, 2, and 3. The numbers shown in each plot refer to the treatment numbers given in Table 1.

Plantation Establishment, Fertilizer Applications, and Cultural Treatments

In order to test the effects of the fertilizers under varied climatic and soil conditions, three locations were arbitrarily selected for establishing the plantations. One plantation was established on the North Louisiana Hill Farm Experiment Station near Homer in Claiborne Parish in the northern part of the state (approximately 32°45'N latitude, 93°04'W longitude). The second plantation was located in central Louisiana on the Johnson Tract of the Kisatchie National Forest in Rapides Parish approximately 15 miles southwest of Alexandria (approximately 31°09'N latitude, 92°40'W longitude). The third plantation was established in southeastern Louisiana on the Lee Memorial Forest in Washington Parish, 10 miles east of Franklinton (approximately 30°52'N latitude, 89°59'W longitude).

The soil types used include Shubuta sandy loam to loamy sand at Homer; a complex of Bowie fine sandy loam, Ruston loam, and Beauregard loam at Alexandria with the Bowie series predominating; and Ruston sandy loam to loamy sand in the Washington Parish plantation. Complete descriptions of the typical profile of each of these soils and their

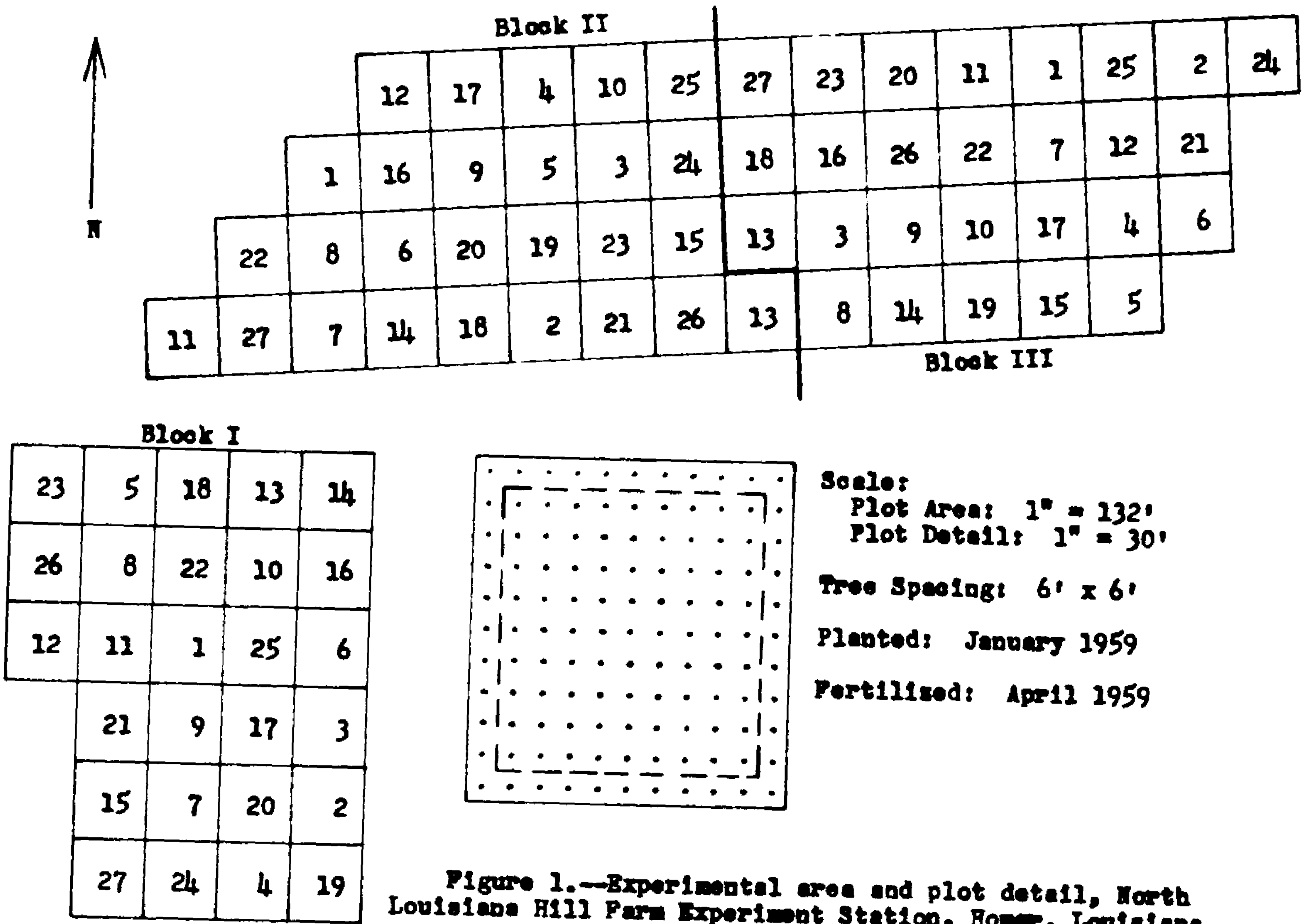
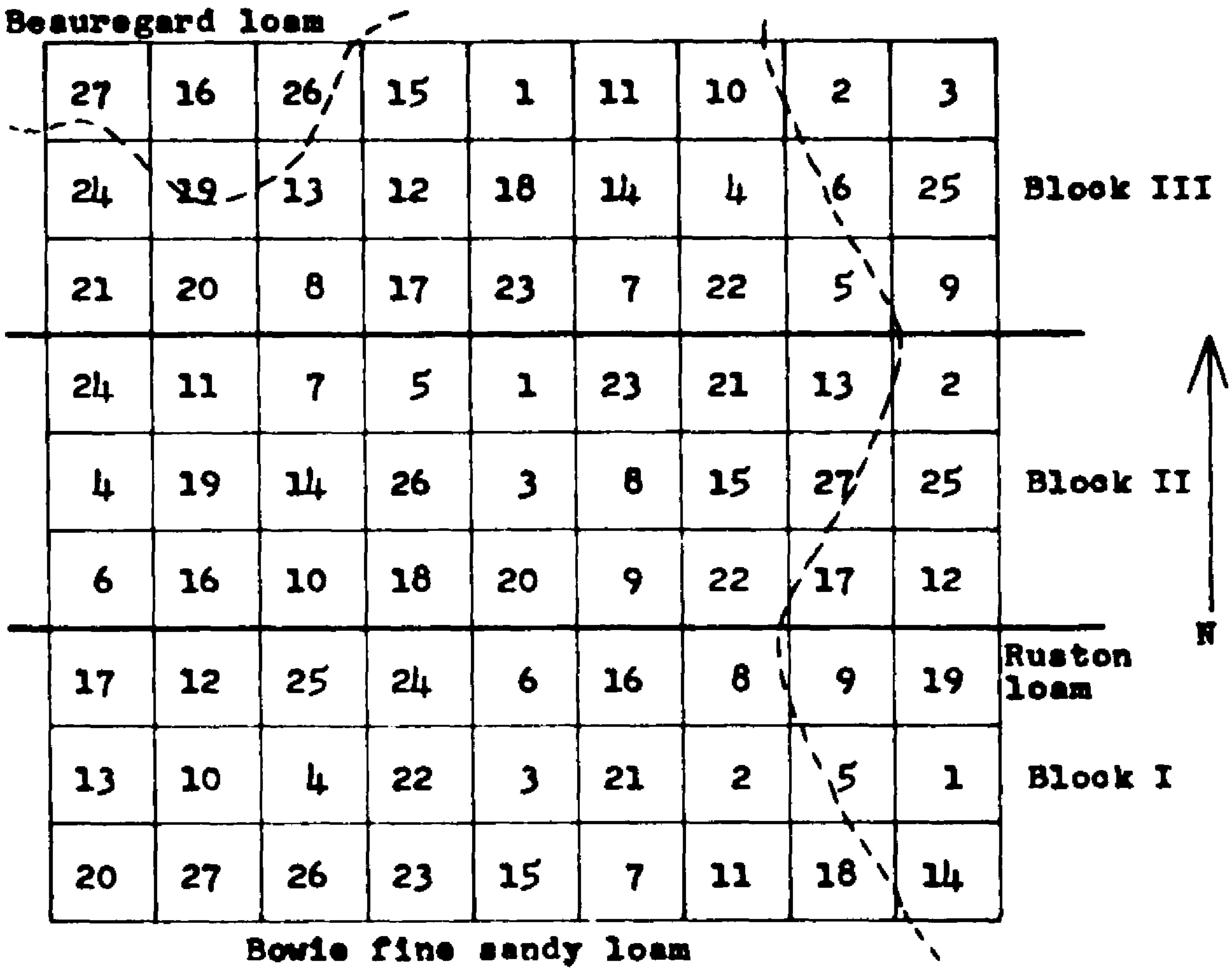


Figure 1.--Experimental area and plot detail, North Louisiana Hill Farm Experiment Station, Homer, Louisiana.



Scale: 1" = 132' Planted: January 1959

Tree Spacing: 6' x 6' Fertilized: May 1959

Figure 2.--Experimental area and plot layout, Johnson Tract, Kisatchie National Forest, Alexandria, Louisiana.

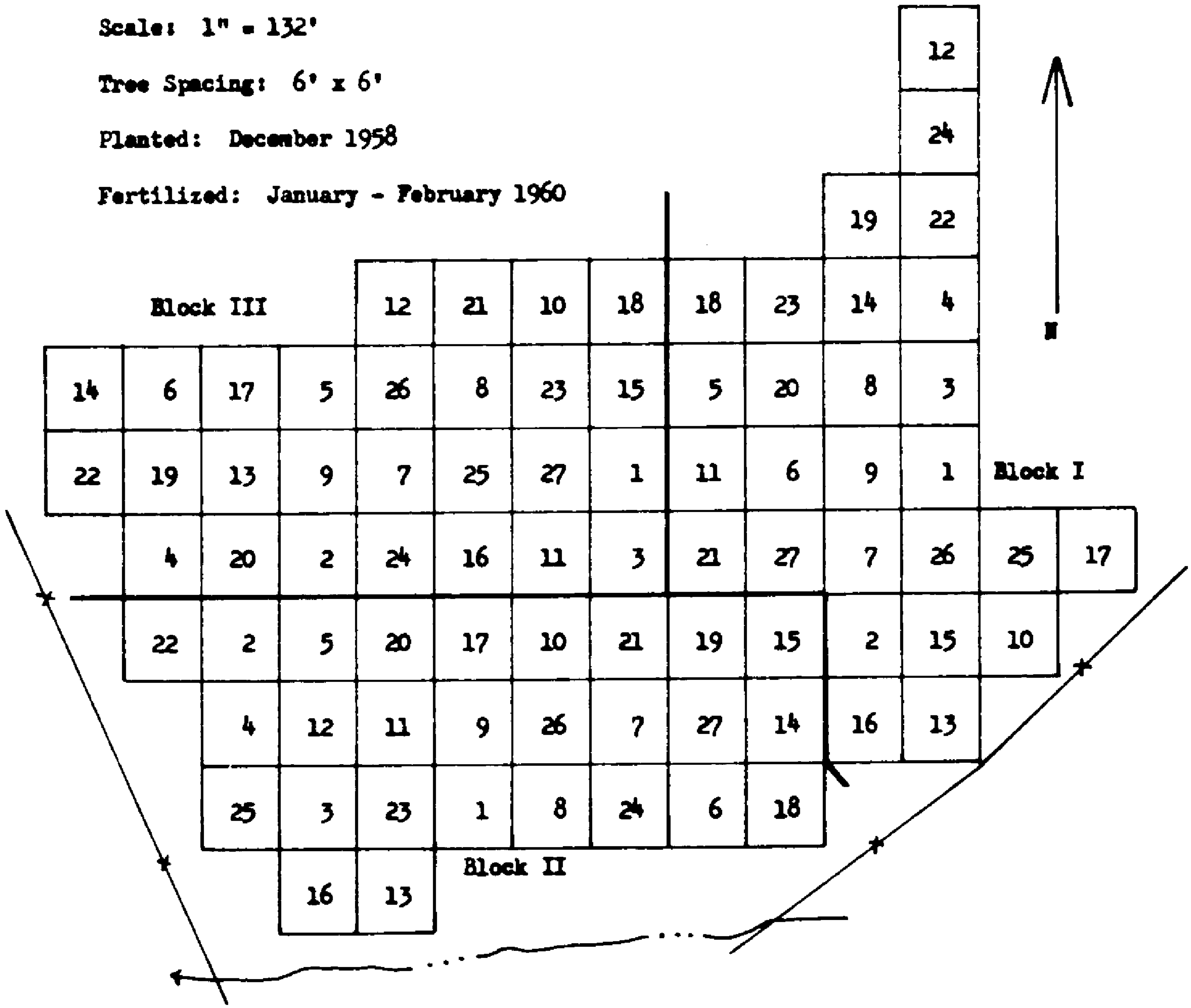


Figure 3.—Experimental area and plot layout, Lee Memorial Forest, Washington Parish, Louisiana.

chemical composition are given in Appendix A and B.

The history of the Homer site is not definitely known, but it is believed to have been in cultivation possibly as late as 1947. At any rate, it was abandoned and overgrown with briars and broomsedge (*Andropogon virginicus* L.) in 1949. The site was prepared in 1958 by clearing off all woody vegetation, including some scattered loblolly pine which had become established since the cessation of row-cropping. Clearing was followed by disking to eliminate all vegetation and prepare a clean surface prior to planting. The loblolly pine seedlings were hand planted with planting bars in January 1959. Fertilizers were applied to individual trees in April.

A special "furrow-maker" was devised by personnel at the North Louisiana Hill Farm Experiment Station for use in applying fertilizer around each seedling. This device is shown in Figure 4. Briefly, the "furrow-maker" consisted of two concentric rings mounted on the shaft of a post-hole digger hydraulically operated and power-driven from a farm tractor. The hydraulic lift lever and clutch and brake pedals on the tractor were modified to permit operation by a two-man crew. The inner ring was six inches from the shaft and was fitted with three plows while the outer ring was 12 inches from the shaft and had six plows. As the shaft revolved, the plows dug two circular trenches or furrows about four inches deep around the newly-planted trees. The machine in operation and the resulting furrows are shown in

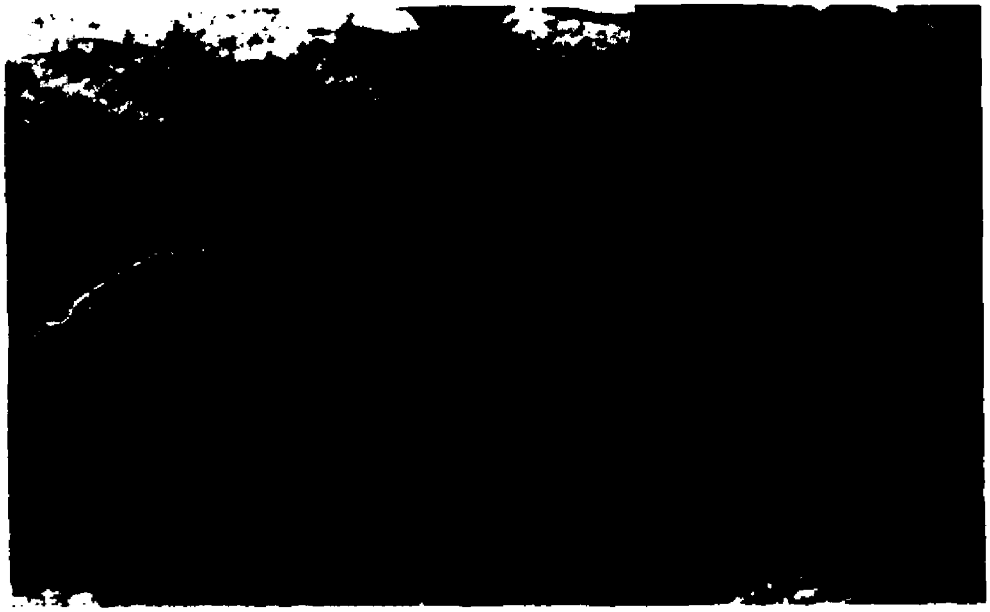


Figure 4.--The "furrow-maker". The upper photograph shows the two concentric rings with the attached small plows which dug the furrows. The lower photograph shows the two-man crew required to operate the tractor and "furrow-maker".

Figure 5. The phosphate fertilizer at the required rate per tree was applied by hand in the inner furrow, six inches from the base of the tree, and the urea and potash fertilizers were applied in the outer 12-inch furrow. The last step in the procedure was covering the fertilizer with loose soil with a hoe.

Cultural treatments in the Homer plantation during the 1959 and 1960 growing seasons included periodic shallow diskings to eliminate weeds, hand hoeing around the base of the trees where disking could not be done, and periodic applications of a 0.125 percent DDT solution to control the Nantucket pine moth (Rhyacionia frustrana [Comst.]), commonly called "tip moth". Since there may be as many as four to six generations of tip moth annually in the South (81), it was necessary to spray each month during the growing season and more frequently during rainy periods. These frequent sprayings gave complete control both years since there was no noticeable tip moth damage at any time.

To prevent excessive soil erosion during the 1959-60 fall and winter, Italian ryegrass (Lolium multiflorum Lam.) was seeded in three-foot strips between the rows perpendicular to the prevailing slopes in September of 1959. The grass was mowed periodically to minimize its usage of the fertilizers applied to the trees. Figure 6 is a general view of a part of the plantation showing the ryegrass strips. As soon as tree growth began in the spring of 1960, the ryegrass was sprayed with a chemical weedkiller and the sod

Figure 5.--The "furrow-maker" in operation (top) and a close-up of the resulting furrows around the pine seedling (bottom).

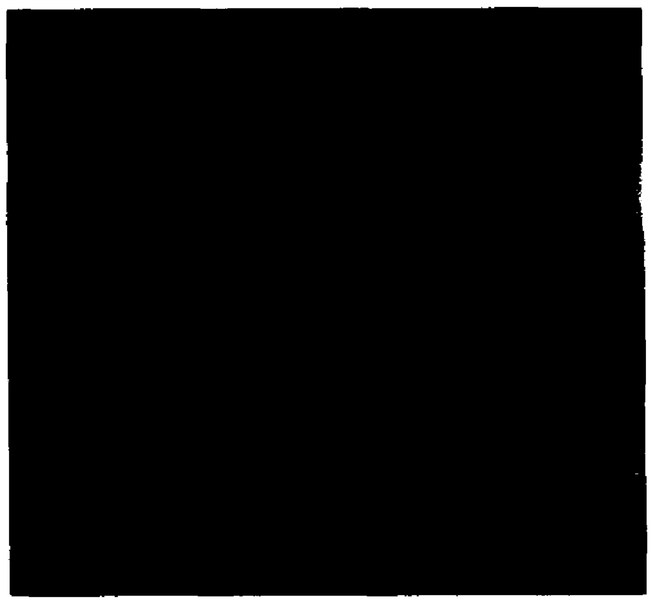


Figure 6.--A general view of the Homer plantation showing the ryegrass strips planted for erosion control. Picture was taken in October, 1959.

left to afford continued protection against soil erosion.

The plantation at Alexandria was established on an upland site which was originally stocked with virgin longleaf pine. In the mid-1930's, the area was planted to slash pine which was clearcut in 1951 following a severe ice storm. The over-all area of about 200 acres was burned and direct seeded with longleaf in November 1951 and used for research purposes by the Alexandria Research Center of the Southern Forest Experiment Station. In the fall of 1958, an area suitable for this fertilizer study was located and cleared by bulldozer. The brush and debris were piled and burned. A number of old longleaf stumps could not be pushed and had to be left on the area.

Woody vegetation growing on the Alexandria area consisted of a few scattered slash and longleaf pines and clumps of blackjack oak (*Quercus marilandica* Muenchh.), post oak (*Q. stellata* Wangenh.), sweetgum (*Liquidambar styraciflua* L.), and waxmyrtle (*Myrica* spp.). Pinehills bluestem (*Andropogon divergens* [Hack.] Anderss. ex Hitchc.) was the predominant grass. Also included in the herbaceous vegetation were big bluestem (*A. gerardi* Vitman), slender bluestem (*A. tener* [Nees] Kunth.), Indiangrass (*Sorghastrum nutans* [L.] Nash), three-awn (*Aristida* spp.), and various forbs, the most important of which was swamp sunflower (*Helianthus angustifolius* L.). Since the area had not been grazed for several years, a heavy rough had accumulated. An attempt to burn the rough failed due to unfavorable weather conditions.

The 8.1-acre area was disked once in November and cross-disked in December of 1958. Because of the heavy rough, disking the area did not result in as good a seedbed as was desired. A general view of the area is shown in Figure 7.

The loblolly pine seedlings were planted by hand with student labor in January 1959. Survival was not as good as desired in several plots due to improper planting by some of the students. It was also decreased by the wet soil conditions and rough condition of the surface at planting time.

The fertilizers were applied to individual trees at the equivalent per acre rates in May 1959 by use of student labor. A series of holes was made with a tree-planting bar or dibble around each tree seedling. The superphosphate was applied in four holes more-or-less equally spaced in a circle six inches from the tree while the urea nitrogen and muriate of potash were poured into six holes in a circle 12 inches from the tree. At the high rates of application, the fertilizers often filled the holes from their eight inches of depth up to the soil surface. An attempt was made to distribute the fertilizer as uniformly as possible between the holes. Figure 8 illustrates this method of application.

During the 1959 growing season, an attempt was made to control weed growth by hand spraying with Varsol, a petroleum derivative similar to kerosene. This effectively controlled grasses but not the broad-leaf weeds; consequently this method of control was abandoned. In the spring

Figure 7.--General view of the Alexandria plantation three months after the trees were planted. The stumps are from virgin longleaf pine logged during the 1920's. Brush sprouts and weeds are beginning to grow even though the area was cleared and double-disked prior to planting.

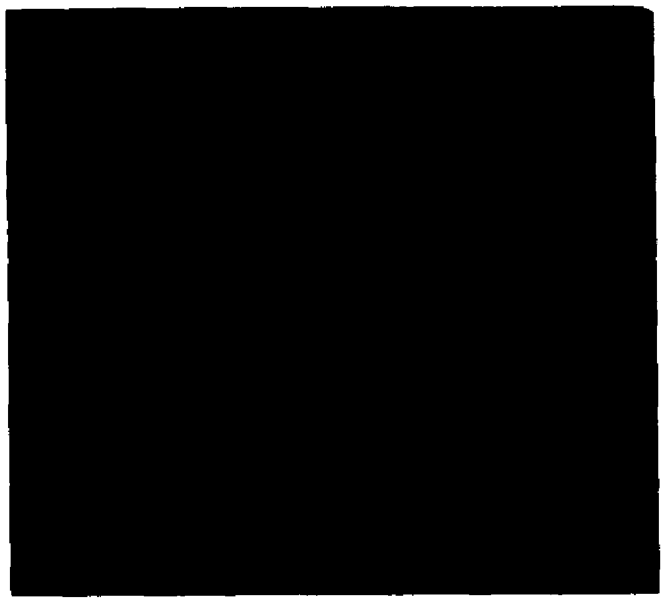


Figure 8.--Fertilizer application holes made with a tree-planting bar. Two of the inner holes in which superphosphate was applied are at the right front and left rear of the tree. The four holes beginning at the bottom of the picture and proceeding around the tree to the left are 12 inches from the tree. Urea nitrogen and muriate of potash were applied in these holes.

of 1960, a small amount of Amizine[1] was secured for testing on weed control. This material was effective in killing some weeds, but ineffective on others. Due to the high cost of a sufficient quantity to treat the plantation and the labor involved in its application by hand sprayers, this method of control was also abandoned. Consequently weed growth was not eliminated from this plantation. Brush sprouts, however, were effectively controlled by periodic spraying with 2,4,5-T hormone herbicide.

The plantation was sprayed several times in 1959 and 1960 with DDT solutions for tip moth control. However, the applications were not frequent enough nor timed properly to give any effective degree of control; so the tip moth infestation and resulting damages were heavy, particularly during 1960.

The Washington Parish plantation was established on a terraced field which had been in cultivation for at least 30 years. Hay was the last crop grown on the field in 1957. In the fall of 1958, the field was disked twice to destroy the annual weeds and grasses. The loblolly pine seedlings were planted by hand in December 1958. Due to the lack of labor, fertilizers were not applied to this plantation the following spring as was done in the other two plantations. Instead, fertilizer applications were made in late January

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[1]Trade name for a mixture of 15% amitrol (3-amino 1,2,4-triazole) and 45% simazin (2-chloro-4,6-bis-ethylamino-s-triazine) produced by Amchem Products, Inc., Ambler, Pa.

and early February of 1960. Student labor was used and the same procedure was followed as outlined for the Alexandria location.

During the 1959 and 1960 growing seasons, unsuccessful attempts were made to control weed growth by mowing, hoeing, and hand spraying with Varsol and Amizine. However, the cost of these treatments and the lack of sufficient quantities of chemicals and equipment suitable for their application on such a large area were prohibitive. Briars and root sprouts of sassafras (*Sassafras albidum* [Nutt.] Nees), on the other hand, were controlled by periodic applications of 2,4,5-T with hand sprayers.

Periodic applications of DDT solution with hand sprayers were made to minimize tip moth infestations. The same difficulties were experienced here as on the Alexandria location; as a result tip moth damage was heavy, especially during the latter part of 1960.

Collection of Field Data

Growth data was collected indirectly through height measurements of the 81 measurement trees in each plot. The trees were measured before fertilization and at the end of each growing season, usually in November and December. Height measurements and supplemental observations were recorded on field data sheets as illustrated in Figure 9.

In order to catalogue changes in the nutrient level of

School of Forestry
Louisiana Agricultural Experiment Station

L.S. No. 989: FERTILIZATION OF PLANTED LOBLOLLY PINE

Height of Measurement Trees

Block: I Crew: Cooley & Linnartz

Plot No.: 22 Date: 11/26/60

North ↑ (South at bottom)

Row 1	Row 2	Row 3	Row 4	Row 5	Row 6	Row 7	Row 8	Row 9	Row 10	Row 11
B	O	R	D	E	R		R	O	W	W
W	6.4	T 8.5	4.7	4.8	6.5	5.3	5.8	T 7.1	T 6.2	O
O	X	X	5.7	T 4.6	6.3	5.8	T 6.1	T 6.1	T 5.8	R
R	6.2	6.5	5.4	5.9	X	T 5.3	6.4	T 5.6	4.3	
	5.0	Cron. 3.7	T 5.8	4.1	4.0	5.6	T 4.7	3.6	4.9	R
R	X	6.3	4.0	T 5.4	X	3.0	3.3	X	2.7	E
E	6.9	6.5	T 7.1	4.6	T 4.6	X	T 6.3	5.4	4.5	D
D	T 5.7	X	X	T 5.5	5.0	3.4	5.6	4.6	X	R
R	X	6.2	3.3	6.5	X	5.6	T 7.5	4.5	3.7	O
O	6.5	5.7	4.4	2.8	X	4.9	3.5	T 6.4	T 6.9	B
B	B	O	R	D	E	R		R	O	W

West --→ East

Take all measurements (1) at the end of the growing season, (2) from ground line to the tip of the bud, and (3) to the nearest tenth of a foot.

X = Missing or Dead. T = Tipmoth.

Cron. = Cronartium.

Figure 9.—Sample field data sheet.

the soil resulting from the application of fertilizers and subsequent usage by the trees, soil samples for chemical analysis were collected systematically from each plot prior to the application of fertilizers and at the end of each growing season following fertilization. Both the A and B horizons were sampled with a soil sampling tube at alternate trees in alternate rows in each plot and the resulting composite samples collected in pint ice cream cartons properly identified with the block and plot number and horizon. The samples were allowed to air-dry, ground to pass through a 2-mm. sieve, and stored for later analysis.

Needle samples were collected for chemical analysis at the end of the 1959 and 1960 growing seasons. Alternate trees were selected for needle collection so that about one-half of the trees in each plot were sampled. Needles produced during the growing season were pulled by hand from all positions in the tree both vertically and horizontally. The needles were collected in large kraft paper bags and dried at 115-120°F in a drying room within a few days after collection. After drying, the needles were ground in a Wiley mill and a representative sample of the ground material from each plot was stored in a small capped glass bottle for future analysis.

Chemical Analyses of Soil and Tissue Samples

The collected soil samples were analyzed by the Soil

Testing Laboratory for available phosphorus, potassium, calcium, magnesium, and sodium. Phosphorus was extracted with Bray's solution of 0.1 normal HCl and 0.03 normal NH_4F (14) at a ratio of 20 parts of extractant to one part of soil. Past results from this method for extracting available phosphorus have correlated very well with plant responses to phosphorus fertilization in field experiments on the relatively infertile soils of the Coastal Plain of Louisiana. The bases were extracted with 0.1 normal HCl (33) at a ratio of 20 parts of acid to one part of soil.

The extracted phosphorus and magnesium were determined colorimetrically on a Bausch and Lomb Spec 20 spectrophotometer. Potassium, calcium and sodium were determined on a Perkin-Elmer flame spectrophotometer.

Soil reaction was also determined by the Soil Testing Laboratory using a Coleman Model H-2 pH meter with a 1:1 soil-water suspension (49).

Exchangeable hydrogen was determined on samples collected before fertilization in order to calculate the percent base saturation and the base exchange capacity by summation. The base exchange capacity is often estimated by the sum of the exchangeable hydrogen, calcium, magnesium, potassium, and sodium and is expressed as milliequivalents per 100 grams of soil (33). Base saturation is calculated from the equation:

$$\% \text{ Base Saturation} = \frac{\text{Total Exch. Metallic Cations}}{\text{Base Exchange Capacity}} \times 100.$$

According to Parker (46), all exchangeable H^+ can be

replaced by Ba^{++} of a neutral solution of barium acetate. In this study, a modified barium acetate method was used for determining exchangeable hydrogen. A 15-gram sample of soil was leached with 0.5 normal barium acetate, adjusted to pH 7.0 with normal barium hydroxide, and the leachate was titrated with 0.1 normal sodium hydroxide.

The organic matter content of the pre-fertilization samples was determined by the gravimetric dry combustion method (5). The percent of organic matter was computed from the weight of CO_2 absorbed by Nesbit ascarite absorption bulbs. The computation was made on the IBM-650 computer by use of a program written by Dr. W. H. Patrick, Jr.

No attempt was made to determine available nitrogen in the soil samples, since Allison (3) and numerous others have pointed out the difficulties in attempting to account for all soil nitrogen gains and losses. The amount of symbiotic and non-symbiotic nitrogen fixed is not known, neither is the magnitude of volatilization or leaching losses known. Furthermore, the amount of nitrogen which becomes available from the decomposition of organic matter and the amount of applied nitrogen assimilated by decomposition microorganisms is extremely variable. The total nitrogen content of the soil organic matter could have been estimated from the organic matter content.

The total nitrogen content of the needle samples was determined by the Louisiana State University Feed and Fertilizer Laboratory by use of the standard Kjeldahl method.

Through sampling only needles produced during the current growing season for this analysis, the nitrogen uptake by the trees was related to the nitrogen fertilization levels.

The needle samples were analyzed for phosphorus, potassium, calcium, and magnesium in the North Louisiana Hill Farm Experiment Station laboratory using procedures established by Russell (59). Sodium was also determined on the 1959 tissue samples; however, the results were highly erratic, ranging from 0 to 7,840 ppm. Therefore, sodium was not included in the analyses of the 1960 samples.

Statistical Analysis of Data

A statistical analysis of the effect of fertilizer treatments on tree growth was accomplished through the usual analysis of variance for a factorial experiment in a randomized block design (61, 15). The analysis was computed by the use of the ANOV II, 6.0.012 L, program for the IBM-650 computer in the L.S.U. Computer Research Center. In order to utilize this program, it was necessary to code the height measurements recorded on the field data sheets for key-punching on IBM cards, one card per tree. Each card included the location code, block number, the level of each fertilizer element, the three height measurements (initial height, height after the 1959 growing season, and height after the 1960 growing season), tree number, and plot identification. Only the trees which survived the full two

years were included in the analysis.

A short routine was included in the ANOV II program deck to convert individual tree heights to the annual and biennial growth for each tree. Once the average growth per plot was secured in this manner, the plot means for growth became the measurement of fertilizer effect tested in the analysis of variance.

In order to test the different rates of the fertilizer elements shown by the analysis of variance to be significantly related to growth, orthogonal comparisons among the levels of fertilization were made (61).

Analysis of variance was also used to test the effect of fertilizer treatments on survival, on percentage of trees whose growing tips were damaged by tip moth in the Alexandria and Washington Parish plantations, and on the incidence of fusiform rust in the Washington Parish plantation only.

RESULTS AND DISCUSSION

Chemical Analyses of Soils

Results of the chemical analyses of the soil samples collected before fertilizers were applied are given in Tables 2, 3, and 4. Included in these tables are the chemical content of both the A and B horizons for every plot at each location.

The Shubuta soils in the Homer plantation were uniformly low in all elements (Table 2). The A horizon ranged from 3 to 8 ppm. P, 20 to 53 ppm. K, 86 to 238 ppm. Ca, and 13 to 97 ppm. Mg. The topsoil averaged 0.6 percent organic matter and the pH ranged from 5.1 to 6.1. The exchange capacity was also very low, due principally to the high sand and low organic matter contents. The B horizon generally was higher in exchange capacity and bases, but lower in P, organic matter, and pH. The base saturation ranged from approximately 47 to 81 percent in the topsoil and from 37 to 87 percent in the subsoil.

The topsoils from the Alexandria location were also very low in available nutrients, particularly P (Table 3). Due to their loamy texture and higher organic matter content, however, these soils were generally higher in K, Ca, Mg, and exchange capacity than the topsoil in the Homer plantation. The organic matter content ranged from 1.5 to

Table 2.--Chemical characteristics of soil at Homer location before fertilization.

Plot No.*		Available (ppm.) K	Ca	Mg	Na	P	Exch. Cap., me./100 g.	% Base Sat.	pH	Organic Matter (%)
I- 1	A	39	130	25	43	7	2.130	53.8	6.0	.506
	B	59	367	203	39	2	5.818	66.1	5.7	.459
I- 2	A	50	173	49	39	4	2.819	55.7	5.9	.732
	B	76	324	328	39	2	8.592	54.9	5.1	.455
I- 3	A	41	194	203	39	4	4.185	70.2	5.7	.668
	B	66	302	320	39	2	8.193	55.1	5.2	.458
I- 4	A	39	151	60	35	6	2.558	58.9	5.9	.573
	B	74	389	313	73	2	7.949	63.7	5.2	.419
I- 5	A	36	108	49	35	5	1.980	60.2	5.9	.505
	B	65	799	188	43	1	7.952	74.4	5.5	.369
I- 6	A	50	151	38	48	4	2.328	60.5	5.8	.581
	B	88	432	313	39	2	8.776	58.8	5.1	.522
I- 7	A	44	173	85	35	6	2.954	62.2	6.0	.727
	B	74	475	328	48	2	9.447	58.3	5.2	.629
I- 8	A	38	151	25	35	6	2.131	56.9	6.0	.510
	B	71	410	210	43	2	6.927	60.2	5.2	.344
I- 9	A	41	151	25	35	6	2.336	52.2	6.1	.563
	B	85	540	277	43	2	7.777	69.6	5.7	.609
I-10	A	41	151	38	112	4	2.715	61.3	6.1	.578
	B	77	475	238	48	2	7.653	62.3	5.4	.482
I-11	A	38	130	13	35	5	1.926	52.3	5.9	.579
	B	76	454	228	43	2	6.588	69.1	5.5	.348
I-12	A	38	151	13	30	6	2.206	49.4	6.1	.600
	B	77	475	165	43	2	5.973	69.2	5.7	.389
I-13	A	42	130	49	35	4	2.237	58.9	5.9	.434
	B	77	432	238	43	2	6.694	67.6	5.5	.354
I-14	A	39	130	13	39	3	2.144	47.9	6.1	.574
	B	101	583	332	43	2	9.017	68.0	5.5	.502

*Roman numeral = block; arabic number = fertilizer treatment; A = A horizon (topsoil); B = B horizon (subsoil).

Table 2.--(Continued)

Plot No.		Available (ppm.)					Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
		K	Ca	Mg	Na	P				
I-15	A	42	130	49	35	5	2.697	48.9	5.9	.448
	B	89	497	313	43	1	8.266	66.6	5.4	.520
I-16	A	53	238	25	108	5	2.661	75.3	6.0	.598
	B	97	562	350	52	1	9.223	67.2	5.5	.472
I-17	A	35	130	38	35	6	2.457	49.2	6.1	.643
	B	89	389	396	48	2	8.703	65.3	5.6	.519
I-18	A	35	130	55	35	6	2.138	63.1	5.9	.446
	B	103	475	245	48	2	7.320	66.8	5.4	.361
I-19	A	45	151	49	35	5	2.678	53.4	6.0	.689
	B	100	324	380	39	2	8.496	61.4	5.4	.475
I-20	A	53	194	97	35	6	3.379	61.1	5.7	.757
	B	83	194	343	52	2	8.995	47.4	5.3	.489
I-21	A	38	130	38	35	5	2.135	57.0	6.1	.464
	B	76	281	238	43	2	5.346	70.5	5.5	.377
I-22	A	39	173	38	35	6	2.485	57.7	6.0	.635
	B	79	497	228	52	1	6.521	73.8	5.5	.401
I-23	A	35	151	25	35	5	2.190	55.0	5.8	.553
	B	73	389	155	43	2	4.793	75.5	5.5	.311
I-24	A	41	130	13	35	7	2.066	49.1	5.8	.616
	B	76	410	305	43	2	7.338	67.8	5.3	.504
I-25	A	41	130	13	35	6	2.066	49.1	6.1	.723
	B	94	389	368	43	1	8.001	68.0	5.4	.615
I-26	A	36	130	13	39	6	2.005	50.9	5.9	.536
	B	71	454	221	43	2	6.188	72.4	5.5	.420
I-27	A	32	151	13	39	5	2.100	53.1	5.7	.477
	B	79	302	285	48	2	6.464	66.5	5.3	.418
II- 1	A	45	173	38	43	5	2.535	58.5	5.9	.688
	B	45	475	313	43	1	6.073	87.0	5.2	.575
II- 2	A	33	151	71	35	4	2.832	55.9	5.4	.573
	B	79	173	285	43	2	8.489	42.8	4.8	.436

Table 2.--(Continued)

Plot No.		Available (ppm.) K	Ca	Mg	Na	P	Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
II- 3	A	39	130	41	39	5	2.378	53.1	5.6	.707
	B	74	302	309	43	2	8.139	54.8	4.8	.558
II- 4	A	44	130	40	39	6	2.251	56.2	5.6	.766
	B	100	389	380	39	1	10.791	51.3	4.7	.684
II- 5	A	45	151	40	35	5	2.603	52.1	5.5	.712
	B	65	173	270	39	2	9.593	37.0	5.0	.453
II- 6	A	45	194	55	35	5	2.483	68.3	6.0	.772
	B	83	432	354	43	1	9.187	60.0	5.1	.538
II- 7	A	41	151	49	39	4	2.160	66.6	5.7	.525
	B	64	324	238	43	2	6.515	60.7	5.0	.426
II- 8	A	44	194	75	39	4	2.732	68.7	5.5	.783
	B	59	346	273	43	2	8.217	52.9	5.0	.434
II- 9	A	39	151	25	43	6	1.907	65.5	5.7	.700
	B	77	389	285	43	2	8.447	55.7	4.9	.500
II-10	A	41	86	49	39	6	1.376	80.9	5.6	.672
	B	94	216	387	43	1	11.103	42.6	4.7	.739
II-11	A	38	130	38	30	6	1.982	60.2	5.9	.702
	B	77	518	270	43	2	7.063	74.0	5.4	.515
II-12	A	36	130	19	30	6	1.884	54.7	5.8	.680
	B	103	626	387	43	1	9.827	69.3	5.1	.666
II-13	A	26	108	32	30	6	1.858	54.0	5.5	.584
	B	54	238	255	48	2	7.142	51.3	4.9	.419
II-14	A	38	173	78	43	5	2.718	66.2	5.7	.660
	B	56	324	290	43	2	7.586	57.6	5.0	.418
II-15	A	23	86	25	39	4	1.458	59.5	5.6	.452
	B	64	173	277	43	2	6.742	52.3	5.0	.345
II-16	A	38	151	49	35	4	2.200	64.2	5.7	.725
	B	91	346	358	39	2	9.319	54.9	4.9	.583
II-17	A	39	130	29	30	5	2.041	55.0	5.7	.723
	B	82	562	358	43	2	8.948	69.2	5.1	.588

Table 2.--(Continued)

Plot No.		Available (ppm.) K	Ca	Mg	Na	P	Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
II-18	A	41	173	85	39	4	2.964	62.3	5.4	.667
	B	64	259	320	48	1	9.720	44.6	4.9	.489
II-19	A	30	108	38	30	4	1.918	55.5	5.7	.526
	B	62	367	299	43	1	7.825	59.7	5.0	.376
II-20	A	36	151	60	39	5	2.699	56.2	5.5	.815
	B	62	194	328	43	2	9.893	40.9	4.8	.494
II-21	A	35	130	49	35	3	2.219	58.6	5.4	.540
	B	57	238	259	43	2	7.687	47.9	4.9	.358
II-22	A	42	173	52	35	4	2.346	66.4	5.6	.602
	B	56	367	245	43	2	7.491	56.2	5.1	.308
II-23	A	36	108	62	39	5	2.304	57.2	5.2	.662
	B	50	151	253	43	2	8.366	38.0	4.8	.444
II-24	A	36	108	19	39	5	2.011	47.7	5.3	.675
	B	73	173	320	43	1	10.407	37.5	4.8	.546
II-25	A	50	130	30	39	6	2.183	54.8	5.5	.777
	B	127	216	320	43	2	9.250	46.0	4.9	.556
II-26	A	26	86	19	39	4	1.744	47.3	5.4	.562
	B	47	173	216	43	3	7.307	40.6	4.8	.382
II-27	A	47	173	80	39	5	2.677	68.1	5.8	.674
	B	68	518	326	43	2	8.228	68.8	5.4	.484
III- 1	A	32	130	51	43	6	2.657	50.6	5.3	.822
	B	56	173	257	48	1	9.533	35.2	4.9	.471
III- 2	A	33	130	15	52	5	2.202	49.3	5.6	.685
	B	60	389	313	52	1	9.661	51.1	5.1	.429
III- 3	A	33	86	50	35	4	2.529	42.9	5.1	.621
	B	69	130	285	43	2	9.496	35.7	5.0	.462
III- 4	A	20	605	13	35	9	3.402	98.1	6.0	.538
	B	82	475	242	43	2	8.335	57.5	5.1	.481
III- 5	A	33	194	49	35	5	2.797	57.7	5.7	.641
	B	60	302	231	43	2	7.979	47.3	5.0	.402

Table 2.--(Continued)

Plot No.		Available (ppm.)					Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
		K	Ca	Mg	Na	P				
III- 6	A	23	216	25	43	6	2.519	60.9	5.9	.648
	B	60	518	257	48	2	8.378	60.8	5.2	.446
III- 7	A	30	238	13	30	6	2.556	58.9	5.9	.568
	B	60	389	238	43	2	8.472	50.4	5.1	.433
III- 8	A	39	130	38	35	5	2.532	48.1	5.7	.711
	B	56	216	285	43	1	9.105	41.6	5.0	.480
III- 9	A	30	108	19	30	4	1.759	51.4	5.9	.499
	B	82	302	313	43	2	7.798	57.9	5.1	.323
III-10	A	26	108	13	30	5	1.699	49.7	5.9	.471
	B	65	346	231	39	2	8.392	47.6	4.9	.413
III-11	A	35	194	49	35	3	2.868	56.5	5.8	.770
	B	52	346	263	43	2	8.510	49.8	5.1	.444
III-12	A	30	108	38	30	4	1.983	53.7	5.9	.507
	B	56	216	210	39	2	7.741	40.6	5.0	.398
III-13	A	26	108	25	35	8	2.018	47.9	5.7	.589
	B	65	281	299	43	2	9.439	45.0	4.8	.428
III-14	A	35	108	25	35	6	2.041	48.5	5.8	.581
	B	69	216	291	39	1	9.302	41.4	5.1	.477
III-15	A	30	108	32	35	4	1.955	53.0	5.8	.493
	B	65	389	270	43	2	7.964	57.1	5.1	.359
III-16	A	48	151	38	35	6	2.595	51.9	6.0	.817
	B	91	454	336	43	2	10.284	53.4	5.0	.416
III-17	A	30	151	32	35	4	2.105	59.4	6.0	.527
	B	56	432	255	39	3	8.473	54.3	5.1	.455
III-18	A	43	108	38	30	7	2.213	49.6	5.7	.696
	B	99	259	372	39	2	11.057	43.6	5.0	.585
III-19	A	26	86	19	35	5	1.595	50.6	5.8	.421
	B	65	367	277	39	2	7.632	58.7	5.2	.305
III-20	A	30	108	13	35	5	1.731	50.7	6.0	.566
	B	83	367	270	39	1	8.014	55.8	5.1	.374

Table 2.--(Continued)

Plot No.		Available (ppm.) K	Ca	Mg	Na	P	Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
III-21	A	30	108	25	35	4	2.093	46.7	5.9	.664
	B	65	324	320	48	2	9.391	49.7	5.1	.449
III-22	A	39	130	25	35	4	2.358	47.1	5.7	.688
	B	65	432	231	39	1	8.362	52.9	5.2	.493
III-23	A	43	130	13	39	7	2.089	49.7	6.0	.739
	B	134	497	343	39	2	8.484	69.0	5.5	.370
III-24	A	30	108	38	35	5	2.268	47.9	5.7	.684
	B	65	324	291	39	2	9.494	46.2	5.1	.587
III-25	A	30	130	25	35	5	2.269	47.9	5.8	.742
	B	65	432	299	39	2	10.047	49.7	5.0	.499
III-26	A	43	173	38	39	7	2.775	52.7	5.8	.815
	B	73	259	270	39	1	9.615	40.6	5.0	.467
III-27	A	52	173	38	35	7	2.649	55.4	5.9	.877
	B	112	324	291	43	3	9.313	48.5	5.1	.557

Table 3.--Chemical characteristics of soils at Alexandria location before fertilization.

Plot No.*		Available (ppm.) K	Ca	Mg	Na	P	Exch. Cap., me./100 g.	% Base Sat.	pH	Organic Matter (%)
I- 1	A	43	216	49	56	6	3.417	53.9	5.6	1.630
	B	39	216	129	26	3	4.601	51.5	4.6	.449
I- 2	A	39	281	49	39	6	5.169	40.3	5.4	2.891
	B	30	194	171	26	1	6.394	40.4	4.8	.696
I- 3	A	39	324	71	39	5	5.503	45.1	5.4	2.965
	B	30	238	165	30	3	5.530	50.1	5.1	.678
I- 4	A	39	173	78	43	5	4.691	38.4	5.2	2.691
	B	22	65	129	30	2	6.117	25.9	4.9	.733
I- 5	A	43	367	71	39	4	5.793	46.7	5.4	3.147
	B	35	259	155	30	1	4.449	63.1	5.3	.550
I- 6	A	30	302	71	35	6	4.958	47.0	5.5	2.392
	B	22	151	155	30	3	5.713	39.1	5.0	.506
I- 7	A	43	259	60	35	6	4.552	45.0	5.4	2.744
	B	30	130	147	30	3	5.825	35.7	4.9	.772
I- 8	A	35	216	38	30	5	3.653	44.3	5.5	2.197
	B	30	173	155	30	1	5.319	44.4	5.1	.617
I- 9	A	39	367	67	35	6	5.009	52.8	5.5	2.394
	B	35	173	155	30	1	5.135	46.3	5.0	.571
I-10	A	43	346	112	35	6	5.420	54.0	5.6	2.700
	B	22	108	138	35	3	6.232	30.5	5.1	.650
I-11	A	48	281	38	35	5	4.624	43.2	5.5	2.783
	B	26	151	165	30	3	5.807	40.1	5.1	.567
I-12	A	43	281	99	35	5	4.922	50.6	5.4	2.397
	B	17	86	138	30	3	5.825	30.1	5.1	.546
I-13	A	39	194	67	35	6	4.013	44.4	5.5	2.324
	B	22	130	129	30	4	5.917	32.3	5.1	.721
I-14	A	39	324	60	30	3	4.123	57.0	5.8	2.058
	B	39	194	138	26	3	4.172	55.9	5.3	.445

*Roman numeral = block; arabic number = fertilizer treatment; A = A horizon (topsoil); B = B horizon (subsoil).

Table 3.--(Continued)

Plot No.		Available (ppm.) K	Ca	Mg	Na	P	Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
I-15	A	39	173	49	30	3	3.867	38.9	5.3	2.262
	B	30	130	171	30	3	6.682	34.2	5.1	.704
I-16	A	39	302	49	35	4	4.862	44.6	5.5	2.697
	B	30	238	175	26	4	4.874	58.2	5.3	.551
I-17	A	65	238	85	35	5	4.450	49.8	5.3	2.283
	B	39	151	171	35	2	6.175	39.4	4.9	.697
I-18	A	56	497	97	35	3	6.872	52.2	5.5	3.476
	B	26	151	165	39	3	4.862	48.7	5.2	.450
I-19	A	39	281	40	26	7	3.724	52.4	5.4	1.726
	B	43	216	120	35	3	4.115	56.9	5.2	.505
I-20	A	35	281	78	26	4	4.753	47.5	5.3	2.383
	B	17	86	97	39	3	3.882	37.4	5.1	.512
I-21	A	43	346	71	26	5	5.303	48.0	5.5	2.866
	B	30	151	147	39	3	5.116	43.5	5.0	.668
I-22	A	43	367	85	30	6	5.869	47.4	5.3	2.874
	B	22	130	155	39	5	5.648	38.4	5.0	.790
I-23	A	39	281	71	26	5	4.574	48.3	5.4	2.287
	B	22	65	129	39	3	5.697	28.5	5.0	.657
I-24	A	39	389	108	26	6	6.210	49.2	5.4	3.042
	B	22	108	147	43	1	5.685	35.3	5.3	.617
I-25	A	56	389	97	26	6	6.228	48.3	5.3	3.159
	B	26	43	112	43	3	5.276	26.6	5.2	.557
I-26	A	35	281	90	26	3	5.379	43.8	5.1	2.812
	B	17	43	90	43	1	5.399	22.2	5.3	.652
I-27	A	35	238	97	26	4	5.025	43.8	5.2	2.392
	B	17	86	108	30	2	4.787	31.4	5.2	.563
II- 1	A	43	281	67	30	5	5.027	43.8	5.7	2.949
	B	22	86	108	30	3	5.653	26.8	5.2	.554
II- 2	A	65	454	90	26	7	6.058	54.5	6.0	2.758
	B	35	194	203	30	1	5.049	57.1	5.2	.411

Table 3.--(Continued)

Plot No.		Available (ppm.) K	Ca	Mg	Na	P	Exch. Cap., me./100 g.	% Base Sat.	pH	Organic Matter (%)
II- 3	A	56	540	120	30	6	7.914	50.2	5.8	3.898
	B	17	65	120	30	5	5.111	29.3	5.0	.406
II- 4	A	48	389	97	30	6	5.895	51.0	5.8	3.184
	B	17	65	129	35	1	5.470	29.2	5.1	.480
II- 5	A	432	259	49	52	6	4.482	67.8	6.1	2.319
	B	69	65	143	39	2	6.067	30.7	4.8	.530
II- 6	A	69	367	90	30	6	5.650	51.2	5.7	2.952
	B	30	86	165	35	1	6.105	33.3	5.1	.504
II- 7	A	39	194	49	22	6	4.135	38.1	5.8	2.091
	B	30	86	175	35	3	5.269	40.2	5.2	.497
II- 8	A	43	367	97	26	9	3.982	72.0	6.0	2.763
	B	26	65	138	30	1	5.612	29.8	5.2	.486
II- 9	A	35	324	67	26	5	5.139	46.3	5.8	2.546
	B	17	130	147	30	5	5.529	37.1	5.2	.498
II-10	A	69	432	112	30	7	6.946	49.0	5.7	3.471
	B	22	43	129	30	1	6.138	24.0	5.1	.476
II-11	A	35	281	85	30	6	5.157	45.2	5.6	2.689
	B	22	108	120	30	3	5.403	31.9	5.1	.472
II-12	A	48	389	71	30	6	5.088	54.8	5.8	2.235
	B	39	259	151	26	1	4.933	56.1	5.4	.407
II-13	A	73	562	112	26	7	6.341	63.8	6.0	3.239
	B	39	151	171	26	3	5.939	40.3	5.3	.429
II-14	A	35	302	85	30	9	5.196	46.9	5.7	2.468
	B	17	86	135	35	1	6.545	26.8	5.1	.478
II-15	A	48	389	102	26	6	5.723	53.0	5.9	2.652
	B	22	130	160	30	5	6.372	34.0	5.2	.510
II-16	A	39	259	97	26	7	4.877	47.5	5.7	2.633
	B	17	65	120	30	2	6.687	22.4	5.0	.495
II-17	A	43	324	67	26	6	4.437	54.1	5.9	2.095
	B	26	86	129	26	3	5.559	30.3	5.2	.410

Table 3.--(Continued)

Plot No.		Available (ppm.)					Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
		K	Ca	Mg	Na	P				
II-18	A	52	410	102	26	8	6.823	40.1	5.6	3.644
	B	216	130	160	43	2	6.007	45.3	4.8	.496
II-19	A	35	238	85	30	7	4.285	49.4	5.7	2.242
	B	22	108	120	35	3	5.885	29.7	5.2	.465
II-20	A	56	432	112	30	10	7.176	46.9	5.7	3.690
	B	26	86	129	30	1	6.814	25.0	5.0	.502
II-21	A	56	302	85	26	6	4.511	54.9	6.0	2.423
	B	22	108	147	30	6	6.407	30.5	5.2	.478
II-22	A	39	324	71	26	6	4.658	52.1	5.9	2.299
	B	26	130	180	26	2	6.927	33.6	5.2	.433
II-23	A	43	259	67	26	5	4.440	46.8	5.8	2.421
	B	27	86	120	35	2	5.788	28.5	4.9	.447
II-24	A	35	238	90	26	6	4.901	43.7	5.6	3.050
	B	26	86	108	35	2	5.883	26.3	4.9	.501
II-25	A	65	497	97	26	7	6.068	58.9	5.9	2.691
	B	36	324	199	30	2	5.930	59.0	5.3	.454
II-26	A	52	389	97	26	6	6.742	44.5	5.6	3.787
	B	26	86	147	35	1	6.779	27.6	4.9	.499
II-27	A	60	410	102	26	6	5.465	58.0	5.9	2.551
	B	29	151	155	35	2	5.950	38.2	5.0	.435
III- 1	A	44	346	49	26	4	4.925	48.0	5.7	2.471
	B	51	86	138	65	2	5.671	35.2	4.9	.310
III- 2	A	56	367	71	26	5	5.048	53.2	5.9	2.242
	B	51	194	171	35	1	6.552	40.9	5.0	.401
III- 3	A	74	497	108	26	6	6.577	56.1	6.0	2.888
	B	60	194	151	43	2	5.655	45.4	5.1	.444
III- 4	A	48	302	55	26	5	4.962	44.4	5.5	2.246
	B	48	86	171	43	1	6.039	35.9	5.0	.280
III- 5	A	71	475	85	26	4	5.873	57.5	5.8	2.538
	B	41	151	160	43	2	5.598	42.5	5.0	.373

Table 3.--(Continued)

Plot No.		Available (ppm.)					Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
		K	Ca	Mg	Na	P				
III- 6	A	59	432	71	26	5	5.774	52.2	5.9	2.581
	B	51	216	169	39	1	5.350	52.1	5.2	.369
III- 7	A	56	281	49	26	5	4.762	43.5	5.6	2.387
	B	36	86	155	43	2	6.729	29.7	4.9	.516
III- 8	A	91	216	60	30	5	4.110	47.3	6.1	2.278
	B	36	86	129	43	1	6.446	27.7	4.7	.588
III- 9	A	74	432	85	26	4	6.126	51.8	5.8	2.488
	B	47	173	180	43	1	5.037	53.1	5.1	.395
III-10	A	53	324	49	26	5	4.969	45.8	5.8	2.194
	B	51	173	180	39	1	5.818	45.8	5.2	.354
III-11	A	45	238	49	30	4	4.076	45.2	5.8	1.951
	B	41	151	147	39	2	5.867	38.4	5.0	.356
III-12	A	53	259	60	35	5	4.775	43.6	5.7	2.312
	B	32	108	155	43	2	6.172	34.0	5.0	.365
III-13	A	48	281	49	26	4	5.201	39.4	5.5	2.391
	B	26	108	138	43	2	6.212	31.3	5.0	.471
III-14	A	50	238	49	22	5	4.317	42.2	5.7	2.113
	B	32	130	155	43	1	7.323	30.2	4.9	.473
III-15	A	42	346	71	26	5	5.432	46.8	5.6	2.622
	B	27	86	108	43	2	6.774	23.4	4.9	.413
III-16	A	39	194	71	39	5	5.312	34.5	5.4	2.435
	B	29	86	90	48	2	6.575	22.3	4.9	.415
III-17	A	151+	151	25	48	5	3.069	50.8	6.4	1.556
	B	132	130	160	48	1	5.025	50.3	5.3	.488
III-18	A	51	475	71	39	6	6.748	48.4	5.7	3.069
	B	32	151	221	43	1	7.069	40.5	5.0	.500
III-19	A	48	194	55	48	4	3.927	44.8	5.7	1.824
	B	26	86	165	43	1	6.524	31.6	5.0	.396
III-20	A	107	605	108	48	7	8.151	54.1	6.2	4.051
	B	48	86	147	43	2	6.365	30.9	4.8	.502

Table 3.--(Continued)

Plot No.		Available (ppm.)					Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
		K	Ca	Mg	Na	P				
III-21	A	62	324	102	43	5	6.493	43.4	5.8	2.944
	B	35	86	97	43	2	5.783	26.2	4.9	.436
III-22	A	60	389	71	35	7	5.273	53.9	5.9	2.614
	B	35	151	147	43	2	5.869	38.5	5.0	.485
III-23	A	44	302	49	35	5	5.269	41.4	5.6	2.566
	B	27	86	151	43	1	6.803	28.6	5.1	.489
III-24	A	44	410	90	43	6	6.777	45.7	5.6	2.998
	B	27	86	120	48	1	6.896	24.8	5.0	.445
III-25	A	77	583	108	39	6	6.940	60.3	6.0	3.067
	B	50	216	155	43	1	5.576	48.2	5.2	.432
III-26	A	38	173	78	35	6	4.653	37.9	5.5	2.280
	B	33	86	71	43	1	5.956	21.7	4.9	.407
III-27	A	41	216	38	43	6	5.104	33.1	5.4	2.576
	B	30	86	97	43	1	7.084	21.2	5.0	.431

Table 4.--Chemical characteristics of soil in Washington Parish plantation before fertilization.

Plot No.*		Available (ppm.) K	Ca	Mg	Na	P	Exch. Cap., me./100 g.	% Base Sat.	pH	Organic Matter (%)
I- 1	A	52	194	38	30	23	4.571	33.9	5.7	2.185
	B	35	151	71	43	1	3.660	44.4	5.3	.385
I- 2	A	35	173	38	35	27	3.854	36.9	5.7	1.626
	B	22	216	67	43	2	3.457	54.4	5.4	.354
I- 3	A	48	173	25	30	24	4.084	32.5	5.7	2.109
	B	35	173	78	39	1	4.402	40.3	5.2	.430
I- 4	A	39	173	25	35	25	4.149	31.9	5.7	2.192
	B	26	194	90	39	1	4.124	47.5	5.3	.393
I- 5	A	56	173	13	35	25	3.896	32.6	5.7	1.970
	B	30	173	108	35	2	4.358	45.8	5.2	.356
I- 6	A	43	151	13	30	28	3.730	29.6	5.7	2.138
	B	26	130	60	48	2	4.184	34.1	5.2	.433
I- 7	A	43	151	49	35	29	3.723	38.3	5.7	1.676
	B	30	194	85	43	1	4.240	45.8	5.3	.441
I- 8	A	52	173	49	30	24	3.834	40.1	5.9	1.769
	B	22	173	102	39	1	4.502	43.1	5.3	.373
I- 9	A	39	130	25	35	26	3.014	36.8	5.8	1.417
	B	30	151	85	39	1	4.337	39.4	5.3	.421
I-10	A	39	173	25	35	23	3.820	34.7	5.8	1.731
	B	26	216	85	43	1	4.340	47.1	5.4	.438
I-11	A	48	151	32	35	32	3.398	38.2	5.8	1.450
	B	35	173	108	43	1	4.732	43.1	5.2	.400
I-12	A	69	432	60	39	48	7.801	38.5	5.7	3.650
	B	35	238	108	43	2	4.403	53.8	5.4	.467
I-13	A	43	194	19	35	23	4.411	31.5	5.7	1.986
	B	22	194	102	48	1	3.989	52.3	5.4	.446
I-14	A	65	238	60	35	24	4.767	42.1	5.9	2.248
	B	30	238	129	48	1	4.455	57.3	5.4	.371

*Roman numeral = block; arabic number = fertilizer treatment; A = A horizon (topsoil); B = B horizon (subsoil).

Table 4.--(Continued)

Plot No.		Available (ppm.) K	Ca	Mg	Na	P	Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
I-15	A	35	194	43	43	23	3.641	44.1	5.8	1.815
	B	26	173	71	43	1	3.878	44.1	5.1	.323
I-16	A	35	302	38	43	11	3.614	58.2	6.0	1.706
	B	22	238	108	43	0	3.975	58.7	5.4	.332
I-17	A	30	151	25	43	18	3.000	40.9	5.8	1.815
	B	35	194	120	43	1	4.545	49.4	5.2	.554
I-18	A	52	238	38	35	24	4.419	40.6	5.8	2.686
	B	22	108	67	39	1	4.148	31.9	5.2	.415
I-19	A	52	281	49	43	23	4.694	45.4	5.8	2.770
	B	30	194	71	43	1	5.088	41.9	5.2	.416
I-20	A	35	151	19	39	26	3.274	35.8	5.7	2.067
	B	22	194	108	43	1	4.477	47.2	5.2	.347
I-21	A	30	108	13	39	24	2.077	43.1	5.7	1.334
	B	30	151	43	43	2	3.478	39.6	5.3	.407
I-22	A	39	194	49	39	16	3.749	44.0	5.8	2.134
	B	30	194	120	39	1	4.515	49.1	5.3	.410
I-23	A	43	281	38	39	23	4.694	42.7	5.7	2.845
	B	26	173	71	43	1	4.206	40.7	5.3	.414
I-24	A	52	324	55	35	18	4.924	48.0	5.8	2.791
	B	30	216	143	43	1	4.966	51.1	5.3	.387
I-25	A	39	194	38	43	15	3.544	44.4	5.7	1.942
	B	35	151	97	43	1	4.861	37.9	5.2	.468
I-26	A	35	194	43	43	21	3.706	43.3	5.7	1.869
	B	22	173	97	43	1	4.543	42.2	5.3	.404
I-27	A	22	108	38	39	22	2.790	38.8	5.6	1.626
	B	22	151	49	48	1	3.332	42.9	5.2	.355
II- 1	A	35	194	38	39	13	3.648	42.4	5.7	1.923
	B	26	194	102	48	3	3.869	54.2	5.4	.313
II- 2	A	39	259	38	39	17	3.852	48.9	5.9	2.066
	B	26	238	55	43	2	3.347	56.8	5.4	.383

Table 4.--(Continued)

Plot No.		Available (ppm.) K	Ca	Mg	Na	P	Exch. Cap., me./100 g.	% Base Sat.	pH	Organic Matter (%)
II- 3	A	30	151	32	43	18	2.928	43.9	5.8	1.582
	B	35	173	97	35	2	4.148	46.2	5.2	.336
II- 4	A	48	324	38	43	22	4.414	50.9	5.8	2.420
	B	30	216	97	43	1	4.188	51.4	5.3	.320
II- 5	A	35	151	38	39	18	3.302	40.3	5.6	1.843
	B	22	86	67	39	1	3.381	35.9	5.1	.301
II- 6	A	48	324	49	48	13	4.264	55.3	6.0	1.793
	B	30	324	125	43	1	4.765	61.4	5.4	.369
II- 7	A	35	302	38	43	22	4.337	48.5	5.8	2.135
	B	22	238	85	43	1	3.390	63.2	5.5	.298
II- 8	A	35	194	32	48	12	3.506	43.8	5.7	1.677
	B	22	238	90	39	2	3.545	61.1	5.4	.274
II- 9	A	35	194	25	48	16	3.841	38.5	5.7	2.260
	B	30	151	85	39	2	3.417	50.0	5.3	.348
II-10	A	26	130	13	43	17	2.851	35.5	5.7	1.717
	B	22	151	67	39	1	3.049	50.5	5.3	.372
II-11	A	30	151	32	39	18	3.370	37.7	5.7	2.156
	B	22	130	85	39	1	3.620	43.8	5.1	.354
II-12	A	39	151	38	39	15	3.181	42.2	5.8	1.910
	B	30	151	85	43	1	4.354	39.7	5.2	.291
II-13	A	39	108	25	39	15	2.528	40.3	5.9	1.272
	B	22	151	38	35	3	2.396	53.4	5.5	.294
II-14	A	39	281	38	39	13	4.290	46.4	5.8	2.168
	B	26	216	97	39	2	4.095	51.9	5.3	.327
II-15	A	22	130	25	39	18	2.923	37.1	5.6	1.524
	B	22	151	67	43	2	4.314	36.1	5.2	.323
II-16	A	26	130	49	39	18	2.543	50.9	5.6	1.027
	B	30	86	71	43	2	4.635	27.7	5.1	.321
II-17	A	22	151	25	39	17	3.093	38.4	5.7	1.907
	B	26	151	138	35	2	4.094	51.9	5.4	.384

Table 4.--(Continued)

Plot No.		Available (ppm.) K	Ca	Mg	Na	P	Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
II-18	A	48	367	60	39	17	4.204	62.5	6.0	2.043
	B	30	280	199	39	1	5.406	61.1	5.1	.416
II-19	A	30	151	25	35	18	3.293	36.2	5.7	1.936
	B	22	173	169	39	1	4.403	56.8	5.4	.306
II-20	A	26	151	25	35	16	3.349	35.3	5.6	2.045
	B	26	130	228	35	1	4.936	56.1	5.4	.331
II-21	A	22	173	25	35	18	3.448	37.2	5.7	1.912
	B	26	173	138	35	2	3.941	56.7	5.3	.364
II-22	A	46	216	49	39	18	5.125	34.7	5.6	2.834
	B	39	151	155	35	2	4.794	48.0	5.2	.393
II-23	A	30	151	32	43	19	2.205	58.3	5.7	1.604
	B	39	151	155	35	2	4.466	51.5	5.3	.310
II-24	A	39	238	38	35	12	3.926	44.8	5.7	2.046
	B	30	173	165	35	1	4.036	53.3	5.2	.329
II-25	A	35	173	32	35	21	4.854	28.3	5.7	2.019
	B	39	86	165	35	1	5.537	37.2	5.0	.283
II-26	A	26	173	38	35	13	3.437	40.8	5.7	1.808
	B	26	173	171	39	1	4.431	57.0	5.3	.296
II-27	A	35	238	32	39	15	4.147	41.4	5.8	2.397
	B	26	173	155	42	2	4.246	56.7	5.3	.317
III- 1	A	35	130	19	39	24	1.790	59.7	5.8	1.755
	B	30	173	210	39	2	5.883	48.6	5.2	.414
III- 2	A	26	216	43	35	17	2.970	55.8	5.8	2.325
	B	30	194	147	39	2	3.952	61.8	5.4	.358
III- 3	A	26	108	25	43	21	1.659	60.4	5.6	1.636
	B	30	173	112	35	1	4.391	46.2	5.2	.342
III- 4	A	30	194	49	43	14	2.627	62.5	5.8	1.873
	B	30	194	138	35	1	4.319	54.4	5.3	.355
III- 5	A	43	216	38	35	26	3.169	52.4	5.7	2.272
	B	30	173	169	43	1	5.295	47.9	5.2	.331

Table 4.--(Continued)

Plot No.		Available K	Ca	Mg	Na	P	Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
III- 6	A	30	130	38	35	18	1.787	66.9	5.9	1.332
	B	35	194	165	43	2	5.446	48.1	5.3	.339
III- 7	A	35	194	97	39	19	2.892	70.5	5.9	1.708
	B	30	194	175	39	1	4.908	54.5	5.4	.331
III- 8	A	35	216	25	35	16	3.566	42.9	5.8	2.508
	B	26	194	151	35	2	4.483	54.6	5.2	.360
III- 9	A	43	194	60	35	25	3.177	54.5	5.8	2.251
	B	30	194	125	35	1	4.605	48.7	5.2	.335
III-10	A	60	302	55	35	32	5.426	41.9	5.8	2.696
	B	35	130	108	30	1	5.185	34.1	5.1	.387
III-11	A	26	108	13	43	14	2.675	33.7	5.8	1.401
	B	30	151	108	35	1	3.920	48.1	5.2	.409
III-12	A	69	346	55	48	51	6.317	40.7	5.8	3.159
	B	35	151	102	30	2	4.517	40.4	5.1	.350
III-13	A	35	151	19	39	19	2.683	43.7	5.9	1.366
	B	30	173	138	30	1	4.980	44.6	5.1	.347
III-14	A	43	130	38	39	36	3.348	37.2	5.9	1.544
	B	35	130	129	30	1	4.178	46.6	5.3	.369
III-15	A	48	173	25	35	20	3.581	37.6	5.9	1.883
	B	26	238	195	35	1	5.201	58.3	5.4	.357
III-16	A	22	130	25	35	19	3.536	35.1	5.8	1.682
	B	30	173	138	35	1	4.148	54.1	5.3	.351
III-17	A	48	173	43	39	15	3.158	48.0	6.0	1.449
	B	26	173	147	35	1	4.739	48.7	5.3	.343
III-18	A	73	302	60	43	24	5.208	45.8	5.9	2.606
	B	30	173	143	35	1	4.716	48.5	5.3	.368
III-19	A	39	130	7	35	20	2.405	39.9	6.0	1.352
	B	35	194	129	35	1	4.914	46.5	5.3	.333
III-20	A	30	194	19	39	20	3.805	36.1	5.9	2.210
	B	26	151	129	30	2	3.669	55.2	5.4	.275

Table 4.--(Continued)

Plot No.		Available (ppm.) K	Ca	Mg	Na	P	Exch. Cap., me./ 100 g.	% Base Sat.	pH	Organic Matter (%)
III-21	A	78	389	43	43	50	6.039	44.5	5.9	3.043
	B	39	238	188	30	1	5.351	55.8	5.3	.381
III-22	A	39	151	13	39	22	3.130	36.5	5.9	1.839
	B	39	173	195	30	1	5.084	53.5	5.3	.346
III-23	A	73	259	49	43	15	6.057	37.1	5.8	3.260
	B	30	173	188	30	1	4.937	53.5	5.2	.384
III-24	A	35	151	13	39	18	2.699	41.6	5.8	1.619
	B	17	194	143	35	1	3.934	59.9	5.5	.345
III-25	A	48	173	13	39	20	4.878	26.0	5.7	3.045
	B	22	194	155	30	1	4.615	53.0	5.3	.322
III-26	A	52	216	32	39	21	3.817	43.2	5.9	2.156
	B	22	173	147	35	2	4.596	50.0	5.3	.337
III-27	A	43	173	25	39	20	4.505	30.0	5.6	2.740
	B	26	173	175	35	1	4.906	51.8	5.2	.349

over 4 percent and the pH from 5.4 to 6.4. In contrast to the Shubuta subsoil from the Homer plantation, the subsoils at Alexandria were only slightly higher in exchange capacity and generally lower in bases than the topsoils. Available Mg was the only base that was higher in the finer-textured subsoils.

The Ruston soil in the Washington Parish plantation was similar in chemical nature to the Alexandria soils with the exception of available phosphorus, which ranged from 11 to 51 ppm. (Table 4). This relatively higher available phosphorus is largely residual from fertilization practices followed while the field was cropped.

The available nutrients in these soils were so low that the addition of fertilizers would have been required for ordinary crop production. The sandy loam and very fine sandy loam soils of the rolling and hilly areas of the Coastal Plain have generally been shown to require fertilizer additions when they contain as little as 40 ppm. P, 80 ppm. K, 500 ppm. Ca, 50 ppm. Mg, and 70 percent base saturation (63). The topsoils tested in this study were generally far below these fertility levels with the possible exception of magnesium.

The results of all soil tests are given in Appendix D. Due to the manner in which fertilizers were applied and the soil was sampled, the soil samples collected one and two years after fertilization were extremely variable in available nutrients. Since the fertilizers were applied in

circular bands or holes rather than uniformly broadcast, soil analyses frequently showed very high concentrations of fertilizer elements, particularly of the relatively insoluble phosphate. In spite of this variability, it may be stated that there were definitely residual effects from the applied phosphate and potash. These effects tended to vary with the rates of phosphate and potash applied and the lapse of time since their application.

Effects of Fertilizer Treatments on Growth

The average heights and growth of the surviving trees for each fertilizer treatment in the three plantations are given in Tables 5, 6, and 7. The average growth in the Homer plantation (Table 5) was over 50 percent greater than the average growth in the Alexandria plantation (Table 6); in fact, the differences in growth of the unfertilized plots in the two plantations were even more pronounced. This greater growth at Homer must be largely attributed to the complete eradication of weeds. In the Alexandria plantation weeds were not effectively controlled and their growth was stimulated by the fertilizers.

The 30 inches of rainfall received at the Homer location during the six-months period from April through September exceeded the rainfall for the same period at the Alexandria location by 5.5 inches in 1959, but it was almost 8 inches less during the same period in 1960 (Appendix C).

Table 5.--Average heights and growth of surviving trees, Homer plantation.

Fertilizer Treatment ($N-P_2O_5-K_2O$)	Number of Trees*	Average Ht. (ft.) Mar. 1959	Nov. 1959	Dec. 1960	Average Growth (ft.) 1959	1960	1959 & 1960
0- 0- 0	184	0.69	2.22	6.18	1.529	3.898	5.427
0- 0-100	189	0.71	1.93	5.44	1.222	3.522	4.744
0- 0-200	206	0.69	2.14	6.31	1.460	4.166	5.625
0-100- 0	181	0.69	2.52	6.80	1.828	4.243	6.070
0-100-100	191	0.74	2.67	7.04	1.930	4.373	6.304
0-100-200	197	0.70	2.57	6.67	1.861	4.094	5.955
0-200- 0	198	0.63	2.45	6.62	1.813	4.176	5.989
0-200-100	191	0.65	2.50	6.74	1.847	4.235	6.081
0-200-200	193	0.70	2.45	6.54	1.757	4.087	5.844
100- 0- 0	199	0.69	1.92	6.02	1.221	4.088	5.310
100- 0-100	200	0.64	1.98	5.90	1.346	3.926	5.271
100- 0-200	180	0.74	2.15	6.04	1.445	3.913	5.358
100-100- 0	199	0.58	2.30	6.70	1.717	4.442	6.159
100-100-100	205	0.63	2.38	6.44	1.748	4.038	5.786
100-100-200	198	0.66	2.48	6.85	1.821	4.385	6.207
100-200- 0	185	0.69	2.30	6.43	1.614	4.106	5.720
100-200-100	188	0.65	2.47	6.93	1.821	4.459	6.280
100-200-200	198	0.68	2.32	6.53	1.640	4.176	5.816
200- 0- 0	177	0.73	1.75	5.54	1.012	3.740	4.752
200- 0-100	175	0.71	1.85	5.58	1.116	3.684	4.800
200- 0-200	188	0.73	1.86	5.29	1.145	3.457	4.602
200-100- 0	172	0.71	2.20	6.40	1.502	4.198	5.700
200-100-100	189	0.70	2.42	6.88	1.724	4.406	6.130
200-100-200	182	0.66	2.13	6.26	1.479	4.134	5.613
200-200- 0	171	0.73	2.33	6.74	1.599	4.400	5.999
200-200-100	194	0.66	2.16	6.59	1.535	4.377	5.912
200-200-200	204	0.62	2.20	6.28	1.578	4.077	5.656
Average	190	0.68	2.25	6.36	1.571	4.106	5.677

*Total of three blocks.

Table 6.--Average heights and growth of surviving trees, Alexandria plantation.

Fertilizer Treatment ($N-P_2O_5-K_2O$)	Number of Trees*	Average Ht. (ft.)			Average Growth (ft.)		
		Apr. 1959	Nov. 1959	Nov. 1960	1959	1960	1959 & 1960
0- 0- 0	218	0.91	1.27	2.98	0.359	1.680	2.039
0- 0-100	207	0.89	1.41	3.37	0.517	1.920	2.437
0- 0-200	197	0.92	1.28	3.03	0.349	1.703	2.052
0-100- 0	212	0.92	1.52	3.73	0.583	2.187	2.771
0-100-100	202	0.88	1.40	3.42	0.519	1.967	2.487
0-100-200	209	0.77	1.39	3.39	0.618	1.994	2.612
0-200- 0	207	1.02	1.68	3.85	0.652	2.156	2.807
0-200-100	212	1.01	1.55	3.57	0.539	1.993	2.533
0-200-200	199	0.89	1.43	3.39	0.544	1.948	2.491
100- 0- 0	203	0.91	1.33	2.98	0.417	1.594	2.011
100- 0-100	205	0.92	1.30	2.83	0.373	1.428	1.800
100- 0-200	177	0.90	1.34	3.04	0.435	1.621	2.056
100-100- 0	207	1.00	2.36	5.39	1.357	2.966	4.322
100-100-100	206	0.98	2.32	5.09	1.333	2.779	4.112
100-100-200	197	0.94	2.40	5.39	1.466	2.938	4.404
100-200- 0	189	0.84	2.12	4.83	1.294	2.706	4.000
100-200-100	188	0.82	2.08	4.69	1.268	2.597	3.865
100-200-200	194	0.99	2.43	4.95	1.448	2.520	3.968
200- 0- 0	188	0.91	1.23	2.53	0.324	1.200	1.524
200- 0-100	209	0.92	1.20	2.68	0.283	1.414	1.697
200- 0-200	176	0.84	1.13	2.50	0.286	1.230	1.516
200-100- 0	194	0.99	2.29	5.38	1.295	3.110	4.405
200-100-100	203	1.04	2.48	5.62	1.444	3.152	4.596
200-100-200	185	0.73	1.74	4.43	1.015	2.652	3.666
200-200- 0	182	0.85	2.21	5.28	1.371	3.049	4.420
200-200-100	204	1.03	2.46	5.68	1.426	3.200	4.626
200-200-200	183	0.78	1.95	4.90	1.257	2.909	4.166
Average	198	0.91	1.75	4.03	0.838	2.242	3.081

*Total of three blocks.

Table 7.--Average heights and growth of surviving trees in Washington Parish plantation.

Fertilizer Treatment (N-P_2O_5-K_2O)	Number of Trees*	Average Ht. (ft.) Apr. 1959	Dec. 1959	Dec. 1960	Average Growth (ft.) 1959	1960**	1959 & 1960
0- 0- 0	216	1.03	1.70	3.41	0.663	1.715	2.378
0- 0-100	219	1.06	1.59	3.28	0.532	1.680	2.212
0- 0-200	220	1.00	1.60	3.36	0.603	1.766	2.369
0-100- 0	217	0.97	1.44	3.10	0.472	1.664	2.136
0-100-100	217	1.03	1.69	3.52	0.652	1.837	2.488
0-100-200	216	0.99	1.59	3.43	0.602	1.838	2.440
0-200- 0	216	1.01	1.66	3.35	0.650	1.694	2.344
0-200-100	219	0.98	1.53	3.19	0.548	1.650	2.194
0-200-200	223	1.08	1.70	3.45	0.622	1.746	2.368
100- 0- 0	202	0.91	1.44	3.20	0.531	1.761	2.291
100- 0-100	193	1.06	1.65	3.53	0.596	1.877	2.473
100- 0-200	198	0.95	1.64	3.72	0.694	2.078	2.772
100-100- 0	206	0.99	1.63	3.74	0.643	2.111	2.754
100-100-100	197	0.87	1.43	3.25	0.559	1.813	2.372
100-100-200	206	0.96	1.60	3.57	0.634	1.974	2.608
100-200- 0	220	1.04	1.59	3.36	0.550	1.769	2.319
100-200-100	211	1.01	1.64	3.56	0.638	1.914	2.552
100-200-200	192	0.81	1.39	3.29	0.587	1.892	2.478
200- 0- 0	173	0.87	1.39	3.22	0.521	1.832	2.354
200- 0-100	162	1.08	1.67	3.48	0.597	1.802	2.399
200- 0-200	169	0.98	1.80	3.66	0.820	1.815	2.653
200-100- 0	209	0.92	1.43	3.56	0.504	2.118	2.626
200-100-100	186	0.98	1.61	3.38	0.625	1.741	2.384
200-100-200	192	0.92	1.47	3.25	0.553	1.752	2.319
200-200- 0	208	1.01	1.57	3.41	0.559	1.833	2.394
200-200-100	208	1.04	1.70	3.66	0.665	1.949	2.616
200-200-200	203	1.06	1.72	3.56	0.660	1.821	2.487
Average	204	0.99	1.59	3.43	0.603	1.831	2.436

*Total of three blocks.

**Only growth period affected by treatments, since fertilizers were applied at the beginning of 1960.

The total annual rainfall of 50 inches during 1959 was 1.74 inches greater at Homer than at the Alexandria location. During 1960, the total rainfall of 50 inches at Homer was over 11 inches less than the total received at Alexandria. The differences in nutrient status of the soil before fertilization were not great enough to explain the greater growth at Homer. In fact, the topsoils in the Alexandria plantation were generally higher in organic matter and bases than at Homer (Tables 2 and 3). Therefore, differences in growth between these two locations were probably due more to weeds competing for nutrients and moisture in the Alexandria plantation than to differences in rainfall or to differences in native fertility of the soils. The effect of vigorously growing weeds on reducing soil moisture to a critical point for first-year pine seedlings has been stressed by Cummings (18), Derr (20), Doolittle (21), Walker (68), and others.

A second observation to be noted is that average growth for the second year after fertilization was 2.6 times the average growth for the first year at both the Homer and Alexandria locations. The Homer plantation grew an average of 1.571 feet in 1959 and 4.106 feet during 1960. The Alexandria plantation grew 0.838 foot in 1959 and 2.242 feet in 1960. The Washington Parish plantation grew 1.831 feet in 1960, the first year after fertilization. Whether the increased second-year growth was caused by the additional year of age the trees had attained or whether the effects

of fertilizers on growth were more pronounced the second year after fertilization remains to be answered. Since the ages of the trees in all plantations were the same, the fertilizer effects during 1960 would have been expected to be similar for the three plantations. However, the 1960 growth in the Washington Parish plantation was more nearly of the same magnitude as the 1959 growth in the two other plantations. When one considers the originally higher fertility status of the soil in the Washington Parish plantation (Table 4), it appears that the effects of the fertilizers were more obvious the second year after application. The more extensive root systems of the older trees and possibly more widespread distribution of the soluble fertilizer elements in the soil during the second year might have caused this greater growth. A comparison of the 1961 growth in the Washington Parish plantation with its 1960 growth should supply additional evidence in support of this point.

According to Walker (70), some forest physiologists believe that a one-year delay in obtaining height growth response to fertilizer applications is inevitable. Pritchett and Robertson (54) investigated the effect of tree age at time of application on the response to fertilizers. Three rates of 8-8-8 fertilizer were applied to slash pine at 4 and 16 months after transplanting on Lakeland fine sand in Florida. There was no significant response to fertilizer application among trees to which

fertilizer was applied at 4 months after transplanting; however, the same rate of fertilizer per acre resulted in significant height growth responses in the older trees.

Variations in growth among fertilizer treatments may also be noted in the foregoing tables. Data in Table 5 indicate a stimulation of growth by phosphorus and a retardation of growth in 1959 by nitrogen in the Homer plantation. The analysis of variance for 1959 growth at Homer proved the main effects of both nitrogen and phosphorus to be highly significant (Table 8). The effect of nitrogen on growth, however, was not significant in the analysis of variance for 1960 growth, but phosphorus continued to have a highly significant effect (Table 9). The detrimental effect of nitro en on 1959 growth was so severe as to cause the nitrogen effect to be apparently highly significant in the analysis of variance for total growth for the two-year period (Table 10). Although the interaction of nitrogen with phosphorus did not prove to be significant in any of the three analyses of variance, the addition of phosphorus appeared to overcome some of the detrimental effects of nitrogen on growth. By orthogonal comparison of application rates, it was found that the effect of nitrogen was linear whereas the effect of phosphorus was both linear and quadratic. These effects are illustrated in Figures 10 and 11.

The analyses of variance for 1959 growth (Table 11), for 1960 growth (Table 12), and for the total growth for the

Table 8.--Analysis of variance for 1959 growth in the Homer plantation.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Blocks	2	0.247780	0.123890	7.65**
Treatments:				
N	2	1.124380	0.562190	34.70**
P	2	3.414091	1.707046	105.37**
K	2	0.032610	0.016305	1.01
NxP	4	0.028325	0.007081	0.44
NxK	4	0.090466	0.022616	1.40
PxK	4	0.108437	0.027109	1.67
NxPxK	8	0.259432	0.032429	2.00
Combined error	52	0.842418	0.016200	
Total	80	6.147939		

**Significant at the 0.01 level of probability.

Table 9.--Analysis of variance for 1960 growth in the Homer plantation.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Blocks	2	1.867938	0.933969	13.57**
Treatments:				
N	2	0.173281	0.086640	1.26
P	2	3.222882	1.611441	23.42**
K	2	0.148878	0.074439	1.08
NxP	4	0.428600	0.107150	1.56
NxK	4	0.375024	0.093756	1.36
PxK	4	0.353746	0.088436	1.29
NxPxK	8	0.992263	0.124032	1.80
Combined error	52	3.577919	0.068806	
Total	80	11.140531		

**Significant at the 0.01 level of probability.

Table 10.--Analysis of variance for two-year growth in the Homer plantation.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Blocks	2	2.450006	1.225003	9.48**
Treatments:				
N	2	1.684381	0.842190	6.52**
P	2	13.267376	6.633688	51.36**
K	2	0.177624	0.058812	0.46
NxP	4	0.636442	0.159110	1.23
NxK	4	0.584200	0.146050	1.13
PxK	4	0.731584	0.182896	1.41
NxPxK	8	1.806621	0.225827	1.75
Combined error	52	6.715747	0.129149	
Total	80	27.993981		

**Significant at the 0.01 level of probability.

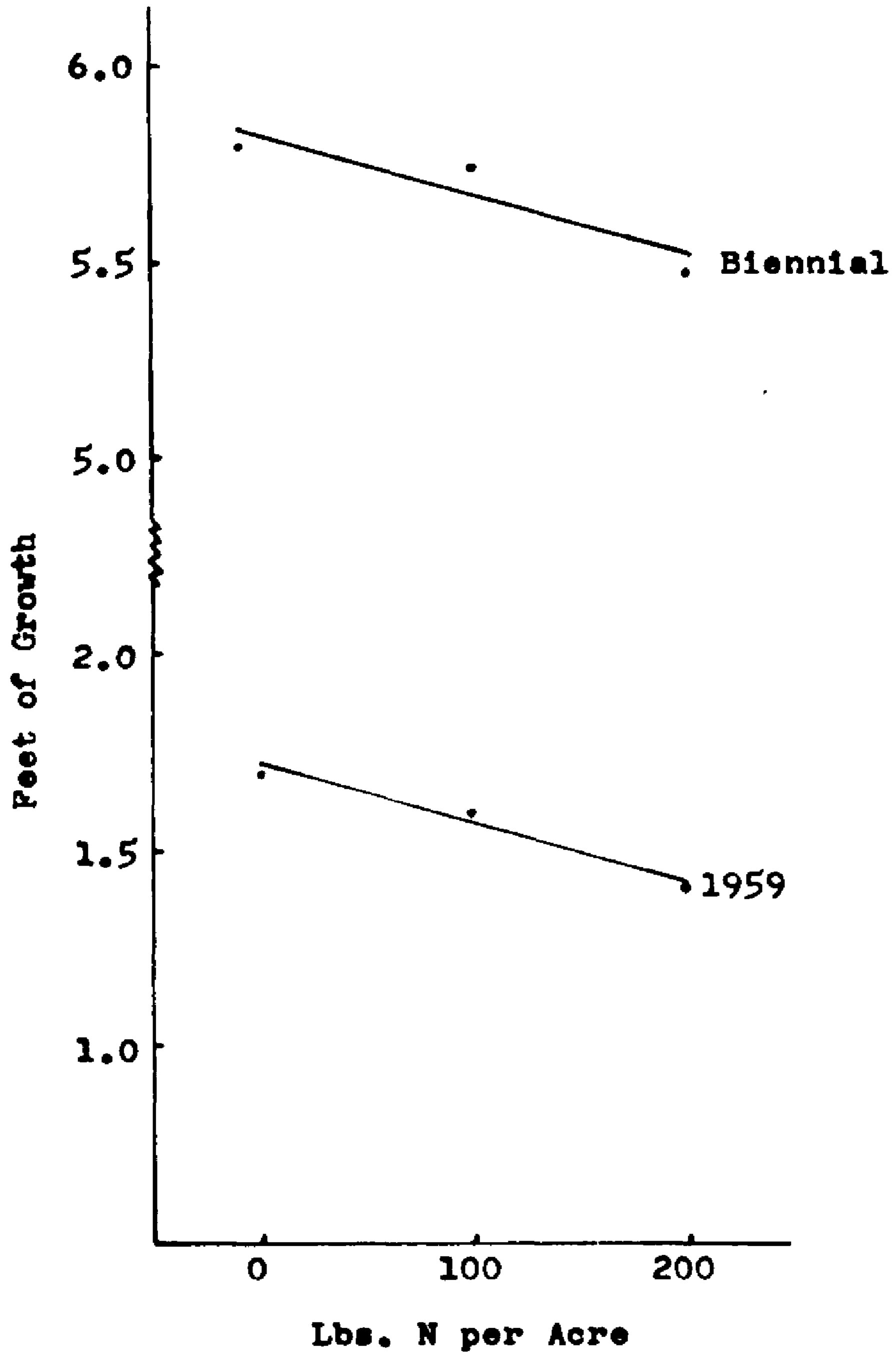

Figure 10.--The effect of nitrogen on growth of loblolly pine on Shubuta sandy loam and loamy fine sand at Homer, La.

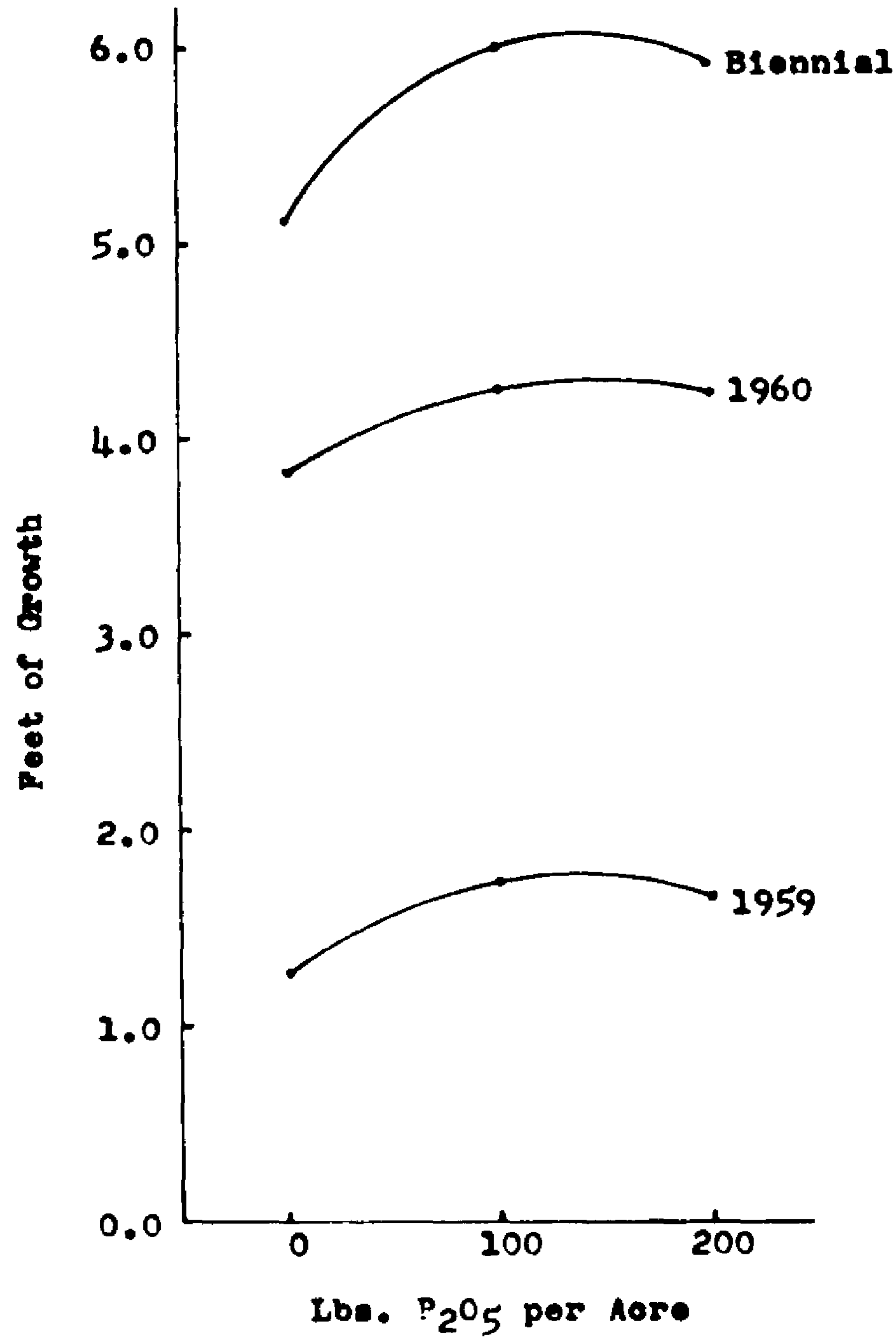

Figure 11.--The effect of phosphorus on growth of loblolly pine on Shubuta sandy loam and loamy fine sand at Homer, La.

Table 11.--Analysis of variance for 1959 growth in the Alexandria plantation.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Blocks	2	0.011049	0.005524	0.12
Treatments:				
N	2	4.224434	2.112217	67.64**
P	2	8.833221	4.416610	141.43**
K	2	0.029615	0.014807	0.47
NxP	4	2.597517	0.649379	20.80**
NxK	4	0.302207	0.075552	2.42
PxK	4	0.010034	0.002508	0.08
NxPxK	8	0.245276	0.030659	0.98
Combined error	52	1.623853	0.031228	
Total	80	17.877206		

**Significant at the 0.01 level of probability.

Table 12.--Analysis of variance for 1960 growth in the Alexandria plantation.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Blocks	2	0.032108	0.016054	0.23
Treatments:				
N	2	3.530408	1.765204	25.30**
P	2	20.267006	10.133503	145.22**
K	2	0.267526	0.133763	1.92
NxP	4	6.677848	1.669462	23.92**
NxK	4	0.433714	0.108428	1.55
PxK	4	0.196620	0.049155	0.70
NxPxK	8	0.240295	0.030037	0.43
Combined error	52	3.628657	0.069782	
Total	80	35.274182		

**Significant at the 0.01 level of probability.

two years (Table 13) in the Alexandria plantation showed the main effects and the interaction of nitrogen and phosphorus to be highly significant. When applied alone or with potash, nitrogen retarded growth. In combination with phosphorus, however, nitrogen increased growth above the growth of the unfertilized plots. In the same manner, the addition of nitrogen with phosphorus increased the beneficial effect of phosphorus. The orthogonal comparison of application rates proved the rates to be influential on growth in both linear and quadratic forms. Because the NxP interaction was significant in the analysis of variance, the influence of each element could be illustrated only at each of the three levels of the other as shown in Figures 12 through 17. The optimum growth response was obtained with a combined application of N and P at the rate of 100 pounds per acre of each, although the maximum growth over the two-year period was obtained at the 200-pound rate of each.

Growth during the first year after application of fertilizers in the Washington Parish plantation was significantly affected only by nitrogen (Table 14). The maximum growth was obtained at the rate of 100 pounds per acre (Figure 18). The beneficial effect of nitrogen application in this plantation was in direct contrast to the detrimental effect obtained at the other locations. The significant N and P interaction in the Alexandria plantation may offer a possible explanation for the diversity. It should be

Table 13.--Analysis of variance for two-year growth in the Alexandria plantation.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Blocks	2	0.007473	0.003736	0.02
Treatments:				
N	2	15.124133	7.562066	47.71**
P	2	55.794123	27.897062	176.01**
K	2	0.466180	0.233090	1.47
NxP	4	17.132639	4.283160	27.02**
NxK	4	1.370082	0.342520	2.16
PxK	4	0.249997	0.062499	0.39
NxPxK	8	0.853184	0.106648	0.67
Combined error	52	8.241995	0.158500	
Total	80	99.239806		

**Significant at the 0.01 level of probability.

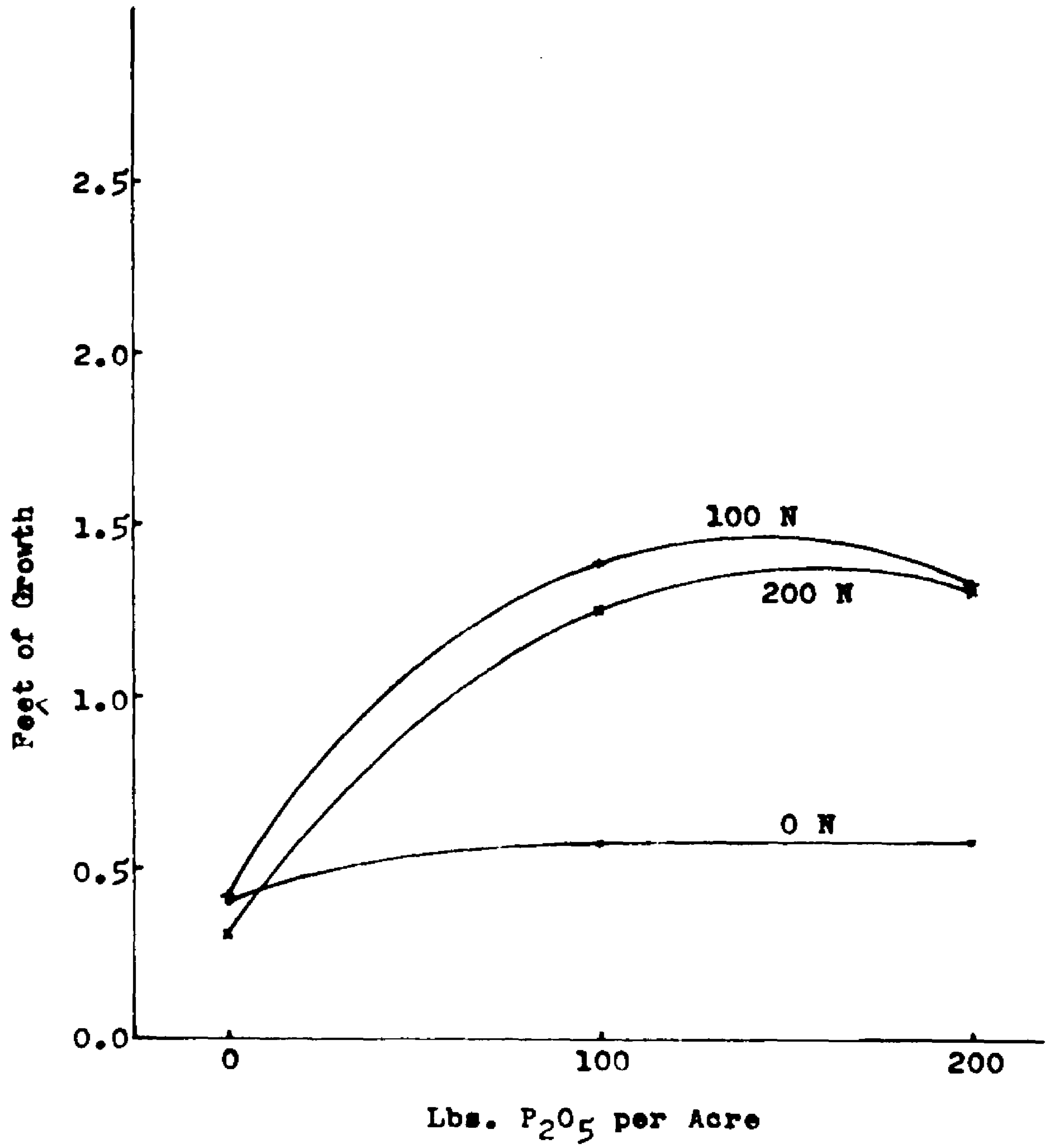

Figure 12.--Effect of phosphorus on 1959 growth of loblolly pine on Bowie fine sandy loam, Ruston loam, and Beauregard loam near Alexandria, La.

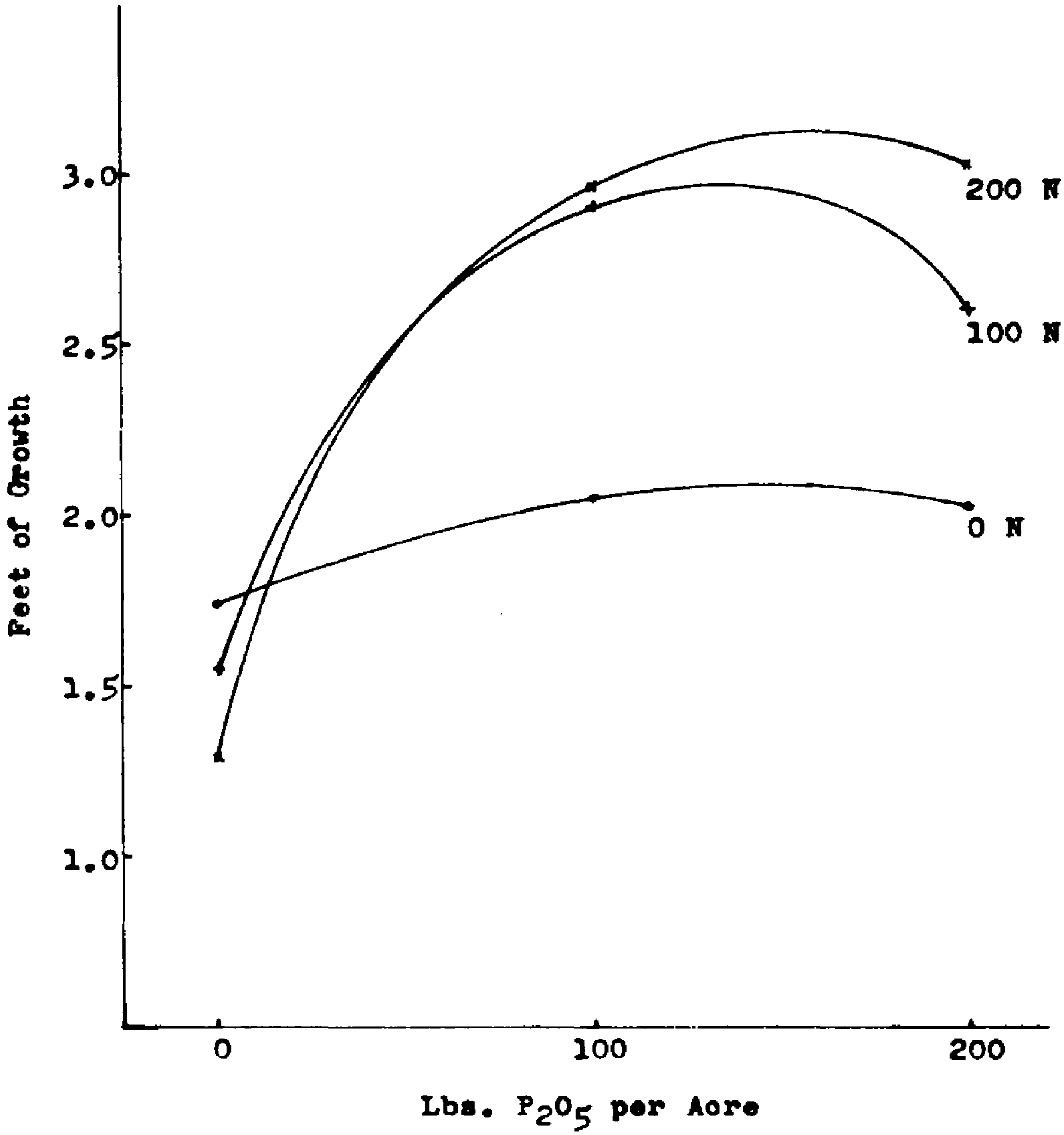

Figure 13.--Effect of phosphorus on 1960 growth of loblolly pine in the Alexandria plantation.

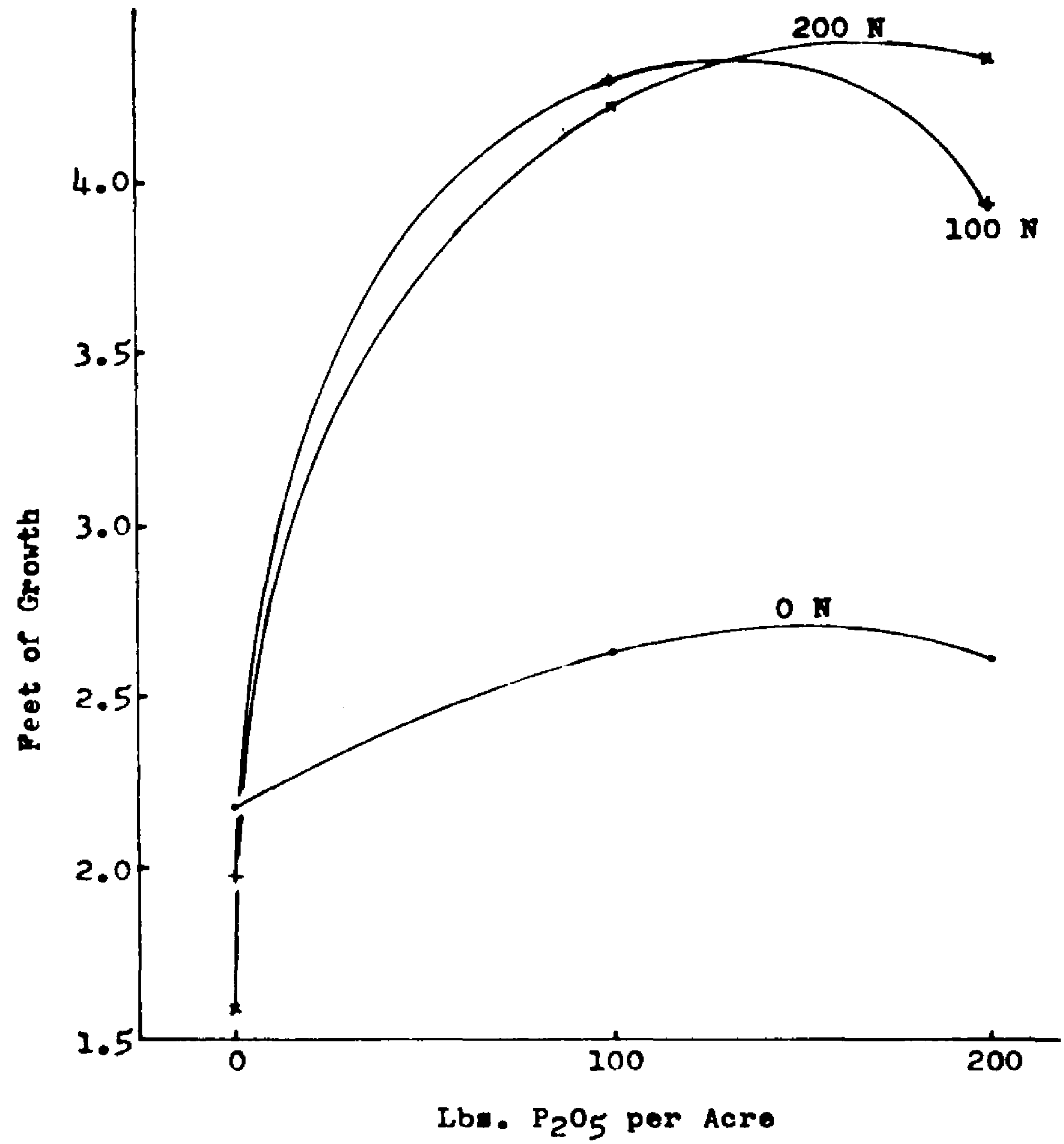

Figure 14.--Effect of phosphorus on two-year growth of loblolly pine in the Alexandria plantation.

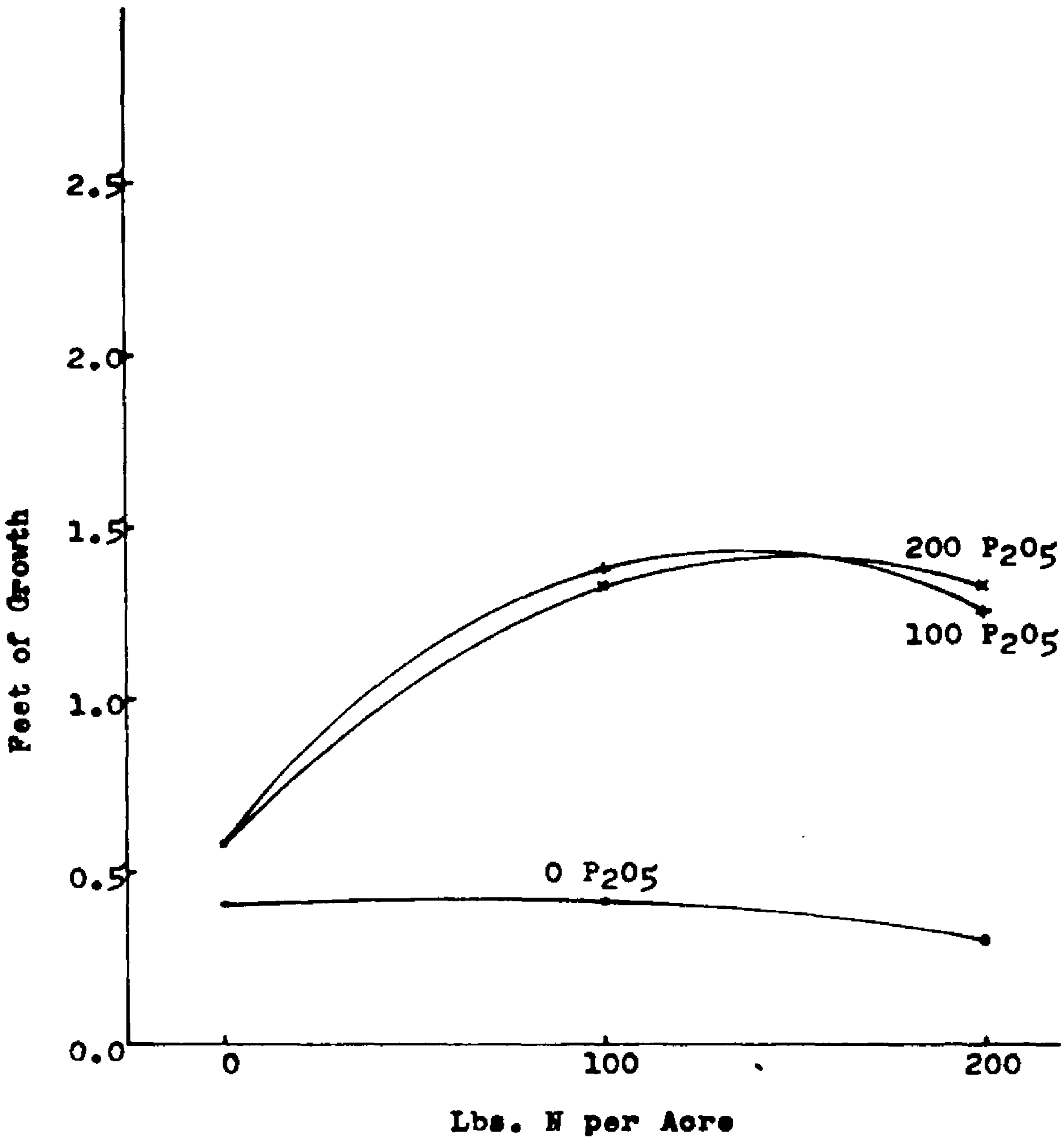

Figure 15.--Effect of nitrogen on 1959 growth of loblolly pine in the Alexandria plantation.

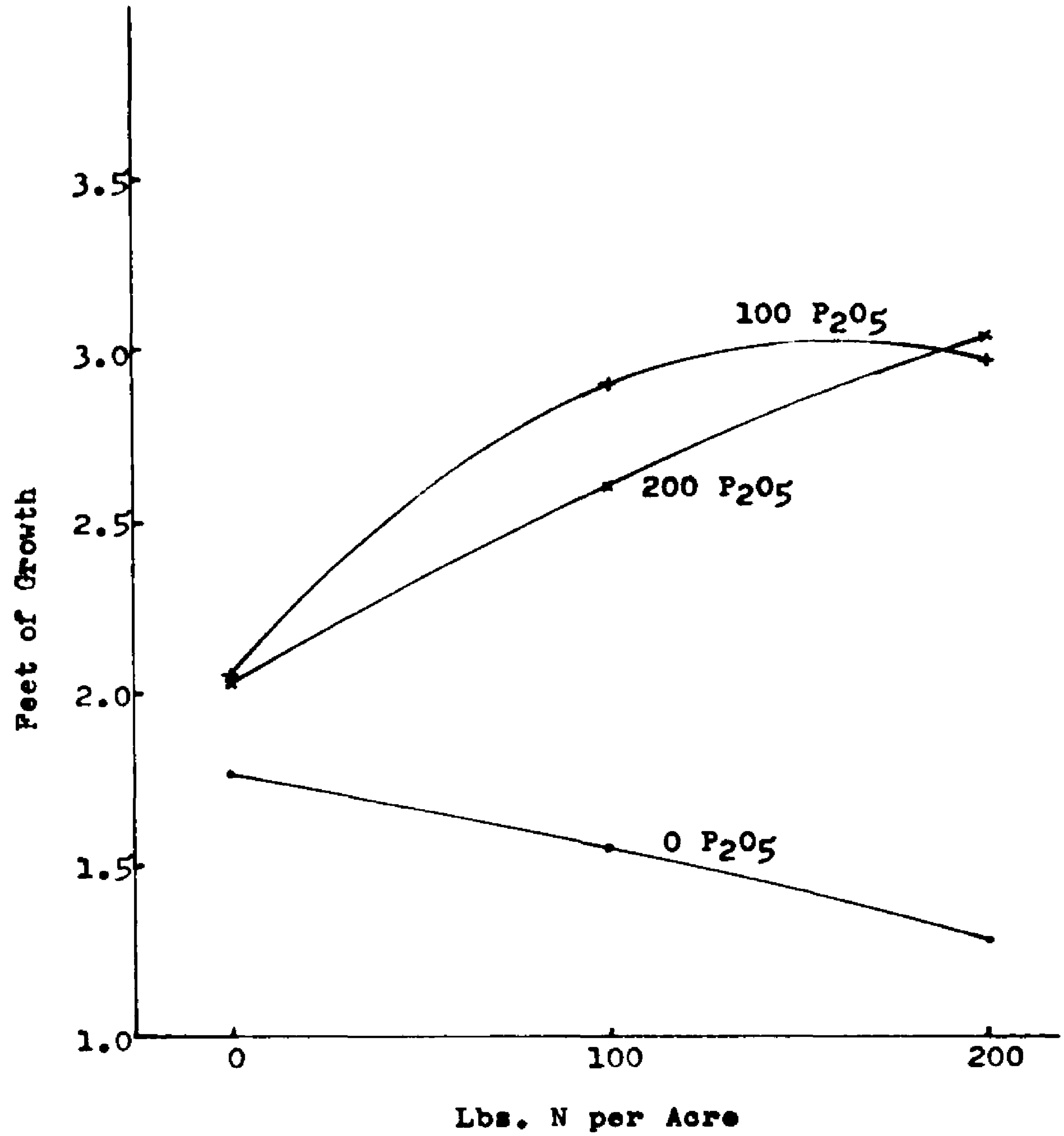

Figure 16.--Effect of nitrogen on 1960 growth of loblolly pine in the Alexandria plantation.

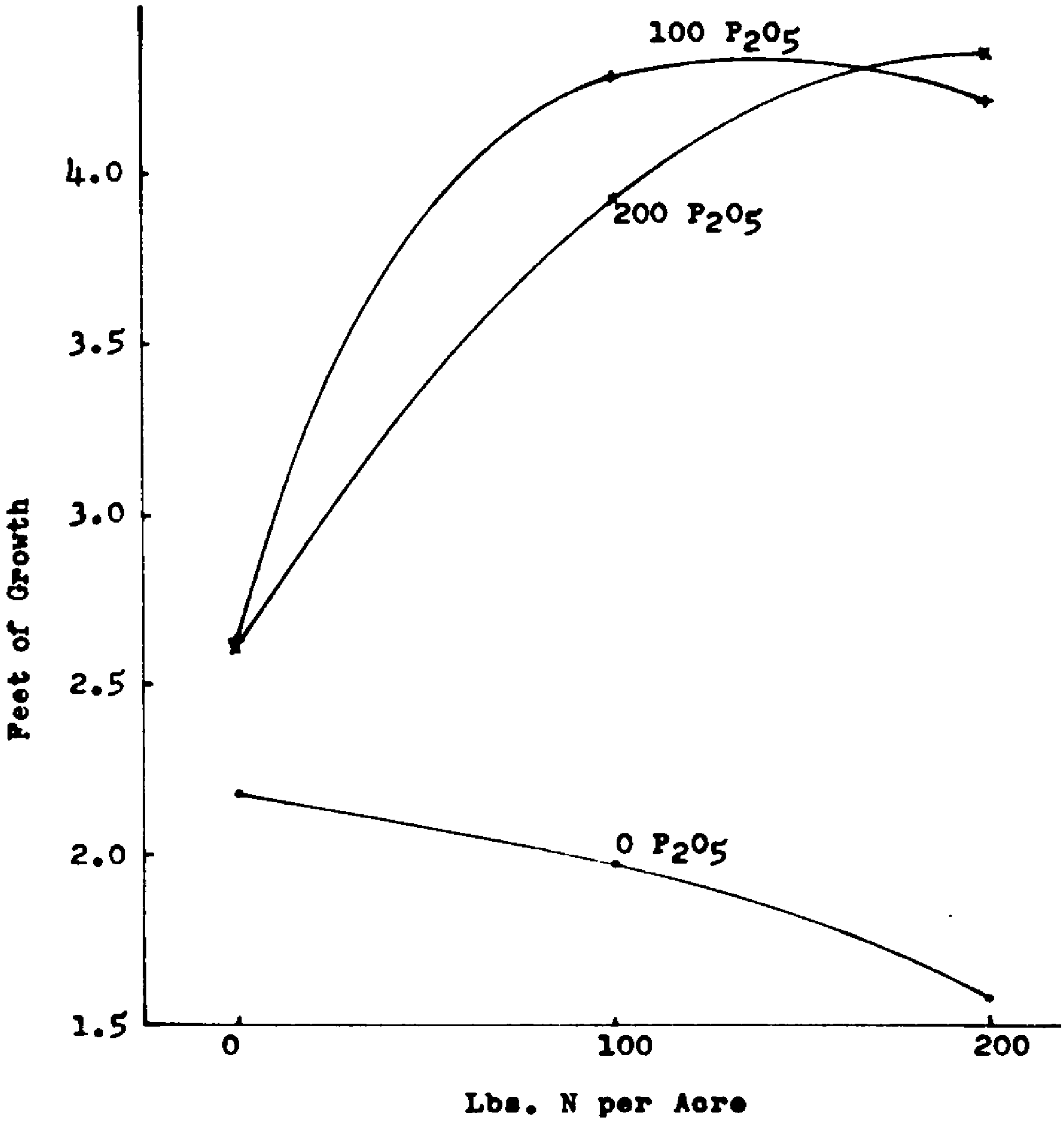

Figure 17.--Effect of nitrogen on two-year growth of loblolly pine in the Alexandria plantation.

Table 14.--Analysis of variance for 1960 growth in the Washington Parish plantation.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F
Blocks	2	1.069382	0.534691	10.45**
Treatments:				
N	2	0.426555	0.213278	4.17*
P	2	0.052603	0.026302	0.51
K	2	0.020521	0.010260	0.20
NxP	4	0.045269	0.011317	0.22
NxK	4	0.211275	0.052819	1.03
PxK	4	0.191332	0.047833	0.93
NxPxK	8	0.328926	0.041116	0.80
Combined error	52	2.660203	0.051158	
Total	80	5.006066		

*Significant at the 0.05 level of probability.
**Significant at the 0.01 level of probability.

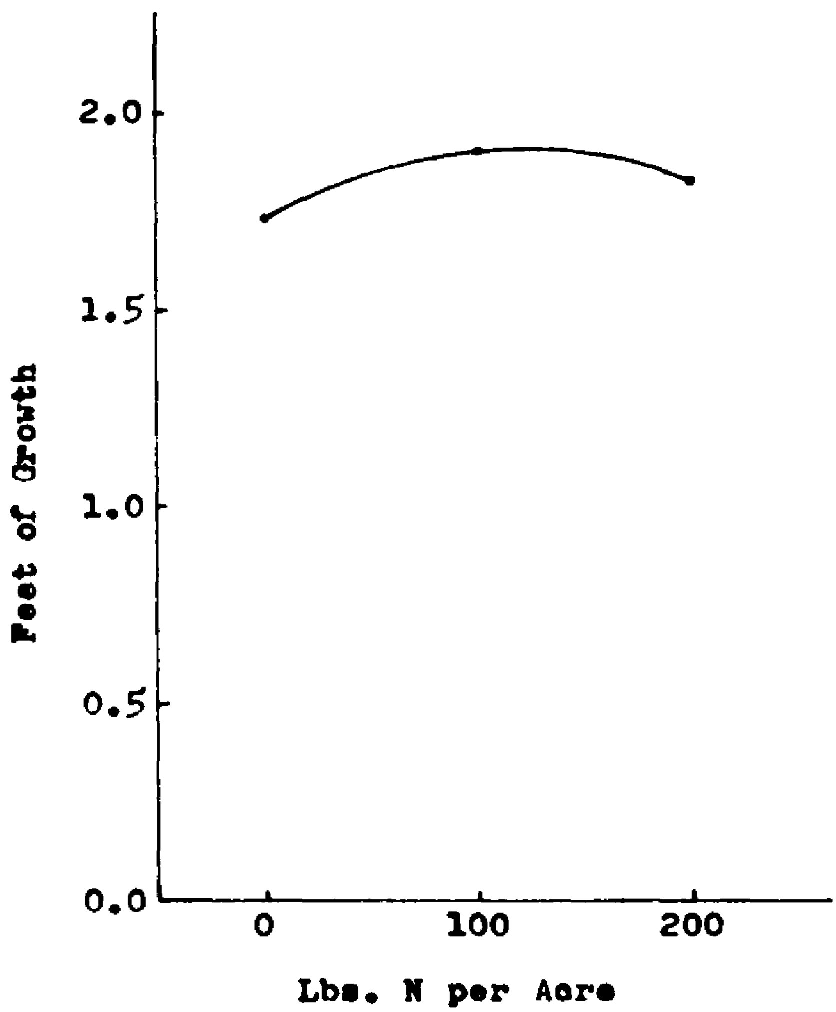

Figure 18.--Effect of nitrogen on 1960 growth of loblolly pine on Ruston sandy loam to loamy sand in the Washington Parish plantation.

recalled that samples of the topsoil from the Washington Parish plantation contained an average of 21 ppm. of available phosphorus before the fertilizers were applied. This amount of soil phosphorus may have been enough to support the increase in growth from the applied nitrogen, in which case added phosphorus was unnecessary. In the same manner, the application of more than 100 pounds per acre of P_2O_5 produced little or no increase in growth at either Alexandria or Homer. Loblolly pine may also be more capable of utilizing applied nitrogen once the root system has become well established after out-planting.

The survival rate in all three plantations was significantly reduced by nitrogen applied in the form of urea. The greater mortality in the urea-treated plots was attributed to toxicity. In the same manner, normal growth might also have been retarded by the toxic effect of the urea. Under normal temperature and soil moisture conditions, urea is rapidly hydrolized and free NH_3 may be produced in the process. In large quantities, NH_3 is usually harmful to the roots of plants. In a greenhouse study attempted by the author, young loblolly seedlings were rapidly killed by NH_3 produced very soon after the addition of relatively small amounts of urea fertilizer. An excess of ammonium salts resulting from the hydrolysis of urea might have also increased the osmotic concentration of the soil solution so that harm to the plants occurred. The manner in which the fertilizers were applied in this study undoubtedly produced

much higher salt concentrations in the vicinity of the roots than would have occurred if the fertilizers had been uniformly broadcast. Injurious effects from the application of soluble fertilizers have been noted in many of the reports covered in the review of literature section.

Muriate of potash produced no significant growth increases at either of the three locations. Woodwell (80) proposed that from 25-300 ppm. of available K was optimum for loblolly pine growth. In most plots, the soil samples contained enough available K to be well above the lower limit of this range. Slash pine responded to additions of potash only when the soil level of K_2O was below 40 ppm. (52). Very low amounts of available potassium may therefore also be sufficient to satisfy the requirements of loblolly pine.

Further research with fertilizers applied at rates below 100 pounds per acre of N and P is needed to determine what rates are optimum for loblolly pine growth under the conditions existing in Louisiana. The same amount of growth might have been obtained at lower levels of fertilizers than were used in this study.

Results of Foliar Analyses

The results of the Chemical analyses of needles collected from the Homer plantation after the 1959 and 1960 growing seasons are given in Table 15. No definite trends

Table 15.--Nutrient content of needles collected from the Homer plantation.

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(percent of oven-dry weight)				
			1959			
0- 0- 0	I	1.74	.086	.640	.282	.080
	II	1.93	.082	.378	.816	.107
	III	1.90	.054	.760	.356	.107
0- 0-100	I	1.64	.104	.640	.282	.064
	II	1.83	.113	.378	.592	.133
	III	1.96	.057	.664	.333	.093
0- 0-200	I	1.66	.076	.872	.259	.064
	II	1.83	.106	.378	.464	.133
	III	2.15	.060	.728	.311	.080
0-100- 0	I	1.79	.090	.728	.329	.064
	II	1.76	.096	.333	.616	.093
	III	2.06	.072	.792	.333	.093
0-100-100	I	1.61	.092	.752	.259	.048
	II	1.87	.100	.333	.624	.107
	III	1.76	.076	.656	.289	.093
0-100-200	I	1.88	.060	.800	.259	.048
	II	1.80	.086	.311	.680	.080
	III	2.09	.072	.544	.444	.107
0-200- 0	I	1.87	.064	.768	.235	.048
	II	2.08	.100	.311	.768	.067
	III	1.70	.082	.840	.311	.093
0-200-100	I	1.65	.048	.456	.259	.064
	II	1.91	.116	.356	.592	.080
	III	2.13	.060	.664	.422	.133
0-200-200	I	1.59	.079	.568	.235	.080
	II	1.88	.120	.333	.504	.107
	III	2.68	.058	.864	.311	.080
100- 0- 0	I	1.66	.110	.624	.188	.032
	II	1.77	.079	.356	.704	.053
	III	1.82	.084	.952	.311	.080
100- 0-100	I	1.89	.062	.552	.353	.096
	II	2.07	.077	.333	.584	.093
	III	1.75	.077	.568	.311	.147

Table 15.--(Continued)

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(Percent of oven-dry weight)				
100- 0-200	I	1.72	.079	.672	.306	.112
	II	2.74	.068	.333	.528	.093
	III	2.26	.080	.568	.378	.093
100-100- 0	I	1.61	.070	.504	.259	.064
	II	2.50	.074	.333	.696	.093
	III	1.95	.092	.680	.356	.093
100-100-100	I	1.72	.116	.512	.282	.064
	II	1.73	.123	.311	.648	.120
	III	1.87	.096	.632	.378	.107
100-100-200	I	1.75	.058	.672	.353	.080
	II	1.93	.130	.289	.560	.120
	III	1.82	.079	.784	.356	.080
100-200- 0	I	1.68	.086	.440	.329	.080
	II	2.09	.113	.378	.568	.120
	III	1.91	.106	.576	.378	.080
100-200-100	I	2.08	.057	.632	.235	.080
	II	1.78	.076	.333	.664	.120
	III	1.74	.080	.862	.356	.080
100-200-200	I	1.77	.058	.568	.259	.064
	II	1.78	.090	.356	.576	.120
	III	1.68	.104	.592	.378	.120
200- 0- 0	I	1.88	.062	.488	.282	.080
	II	1.65	.082	.311	.744	.133
	III	1.81	.072	.560	.356	.120
200- 0-100	I	2.07	.056	.568	.282	.064
	II	1.71	.086	.289	.608	.107
	III	1.85	.062	.640	.356	.080
200- 0-200	I	1.84	.060	.472	.306	.064
	II	1.75	.070	.333	.872	.120
	III	2.42	.056	.592	.311	.067
200-100- 0	I	1.82	.062	.600	.282	.064
	II	2.05	.102	.333	.640	.107
	III	1.63	.076	.648	.311	.093
200-100-100	I	1.81	.096	.480	.259	.064
	II	1.98	.077	.744	.311	.053
	III	1.79	.072	.608	.378	.093

Table 15.--(Continued)

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
			(Percent of oven-dry weight)			
200-100-200	I	1.58	.056	.576	.235	.048
	II	2.14	.086	.616	.289	.120
	III	1.83	.074	.736	.334	.067
200-200- 0	I	1.76	.060	.680	.212	.064
	II	1.74	.077	.640	.311	.107
	III	2.37	.066	.252	.356	.080
200-200-100	I	1.77	.080	.696	.235	.080
	II	1.72	.102	.688	.333	.107
	III	1.98	.068	.656	.356	.093
200-200-200	I	2.40	.102	.704	.235	.048
	II	1.75	.088	.832	.333	.080
	III	1.72	.104	.672	.333	.107
			1960			
0- 0- 0	I	1.41	.074	.560	.189	.107
	II	1.38	.116	.512	.133	.093
	III	1.40	.066	.464	.141	.095
0- 0-100	I	1.41	.088	.624	.145	.100
	II	1.40	.116	.480	.126	.093
	III	1.42	.062	.544	.148	.088
0- 0-200	I	1.39	.123	.600	.138	.089
	II	1.42	.106	.600	.131	.091
	III	1.45	.076	.552	.094	.051
0-100- 0	I	1.32	.113	.568	.145	.107
	II	1.36	.096	.544	.116	.104
	III	1.40	.070	.488	.153	.078
0-100-100	I	1.43	.113	.560	.162	.085
	II	1.35	.120	.600	.109	.093
	III	1.36	.079	.544	.141	.082
0-100-200	I	1.40	.102	.616	.153	.096
	II	1.35	.116	.568	.119	.087
	III	1.34	.077	.544	.146	.081
0-200- 0	I	1.33	.084	.544	.155	.120
	II	1.40	.106	.552	.104	.087
	III	1.35	.079	.504	.148	.086

Table 15.--(Continued)

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(Percent of oven-dry weight)				
0-200-100	I	1.41	.123	.600	.187	.088
	II	1.43	.126	.560	.128	.093
	III	1.35	.074	.544	.092	.078
0-200-200	I	1.42	.090	.576	.174	.100
	II	1.40	.120	.584	.128	.083
	III	1.25	.076	.592	.092	.054
100- 0- 0	I	1.48	.100	.528	.170	.095
	II	1.40	.120	.544	.136	.083
	III	1.38	.074	.520	.141	.050
100- 0-100	I	1.49	.079	.552	.158	.073
	II	1.43	.096	.536	.136	.083
	III	1.40	.074	.592	.122	.053
100- 0-200	I	1.49	.126	.608	.148	.083
	II	1.40	.120	.656	.114	.083
	III	1.44	.076	.560	.141	.042
100-100- 0	I	1.35	.126	.576	.153	.096
	II	1.36	.082	.504	.131	.100
	III	1.40	.070	.496	.155	.065
100-100-100	I	1.27	.106	.592	.114	.096
	II	1.39	.104	.552	.119	.096
	III	1.35	.072	.568	.092	.054
100-100-200	I	1.46	.086	.600	.145	.083
	II	1.35	.102	.616	.121	.072
	III	1.33	.074	.584	.134	.039
100-200- 0	I	1.39	.084	.600	.150	.091
	II	1.40	.100	.560	.128	.093
	III	1.45	.080	.576	.155	.065
100-200-100	I	1.41	.068	.608	.114	.080
	II	1.36	.120	.544	.121	.083
	III	1.37	.077	.584	.158	.051
100-200-200	I	1.40	.080	.592	.138	.067
	II	1.46	.123	.552	.114	.104
	III	1.41	.079	.640	.129	.050
200- 0- 0	I	1.44	.110	.528	.128	.084
	II	1.50	.110	.512	.121	.093
	III	1.39	.079	.536	.164	.058

Table 15.--(Continued)

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
			(Percent of oven-dry weight)			
200- 0-100	I	1.42	.084	.568	.109	.085
	II	1.42	.116	.600	.112	.087
	III	1.39	.077	.608	.134	.035
200- 0-200	I	1.43	.116	.584	.153	.073
	II	1.46	.077	.600	.126	.085
	III	1.45	.079	.616	.129	.055
200-100- 0	I	1.50	.104	.488	.160	.080
	II	1.44	.088	.544	.114	.091
	III	1.42	.076	.528	.155	.073
200-100-100	I	1.45	.079	.616	.153	.069
	II	1.41	.116	.592	.126	.080
	III	1.39	.080	.656	.146	.043
200-100-200	I	1.39	.086	.592	.148	.080
	II	1.42	.106	.584	.114	.073
	III	1.38	.079	.552	.141	.047
200-200- 0	I	1.40	.110	.528	.158	.113
	II	1.38	.106	.592	.126	.080
	III	1.39	.080	.544	.164	.061
200-200-100	I	1.44	.110	.624	.158	.067
	II	1.38	.104	.576	.121	.080
	III	1.45	.079	.656	.165	.046
200-200-200	I	1.41	.126	.600	.138	.071
	II	1.42	.110	.576	.116	.080
	III	1.35	.079	.672	.150	.053

in the uptake of nitrogen, phosphorus, or potassium as a result of applied fertilizers are shown in the nutrient content of the 1959 needles. Extreme variations between replications were noted. For example, potassium in needles collected from trees in the second replication was consistently lower than in the first and third replications. Calcium, on the other hand, was highest in the second replication. The nitrogen content of needles from some plots to which no nitrogen was added exceeded the nitrogen content of needles from some plots to which nitrogen was added. Nitrogen, phosphorus, potassium, and magnesium are readily translocated from old to young tissues (35), and it may well be that the needles produced during 1959 would have contained amounts of these elements which were in the foliage of the trees at the time of planting. The content of nutrient elements in 1960 foliage was generally lower than in the 1959 foliage. It should be pointed out, however, that the total amounts in the trees may have increased even though percentages decreased. The trees grew much taller and produced considerably more needles during 1960 than during 1959; so the total weight of foliage produced the second year far exceeded the weight of foliage the first year after fertilization. An increase in total dry weight of needles causes the concentration of some elements to decrease while absolute amounts are increasing (35). Differences between replications were smaller in the 1960 needle samples than in the 1959 samples, but again no trends in uptake resulting

from fertilizer applications are apparent from the percentage concentrations.

The relationship between applied fertilizers and nutrient content of the foliage collected from the Alexandria plantation is much clearer. Trees receiving applications of urea N alone or in combination with potash contained rather high percentages, 2.0 to 2.7, of nitrogen in the 1959 foliage (Table 16). The nitrogen content of needles from trees which received phosphate applications in addition to urea was somewhat lower. This difference can be explained by the larger weight of needles produced by these trees when compared to the much smaller trees which did not receive the combination of phosphorus and nitrogen fertilizers. On a total-growth basis, the amount of nitrogen may have been the same. The percentages of potassium and phosphorus also tended to increase with the application of phosphate and potash. Foliage collected after the 1960 growing season contained less nutrients on a percentage basis than did the 1959 foliage. The greater amount of needles produced by the larger trees during 1960 would cause the percentage contents to decrease while the total nutrient content may have shown little change.

A comparison of the nutrient content of needles collected from the Washington Parish plantation before the application of fertilizers with the nutrient content of needles collected after the first year of fertilization can be made from data in Table 17. Nutrient content was rather

Table 16.--Nutrient content of needles collected from the Alexandria plantation.

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(Percent of oven-dry weight)				
		1959				
0- 0- 0	I	1.62	.113	.504	.100	.152
	II	1.59	.056	.464	.282	.224
	III	1.33	.120	.528	.282	.160
0- 0-100	I	1.53	.079	.528	.090	.124
	II	1.51	.110	.568	.235	.176
	III	1.51	.102	.600	.259	.160
0- 0-200	I	1.40	.096	.560	.090	.152
	II	1.48	.084	.568	.259	.160
	III	1.46	.104	.592	.259	.128
0-100- 0	I	1.49	.102	.464	.090	.152
	II	1.42	.080	.480	.282	.224
	III	1.58	.116	.552	.235	.128
0-100-100	I	1.48	.092	.608	.090	.152
	II	1.49	.113	.544	.282	.160
	III	1.42	.074	.568	.259	.144
0-100-200	I	1.38	.102	.568	.110	.600
	II	1.39	.126	.568	.259	.160
	III	1.42	.126	.600	.259	.144
0-200- 0	I	1.32	.113	.560	.130	----
	II	1.46	.070	.552	.282	.224
	III	1.48	.136	.560	.282	.128
0-200-100	I	1.41	.113	.512	.120	.152
	II	1.35	.133	.568	.282	.224
	III	1.38	.106	.568	.282	.176
0-200-200	I	1.34	.082	.560	.110	.138
	II	1.42	.110	.552	.259	.224
	III	1.31	.126	.552	.259	.144
100- 0- 0	I	2.29	.058	.376	.090	.110
	II	2.32	.080	.432	.235	.224
	III	2.34	.044	.416	.212	.128
100- 0-100	I	2.19	.057	.504	.080	.290
	II	2.35	.066	.496	.235	.144
	III	2.12	.077	.528	.212	.112

Table 16.--(Continued)

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(Percent of oven-dry weight)				
100- 0-200	I	1.32	.066	.504	.060	.110
	II	2.11	.054	.608	.235	.128
	III	2.17	.066	.512	.212	.160
100-100- 0	I	1.67	.106	.424	1.264	.303
	II	1.62	.082	.424	.212	.160
	III	1.52	.106	.480	.259	.160
100-100-100	I	1.58	.126	.552	.110	.152
	II	1.77	.090	.528	.259	.144
	III	1.66	.140	.536	.235	.144
100-100-200	I	1.64	.100	.568	.100	.110
	II	1.54	.082	.552	.235	.160
	III	1.44	.150	.608	.259	.144
100-200- 0	I	1.76	.080	.448	.110	.110
	II	1.46	.130	.480	.259	.128
	III	1.39	.136	.560	.259	.144
100-200-100	I	1.77	.120	.528	.090	.400
	II	1.57	.136	.536	.259	.128
	III	1.80	.140	.504	.259	.144
100-200-200	I	1.47	.086	.488	.100	.138
	II	1.41	.113	.616	.259	.128
	III	1.57	.100	.616	.235	.144
200- 0- 0	I	2.66	.046	.336	.080	.083
	II	2.71	.068	.408	.212	.128
	III	2.49	.056	.416	.212	.144
200- 0-100	I	2.24	.058	.528	.080	.110
	II	2.51	.064	.552	.212	.112
	III	2.54	.070	.576	.235	.128
200- 0-200	I	2.55	.057	.504	.080	.345
	II	2.56	.077	.512	.235	.112
	III	2.54	.066	.512	.212	.048
200-100- 0	I	2.06	.113	.384	.100	.124
	II	2.39	.074	.408	.235	.112
	III	2.03	.130	.440	.259	.144
200-100-100	I	2.14	.104	.456	.100	.138
	II	1.84	.086	.480	.259	.128
	III	2.20	.140	.472	.235	.144

Table 16.--(Continued)

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(Percent of oven-dry weight)				
200-100-200	I	2.00	.088	.536	.090	.800
	II	2.23	.088	.480	.259	.128
	III	1.79	.145	.552	.259	.160
200-200- 0	I	1.80	.104	.456	.100	.179
	II	2.27	.079	.416	.259	.128
	III	2.09	.133	.448	.235	.160
200-200-100	I	2.13	.130	.472	.090	.083
	II	2.13	.145	.512	.259	.128
	III	1.91	.133	.416	.259	.176
200-200-200	I	1.86	.082	.552	.100	.096
	II	1.89	.116	.528	.235	.144
	III	1.91	.102	.480	.235	.176
			1960			
0- 0- 0	I	1.53	.080	.416	.184	.110
	II	1.47	.088	.400	.235	.124
	III	1.61	.123	.432	.235	.117
0- 0-100	I	1.56	.106	.432	.223	.120
	II	1.57	.120	.488	.165	.131
	III	1.53	.120	.424	.235	.138
0- 0-200	I	1.51	.104	.456	.193	.115
	II	1.65	.130	.464	.212	.138
	III	1.57	.116	.472	.212	.138
0-100- 0	I	1.61	.110	.472	.202	.104
	II	1.60	.133	.440	.212	.124
	III	1.61	.116	.456	.212	.124
0-100-100	I	1.51	.102	.432	.233	.131
	II	1.52	.110	.432	.235	.124
	III	1.50	.113	.416	.223	.124
0-100-200	I	1.53	.110	.440	.254	.126
	II	1.52	.102	.408	.200	.131
	III	1.61	.123	.440	.188	.110
0-200- 0	I	1.55	.116	.464	.223	.126
	II	1.50	.100	.456	.212	.138
	III	1.50	.102	.416	.223	.124

Table 16.--(Continued)

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(Percent of oven-dry weight)				
0-200-100	I	1.56	.116	.472	.235	.135
	II	1.49	.113	.448	.193	.138
	III	1.50	.106	.448	.200	.124
0-200-200	I	1.57	.102	.472	.200	.124
	II	1.55	.120	.432	.223	.145
	III	1.53	.116	.464	.188	.124
100- 0- 0	I	1.55	.096	.424	.188	.120
	II	1.51	.113	.440	.212	.138
	III	1.50	.110	.376	.165	.110
100- 0-100	I	1.46	.100	.408	.223	.120
	II	1.51	.090	.408	.235	.152
	III	1.52	.110	.416	.212	.117
100- 0-200	I	1.55	.106	.560	.202	.118
	II	1.58	.100	.448	.165	.124
	III	1.55	.110	.480	.212	.117
100-100- 0	I	1.65	.110	.360	.202	.128
	II	1.46	.120	.408	.165	.124
	III	1.42	.110	.360	.212	.124
100-100-100	I	1.52	.104	.464	.282	.141
	II	1.48	.116	.440	.188	.138
	III	1.54	.110	.448	.212	.117
100-100-200	I	1.51	.106	.448	.181	.108
	II	1.50	.090	.408	.176	.138
	III	1.45	.106	.408	.212	.131
100-200- 0	I	1.60	.106	.424	.186	.133
	II	1.46	.126	.400	.165	.131
	III	1.43	.106	.360	.212	.124
100-200-100	I	1.48	.102	.408	.165	.115
	II	1.48	.104	.424	.188	.124
	III	1.49	.110	.464	.165	.110
100-200-200	I	1.56	.106	.456	.200	.149
	II	1.47	.116	.424	.165	.124
	III	1.55	.116	.456	.165	.110
200- 0- 0	I	1.58	.113	.472	.151	.114
	II	1.53	.096	.400	.212	.131
	III	1.59	.113	.392	.200	.117

Table 16.--(Continued)

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(Percent of oven-dry weight)				
200- 0-100	I	1.52	.104	.408	.261	.146
	II	1.42	.102	.408	.188	.117
	III	1.42	.102	.400	.212	.096
200- 0-200	I	1.55	.110	.440	.188	.111
	II	1.49	.120	.416	.188	.124
	III	1.49	.104	.472	.235	.103
200-100- 0	I	1.62	.113	.456	.141	.101
	II	1.61	.126	.432	.176	.117
	III	1.55	.106	.392	.188	.110
200-100-100	I	1.57	.113	.480	.200	.112
	II	1.40	.104	.384	.176	.110
	III	1.57	.113	.480	.188	.110
200-100-200	I	1.59	.116	.528	.179	.106
	II	1.44	.113	.424	.212	.124
	III	1.44	.106	.408	.165	.117
200-200- 0	I	1.57	.113	.440	.155	.111
	II	1.60	.120	.400	.176	.131
	III	1.57	.110	.384	.212	.110
200-200-100	I	1.53	.113	.408	.200	.119
	II	1.46	.096	.432	.188	.124
	III	1.58	.106	.424	.176	.110
200-200-200	I	1.55	.110	.408	.200	.100
	II	1.56	.123	.488	.212	.138
	III	1.53	.113	.440	.176	.110

Table 17.--Nutrient content of needles collected from the Washington Parish plantation.

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(Percent of oven-dry weight)				
		1959 (Before fertilization)				
0- 0- 0	I	1.67	.116	.504	.225	.194
	II	1.64	.126	.488	.225	.142
	III	1.80	.074	.488	.110	.166
0- 0-100	I	1.69	.126	.480	.275	.168
	II	1.63	.060	.488	.225	.116
	III	1.69	.120	.504	.130	.124
0- 0-200	I	1.72	.123	.488	.225	.168
	II	1.70	.076	.536	.325	.129
	III	1.77	.086	.520	.140	.124
0-100- 0	I	1.83	.123	.488	.275	.155
	II	1.61	.140	.528	.225	.116
	III	1.76	.088	.480	.110	.110
0-100-100	I	1.72	.104	.464	.225	.155
	II	1.62	.110	.544	.250	.129
	III	1.72	.088	.504	.110	.096
0-100-200	I	1.77	.102	.480	.275	.168
	II	1.63	.110	.472	.275	.116
	III	1.70	.126	.504	.100	.096
0-200- 0	I	1.71	.116	.496	.275	.129
	II	1.64	.145	.512	.250	.129
	III	1.65	.092	.512	.110	.386
0-200-100	I	1.78	.136	.432	.225	.155
	II	1.57	.110	.464	.225	.116
	III	1.69	.086	.480	.100	.055
0-200-200	I	1.70	.090	.464	.225	.116
	II	1.68	.110	.480	.250	.142
	III	1.60	.106	.496	.120	.124
100- 0- 0	I	1.73	.120	.480	.250	.129
	II	1.65	.116	.472	.250	.142
	III	1.84	.082	.504	.110	.096
100- 0-100	I	1.75	.102	.456	.275	.155
	II	1.63	.136	.512	.250	.155
	III	1.60	.113	.544	.110	.096

Table 17.--(Continued)

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(Percent of oven-dry weight)				
100- 0-200	I	1.88	.092	.552	.225	.142
	II	1.62	.092	.544	.250	.142
	III	1.78	.130	.504	.100	.193
100-100- 0	I	1.82	.104	.464	.175	.155
	II	1.72	.110	.576	.250	.116
	III	1.71	.106	.496	.130	.096
100-100-100	I	1.77	.120	.456	.250	.129
	II	1.73	.096	.528	.275	.155
	III	1.66	.104	.512	.110	.069
100-100-200	I	1.66	.130	.464	.250	.129
	II	1.76	.145	.488	.250	.142
	III	1.73	.092	.464	.120	.179
100-200- 0	I	1.68	.140	.504	.225	.116
	II	1.68	.126	.472	.250	.142
	III	1.78	.116	.496	.110	.110
100-200-100	I	1.61	.120	.504	.250	.155
	II	1.77	.130	.520	.250	.142
	III	1.67	.092	.480	.090	.083
100-200-200	I	1.84	.100	.528	.225	.129
	II	1.63	.120	.528	.275	.142
	III	1.82	.092	.472	.070	.083
200- 0- 0	I	1.79	.116	.472	.275	.129
	II	1.71	.130	.528	.225	.129
	III	1.80	.090	.536	.110	.096
200- 0-100	I	1.78	.086	.520	.200	.129
	II	1.69	.102	.536	.300	.155
	III	1.69	.084	.480	.120	.069
200- 0-200	I	1.68	.074	.552	.275	.142
	II	1.84	.090	.568	.300	.116
	III	1.84	.120	.464	.100	.096
200-100- 0	I	1.85	.086	.496	.250	.103
	II	1.70	.088	.488	.275	.129
	III	1.70	.080	.480	.120	.124
200-100-100	I	1.65	.092	.416	.225	.116
	II	1.68	.088	.504	.275	.142
	III	1.73	.130	.488	.110	.138

Table 17.--(Continued)

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(Percent of oven-dry weight)				
200-100-200	I	1.88	.096	.536	.275	.116
	II	1.68	.092	.512	.275	.116
	III	1.72	.136	.512	.100	.138
200-200- 0	I	1.71	.110	.464	.225	.155
	II	1.72	.100	.528	.225	.129
	III	1.72	.088	.488	.110	.152
200-200-100	I	1.83	.110	.472	.300	.155
	II	1.65	.096	.496	.275	.116
	III	1.78	.088	.528	.100	.152
200-200-200	I	1.68	.106	.472	.250	.155
	II	1.71	.120	.520	.250	.142
	III	1.72	.090	.456	.100	.138
		1960 (After fertilization)				
0- 0- 0	I	1.50	.100	.440	.188	.128
	II	1.59	.102	.448	.235	.157
	III	1.61	.096	.440	.188	.128
0- 0-100	I	1.47	.106	.400	.176	.121
	II	1.62	.123	.488	.212	.143
	III	1.60	.116	.504	.212	.114
0- 0-200	I	1.45	.048	.440	.235	.136
	II	1.52	.104	.496	.212	.114
	III	1.61	.110	.504	.444	.143
0-100- 0	I	1.39	.082	.392	.188	.143
	II	1.53	.113	.440	.223	.143
	III	1.65	.110	.488	.212	.128
0-100-100	I	1.47	.106	.432	.212	.128
	II	1.63	.120	.536	.223	.128
	III	1.59	.120	.504	.200	.128
0-100-200	I	1.45	.092	.432	.212	.136
	II	1.51	.116	.512	.212	.143
	III	1.62	.116	.496	.188	.114
0-200- 0	I	1.47	.082	.440	.212	.150
	II	1.47	.104	.488	.245	.143
	III	1.60	.110	.488	.212	.128

Table 17.--(Continued)

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(Percent of oven-dry weight)				
0-200-100	I	1.58	.116	.488	.212	.143
	II	1.52	.110	.496	.235	.128
	III	1.56	.116	.496	.235	.128
0-200-200	I	1.66	.116	.496	.212	.128
	II	1.56	.116	.528	.235	.143
	III	1.59	.113	.488	.200	.114
100- 0- 0	I	1.57	.088	.352	.235	.157
	II	1.61	.106	.464	.254	.157
	III	1.71	.092	.480	.200	.114
100- 0-100	I	1.47	.072	.416	.235	.128
	II	1.64	.102	.496	.247	.143
	III	1.73	.100	.504	.200	.100
100- 0-200	I	1.54	.082	.416	.212	.128
	II	1.66	.104	.480	.212	.128
	III	1.70	.090	.488	.188	.114
100-100- 0	I	1.49	.076	.400	.223	.143
	II	1.52	.120	.512	.200	.128
	III	1.58	.116	.472	.193	.128
100-100-100	I	1.43	.088	.456	.176	.128
	II	1.54	.120	.544	.223	.114
	III	1.65	.123	.520	.188	.114
100-100-200	I	1.42	.102	.464	.200	.114
	II	1.58	.140	.600	.259	.143
	III	1.67	.120	.536	.165	.114
100-200- 0	I	1.47	.090	.440	.188	.143
	II	1.60	.123	.456	.212	.157
	III	1.68	.120	.424	.235	.143
100-200-100	I	1.43	.104	.408	.165	.136
	II	1.62	.116	.488	.198	.128
	III	1.67	.120	.528	.176	.128
100-200-200	I	1.40	.100	.432	.176	.136
	II	1.55	.120	.544	.212	.143
	III	1.60	.116	.536	.179	.128
200- 0- 0	I	1.79	.090	.408	.223	.143
	II	1.85	.086	.408	.247	.136
	III	1.77	.086	.456	.200	.128

Table 17.--(Continued)

Fertilizer Treatment	Rep. No.	N	P	K	Ca	Mg
		(Percent of oven-dry weight)				
200- 0-100	I	1.57	.084	.440	.219	.114
	II	1.65	.080	.488	.212	.128
	III	1.70	.102	.496	.212	.114
200- 0-200	I	1.55	.084	.448	.176	.128
	II	1.69	.092	.488	.212	.114
	III	1.73	.088	.480	.200	.128
200-100- 0	I	1.39	.100	.400	.188	.157
	II	1.53	.106	.432	.200	.136
	III	1.60	.102	.456	.165	.114
200-100-100	I	1.42	.080	.400	.188	.136
	II	1.55	.110	.488	.188	.128
	III	1.65	.120	.528	.165	.114
200-100-200	I	1.42	.102	.448	.165	.136
	II	1.59	.116	.488	.176	.114
	III	1.59	.110	.504	.165	.114
200-200- 0	I	1.39	.104	.400	.176	.128
	II	1.62	.110	.432	.188	.114
	III	1.75	.155	.584	.235	.157
200-200-100	I	1.37	.102	.432	.188	.128
	II	1.53	.110	.496	.165	.100
	III	1.67	.133	.504	.165	.128
200-200-200	I	1.48	.116	.448	.188	.114
	II	1.54	.113	.456	.165	.128
	III	1.68	.133	.544	.165	.100

uniform throughout the plantation both before and after fertilization. The percentages of nutrients apparently were not greatly influenced by fertilizer applications, although the nitrogen, phosphorus, and potassium tended to be somewhat higher in trees which received applications of those elements.

From the foregoing discussion it should be apparent that the total weight of needles produced by the trees should be obtained in order to calculate the total amounts of nutrients absorbed by the trees. Differences in nutrient contents influenced by fertilizer treatments might be revealed which are not evident from the percentage composition of the collected needles.

Very little work has been published on the nutrient content of current needles of loblolly pine which can be compared with the results obtained in this study. In 4-, 5-, and 8-year-old plantations, Zahner (87) found that all fertilized trees contained significantly more nitrogen in their foliage than any of the control trees at the end of the first growing season. Trees fertilized with 300 pounds of N per acre contained more foliar nitrogen than trees fertilized with only 100 pounds. After three growing seasons, the difference between the high-nitrogen treatment and the control had disappeared. In the first year, foliar phosphorus and potassium were significantly higher in trees heavily fertilized with NPK than in trees receiving lighter applications or in control trees. Current needles one year

after fertilization contained from 1.31 to 1.47 percent nitrogen as compared with 1.12 percent in unfertilized trees. Heavily fertilized trees contained 0.105 percent phosphorus and 0.566 percent potassium, compared with 0.091 percent and 0.475 percent, respectively, in control trees. According to Fowells and Krauss (24), foliar concentrations of 0.14 to 0.16 percent phosphorus and 1.7 to 2.3 percent nitrogen indicated satisfactory nutrition of loblolly pine in greenhouse studies.

The state of maturity greatly affects the nutrient content of needles. Freshly fallen needles of loblolly pine have been shown to contain from 0.31 to 0.891 percent N, 0.40 to 0.43 percent Ca, and 0.15 percent Mg (16, 41). The mature needles are much lower in nitrogen than physiologically active current needles.

Although no clear relationship was found to exist between nutrient uptake and applied fertilizers from the results of the foliar analyses, it was felt that the nutrient compositions will need to be considered in future studies. Close control of the date of sampling, crown position of the sample, and the total amount of growth obviously will have to be considered.

SUMMARY AND CONCLUSIONS

In view of the widespread interest in the use of fertilizers in Southern forestry, a study was started in 1959 to supply basic research data on the response of forest trees to the application of commercial fertilizers. The objective of the study was to discover the level of fertilization needed to supply the proper nutrition to young loblolly pine plantations for maximum growth.

Loblolly pine plantations were established at three different locations in Louisiana in order to test the effects of the fertilizers under varied climatic and soil conditions. One plantation was established on Shubuta sandy loam to loamy sand at Homer in the northern part of the state. Another was established on a complex of Bowie fine sandy loam, Ruston loam, and Beauregard loam near Alexandria in central Louisiana. The third plantation was located in the southeastern part of the state on Ruston sandy loam to loamy sand in Washington Parish.

Each plantation included 27 fertilizer treatments replicated three times in randomized blocks. The plots were 0.1-acre in size and contained 121 trees each. Urea, superphosphate, and muriate of potash were applied by hand in circular bands or in holes around the individual trees at rates equivalent to 0, 100, and 200 pounds per acre of N, P_2O_5, and K_2O.

Height measurements of the surviving trees in each plot were recorded prior to the application of fertilizers and at the end of the 1959 and 1960 growing seasons. In addition, soil samples from the A and B horizons in each plot were collected before fertilization and at the end of each growing season. Samples of needles produced during the year were collected in the early winter in 1959 and 1960. The soil samples were analyzed for total exchange capacity, base saturation, pH, organic matter, and exchangeable bases. Foliar samples were analyzed for total nitrogen, phosphorus, potassium, calcium, and magnesium.

A statistical analysis of the 1959, 1960, and total biennial growth was made by the analysis of variance method to test the effects of the fertilizer treatments.

The following conclusions may be drawn from the results of this study:

1. The fertility level of the soils involved in this study was below the level normally required for crop production.

2. Some of the applied phosphorus and potassium remained in the soil through the second year. The amount of available P and K was increased by the addition of fertilizers. The rates of increase were in proportion to the amounts applied. After the first year the available P and K remaining in the soil decreased.

3. The effects of the applied fertilizers on increasing growth were greater for the second year after application

than for the first year.

4. The complete eradication of weeds in the Homer plantation probably accounted for the average growth being 50 percent greater there than in the Alexandria plantation where weed growth was not controlled.

5. The effects of the applied nitrogen and phosphorus fertilizers varied between the three locations. In the Homer plantation, growth in 1959 and total growth were significantly retarded by nitrogen. Phosphorus significantly increased growth both years. In the Alexandria plantation, the best growth was made by trees receiving both urea and superphosphate. The phosphate alone increased growth over unfertilized trees, but nitrogen without phosphate produced less tree growth than the unfertilized trees. The 1960 growth in the Washington Parish plantation was significantly greater in plots to which urea N had been applied. The superphosphate did not increase growth above that of unfertilized trees.

6. The optimum rates of application were 100 pounds per acre of P_2O_5 at Homer, 100 pounds per acre each of N and P_2O_5 at Alexandria, and 100 pounds of N alone in Washington Parish.

7. Muriate of potash had no significant effect on growth at any of the three locations.

8. The survival rate was significantly reduced by the application of urea at every location.

9. Results of the foliar analyses were less conclusive

than expected. The percentage concentration of nutrient elements in needles remained fairly constant, with one exception. The 1959 foliage collected from plots fertilized with nitrogen at Alexandria contained over two percent nitrogen. The foliage of trees to which no nitrogen was added contained less than 1.5 percent nitrogen.

10. Additional experiments with nitrogenous and phosphatic fertilizers applied at varying rates below 100 pounds per acre of N and P_2O_5 are needed.

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APPENDIX A

SOIL PROFILE DESCRIPTIONS[1]

Location: North Louisiana Hill Farm Experiment Station, Homer, Louisiana

Shubuta loamy fine sand

A_p	0- 5"	Brown (10YR 5/3) loamy fine sand (76% sand, 19% silt, 5% clay[2]) to fine sandy loam; loose and very friable; moderate medium and coarse granular structure; contains many medium and fine roots of broomsedge and carpetgrass.
A_2	5-10"	Brown to yellowish brown (10YR 5/3-5/4) fine sandy loam (71% sand, 21% silt, 8% clay); loose and very friable but slightly firm in place; weak coarse platy structure which breaks down into moderate coarse subangular blocky structure; contains many fine roots.
B_1	10-13"	Pink (7.5YR 7/4) fine sandy loam (73% sand, 22% silt, 5% clay); slightly firm moist but loose and friable when broken down; massive to weak coarse subangular blocky structure; contains a few fine roots.
B_{21}	13-26"	Reddish brown (5YR 4/4) clay (40% sand, 9% silt, 51% clay); firm when moist; strong fine and medium subangular blocky structure, with thin patchy reddish brown clay films common; contains many fine roots.
B_{22}	26-34"	Yellowish red (5YR 4/8), mottled with yellowish brown (10YR 5/8) and very pale brown (10YR 7/4), sandy clay (49% sand, 13% silt, 38% clay); friable; strong medium

[1]A typical profile of each of the soil series included in the experimental areas was described by S. A. Lytle, Soil Scientist, L.S.U. Department of Agronomy.

[2]Mechanical analyses made by modified hydrometer method of Patrick (47).

subangular blocky structure, with common thin patchy yellowish red clay films; contains thin lenses of brownish yellow (10YR 6/6) and red (10R 4/6) sandy clay loam; contains a few fine roots.

C 34-42"+ Red (10R 4/6) heavy sandy clay stratified with thin lenses of light gray (10YR 7/2) clay and brownish yellow (10YR 6/6) sandy clay loam and sandy loam; contains a few small to large ironstone gravels and rocks.

Shubuta sandy loam

A_p 0- 5" Brown (10YR 5/3) sandy loam (66% sand, 27% silt, 7% clay); loose and very friable; weak coarse platy and moderate medium and coarse granular structure; contains a few fine roots.

A_2 5- 8" Very pale brown (10YR 7/3-7/4) fine sandy loam (65% sand, 27% silt, 8% clay); loose and friable; structureless to weak coarse granular structure; contains a few fine roots.

A_3 8-14" Very pale brown (10YR 7/3) fine sandy loam (63% sand, 29% silt, 8% clay); loose and very friable moist; structureless which breaks down into weak medium and fine granules; contains many fine roots.

B_{21} 14-21" Strong brown (7.5YR 5/6) clay loam (42% sand, 26% silt, 32% clay); slightly firm moist; strong medium subangular blocky structure with thin patchy clay films on structure particles; contains a few fine roots.

B_{22} 21-29" Yellowish brown (10YR 5/6) clay loam (39% sand, 27% silt, 34% clay), mottled 5% with red (2.5YR 4/6); slightly firm moist; moderate medium subangular blocky structure with a few thin patchy clay films; contains a few fine roots and a few small ironstone rock fragments.

B_3 29-38" Yellowish brown (10YR 5/6) clay loam (41% sand, 31% silt, 28% clay), mottled 3% with light gray (10YR 7/2) and contains 3% red (2.5YR 4/6) soft concretions; occasional thin patchy clay films; friable; weak to

moderate medium subangular blocky structure.

C	38-42"+	Red (2.5YR 4/6) sandy clay stratified with thin (1/8 to 1 inch) lenses of light gray clay and brownish yellow sandy clay loam; friable; structureless; contains a few small and large ironstone rock fragments and rocks.

Location: Johnson Tract, Kisatchie National Forest, 15 miles southwest of Alexandria, Louisiana

Bowie fine sandy loam

A_{21}	0- 5"	Pale brown (10YR 6/3) fine sandy loam (54% sand, 41% silt, 5% clay) with stains of grayish brown organic matter; friable; weak medium granular structure; gray (10YR 5/1) and grayish brown (10YR 5/2) materials in root channels and as worm casts; contains many coarse and fine roots.
A_{22}	5- 8"	Very pale brown (10YR 7/4) fine sandy loam (50% sand, 44% silt, 6% clay); slightly firm moist; structureless to weak coarse platy structure; contains many fine roots and many worm casts and root channels filled with grayish brown material; contains a few soft and hard brown concretions.
B_{21}	8-18"	Brownish yellow (10YR 6/6-6/8) clay loam (35% sand, 34% silt, 31% clay); friable; moderate medium and fine subangular blocky structure with a few thin patchy brownish yellow clay films; contains a few fine roots and 3% soft and hard brown and black concretions.
B_{22}	18-27"	Brownish yellow (10YR 6/6) loam to clay loam (39% sand, 34% silt, 27% clay); friable; weak to moderate medium subangular blocky structure; occasional thin clay films; contains a few fine roots; contains 5% strong brown (7.5YR 5/8) soft concretions and 3% rounded hard and soft brown and black concretions. This layer is more friable than the layer at 8-18 inches.
B_3	27-32"	Uniformly mottled yellowish brown (10YR 5/6) and brownish yellow (10YR 6/6) loam (38% sand, 38% silt, 24% clay); friable; weak to moderate medium subangular blocky

and weak medium platy structure; contains 3% hard brown concretions and 2% yellowish red (5YR 5/8) soft concretions; has a few thin patchy clay films on some ped surfaces.

C	32-42"+	Brownish yellow (10YR 6/8) sandy loam, mottled 10% with very pale brown (10YR 7/3); friable; structureless; contains a few thin lenses of sandy clay loam; contains 5% yellowish red (5YR 4/8) soft concretions and a few rounded hard brown concretions.

Ruston loam

A_{11}	0- 3"	Dark brown (10YR 4/3) moist, light brownish gray (10YR 6/2) dry, loam (41% sand, 49% silt, 10% clay); friable; moderate to strong medium granular structure; contains many fine and coarse roots.
A_{12}	3- 6"	Dark brown (10YR 3/3) loam; friable; moderate to strong medium granular structure; contains many small pieces of charcoal and many fine roots.
B_1	6-10"	Dark yellowish brown (10YR 4/4) loam (37% sand, 43% silt, 20% clay); somewhat firm moist; structureless which breaks down into friable weak subangular blocks; 25% worm casts filled with dark grayish brown (10YR 4/2) fine sandy loam; contains many fine roots.
B_{21}	10-18"	Yellowish red (5YR 4/8) loam to clay loam (33% sand, 40% silt, 27% clay); friable moist; moderate medium subangular blocky structure with a few thin patchy clay films; contains many fine roots and 1% hard brown concretions.
B_{22}	18-30"	Yellowish red (5YR 4/8) clay loam (32% sand, 39% silt, 29% clay); friable; moderate medium subangular blocky structure with common thin yellowish red clay films; contains 2% hard and soft brown and black concretions.
C	30-42"+	Yellowish red (5YR 4/8) sandy loam; friable; structureless; contains 1% soft brown and black concretions.

Beauregard loam

A_1	0- 4"	Dark grayish brown (10YR 4/2) moist, light brownish gray (10YR 6/2) dry, loam (42% sand, 49% silt, 9% clay); friable; strong fine and medium granular structure; contains many coarse and fine roots and 3% soft and hard small brown and black concretions.
A_2	4- 7"	Light yellowish brown (10YR 6/4) loam, mottled 20% with grayish brown (10YR 5/2) and dark brown which are fillings of worm casts; slightly firm but friable; structureless but breaks down into weak coarse granules; contains many fine roots.
B_1	7-10"	Light yellowish brown (10YR 6/4) loam (38% sand, 46% silt, 16% clay), mottled 5% with yellowish brown (10YR 5/6); friable; weak medium and coarse subangular blocky structure; common fine plant roots and a few veins of pale brown (10YR 6/3) very fine sandy loam; contains 3% soft and hard brown and black concretions.
B_2	10-18"	Pale brown (10YR 6/3) loam (32% sand, 44% silt, 24% clay), mottled 10% with light yellowish brown (10YR 6/4) and yellowish brown (10YR 5/8); friable; moderate medium subangular blocky structure; contains many fine roots and root channels filled with light brownish gray (10YR 6/2) and pale brown (10YR 6/3) very fine sandy loam.
B_3	18-28"	Yellowish brown (10YR 5/4) loam (33% sand, 47% silt, 20% clay), mottled 20% with light brownish gray (10YR 6/2); friable; weak medium subangular blocky structure; contains many vertical veins of light brownish gray very fine sandy loam, mottled 5% with strong brown (7.5YR 5/8) and yellowish red (5YR 4/6) which appears to be weak concretions.
C	28-42"+	Mottled light yellowish brown (10YR 6/4) and light gray (10YR 7/2) very fine sandy loam; structureless; friable; contains 5% brown and black soft and hard concretions and yellowish brown (10YR 5/8) soft concretions.

Location: Lee Memorial Forest, Washington Parish, Louisiana

Ruston sandy loam

A_p	0- 8"	Dark grayish brown (10YR 4/2) moist, brown (10YR 5/3) dry, sandy loam (66% sand, 28% silt, 6% clay); friable; moderate medium and coarse granular structure; contains many fine and coarse roots.
B_1	8-12"	Dark brown (7.5YR 4/4) moist loam (46% sand, 41% silt, 13% clay); firm; massive; contains a few fine roots.
B_{21}	12-18"	Yellowish red (5YR 4/8) loam (41% sand, 35% silt, 24% clay); friable; weak to moderate medium subangular blocky structure; contains many fine roots and a few thin patchy clay films.
B_{22}	18-34"	Yellowish red (5YR 4/8) sandy loam to sandy clay loam (61% sand, 20% silt, 19% clay); friable; moderate fine and medium subangular blocky structure; numerous fine roots; contains many thin patchy clay films.
C	34-44"+	Reddish brown (5YR 4/4) sandy loam; friable; loose.

Variations:

1. A small area of Ruston sandy clay loam, eroded phase, occurs on the southwestern edge of the area on slopes of 8 to 12%.
2. Small areas of slopes above 8% in the western and northwestern part of the area have a loamy sand surface layer.
3. Small areas in the north central part of the area on a 2% slope have a strong brown (7.5YR 5/8) subsoil.
4. Small areas in the northeastern part of the area have a heavy sandy clay substratum with ironstones at below 36 inches and approaches Ruston sandy loam, hard substratum phase.
5. The B_2 horizon is usually underlain at 30 inches or less by sandy loam or sand.
6. The greater part of the area ranges from 2 to 5 percent in slope.
7. No A_3 layer was observed because this area is in an old cultivated field.
8. In a few places, where underlain by sandy clays, the B_2 horizon extended to depths of 36 inches.
9. A few spots contained enough silt to have a silty clay loam B horizon and resembled Lexington.

APPENDIX B

CHEMICAL ANALYSIS OF SOIL TYPE PROFILES

Location	Soil Series and Type	Horizon	Depth (in.)	Organic Matter (%)	pH	P (ppm.)	K (ppm.)	Ca (ppm.)	Mg (ppm.)	Na (ppm.)	Exchangeable H^+ (me./100 g.)	Cation Exchange Capacity (me./100 g.)	% Base Saturation
Homer	Shubuta loamy fine sand	A_p	0- 5	.962	6.2	11	35	259	71	17	1.182	3.196	63.0
		A_2	5-10	.808	5.4	5	22	130	25	17	1.773	2.761	35.8
		B_1	10-13	.349	5.3	3	22	130	38	22	1.116	2.235	50.1
		B_{21}	13-26	.766	4.9	3	91	346	380	26	8.865	14.108	37.2
		B_{22}	26-34	.328	5.0	2	65	130	263	30	9.325	12.464	25.2
Homer	Shubuta sandy loam	A_p	0- 5	.584	5.3	7	22	130	38	22	1.510	2.629	42.6
		A_2	5- 8	.300	5.4	3	13	130	25	22	.657	1.644	60.0
		A_3	8-14	.194	5.8	1	13	130	25	22	.394	1.381	71.5
		B_{21}	14-21	.430	6.2	3	65	734	372	35	2.364	9.453	75.0
		B_{22}	21-29	.311	5.2	3	69	432	380	35	3.612	9.268	61.0
		B_3	29-38	.263	5.1	3	73	302	343	30	4.400	9.085	51.6
Alexandria	Bowie fine sandy loam	A_{21}	0- 5	1.771	5.8	3	30	216	60	26	1.839	3.609	49.0
		A_{22}	5- 8	1.042	5.8	3	22	216	60	22	1.051	2.783	62.2
		B_{21}	8-18	.509	5.0	6	26	173	175	30	4.597	7.117	35.4
		B_{22}	18-27	.218	5.1	5	26	130	85	22	4.859	6.380	23.8
		B_3	27-32	.150	5.1	2	22	130	85	22	3.874	5.384	28.0

Location	Soil Series and Type	Horizon	Depth (in.)	Organic Matter (%)	pH	P (ppm.)	K (ppm.)	Ca (ppm.)	Mg (ppm.)	Na (ppm.)	Exchangeable H^+ (me./100 g.)	Cation Exchange Capacity (me./100 g.)	% Base Saturation
Alexandria	Ruston loam	A_{11} A_{12}	0- 3 3- 6	2.277	5.8	3	56	389	120	22	2.495	5.680	56.1
		B_1	6-10	.715	5.7	3	56	302	138	26	1.707	4.624	63.1
		B_{21}	10-18	.339	5.3	3	39	216	184	26	2.824	5.650	50.0
		B_{22}	18-30	.222	5.2	5	43	130	195	26	4.137	6.635	37.6
Alexandria	Beauregard loam	A_1 A_2	0- 4 4- 7	2.058	5.2	6	22	216	112	48	3.283	5.561	41.0
		B_1	7-10	.497	5.2	3	13	130	90	30	3.218	4.781	32.7
		B_2	10-18	.474	5.0	1	22	130	108	30	5.713	7.449	23.3
		B_3	18-28	.389	5.2	1	26	130	108	35	4.794	6.563	27.0
Washington Parish	Ruston sandy loam	A_p	0- 8	1.631	5.8	10	17	259	38	86	2.167	4.197	48.4
		B_1	8-12	.597	6.0	3	26	302	85	30	1.379	3.794	63.7
		B_{21}	12-18	.292	5.5	3	30	346	210	39	2.364	6.091	61.2
		B_{22}	18-34	.101	5.0	3	17	130	102	30	2.758	4.432	37.8
		C	34-44+	.101	5.3	6	22	130	97	30	2.495	4.139	39.7

APPENDIX C

MEAN MONTHLY TEMPERATURES AND TOTAL MONTHLY PRECIPITATION*

Month	Homer Exp. Station[1] Temp., °F 1959	Homer Exp. Station[1] Temp., °F 1960	Homer Exp. Station[1] Prec., in. 1959	Homer Exp. Station[1] Prec., in. 1960	Hineston[2] Temp., °F 1959	Hineston[2] Temp., °F 1960	Hineston[2] Prec., in. 1959	Hineston[2] Prec., in. 1960	Sheridan Fire Tower[3] Prec., in. 1959	Sheridan Fire Tower[3] Prec., in. 1960
January	44.3	44.1	1.56	3.76	45.2	46.2	4.14	6.40	6.00	4.38
February	50.9	42.5	4.68	4.10	51.4	45.5	6.06	5.56	7.12	6.26
March	55.6	45.8	4.59	3.03	54.7	50.2	2.50	4.82	3.03	2.73
April	63.4	65.0	4.30	2.67	63.2	65.9	6.71	1.59	5.91	3.34
May	74.6	68.7	6.05	3.51	74.3	70.5	6.47	2.70	11.59	3.44
June	77.1	76.8	7.37	5.60	78.4	79.5	2.20	2.90	9.04	1.18
July	79.5	80.1	5.66	1.88	80.8	82.5	4.26	5.17	10.96	6.80
August	79.5	80.9	3.17	5.93	80.7	79.7	3.38	11.98	5.37	16.75
September	75.4	76.5	3.65	1.23	77.1	76.0	1.64	4.26	3.29	1.94
October	65.3	67.3	1.87	4.09	68.4	68.9	3.85	6.37	8.71	1.78
November	50.9	56.0	2.24	4.27	52.2	57.9	1.68	1.78	3.63	.91
December	48.9	44.1	5.12	10.14	48.9	46.6	5.63	8.10	2.87	4.85
Annual	63.8	62.3	50.26	50.21	64.6	64.2	48.52	61.63	77.52	54.36

*From: U. S. Dept. of Commerce, Climatological Data--Louisiana (66, 67).

[1]At 32°45'N latitude, 93°04'W longitude.

[2]At 31°11'N latitude, 92°45'W longitude, approximately 4.5 miles west, southwest of Alexandria plantation.

[3]At 30°51'N latitude, 89°59'W longitude, approximately 0.5 mile south, southeast of Washington Parish plantation. No temperature records maintained at this station.

APPENDIX D

RESULTS OF CHEMICAL ANALYSES OF SOIL SAMPLES

Plot No.[1]	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period[2]	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
			Homer Plantation					
I- 1 A	0- 0- 0	1	7	39	130	25	43	6.0
		2	10	30	151	19	48	6.0
		3	10	27	317	38	32	5.6
I- 2 A	0- 0-100	1	4	50	173	49	39	5.9
		2	7	95	173	43	48	5.8
		3	6	82	272	71	23	5.5
I- 3 A	0- 0-200	1	4	41	194	203	39	5.7
		2	6	112	151	25	48	5.7
		3	9	73	136	60	18	5.5
I- 4 A	0-100- 0	1	6	39	151	60	35	5.9
		2	260	22	216	32	43	6.1
		3	84	18	181	38	18	5.5
I- 5 A	0-100-100	1	5	36	108	49	35	5.9
		2	192	65	194	13	52	6.1
		3	292	36	272	25	23	5.6
I- 6 A	0-100-200	1	4	50	151	38	48	5.8
		2	99	130	130	---	56	6.1
		3	99	41	181	38	23	5.6
I- 7 A	0-200- 0	1	6	44	173	85	35	6.0
		2	391	26	238	38	48	6.0
		3	318	32	317	60	23	5.6
I- 8 A	0-200-100	1	6	38	151	25	35	6.0
		2	217	52	151	13	48	6.0
		3	292	45	272	38	23	5.7

[1]Roman numeral = block; arabic number = fertilizer treatment; A = A horizon (topsoil); B = B horizon (subsoil).

[2]Period 1 = before fertilization; period 2 = end of 1959 growing season; period 3 = end of 1960 growing season.

Plot No.	Fertilizer Treatment, N-P_2O_5-K_2O (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
I- 9 A	0-200-200	1	6	41	151	25	35	6.1
		2	285	91	281	38	48	6.1
		3	406	54	499	49	23	5.8
I-10 A	100- 0- 0	1	4	41	151	38	112	6.1
		2	9	30	130	---	52	5.4
		3	9	23	136	25	18	5.2
I-11 A	100- 0-100	1	5	38	130	13	35	5.9
		2	6	86	130	13	48	5.0
		3	8	54	136	38	23	5.3
I-12 A	100- 0-200	1	6	38	151	13	30	6.1
		2	6	134	173	32	52	5.0
		3	14	82	136	38	27	5.4
I-13 A	100-100- 0	1	4	42	130	49	35	5.9
		2	129	22	108	13	43	5.2
		3	72	18	136	38	27	5.1
I-14 A	100-100-100	1	3	39	130	13	39	6.1
		2	248	73	173	25	48	5.9
		3	69	41	181	71	27	5.7
I-15 A	100-100-200	1	5	42	130	49	35	5.9
		2	161	104	108	13	52	5.5
		3	83	32	136	38	27	5.4
I-16 A	100-200- 0	1	5	53	238	25	108	6.0
		2	248	35	194	49	43	5.7
		3	318	27	317	85	23	5.6
I-17 A	100-200-100	1	6	35	130	38	35	6.1
		2	180	73	151	25	48	5.8
		3	172	50	317	49	27	5.4
I-18 A	100-200-200	1	6	35	130	55	35	5.9
		2	284	82	216	13	48	5.7
		3	103	41	136	38	23	5.4
I-19 A	200- 0- 0	1	5	45	151	49	35	6.0
		2	8	43	151	60	48	4.9
		3	10	32	136	43	18	5.2
I-20 A	200- 0-100	1	6	53	194	97	35	5.7
		2	9	112	151	55	48	5.0
		3	11	68	136	60	23	5.2

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
I-21 A	200- 0-200	1	5	38	130	38	35	6.1
		2	5	143	130	---	48	4.9
		3	6	54	317	32	23	5.1
I-22 A	200-100- 0	1	6	39	173	38	35	6.0
		2	198	35	216	38	48	5.2
		3	129	23	136	25	27	5.4
I-23 A	200-100-100	1	5	35	151	25	35	5.8
		2	155	69	151	25	52	5.2
		3	100	41	181	25	23	5.2
I-24 A	200-100-200	1	7	41	130	13	35	5.8
		2	304	143	259	32	52	5.1
		3	154	54	181	32	27	5.2
I-25 A	200-200- 0	1	6	41	130	13	35	6.1
		2	291	30	151	13	48	5.2
		3	267	32	227	38	32	5.4
I-26 A	200-200-100	1	6	36	130	13	39	5.9
		2	298	78	194	13	52	5.3
		3	254	36	227	25	27	5.3
I-27 A	200-200-200	1	5	32	151	13	39	5.7
		2	248	99	151	--	48	5.4
		3	169	41	136	25	27	5.4
II- 1 A	0- 0- 0	1	5	45	173	38	43	5.9
		2	6	35	151	25	48	5.7
		3	7	36	181	60	27	5.6
II- 2 A	0- 0-100	1	4	33	151	71	35	5.4
		2	4	73	130	55	52	5.4
		3	6	73	136	60	23	5.4
II- 3 A	0- 0-200	1	5	39	130	41	39	5.6
		2	7	130	130	13	52	5.2
		3	7	63	136	49	27	5.5
II- 4 A	0-100- 0	1	6	44	130	40	39	5.6
		2	109	26	151	32	52	5.8
		3	123	32	227	60	27	5.7
II- 5 A	0-100-100	1	5	45	151	40	35	5.5
		2	192	86	173	19	48	5.8
		3	120	54	317	60	32	5.6

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.)					pH
			P	K	Ca	Mg	Na	
II- 6 A	0-100-200	1	5	45	194	55	35	6.0
		2	186	160	216	49	52	5.7
		3	84	82	181	49	27	5.8
II- 7 A	0-200- 0	1	4	41	151	49	39	5.7
		2	182	35	238	60	52	6.3
		3	267	32	317	49	27	5.8
II- 8 A	0-200-100	1	4	44	194	75	39	5.5
		2	298	78	216	32	48	6.0
		3	132	50	227	71	32	5.7
II- 9 A	0-200-200	1	6	39	151	25	43	5.7
		2	198	168	173	32	52	5.9
		3	273	68	272	60	27	5.7
II-10 A	100- 0- 0	1	6	41	86	49	39	5.6
		2	8	30	108	25	48	4.8
		3	13	32	136	49	27	5.2
II-11 A	100- 0-100	1	6	38	130	38	30	5.9
		2	6	91	108	--	48	4.9
		3	9	54	136	49	27	5.4
II-12 A	100- 0-200	1	6	36	130	19	30	5.8
		2	8	138	108	13	48	4.8
		3	8	54	136	38	27	5.4
II-13 A	100-100- 0	1	6	26	108	32	30	5.5
		2	275	17	173	38	43	5.2
		3	132	32	272	60	27	5.3
II-14 A	100-100-100	1	5	38	173	78	43	5.7
		2	121	95	324	55	26	5.2
		3	67	59	181	60	23	5.4
II-15 A	100-100-200	1	4	23	86	25	39	5.6
		2	115	104	130	7	26	5.0
		3	96	59	227	38	27	5.3
II-16 A	100-200- 0	1	4	38	151	49	35	5.7
		2	233	26	238	67	26	5.3
		3	172	32	363	49	32	5.3
II-17 A	100-200-100	1	5	39	130	29	30	5.7
		2	---	---	---	--	--	---
		3	337	50	408	49	23	5.5

Plot No.	Fertilizer Treatment, N-P2O5-K2O (lbs./acre)	Sample Period	Available Nutrient Content (ppm.)					pH
			P	K	Ca	Mg	Na	
II-18 A	100-200-200	1	4	41	173	85	39	5.4
		2	309	121	238	67	26	5.4
		3	149	68	272	13	27	5.5
II-19 A	200- 0- 0	1	4	30	108	38	30	5.7
		2	68	26	130	25	26	4.7
		3	6	32	136	25	18	5.2
II-20-A	200- 0-100	1	5	36	151	60	39	5.5
		2	71	104	173	43	26	4.6
		3	6	73	136	38	23	5.2
II-21 A	200- 0-200	1	3	35	130	49	35	5.4
		2	53	134	151	38	26	4.6
		3	6	82	408	49	23	5.2
II-22 A	200-100- 0	1	4	42	173	52	35	5.6
		2	126	26	216	25	22	5.3
		3	54	27	136	38	23	5.3
II-23 A	200-100-100	1	5	36	108	62	39	5.2
		2	161	95	173	43	22	4.9
		3	89	41	136	25	23	5.1
II-24 A	200-100-200	1	5	36	108	19	39	5.3
		2	161	117	108	19	26	4.7
		3	113	54	136	38	27	5.1
II-25 A	200-200- 0	1	6	50	130	30	39	5.5
		2	150	35	151	49	22	4.6
		3	143	36	136	13	27	5.1
II-26 A	200-200-100	1	4	26	86	19	39	5.4
		2	233	69	173	25	26	4.9
		3	200	32	181	13	23	5.1
II-27 A	200-200-200	1	5	47	173	80	39	5.8
		2	368	130	238	13	26	5.2
		3	286	50	317	13	27	5.5
III- 1 A	0- 0- 0	1	6	32	130	51	43	5.3
		2	62	30	194	38	26	5.2
		3	12	32	408	25	32	5.2
III- 2 A	0- 0-100	1	5	33	130	15	52	5.6
		2	62	99	130	13	26	5.2
		3	6	59	136	13	27	5.4

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
III- 3 A	0- 0-200	1	4	33	86	50	35	5.1
		2	62	151	108	38	30	4.9
		3	20	77	227	60	32	5.4
III- 4 A	0-100- 0	1	9	20	605	13	35	6.6
		2	93	17	194	25	26	6.8
		3	107	27	181	49	32	5.2
III- 5 A	0-100-100	1	5	33	194	49	35	5.7
		2	140	86	173	25	26	5.9
		3	88	50	181	60	27	5.7
III- 6 A	0-100-200	1	6	23	216	25	43	5.9
		2	144	99	324	19	26	6.3
		3	74	54	453	60	32	6.1
III- 7 A	0-200- 0	1	6	30	238	13	30	5.9
		2	222	26	173	13	26	5.8
		3	197	27	227	60	32	5.6
III- 8 A	0-200-100	1	5	39	130	38	35	5.7
		2	254	104	194	32	26	5.6
		3	406	63	408	71	32	5.5
III- 9 A	0-200-200	1	4	30	108	19	30	5.9
		2	228	99	173	19	26	5.9
		3	200	50	499	60	32	5.7
III-10 A	100- 0- 0	1	5	26	108	13	30	5.9
		2	73	17	130	19	22	4.9
		3	6	32	136	38	32	5.2
III-11 A	100- 0-100	1	3	35	194	49	35	5.8
		2	---	---	---	--	--	---
		3	7	68	272	60	32	5.2
III-12 A	100- 0-200	1	4	30	108	38	30	5.9
		2	---	---	---	--	--	---
		3	6	63	181	60	36	5.2
III-13 A	100-100- 0	1	8	26	108	25	35	5.7
		2	161	22	173	49	26	5.1
		3	132	27	272	49	32	5.3
III-14 A	100-100-100	1	6	35	108	25	35	5.8
		2	602	73	86	43	22	4.9
		3	109	50	227	60	32	5.2

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
III-15 A	100-100-200	1	4	30	108	32	35	5.8
		2	133	130	130	25	26	5.0
		3	136	50	272	49	32	5.3
III-16 A	100-200- 0	1	6	48	151	38	35	6.0
		2	---	---	---	--	--	---
		3	126	32	181	49	27	5.2
III-17 A	100-200-100	1	4	30	151	32	35	6.0
		2	195	73	151	38	26	5.0
		3	126	50	227	49	32	5.3
III-18 A	100-200-200	1	7	43	108	38	30	5.7
		2	228	125	130	43	26	5.0
		3	160	68	317	38	32	5.2
III-19 A	200- 0- 0	1	5	26	86	19	35	5.8
		2	70	26	130	38	26	4.8
		3	8	23	317	43	32	5.1
III-20 A	200- 0-100	1	5	30	108	13	35	6.0
		2	63	69	108	25	26	4.7
		3	6	50	136	38	27	5.1
III-21 A	200- 0-200	1	4	30	108	25	35	5.9
		2	58	143	108	25	26	4.8
		3	4	73	136	38	32	5.2
III-22 A	200-100- 0	1	4	39	130	25	35	5.7
		2	190	35	238	55	26	4.8
		3	89	32	136	38	32	5.0
III-23 A	200-100-100	1	7	43	130	13	39	6.0
		2	121	99	151	25	22	5.0
		3	172	50	181	49	36	5.2
III-24 A	200-100-200	1	5	30	108	38	35	5.7
		2	135	147	194	43	30	4.8
		3	149	41	136	38	36	5.1
III-25 A	200-200- 0	1	5	30	130	25	35	5.8
		2	288	35	216	49	22	4.9
		3	381	27	317	49	41	5.1
III-26 A	200-200-100	1	7	43	173	38	39	5.8
		2	195	95	259	60	22	4.8
		3	180	54	181	60	36	5.2

Plot No.	Fertilizer Treatment, N-P2O5-K2O (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
III-27 A	200-200-200	1	7	52	173	38	35	5.9
		2	165	147	194	38	26	5.0
		3	254	77	227	49	41	5.4
I- 1 B	0- 0- 0	1	2	59	367	203	39	5.7
		2	-	--	---	---	--	---
		3	6	32	136	49	41	5.8
I- 2 B	0- 0-100	1	2	76	324	328	39	5.1
		2	18	95	324	358	26	4.9
		3	7	68	181	97	36	5.5
I- 3 B	0- 0-200	1	2	66	302	320	39	5.2
		2	27	73	518	277	26	5.1
		3	6	100	136	60	41	5.6
I- 4 B	0-100- 0	1	2	74	389	313	73	5.2
		2	9	82	194	316	26	4.9
		3	76	36	181	67	41	5.8
I- 5 B	0-100-100	1	1	65	799	188	43	5.5
		2	92	86	497	180	26	5.1
		3	126	73	363	49	41	5.6
I- 6 B	0-100-200	1	2	88	432	313	39	5.1
		2	9	117	583	295	26	5.0
		3	80	159	1406	85	32	5.7
I- 7 B	0-200- 0	1	2	74	475	328	48	5.2
		2	---	--	---	---	--	---
		3	194	45	408	97	41	5.8
I- 8 B	0-200-100	1	2	71	410	210	43	5.2
		2	62	73	518	165	30	5.3
		3	89	77	272	43	32	5.9
I- 9 B	0-200-200	1	2	85	540	277	43	5.7
		2	10	143	648	354	30	4.9
		3	235	73	453	102	50	6.1
I-10 B	100- 0- 0	1	2	77	475	238	48	5.4
		2	--	--	---	---	--	---
		3	19	59	317	49	27	5.5
I-11 B	100- 0-100	1	2	76	454	228	43	5.5
		2	-	--	---	---	--	---
		3	8	95	181	38	32	5.4

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.)					pH
			P	K	Ca	Mg	Na	
I-12 B	100- 0-200	1	2	77	475	165	43	5.7
		2	11	104	691	165	30	5.1
		3	11	122	136	25	41	5.6
I-13 B	100-100- 0	1	2	77	432	238	43	5.5
		2	152	91	583	313	30	5.1
		3	49	41	181	38	23	5.3
I-14 B	100-100-100	1	2	101	583	332	43	5.5
		2	--	---	---	---	--	---
		3	45	73	227	55	32	5.4
I-15 B	100-100-200	1	1	89	497	313	43	5.4
		2	--	--	---	---	--	---
		3	52	82	136	25	32	5.4
I-16 B	100-200- 0	1	1	97	562	350	52	5.5
		2	495	69	778	305	43	5.7
		3	305	50	499	112	27	5.7
I-17 B	100-200-100	1	2	89	389	396	48	5.6
		2	54	104	518	251	43	5.1
		3	177	73	227	49	23	5.4
I-18 B	100-200-200	1	2	103	475	245	48	5.4
		2	111	104	454	199	39	4.8
		3	75	54	136	32	41	5.5
I-19 B	200- 0- 0	1	2	100	324	380	39	5.4
		2	-	---	---	---	--	---
		3	6	41	136	25	50	5.3
I-20 B	200- 0-100	1	2	83	194	343	52	5.3
		2	17	108	432	350	43	4.8
		3	7	100	227	120	36	5.1
I-21 B	200- 0-200	1	2	76	281	238	43	5.5
		2	12	130	475	217	43	4.8
		3	5	95	136	32	41	5.1
I-22 B	200-100- 0	1	1	79	497	228	52	5.5
		2	404	73	626	169	43	5.5
		3	7	32	181	25	41	5.7
I-23 B	200-100-100	1	2	73	389	155	43	5.5
		2	--	--	---	---	--	---
		3	84	41	136	13	32	5.4

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
I-24 B	200-100-200	1	2	76	410	305	43	5.3
		2	89	52	389	210	39	5.6
		3	103	68	136	19	45	5.5
I-25 B	200-200- 0	1	1	94	389	368	43	5.4
		2	---	--	---	---	--	---
		3	203	32	227	25	36	5.6
I-26 B	200-200-100	1	2	71	454	221	43	5.5
		2	206	73	540	184	43	5.4
		3	154	41	181	25	32	5.5
I-27 B	200-200-200	1	2	79	302	285	48	5.3
		2	--	--	---	---	--	---
		3	89	59	136	13	32	5.4
II- 1 B	0- 0- 0	1	1	45	475	313	43	5.2
		2	29	52	281	263	35	4.4
		3	6	45	181	38	41	5.6
II- 2 B	0- 0-100	1	2	79	173	285	43	4.8
		2	1	125	583	380	39	4.8
		3	11	77	136	71	41	5.1
II- 3 B	0- 0-200	1	2	74	302	309	43	4.8
		2	-	--	---	---	--	---
		3	9	86	136	32	32	5.4
II- 4 B	0-100- 0	1	1	100	389	380	39	4.7
		2	--	---	---	---	--	---
		3	86	32	181	49	36	5.6
II- 5 B	0-100-100	1	2	65	173	270	39	5.0
		2	--	--	---	---	--	---
		3	67	63	181	60	41	5.4
II- 6 B	0-100-200	1	1	83	432	354	43	5.1
		2	25	104	432	372	43	4.8
		3	24	113	227	55	45	5.8
II- 7 B	0-200- 0	1	2	64	324	238	43	5.0
		2	116	56	367	251	43	5.3
		3	120	36	227	67	36	5.6
II- 8 B	0-200-100	1	2	59	346	273	43	5.0
		2	206	48	432	242	39	4.9
		3	129	86	408	112	41	5.6

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
II- 9 B	0-200-200	1	2	77	389	285	43	4.9
		2	---	--	---	---	--	---
		3	177	73	227	49	41	5.7
II-10 B	100- 0- 0	1	1	94	216	387	43	4.7
		2	-	--	---	---	--	---
		3	9	27	136	32	36	5.2
II-11 B	100- 0-100	1	2	77	518	270	43	5.4
		2	25	86	605	251	39	5.1
		3	5	82	136	25	36	5.4
II-12 B	100- 0-200	1	1	103	626	387	43	5.1
		2	41	104	454	320	48	4.8
		3	6	73	136	38	41	5.3
II-13 B	100-100- 0	1	2	54	238	255	48	4.9
		2	62	69	281	299	43	4.6
		3	92	23	136	49	41	5.3
II-14 B	100-100-100	1	2	56	324	290	43	5.0
		2	50	56	475	299	43	4.7
		3	55	82	227	71	36	5.2
II-15 B	100-100-200	1	2	64	173	277	43	5.0
		2	41	69	324	270	39	4.5
		3	86	63	136	25	41	5.4
II-16 B	100-200- 0	1	2	91	346	358	39	4.9
		2	17	82	389	343	35	4.6
		3	120	27	136	38	41	5.5
II-17 B	100-200-100	1	2	82	562	358	43	5.1
		2	---	--	---	---	--	---
		3	160	45	136	25	41	5.4
II-18 B	100-200-200	1	1	64	259	320	48	4.9
		2	429	86	432	263	43	4.6
		3	126	104	227	102	41	5.1
II-19 B	200- 0- 0	1	1	62	367	299	43	5.0
		2	17	52	346	277	30	4.8
		3	5	23	136	25	32	5.2
II-20 B	200- 0-100	1	2	62	194	328	43	4.8
		2	25	48	324	350	22	4.6
		3	9	63	136	25	41	5.1

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
II-21 B	200- 0-200	1	2	57	238	259	43	4.9
		2	17	65	389	285	26	4.6
		3	9	68	136	38	41	5.1
II-22 B	200-100- 0	1	2	56	367	245	43	5.1
		2	17	91	410	405	22	4.7
		3	33	41	272	97	36	5.0
II-23 B	200-100-100	1	2	50	151	253	43	4.8
		2	58	82	432	350	22	5.1
		3	74	41	136	38	23	5.0
II-24 B	200-100-200	1	1	73	173	320	43	4.8
		2	--	--	---	---	--	---
		3	73	63	136	32	32	5.1
II-25 B	200-200- 0	1	2	127	216	320	43	4.9
		2	---	---	---	---	--	---
		3	189	27	136	25	45	5.1
II-26 B	200-200-100	1	3	47	173	216	43	4.8
		2	99	65	454	263	30	4.7
		3	126	27	136	25	27	5.1
II-27 B	200-200-200	1	2	68	518	326	43	5.4
		2	206	99	691	263	35	4.7
		3	279	77	272	55	18	5.6
III- 1 B	0- 0- 0	1	1	56	173	257	48	4.9
		2	-	52	324	299	26	4.8
		3	9	32	181	43	41	5.3
III- 2 B	0- 0-100	1	1	60	389	313	52	5.1
		2	41	52	518	251	30	4.9
		3	4	63	136	43	18	5.4
III- 3 B	0- 0-200	1	2	69	130	285	43	5.0
		2	-	69	518	277	30	4.6
		3	5	100	136	55	18	5.1
III- 4 B	0-100- 0	1	2	82	475	242	43	5.1
		2	21	52	389	238	26	5.0
		3	112	14	181	38	27	5.9
III- 5 B	0-100-100	1	2	60	302	231	43	5.0
		2	50	151	432	320	30	4.5
		3	62	50	181	49	23	5.4

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
III- 6 B	0-100-200	1	2	60	518	257	48	5.2
		2	25	69	540	277	26	4.9
		3	50	59	272	38	18	6.2
III- 7 B	0-200- 0	1	2	60	389	238	43	5.1
		2	17	121	626	320	26	4.9
		3	140	23	227	38	23	5.7
III- 8 B	0-200-100	1	1	56	216	285	43	5.0
		2	66	91	389	238	30	4.5
		3	189	73	227	71	23	5.4
III- 9 B	0-200-200	1	2	82	302	313	43	5.1
		2	25	73	389	336	30	5.2
		3	157	50	181	60	23	5.7
III-10 B	100- 0- 0	1	2	65	346	231	39	4.9
		2	58	60	475	225	26	4.7
		3	6	18	136	25	23	5.1
III-11 B	100- 0-100	1	2	52	346	263	43	5.1
		2	12	52	367	257	26	4.9
		3	7	59	136	32	27	5.3
III-12 B	100- 0-200	1	2	56	216	210	39	5.0
		2	33	56	994	225	39	5.4
		3	10	68	136	13	27	5.3
III-13 B	100-100- 0	1	2	65	281	299	43	4.8
		2	25	73	454	270	35	4.7
		3	106	18	136	38	27	5.2
III-14 B	100-100-100	1	1	69	216	291	39	5.1
		2	26	52	346	251	39	4.6
		3	73	59	136	25	18	5.2
III-15 B	100-100-200	1	2	65	389	270	43	5.1
		2	14	69	346	299	48	4.7
		3	109	63	136	55	14	5.1
III-16 B	100-200- 0	1	2	91	454	336	43	5.0
		2	9	65	432	295	48	4.5
		3	92	36	181	49	18	5.1
III-17 B	100-200-100	1	3	56	432	255	39	5.1
		2	3	69	518	291	43	4.9
		3	89	41	227	13	14	5.2

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
III-18 B	100-200-200	1	2	99	259	372	39	5.0
		2	1	65	432	365	48	4.7
		3	160	77	136	60	14	5.0
III-19 B	200- 0- 0	1	2	65	367	277	39	5.2
		2	2	48	259	193	39	4.6
		3	7	27	136	19	23	4.9
III-20 B	200- 0-100	1	1	83	367	270	39	5.1
		2	1	69	216	270	43	4.6
		3	6	50	136	13	18	5.1
III-21 B	200- 0-200	1	2	65	324	320	48	5.1
		2	1	39	432	248	43	4.7
		3	9	77	136	25	18	4.9
III-22 B	200-100- 0	1	1	65	432	231	39	5.2
		2	6	39	518	261	43	4.6
		3	73	32	136	38	14	5.0
III-23 B	200-100-100	1	2	134	497	343	39	5.5
		2	2	39	346	302	43	4.9
		3	100	50	136	32	18	5.1
III-24 B	200-100-200	1	2	65	324	291	39	5.1
		2	31	112	346	346	48	4.5
		3	149	59	136	38	18	5.2
III-25 B	200-200- 0	1	2	65	432	299	39	5.0
		2	2	52	432	257	43	4.8
		3	132	32	181	43	18	4.9
III-26 B	200-200-100	1	1	73	259	270	39	5.0
		2	24	82	432	343	43	4.5
		3	166	59	227	38	18	5.1
III-27 B	200-200-200	1	3	112	324	291	43	5.1
		2	8	73	346	309	43	4.6
		3	140	73	181	38	23	5.1
Alexandria Plantation								
I- 1 A	0- 0- 0	1	6	43	216	49	56	5.6
		2	3	43	281	97	35	5.7
		3	8	35	302	60	22	5.7

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
I- 2 A	0- 0-100	1	6	39	281	49	39	5.4
		2	4	60	367	129	35	5.5
		3	3	43	302	67	35	5.6
I- 3 A	0- 0-200	1	5	39	324	71	39	5.4
		2	4	229	367	175	39	5.5
		3	3	147	346	71	35	5.7
I- 4 A	0-100- 0	1	5	39	173	78	43	5.2
		2	671	35	389	207	43	5.4
		3	432	35	302	85	35	5.4
I- 5 A	0-100-100	1	4	43	367	71	39	5.4
		2	168	181	497	138	35	5.6
		3	55	86	389	78	35	5.6
I- 6 A	0-100-200	1	6	30	302	71	35	5.5
		2	226	168	475	108	39	5.6
		3	92	121	389	71	39	5.5
I- 7 A	0-200- 0	1	6	43	259	60	35	5.4
		2	431	35	324	135	35	5.5
		3	864	39	389	71	43	5.6
I- 8 A	0-200-100	1	5	35	216	38	30	5.5
		2	132	95	238	120	35	5.7
		3	36	73	302	60	35	5.7
I- 9 A	0-200-200	1	6	39	367	67	35	5.5
		2	5	35	302	108	35	5.4
		3	86	156	562	85	39	5.7
I-10 A	100- 0- 0	1	6	43	346	112	35	5.6
		2	6	39	281	129	35	5.4
		3	6	39	302	97	35	5.5
I-11 A	100- 0-100	1	5	48	281	38	35	5.5
		2	5	73	324	165	35	5.4
		3	3	56	302	60	35	5.5
I-12 A	100- 0-200	1	5	43	281	99	35	5.4
		2	4	216	281	188	35	5.3
		3	7	125	259	78	39	5.4
I-13 A	100-100- 0	1	6	39	194	67	35	5.5
		2	219	52	389	165	35	5.7
		3	157	35	302	60	78	5.5

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
I-14 A	100-100-100	1	3	39	324	60	30	5.8
		2	323	95	454	147	35	5.9
		3	116	69	389	71	30	5.8
I-15 A	100-100-200	1	3	39	173	49	30	5.3
		2	410	203	475	155	39	5.5
		3	155	112	302	43	30	5.6
I-16 A	100-200- 0	1	4	39	302	49	35	5.5
		2	156	48	475	138	35	5.6
		3	166	48	432	67	35	5.6
I-17 A	100-200-100	1	5	65	238	85	35	5.3
		2	94	134	324	147	35	5.5
		3	286	69	432	71	35	5.4
I-18 A	100-200-200	1	3	56	497	97	35	5.5
		2	553	156	605	138	35	5.5
		3	953	91	1210	129	35	5.6
I-19 A	200- 0- 0	1	7	39	281	40	26	5.4
		2	139	212	475	165	35	5.7
		3	7	35	346	49	30	5.4
I-20 A	200- 0-100	1	4	35	281	78	26	5.3
		2	7	194	389	180	43	5.3
		3	5	73	302	49	30	5.4
I-21 A	200- 0-200	1	5	43	346	71	26	5.5
		2	7	320	410	135	43	5.4
		3	8	151	346	71	35	5.7
I-22 A	200-100- 0	1	6	43	367	85	30	5.3
		2	295	43	410	120	39	5.4
		3	311	30	562	102	30	5.5
I-23 A	200-100-100	1	5	39	281	71	26	5.4
		2	310	99	389	160	39	5.5
		3	199	56	389	71	35	5.4
I-24 A	200-100-200	1	6	39	389	108	26	5.4
		2	133	251	475	188	43	5.6
		3	406	108	734	85	35	5.5
I-25 A	200-200- 0	1	6	56	389	97	26	5.3
		2	112	73	432	138	43	5.5
		3	597	35	864	125	30	5.5

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
I-26 A	200-200-100	1	3	35	281	90	26	5.1
		2	274	130	410	165	39	5.5
		3	267	43	346	71	30	5.4
I-27 A	200-200-200	1	4	35	238	97	26	5.2
		2	252	147	410	180	39	5.5
		3	203	82	432	97	35	5.4
II- 1 A	0- 0- 0	1	5	43	281	67	30	5.7
		2	5	39	259	171	43	5.4
		3	3	35	302	85	30	5.4
II- 2 A	0- 0-100	1	7	65	454	90	26	6.0
		2	3	233	367	195	39	5.9
		3	3	173	432	90	26	5.7
II- 3 A	0- 0-200	1	6	56	540	120	30	5.8
		2	5	272	367	195	43	5.5
		3	7	229	432	108	30	5.6
II- 4 A	0-100- 0	1	6	48	389	97	30	5.8
		2	822	35	540	165	43	5.5
		3	394	43	518	108	30	5.4
II- 5 A	0-100-100	1	6	432	259	49	52	6.1
		2	600	117	432	147	39	5.6
		3	158	104	259	49	30	5.5
II- 6 A	0-100-200	1	6	69	367	90	30	5.7
		2	305	173	367	135	43	5.5
		3	234	138	346	90	30	5.4
II- 7 A	0-200- 0	1	6	39	194	49	22	5.8
		2	711	30	518	151	39	5.5
		3	141	43	216	49	26	5.5
II- 8 A	0-200-100	1	9	43	367	97	26	6.0
		2	616	117	432	120	39	5.7
		3	267	134	302	97	35	5.5
II- 9 A	0-200-200	1	5	35	324	67	26	5.8
		2	176	289	302	129	39	5.7
		3	457	160	346	55	30	5.6
II-10 A	100- 0- 0	1	7	69	432	112	30	5.7
		2	5	48	367	188	39	5.0
		3	3	43	302	97	35	5.3

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
II-11 A	100- 0-100	1	6	35	281	85	30	5.6
		2	3	125	194	135	39	5.1
		3	4	108	259	55	35	5.3
II-12 A	100- 0-200	1	6	48	389	71	30	5.8
		2	4	229	324	171	35	5.8
		3	3	147	216	38	30	5.7
II-13 A	100-100- 0	1	7	73	562	112	26	6.0
		2	245	69	583	199	39	6.0
		3	572	73	784	120	30	5.7
II-14 A	100-100-100	1	9	35	302	85	30	5.7
		2	585	138	459	120	39	5.6
		3	48	78	216	67	30	5.3
II-15 A	100-100-200	1	6	48	389	102	26	5.9
		2	431	207	475	171	43	5.8
		3	167	156	432	97	30	5.6
II-16 A	100-200- 0	1	7	39	259	97	26	5.7
		2	305	30	281	160	43	5.6
		3	349	35	302	71	56	5.4
II-17 A	100-200-100	1	6	43	324	67	26	5.9
		2	158	194	346	199	35	6.0
		3	889	86	778	60	35	5.8
II-18 A	100-200-200	1	8	52	410	102	26	5.6
		2	274	138	410	188	39	5.5
		3	813	143	691	71	30	5.5
II-19 A	200- 0- 0	1	7	35	238	85	30	5.7
		2	5	26	194	195	35	5.3
		3	4	30	173	60	30	5.2
II-20 A	200- 0-100	1	10	56	432	112	30	5.7
		2	4	78	238	184	39	5.1
		3	57	73	821	155	43	5.6
II-21 A	200- 0-200	1	6	56	302	85	26	6.0
		2	4	181	216	97	39	5.4
		3	22	117	605	184	43	5.2
II-22 A	200-100- 0	1	6	39	324	71	26	5.9
		2	160	56	475	184	39	5.6
		3	279	26	562	78	43	5.5

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.)					pH
			P	K	Ca	Mg	Na	
II-23 A	200-100-100	1	5	43	259	67	26	5.8
		2	774	99	562	199	39	5.7
		3	356	60	346	78	48	5.4
II-24 A	200-100-200	1	6	35	238	90	26	5.6
		2	473	143	432	171	39	5.3
		3	165	121	302	108	43	5.1
II-25 A	200-200- 0	1	7	65	497	97	26	5.9
		2	853	39	756	231	39	5.7
		3	267	39	518	112	43	5.5
II-26 A	200-200-100	1	6	52	389	97	26	5.6
		2	932	117	799	203	39	5.4
		3	184	78	389	71	43	5.2
II-27 A	200-200-200	1	6	60	410	102	26	5.9
		2	616	151	842	188	39	6.1
		3	235	104	389	108	43	5.5
III- 1 A	0- 0- 0	1	4	44	346	49	26	5.7
		2	13	39	389	171	39	5.7
		3	3	35	346	71	39	5.4
III- 2 A	0- 0-100	1	5	56	367	71	26	5.9
		2	2	73	302	169	36	6.0
		3	3	117	302	71	39	5.6
III- 3 A	0- 0-200	1	6	74	497	108	26	6.0
		2	2	143	389	210	35	5.9
		3	2	177	475	97	39	5.6
III- 4 A	0-100- 0	1	5	48	302	55	26	5.5
		2	226	35	540	165	35	5.8
		3	95	43	389	85	39	6.0
III- 5 A	0-100-100	1	4	71	475	85	26	5.8
		2	244	104	583	108	39	6.6
		3	305	95	605	108	39	5.7
III- 6 A	0-100-200	1	5	59	432	71	26	5.9
		2	680	181	670	40	43	6.4
		3	140	134	432	85	35	5.8
III- 7 A	0-200- 0	1	5	56	281	49	26	5.6
		2	620	39	454	76	43	6.2
		3	343	43	346	97	35	5.4

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
III- 8 A	0-200-100	1	5	91	216	60	30	6.1
		2	568	117	583	40	48	6.0
		3	89	91	216	49	39	5.3
III- 9 A	0-200-200	1	4	74	432	85	26	5.8
		2	614	160	842	112	52	6.5
		3	787	143	907	129	43	5.8
III-10 A	100- 0- 0	1	5	53	324	49	26	5.8
		2	32	39	194	38	43	5.9
		3	12	30	302	49	39	5.7
III-11 A	100- 0-100	1	4	45	238	49	30	5.8
		2	4	125	173	43	39	5.9
		3	3	86	216	49	39	5.6
III-12 A	100- 0-200	1	5	53	259	60	35	5.7
		2	3	112	151	32	48	5.2
		3	4	112	259	49	39	5.4
III-13 A	100-100- 0	1	4	48	281	49	26	5.5
		2	660	26	670	56	48	6.0
		3	140	35	346	60	35	5.2
III-14 A	100-100-100	1	5	50	238	49	22	5.7
		2	673	65	648	40	48	6.1
		3	152	73	302	60	35	5.3
III-15 A	100-100-200	1	5	42	346	71	26	5.6
		2	647	207	648	76	48	5.8
		3	203	99	302	60	35	5.3
III-16 A	100-200- 0	1	5	39	194	71	39	5.4
		2	620	26	821	130	56	5.6
		3	330	39	346	71	48	5.4
III-17 A	100-200-100	1	5	151+	151	25	48	6.4
		2	766	112	648	56	48	5.6
		3	57	95	259	55	35	5.4
III-18 A	100-200-200	1	6	51	475	71	39	5.7
		2	766	229	734	130	43	5.8
		3	267	130	605	85	39	5.3
III-19 A	200- 0- 0	1	4	48	194	55	48	5.7
		2	24	35	173	60	43	5.8
		3	6	30	216	55	35	5.2

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
III-20 A	200- 0-100	1	7	107	605	108	48	6.2
		2	5	207	497	85	43	5.2
		3	7	117	475	60	43	5.2
III-21 A	200- 0-200	1	5	62	324	102	43	5.8
		2	5	238	281	97	48	5.5
		3	2	151	346	108	39	5.3
III-22 A	200-100- 0	1	7	60	389	71	35	5.9
		2	475	43	648	85	43	6.4
		3	95	39	432	71	35	5.5
III-23 A	200-100-100	1	5	44	302	49	35	5.6
		2	370	99	475	78	43	6.0
		3	51	69	302	60	35	5.2
III-24 A	200-100-200	1	6	44	410	90	43	5.6
		2	237	104	389	85	43	6.2
		3	660	99	907	108	39	5.4
III-25 A	200-200- 0	1	6	77	583	108	39	6.0
		2	581	60	1015	166	48	6.4
		3	505	60	734	71	39	5.6
III-26 A	200-200-100	1	6	38	173	78	35	5.5
		2	607	78	972	76	60	5.8
		3	344	35	302	49	39	5.2
III-27 A	200-200-200	1	6	41	216	38	43	5.4
		2	568	117	842	76	60	5.8
		3	406	108	346	43	39	5.2
I- 1 B	0- 0- 0	1	3	39	216	129	26	4.6
		2	6	39	194	143	35	5.3
		3	1	35	216	120	35	5.1
I- 2 B	0- 0-100	1	1	30	194	171	26	4.8
		2	15	108	130	180	39	5.8
		3	1	48	216	155	35	5.1
I- 3 B	0- 0-200	1	3	30	238	165	30	5.1
		2	5	95	216	195	39	4.6
		3	1	143	259	138	35	5.2
I- 4 B	0-100- 0	1	2	22	65	129	30	4.9
		2	15	22	43	125	43	5.1
		3	4	26	130	108	39	5.0

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
I- 5 B	0-100-100	1	1	35	259	155	30	5.3
		2	15	108	259	180	39	4.9
		3	14	108	259	120	30	5.0
I- 6 B	0-100-200	1	3	22	151	155	30	5.0
		2	6	112	130	165	43	4.6
		3	4	69	173	147	35	4.9
I- 7 B	0-200- 0	1	3	30	130	147	30	4.9
		2	7	30	43	165	43	5.1
		3	35	30	173	155	39	5.0
I- 8 B	0-200-100	1	1	30	173	155	30	5.1
		2	38	65	173	180	43	4.9
		3	22	65	216	155	35	5.1
I- 9 B	0-200-200	1	1	35	173	155	30	5.0
		2	34	160	151	165	39	4.7
		3	50	160	216	125	30	4.9
I-10 B	100- 0- 0	1	3	22	108	138	35	5.1
		2	1	26	65	155	43	4.6
		3	1	26	130	129	35	5.0
I-11 B	100- 0-100	1	3	26	151	165	30	5.1
		2	2	95	130	171	39	4.7
		3	2	65	173	100	39	5.0
I-12 B	100- 0-200	1	3	17	86	138	30	5.1
		2	2	65	65	160	43	4.6
		3	1	104	130	71	35	4.8
I-13 B	100-100- 0	1	4	22	130	129	30	5.1
		2	2	26	43	151	39	5.3
		3	14	22	130	108	39	5.0
I-14 B	100-100-100	1	3	39	194	138	26	5.3
		2	13	65	216	155	43	5.0
		3	51	48	259	108	39	5.3
I-15 B	100-100-200	1	3	30	130	171	30	5.1
		2	4	104	130	203	48	4.6
		3	8	121	130	108	39	5.0
I-16 B	100-200- 0	1	4	30	238	175	26	5.3
		2	53	52	216	180	48	5.3
		3	110	26	259	175	39	5.1

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
I-17 B	100-200-100	1	2	39	151	171	35	4.9
		2	102	43	130	180	43	4.9
		3	193	48	216	147	35	4.9
I-18 B	100-200-200	1	3	26	151	165	39	5.2
		2	28	39	151	171	39	4.7
		3	66	65	173	135	35	4.9
I-19 B	200- 0- 0	1	3	43	216	120	35	5.2
		2	49	39	238	129	39	4.7
		3	1	35	173	71	35	4.7
I-20 B	200- 0-100	1	3	17	86	97	39	5.1
		2	2	56	65	112	35	4.5
		3	2	69	173	49	35	5.0
I-21 B	200- 0-200	1	3	30	151	147	39	5.0
		2	2	99	130	175	39	4.5
		3	1	147	173	97	30	4.7
I-22 B	200-100- 0	1	5	22	130	155	39	5.0
		2	5	22	130	188	39	4.7
		3	7	22	173	147	35	5.0
I-23 B	200-100-100	1	3	22	65	129	39	5.0
		2	5	48	86	151	39	4.6
		3	17	48	173	97	30	4.9
I-24 B	200-100-200	1	1	22	108	147	43	5.3
		2	5	117	108	151	43	4.7
		3	25	78	173	85	39	5.0
I-25 B	200-200- 0	1	3	26	43	112	43	5.2
		2	90	35	43	165	43	4.9
		3	152	22	216	97	30	4.8
I-26 B	200-200-100	1	1	17	43	90	43	5.3
		2	24	39	43	125	48	5.0
		3	97	30	173	78	35	4.9
I-27 B	200-200-200	1	2	17	86	108	30	5.2
		2	5	73	65	120	43	4.7
		3	86	52	130	60	35	5.0
II- 1 B	0- 0- 0	1	3	22	86	108	30	5.2
		2	2	22	86	125	39	5.3
		3	3	22	173	85	30	5.2

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
II- 2 B	0- 0-100	1	1	35	194	203	30	5.2
		2	1	117	216	171	39	5.2
		3	4	164	302	97	35	5.5
II- 3 B	0- 0-200	1	5	17	65	120	30	5.0
		2	2	225	86	120	43	4.8
		3	3	125	173	108	35	4.6
II- 4 B	0-100- 0	1	1	17	65	129	35	5.1
		2	93	22	86	120	43	5.1
		3	77	17	259	108	35	5.0
II- 5 B	0-100-100	1	2	69	65	143	39	4.8
		2	68	60	108	108	43	4.9
		3	22	65	130	108	35	4.9
II- 6 B	0-100-200	1	1	30	86	165	35	5.1
		2	127	143	151	138	43	4.8
		3	72	112	216	120	39	4.9
II- 7 B	0-200- 0	1	3	30	86	175	35	5.2
		2	436	13	194	60	35	5.9
		3	119	30	216	138	43	5.1
II- 8 B	0-200-100	1	1	26	65	138	30	5.2
		2	268	52	194	138	43	4.9
		3	22	52	130	129	43	4.8
II- 9 B	0-200-200	1	5	17	130	147	30	5.2
		2	16	125	130	160	43	4.5
		3	292	242	302	85	39	4.8
II-10 B	100- 0- 0	1	1	22	43	129	30	5.1
		2	2	22	86	147	39	4.6
		3	4	26	130	90	35	4.9
II-11 B	100- 0-100	1	3	22	108	120	30	5.1
		2	2	91	86	97	43	4.5
		3	8	65	173	108	43	4.6
II-12 B	100- 0-200	1	1	39	259	151	26	5.4
		2	1	160	259	155	43	4.5
		3	4	156	216	71	35	5.1
II-13 B	100-100- 0	1	3	39	151	171	26	5.3
		2	16	30	173	169	39	4.7
		3	86	35	346	129	39	5.3

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
II-14 B	100-100-100	1	1	17	86	135	35	5.1
		2	82	39	65	71	43	4.8
		3	6	35	173	97	39	4.9
II-15 B	100-100-200	1	5	22	130	160	30	5.2
		2	3	112	151	129	43	4.8
		3	6	99	216	138	39	6.2
II-16 B	100-200- 0	1	2	17	65	120	30	5.0
		2	27	13	65	108	43	5.0
		3	267	26	216	85	43	4.8
II-17 B	100-200-100	1	3	26	86	129	26	5.2
		2	88	73	130	147	39	4.7
		3	80	86	216	55	43	5.0
II-18 B	100-200-200	1	2	216	130	160	43	4.8
		2	156	95	194	147	43	4.9
		3	445	138	346	147	43	4.9
II-19 B	200- 0- 0	1	3	22	108	120	35	5.2
		2	2	9	86	97	43	4.4
		3	6	17	130	32	43	4.6
II-20 B	200- 0-100	1	1	26	86	129	30	5.0
		2	1	60	86	138	39	4.5
		3	4	91	130	71	39	4.6
II-21 B	200- 0-200	1	6	22	108	147	30	5.2
		2	1	143	108	108	35	4.7
		3	4	131	227	85	36	5.0
II-22 B	200-100- 0	1	2	26	130	180	26	5.2
		2	7	35	194	199	39	4.8
		3	40	32	272	143	32	5.0
II-23 B	200-100-100	1	2	27	86	120	35	4.9
		2	20	43	151	102	43	5.2
		3	57	54	453	78	36	5.1
II-24 B	200-100-200	1	2	26	86	108	35	4.9
		2	16	117	86	71	48	4.9
		3	16	68	136	97	27	4.6
II-25 B	200-200- 0	1	2	36	324	199	30	5.3
		2	30	22	281	129	39	5.5
		3	117	41	408	171	32	5.1

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.)					pH
			P	K	Ca	Mg	Na	
II-26 B	200-200-100	1	1	26	86	147	35	4.9
		2	264	39	130	97	43	5.0
		3	169	27	181	120	36	4.8
II-27 B	200-200-200	1	2	29	151	155	35	5.0
		2	142	190	173	102	43	5.3
		3	12	150	181	138	27	5.2
III- 1 B	0- 0- 0	1	2	51	86	138	65	4.9
		2	4	26	108	71	39	5.8
		3	3	36	227	97	23	5.4
III- 2 B	0- 0-100	1	1	51	194	171	35	5.0
		2	2	134	151	108	35	5.5
		3	3	141	227	108	27	5.4
III- 3 B	0- 0-200	1	2	60	194	151	43	5.1
		2	1	173	151	108	35	5.4
		3	3	199	272	108	27	5.4
III- 4 B	0-100- 0	1	1	48	86	171	43	5.0
		2	88	39	108	71	35	5.6
		3	3	45	136	138	32	5.1
III- 5 B	0-100-100	1	2	41	151	160	43	5.0
		2	132	95	173	151	35	5.2
		3	120	86	363	129	27	5.3
III- 6 B	0-100-200	1	1	51	216	169	39	5.2
		2	63	216	173	85	35	5.8
		3	3	168	272	138	32	5.4
III- 7 B	0-200- 0	1	2	36	86	155	43	4.9
		2	207	35	173	135	39	5.1
		3	381	36	408	120	32	4.9
III- 8 B	0-200-100	1	1	36	86	129	43	4.7
		2	488	130	259	120	43	4.9
		3	30	91	136	120	27	4.8
III- 9 B	0-200-200	1	1	47	173	180	43	5.1
		2	132	125	259	151	39	5.5
		3	368	159	363	108	32	5.4
III-10 B	100- 0- 0	1	1	51	173	180	39	5.2
		2	3	39	86	60	35	5.0
		3	6	41	272	61	32	5.2

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
III-11 B	100- 0-100	1	2	41	151	147	39	5.0
		2	2	130	86	49	39	4.7
		3	6	91	136	71	27	5.1
III-12 B	100- 0-200	1	2	32	108	155	43	5.0
		2	1	86	130	71	43	4.8
		3	1	95	453	147	27	5.1
III-13 B	100-100- 0	1	2	26	108	138	43	5.0
		2	85	17	151	112	43	5.2
		3	9	27	408	147	32	5.1
III-14 B	100-100-100	1	1	32	130	155	43	4.9
		2	34	26	151	108	39	5.0
		3	6	32	227	155	36	5.1
III-15 B	100-100-200	1	2	27	86	108	43	4.9
		2	56	108	65	32	43	4.8
		3	17	86	136	85	23	5.0
III-16 B	100-200- 0	1	2	29	86	90	48	4.9
		2	85	13	43	67	43	5.0
		3	20	27	136	97	27	5.0
III-17 B	100-200-100	1	1	132	130	160	48	5.3
		2	330	69	130	55	43	5.2
		3	31	50	227	165	32	5.0
III-18 B	100-200-200	1	1	32	151	221	43	5.0
		2	303	125	194	90	52	5.3
		3	14	100	227	147	32	5.1
III-19 B	200- 0- 0	1	1	26	86	165	43	5.0
		2	1	26	130	97	60	4.6
		3	23	23	181	129	27	4.5
III-20 B	200- 0-100	1	2	48	86	147	43	4.8
		2	2	112	173	108	56	4.7
		3	3	82	227	129	36	4.3
III-21 B	200- 0-200	1	2	35	86	97	43	4.9
		2	2	199	130	97	60	4.7
		3	3	118	136	97	36	4.2
III-22 B	200-100- 0	1	2	35	151	147	43	5.0
		2	15	30	173	129	52	5.3
		3	39	32	272	125	36	5.1

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
III-23 B	200-100-100	1	1	27	86	151	43	5.1
		2	36	73	130	71	56	5.1
		3	6	36	181	155	36	5.0
III-24 B	200-100-200	1	1	27	86	120	48	5.0
		2	21	39	151	85	60	4.9
		3	3	54	227	120	36	4.8
III-25 B	200-200- 0	1	1	50	216	155	43	5.2
		2	236	35	346	138	56	5.7
		3	23	41	544	155	36	5.1
III-26 B	200-200-100	1	1	33	86	71	43	4.9
		2	186	26	86	38	56	4.9
		3	40	27	227	60	41	4.9
III-27 B	200-200-200	1	1	30	86	97	43	5.0
		2	161	43	108	35	56	5.0
		3	16	68	181	85	41	4.8
			Washington Parish Plantation					
I- 1 A	0- 0- 0	1	23	52	194	38	30	5.7
		2*	17	54	227	85	**	5.7
I- 2 A	0- 0-100	1	27	35	173	38	35	5.7
		2	23	45	181	60		5.6
I- 3 A	0- 0-200	1	24	48	173	25	30	5.7
		2	21	86	227	71		5.7
I- 4 A	0-100- 0	1	25	39	173	25	35	5.7
		2	94	54	317	78		5.7
I- 5 A	0-100-100	1	25	56	173	13	35	5.7
		2	40	63	227	71		5.7
I- 6 A	0-100-200	1	28	43	151	13	30	5.7
		2	28	41	181	49		5.6

*Period 2 = end of 1960 growing season.

**Not determined for 1960 soil samples from this plantation.

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
I- 7 A	0-200- 0	1	29	43	151	49	35	5.7
		2	34	50	181	60		5.8
I- 8 A	0-200-100	1	24	52	173	49	30	5.9
		2	66	68	227	49		5.8
I- 9 A	0-200-200	1	26	39	130	25	35	5.8
		2	63	50	181	49		5.8
I-10 A	100- 0- 0	1	23	39	173	25	35	5.8
		2	21	54	227	60		5.7
I-11 A	100- 0-100	1	32	48	151	32	35	5.8
		2	28	63	181	49		5.7
I-12 A	100- 0-200	1	48	69	432	60	39	5.7
		2	30	122	453	90		5.8
I-13 A	100-100- 0	1	23	43	194	19	35	5.7
		2	34	41	272	60		5.7
I-14 A	100-100-100	1	24	65	238	60	35	5.9
		2	31	100	272	67		5.8
I-15 A	100-100-200	1	23	35	194	43	43	5.8
		2	30	73	227	67		5.8
I-16 A	100-200- 0	1	11	35	302	38	43	6.0
		2	114	50	408	71		6.1
I-17 A	100-200-100	1	18	30	151	25	43	5.8
		2	48	73	181	60		5.8
I-18 A	100-200-200	1	24	52	238	38	35	5.8
		2	35	86	227	67		5.6
I-19 A	200- 0- 0	1	23	52	281	49	43	5.8
		2	28	59	272	71		5.6
I-20 A	200- 0-100	1	26	35	151	19	39	5.7
		2	31	73	272	60		5.8
I-21 A	200- 0-200	1	24	30	108	13	39	5.7
		2	31	73	136	49		5.8
I-22 A	200-100- 0	1	16	39	194	49	39	5.8
		2	46	63	317	71		5.8

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content, (ppm.) P	K	Ca	Mg	Na	pH
I-23 A	200-100-100	1	23	43	281	38	39	5.7
		2	29	91	272	71		5.6
I-24 A	200-100-200	1	18	52	324	55	35	5.8
		2	19	113	363	71		5.8
I-25 A	200-200- 0	1	15	39	194	38	43	5.7
		2	86	73	317	60		5.7
I-26 A	200-200-100	1	21	35	194	43	43	5.7
		2	40	68	227	60		5.8
I-27 A	200-200-200	1	22	22	108	38	39	5.6
		2	31	68	136	49		5.8
II- 1 A	0- 0- 0	1	13	35	194	38	39	5.7
		2	17	41	227	60		5.8
II- 2 A	0- 0-100	1	17	39	259	38	39	5.9
		2	16	73	272	60		6.0
II- 3 A	0- 0-200	1	18	30	151	32	43	5.8
		2	17	54	181	49		5.8
II- 4 A	0-100- 0	1	22	48	324	38	43	5.8
		2	42	63	363	78		6.0
II- 5 A	0-100-100	1	18	35	151	38	39	5.6
		2	48	59	136	55		5.8
II- 6 A	0-100-200	1	13	48	324	49	48	6.0
		2	60	91	317	67		6.0
II- 7 A	0-200- 0	1	22	35	302	38	43	5.8
		2	19	54	317	55		6.0
II- 8 A	0-200-100	1	12	35	194	32	48	5.7
		2	73	73	272	60		5.8
II- 9 A	0-200-200	1	16	35	194	25	48	5.7
		2	24	59	227	49		5.8
II-10 A	100- 0- 0	1	17	26	130	13	43	5.7
		2	16	45	136	38		5.5
II-11 A	100- 0-100	1	18	30	151	32	39	5.7
		2	19	77	181	43		5.7

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
II-12 A	100- 0-200	1	15	39	151	38	39	5.8
		2	16	86	181	43		5.7
II-13 A	100-100- 0	1	15	39	108	25	39	5.9
		2	21	36	136	43		5.7
II-14 A	100-100-100	1	13	39	281	38	39	5.8
		2	23	104	317	49		5.7
II-15 A	100-100-200	1	18	22	130	25	39	5.6
		2	30	86	136	32		5.6
II-16 A	100-200- 0	1	18	26	130	49	39	5.6
		2	63	32	136	38		5.5
II-17 A	100-200-100	1	17	22	151	25	39	5.7
		2	23	68	136	38		5.6
II-18 A	100-200-200	1	17	48	367	60	39	6.0
		2	26	95	363	60		5.7
II-19 A	200- 0- 0	1	18	30	151	25	35	5.7
		2	24	59	227	43		5.6
II-20 A	200- 0-100	1	16	26	151	25	35	5.6
		2	19	59	181	43		5.6
II-21 A	200- 0-200	1	18	22	173	25	35	5.7
		2	23	104	227	43		5.7
II-22 A	200-100- 0	1	18	46	216	49	39	5.6
		2	26	73	317	35		5.5
II-23 A	200-100-100	1	19	30	151	32	43	5.7
		2	20	86	181	38		5.7
II-24 A	200-100-200	1	12	39	238	38	35	5.7
		2	26	113	272	49		5.6
II-25 A	200-200- 0	1	21	35	173	32	35	5.7
		2	46	68	181	38		5.6
II-26 A	200-200-100	1	13	26	173	38	35	5.7
		2	23	82	181	38		5.6
II-27 A	200-200-200	1	15	35	238	32	39	5.8
		2	29	104	272	43		5.6

Plot No.	Fertilizer Treatment, N-P_2O_5-K_2O (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
III- 1 A	0- 0- 0	1	24	35	130	19	39	5.8
		2	23	32	136	38		5.5
III- 2 A	0- 0-100	1	17	26	216	43	35	5.8
		2	21	68	227	38		5.7
III- 3 A	0- 0-200	1	21	26	108	25	43	5.6
		2	26	59	136	32		5.6
III- 4 A	0-100- 0	1	14	30	194	49	43	5.8
		2	24	41	227	43		5.6
III- 5 A	0-100-100	1	26	43	216	38	35	5.7
		2	29	73	227	49		5.7
III- 6 A	0-100-200	1	18	30	130	38	35	5.9
		2	26	45	136	38		5.8
III- 7 A	0-200- 0	1	19	35	194	97	39	5.9
		2	37	41	227	38		5.8
III- 8 A	0-200-100	1	16	35	216	25	35	5.8
		2	51	100	272	49		5.7
III- 9 A	0-200-200	1	25	43	194	60	35	5.8
		2	29	50	181	38		5.6
III-10 A	100- 0- 0	1	32	60	302	55	35	5.8
		2	31	63	272	49		5.5
III-11 A	100- 0-100	1	14	26	108	13	43	5.8
		2	20	59	136	32		5.6
III-12 A	100- 0-200	1	51	69	346	55	48	5.8
		2	49	109	363	67		5.6
III-13 A	100-100- 0	1	19	35	151	19	39	5.9
		2	29	45	181	32		5.7
III-14 A	100-100-100	1	36	43	130	38	39	5.9
		2	34	59	136	38		5.6
III-15 A	100-100-200	1	20	48	173	25	35	5.9
		2	21	91	181	43		5.5
III-16 A	100-200- 0	1	19	22	130	25	35	5.8
		2	53	41	181	38		5.5

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
III-17 A	100-200-100	1	15	48	173	43	39	6.0
		2	26	73	181	38		5.6
III-18 A	100-200-200	1	24	73	302	60	43	5.9
		2	26	100	272	49		5.5
III-19 A	200- 0- 0	1	20	39	130	7	35	6.0
		2	20	41	136	32		5.7
III-20 A	200- 0-100	1	20	30	194	19	39	5.9
		2	17	63	181	38		5.7
III-21 A	200- 0-200	1	50	78	389	43	43	5.9
		2	39	86	363	55		5.5
III-22 A	200-100- 0	1	22	39	151	13	39	5.9
		2	37	50	181	43		5.6
III-23 A	200-100-100	1	15	73	259	49	43	5.8
		2	31	82	317	49		5.5
III-24 A	200-100-200	1	18	35	151	13	39	5.8
		2	30	68	227	38		5.7
III-25 A	200-200- 0	1	20	48	173	13	39	5.7
		2	24	54	227	38		5.4
III-26 A	200-200-100	1	21	52	216	32	39	5.9
		2	36	82	227	43		5.6
III-27 A	200-200-200	1	20	43	173	25	39	5.6
		2	24	100	181	38		5.4
I- 1 B	0- 0- 0	1	1	35	151	71	43	5.3
		2	9	45	181	85		5.4
I- 2 B	0- 0-100	1	2	22	216	67	43	5.4
		2	6	82	227	78		5.3
I- 3 B	0- 0-200	1	1	35	173	78	39	5.2
		2	6	177	136	90		5.2
I- 4 B	0-100- 0	1	1	26	194	90	39	5.3
		2	26	41	317	120		5.3
I- 5 B	0-100-100	1	2	30	173	108	35	5.2
		2	41	113	227	85		5.2

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
I- 6 B	0-100-200	1	2	26	130	60	48	5.2
		2	40	100	136	49		5.1
I- 7 B	0-200- 0	1	1	30	194	85	43	5.3
		2	33	45	272	97		5.1
I- 8 B	0-200-100	1	1	22	173	102	39	5.3
		2	166	236	272	97		5.2
I- 9 B	0-200-200	1	1	30	151	85	39	5.3
		2	194	358	181	55		5.2
I-10 B	100- 0- 0	1	1	26	216	85	43	5.4
		2	4	41	227	85		5.0
I-11 B	100- 0-100	1	1	35	173	108	43	5.2
		2	4	82	181	60		5.1
I-12 B	100- 0-200	1	2	35	238	108	43	5.4
		2	6	118	181	49		5.3
I-13 B	100-100- 0	1	1	22	194	102	48	5.4
		2	59	32	272	60		5.2
I-14 B	100-100-100	1	1	30	238	129	48	5.4
		2	24	77	272	102		5.2
I-15 B	100-100-200	1	1	26	173	71	43	5.1
		2	9	50	227	85		5.2
I-16 B	100-200- 0	1	-	22	238	108	43	5.4
		2	215	27	317	67		5.1
I-17 B	100-200-100	1	1	35	194	120	43	5.2
		2	7	73	227	138		5.2
I-18 B	100-200-200	1	1	22	108	67	39	5.2
		2	54	91	136	71		5.1
I-19 B	200- 0- 0	1	1	30	194	71	43	5.2
		2	9	41	181	67		4.6
I-20 B	200- 0-100	1	1	22	194	108	43	5.2
		2	6	73	181	67		4.7
I-21 B	200- 0-200	1	2	30	151	43	43	5.3
		2	6	68	136	71		5.1

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
I-22 B	200-100- 0	1	1	30	194	120	59	5.3
		2	9	32	227	120		4.6
I-23 B	200-100-100	1	1	26	173	71	43	5.3
		2	13	59	227	85		4.9
I-24 B	200-100-200	1	1	30	216	143	43	5.3
		2	6	73	227	78		5.0
I-25 B	200-200- 0	1	1	35	151	97	43	5.2
		2	41	32	136	78		5.0
I-26 B	200-200-100	1	1	22	173	97	43	5.3
		2	40	54	181	71		5.0
I-27 B	200-200-200	1	1	22	151	49	48	5.2
		2	6	331	136	60		5.1
II- 1 B	0- 0- 0	1	3	26	194	102	48	5.4
		2	4	41	227	85		5.5
II- 2 B	0- 0-100	1	2	26	238	55	43	5.4
		2	4	109	227	67		5.5
II- 3 B	0- 0-200	1	2	35	173	97	35	5.2
		2	4	104	181	78		5.4
II- 4 B	0-100- 0	1	1	30	216	97	43	5.3
		2	19	41	272	90		5.3
II- 5 B	0-100-100	1	1	22	86	67	39	5.1
		2	49	91	136	67		5.2
II- 6 B	0-100-200	1	1	30	324	125	43	5.4
		2	31	163	272	90		5.3
II- 7 B	0-200- 0	1	1	22	238	85	43	5.5
		2	4	41	227	60		5.6
II- 8 B	0-200-100	1	2	22	238	90	39	5.4
		2	9	54	272	85		5.4
II- 9 B	0-200-200	1	2	30	151	85	39	5.3
		2	26	100	181	55		5.4
II-10 B	100- 0- 0	1	1	22	151	67	39	5.3
		2	9	27	181	49		5.1

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
II-11 B	100- 0-100	1	1	22	130	85	39	5.1
		2	6	54	181	71		5.3
II-12 B	100- 0-200	1	1	30	151	85	43	5.2
		2	7	91	136	49		5.3
II-13 B	100-100- 0	1	3	22	151	38	35	5.5
		2	7	27	136	49		5.4
II-14 B	100-100-100	1	2	26	216	97	39	5.3
		2	7	54	227	60		5.3
II-15 B	100-100-200	1	2	22	151	67	43	5.2
		2	6	50	136	55		5.2
II-16 B	100-200- 0	1	2	30	86	71	43	5.1
		2	120	27	227	60		5.0
II-17 B	100-200-100	1	2	26	151	138	35	5.4
		2	7	50	227	60		5.3
II-18 B	100-200-200	1	1	30	280	199	39	5.1
		2	20	100	317	97		5.4
II-19 B	200- 0- 0	1	1	22	173	169	39	5.4
		2	4	27	136	32		4.8
II-20 B	200- 0-100	1	1	26	130	228	35	5.4
		2	4	104	136	60		4.8
II-21 B	200- 0-200	1	2	26	173	138	35	5.3
		2	4	104	136	49		5.2
II-22 B	200-100- 0	1	2	39	151	155	35	5.2
		2	9	32	181	71		4.8
II-23 B	200-100-100	1	2	39	151	155	35	5.3
		2	7	54	136	67		5.1
II-24 B	200-100-200	1	1	30	173	165	35	5.2
		2	20	131	136	49		5.0
II-25 B	200-200- 0	1	1	39	86	165	35	5.0
		2	4	36	136	60		5.0
II-26 B	200-200-100	1	1	26	173	171	39	5.3
		2	7	50	181	55		5.2

Plot No.	Fertilizer Treatment, N-P_2O_5-K_2O (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
II-27 B	200-200-200	1	2	26	173	155	42	5.3
		2	7	82	181	55		5.2
III- 1 B	0- 0- 0	1	2	30	173	210	39	5.2
		2	6	41	227	78		5.2
III- 2 B	0- 0-100	1	2	30	194	147	39	5.4
		2	6	104	227	71		5.4
III- 3 B	0- 0-200	1	1	30	173	112	35	5.2
		2	6	127	227	85		5.3
III- 4 B	0-100- 0	1	1	30	194	138	35	5.3
		2	6	41	227	71		5.3
III- 5 B	0-100-100	1	1	30	173	169	43	5.2
		2	10	59	227	85		5.4
III- 6 B	0-100-200	1	2	35	194	165	43	5.3
		2	10	95	181	85		5.3
III- 7 B	0-200- 0	1	1	30	194	175	39	5.4
		2	7	41	272	90		5.4
III- 8 B	0-200-100	1	2	26	194	151	35	5.2
		2	14	50	272	97		5.3
III- 9 B	0-200-200	1	1	30	194	125	35	5.2
		2	34	77	272	60		5.3
III-10 B	100- 0- 0	1	1	35	130	108	30	5.1
		2	4	41	227	78		5.0
III-11 B	100- 0-100	1	1	30	151	108	35	5.2
		2	4	45	181	90		5.3
III-12 B	100- 0-200	1	2	35	151	102	30	5.1
		2	4	82	136	60		5.3
III-13 B	100-100- 0	1	1	30	173	138	30	5.1
		2	7	36	227	85		5.3
III-14 B	100-100-100	1	1	35	130	129	30	5.3
		2	14	54	227	78		5.2
III-15 B	100-100-200	1	1	26	238	195	35	5.4
		2	11	91	227	78		5.3

Plot No.	Fertilizer Treatment, $N-P_2O_5-K_2O$ (lbs./acre)	Sample Period	Available Nutrient Content (ppm.) P	K	Ca	Mg	Na	pH
III-16 B	100-200- 0	1	1	30	173	138	35	5.3
		2	24	32	227	71		5.1
III-17 B	100-200-100	1	1	26	173	147	35	5.3
		2	21	50	272	108		5.3
III-18 B	100-200-200	1	1	30	173	143	35	5.3
		2	17	82	227	97		5.4
III-19 B	200- 0- 0	1	1	35	194	129	35	5.3
		2	9	36	181	60		5.2
III-20 B	200- 0-100	1	2	26	151	129	30	5.4
		2	6	54	227	49		5.0
III-21 B	200- 0-200	1	1	39	238	188	30	5.3
		2	3	50	317	85		5.2
III-22 B	200-100- 0	1	1	39	173	195	30	5.3
		2	15	18	136	25		4.9
III-23 B	200-100-100	1	1	30	173	188	30	5.2
		2	3	27	227	38		5.3
III-24 B	200-100-200	1	1	17	194	143	35	5.5
		2	4	18	181	25		5.2
III-25 B	200-200- 0	1	1	22	194	155	30	5.3
		2	21	82	181	25		5.2
III-26 B	200-200-100	1	2	22	173	147	35	5.3
		2	24	41	227	38		4.8
III-27 B	200-200-200	1	1	26	173	175	35	5.2
		2	3	50	227	38		5.0

VITA

Norwin E. Linnartz was born April 9, 1926, in the rural community of Fischer, Comal County, Texas. He was the fourth of five children born to Eugene John and Emma Jentsch Linnartz.

He received his early educational training in rural schools of central Texas and was graduated from high school at Boerne, Kendall County, Texas, in May 1943. Subsequently he attended Draughons Business College, San Antonio, Texas, where he completed a course of study in general business administration.

On July 26, 1944, Linnartz entered the Navy and served until his release from active duty on August 22, 1946, having attained the rating of Third Class Petty Officer.

In October 1946, he accepted a position as Clerk-Typist with the Soil Conservation Service at Boerne, Texas, and was later transferred to Fredericksburg, Texas. In February 1949, he entered Arlington State College, Arlington, Texas, where he completed four semesters of basic course work in agriculture. In September 1950, he returned to duty with the Soil Conservation Service at Fredericksburg, Texas. In July 1951, he was again granted educational leave to complete his college work at Texas A. and M. College. He was awarded a Bachelor of Science degree in Range and Forestry by Texas A. and M. College in May 1959.

He was then employed as Range Conservationist with the Soil Conservation Service at Fredericksburg and New Braunfels, Texas. In August 1955, he resigned his position to enter private business. In November of the same year, he accepted a position as Range Conservationist with the Soil Conservation Service at DeRidder, Louisiana. In September 1957, he resigned to enter the Graduate School at Louisiana State University.

Linnartz was awarded a Master of Forestry degree by Louisiana State University in January 1959. He is currently seeking the Doctor of Philosophy degree in the Department of Agronomy.

On April 17, 1957, he was married to Melba Jean Robertson of Pineville, Rapides Parish, Louisiana, and they are the parents of a young son.

During his college work, Linnartz was elected to Phi Kappa Phi, Alpha Zeta, Xi Sigma Pi, and Sigma Xi. He is a member of the American Society of Range Management, Society of American Foresters, Soil Science Society of America, International Soil Science Society, and the Louisiana Association of Agronomists.

EXAMINATION AND THESIS REPORT

Candidate: Norwin E. Linnartz

Major Field: Agronomy

Title of Thesis: SOIL PROPERTIES, USE OF FERTILIZERS AND NUTRIENT UPTAKE AS RELATED TO THE GROWTH OF LOBLOLLY PINE (*Pinus taeda* L.)

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Date of Examination:

May 10, 1961