INFLUENCE OF SITE CONDITIONS ON FORM AND GROWTH OF WHITE OAK IN SOUTHERN IOWA

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I. INTRODUCTION

At the time this investigation was started, the State Conservation Commission had recently acquired several thousand acres of southern Iowa forest land, and was confronted with the problem of drawing up management plans for the units. Such plans, however, required definite information concerning these forests which was not available. The Iowa Agricultural Experiment Station, in cooperation with the Forestry Department of Iowa State College, was called upon to set up a number of projects, of which this study was one, in order to secure a more complete knowledge of these areas.

The purpose outlined for this particular problem was to determine the responses in form and growth of white oak pole stands to different site conditions or site factors.

II. HISTORICAL

A review of the literature concerning this subject reveals that a number of studies have been made in the eastern hardwood region dealing with the influence of one or two factors on growth of hardwood species. In the Central States, however, investigations of this kind have been somewhat limited. Few studies have embraced all of the main site factors and their influence on growth in one investigation. The magnitude and difficulty of such a problem have probably limited any activity in this respect. The information that these reports have furnished proves valuable as a basis for the part of this paper dealing with growth.

In regard to tree form, relatively little work has been done in this country in determining the influence of the various factors of site on form. Most of the studies along this line have been carried on by numerous investigators in the highly developed forests of European countries.

A. Site Indicators

In 1921 a committee of six members of the Society of American Foresters (28) considered the following as possible indicators of the quality of forest sites.

1. Height growth of main stand trees.
2. Vegetative indicators.

3. Analyses of soil and climatic factors.

4. Composition of the existing or original forest.

5. Actual measurement of volume growth.

6. Form factor.

7. Color and development of foliage.

The committee had the following comments about some of the more important indicators.

1. Height as site indicator, they said, was the simplest and most convenient, was fairly good, but was not always accurate and should not be used on juvenile stands under twenty years of age.

2. Analysis of the physical factors of soil and climate and comparison with similar sites whose productive capacity was known to be under some conditions as accurate a method as could be devised.

3. Vegetative indicators often give a good line on the productivity of the site.

The committee recommended:

1. The adoption of a standard method of classifying forest sites, on the basis of the actual mean annual growth in cubic volume at approximately the age of culmination of mean volume growth for typical well-stocked natural stands of the species present or to be grown on the site.

2. They also recommended height growth of the main stand for determining site quality.

A further consideration of the suitability of these site indicators is included in the following discussion.

1. Height growth of main stand trees. Although the committee recommended the height growth as an indicator of site quality, no definite study has been made to evaluate it as such. The fact, however, that

foresters in general have accepted height growth as a basis for site index classification and various tables of growth and yield show that in most cases it has proven applicable.

2. Vegetative indicators. In Europe Cajander (9) and other investigators have determined site quality by the use of the subsidiary vegetative cover. The work along this line in the United States has been limited to a few studies, one of which was made by Hazard (16) on White Pine in southern New Hampshire. She found that indicator types may be used to determine the natural fertility and silvicultural treatment of white pine areas.

3. Analyses of soil and climatic factors. The theory behind this indicator is that if a given site, as measured by physical and chemical soil characteristics and the climatic conditions, will produce a certain yield, then any other site with the same species and site properties should produce the same amount. No information is available to substantiate this claim.

4. Composition of the existing or original forest. Whether or not the composition of a stand influences the quality of any given site is a problem yet to be solved. Much discussion has been carried on concerning this point, most of which would indicate composition does indicate the quality of site. No definite proof of this contention, however, is available.

5. Actual measurement of volume growth. It is logical to assume that the volume of a stand on a site should indicate the productivity of

that habitat. Volume is one indicator that measures the sum of all factors. Bates (5) feels that it is the most satisfactory. Others feel that height growth is better. No investigation of the matter has been made, so no definite conclusion can be reached.

6. Form factor. The use of form factor as an indicator brings up much of the discussion concerning the measurement of tree form. Bruce and Schumacher (7) think that there is no factor yet discovered that will express accurately tree form. Chase (19), however, feels that form quotient is satisfactory for the bole of forms. Claughton (11) reports that Jonson found that a large tree is developed exactly as a small tree providing both have the same form quotient. He also says that Schiffel found that height tapers according to a fixed law. It is obvious, therefore, that no definite evidence is available which indicates conclusively that the site quality is indicated by the form factor.

7. Color and development of foliage. Although these have been suggested as a site quality indicator, very little has been done to prove their value as such.

It is apparent from this discussion that although seven site indicators are listed, the ones most adaptable to modern day needs are, primarily, the actual measurement of the volume growth and the height growth of the main stand trees. Undoubtedly the use of vegetative indicators will increase as more information concerning them is made available, but at the present time they are not commonly used. In view of the fact that height growth of the main stand trees has proven satisfactory as an indicator of site quality, the investigator has used it in this study for that purpose.

B. Influence of Site Conditions on Form and Growth

1. Physical characteristics of the soil.

Texture.

Auten (4) in his soil study of the Mont Alto State Forest in Pennsylvania, found that volume growth seemed to be somewhat independent of the soil texture of this area. Haig (44) reported that in his studies he found a correlation between colloidal content and increment. Auten (3) concluded that compactness of the soil was detrimental to growth of walnut. In his study of yellow poplar (2), he could find no definite correlation between texture and growth. Russell (26) writes that a soil may at one time be in a good crumbly state, very suitable to plant growth, and at another time very sticky, lumpy and quite unsuitable.

Humus.

Weaver and Clements (33) define humus as comprising the more or less decayed organic portion of the soil, consisting mostly, but not entirely, of vegetable matter, dark in color, light in weight, and more or less intimately mixed with the other soil components.

The source of humus has been studied for over a hundred years, with many of the investigators endeavoring to make humic bodies by laboratory methods. DuToit, as reported by Russell (26), contends that humus is formed from lignin at the ratio of two and one-half parts of lignin to one part of humus.

Waksman (30) states that forest humus varies in chemical composition under different conditions depending upon surface vegetation, climate, soil structure and microbial activities. Humus of different horizons differsin chemical composition.

Auten (4), in reviewing the work of various investigators, found that the humus of deciduous timber shows a higher pH than that of coniferous timber, mixed humus of hardwoods and conifers being lower than either pure coniferous or hardwood humus. Nemec and Kvapil (22) assert that under a deficient oxygen supply, humus is reduced to intermediary products with an acid reaction.

According to Waksman (30) forest humus is characterized by specific decomposition processes, which affect the vegetative growth of the forest. Coniferous humus and litter decompose slowly leaving lignins to accumulate. The organic mat resulting is acid in reaction, low in nitrogen, slow in decomposition and is easily leached. The broad leaf plant residue is attacked by numerous fungi, bacteria and invertebrates, which decompose the cellulose, hemicelluloses and lignins. The resulting humus is high in bases, is less acid in reaction and is higher in protein.

Waksman (30) summarizes the literature concerning the importance of humus in tree growth by saying that some investigators claim humus is highly important because of its physical, chemical and biological properties, while others think that the best humus is one that is never formed. These two views have developed from observations on two distinct types of humus, one being the incorporated soil humus as found in mull soils, and the other the little decomposed humus which forms the forest floor of the raw humus soils. Romell (25) found that a cover of leaf litter, moss or similar material prevents the soil from becoming sealed by fine particles due to torrential rains, as is the case in bare soils. A sealed soil has poor aeration.

The first investigations of forest humus were made by P. E. Müller, writes Russell (26), on humus types in Danish forests. In beech forests he found two types which he called mull and torf. Mull was free from acid, contained from 5 per cent to 10 per cent completely disintegrated organic matter and most intimately mingled with the mineral matter. Torf was acid and contained about 30 per cent of organic matter not completely disintegrated or mixed. Torf was so tough and compact that rain water could not penetrate it readily. It was not favorable to young tree growth. Mull was formed by earthworms and other similar animals, while fungi gave rise to torf.

Auten (2) states that organic matter influences the growth rate of yellow poplar in a cumulative manner as it grows in amount, but its presence is largely a result and not a cause. In a study of black walnut and black locust, Auten (3) found no correlation between organic carbon and tree growth.

Profile.

In his study of yellow poplar, Auten (2) found no apparent correlation between total depth of the A horizon and plant growth. The same was true of the B horizon. Failure to detect a correlation was probably due to the immature soil profiles. In his study of black locust and black walnut, Auten (3) did not find a correlation between the depth of the B horizon and growth. He did, however, find that growth had a definite correlation with the plasticity, compactness and texture of the subsoil. Porous structure and good oxidation were associated with good growth. Russell (26) reports that soil profile influences the moisture relationships and the reaction of the soil.

Water Relationships.

Auten (2) found the moisture content of the soil to be the limiting factor in the growth of yellow poplar. He further concluded that soil moisture appeared to be the principal factor limiting the satisfactory regeneration and rehabilitation of grazed woodland which have reached the advanced stages of decadence.

Coile (12) discovered a marked relationship between water-holding capacity of the B horizon and the site index. He found no well defined correlation between site index and any other physical characteristic or components of any one horizon. Haig (14) reports a definite correlation between the site index and colloidal content of the A horizon.

Hickock et al (17) found no correlation between subsoil and site index, nor did they find any correlation between site index and clay and silt content above twenty to twenty-five per cent in the A horizon. However, a positive correlation seemed to exist between the moisture equivalent of the A horizon and the site index. Harding (15) asserts that there is a fairly constant relationship between moisture equivalent and various moisture properties of the soil. Diller (13) reports that although the amount of water available for plant growth cannot be determined from the moisture equivalent alone, it is considered the best single value for interpreting the moisture properties of the soil.

Aspect.

Toumey (29) writes that aspect influences forest growth chiefly through its effect on temperature and soil moisture. The effect of aspect on soil temperature is so pronounced that trees often are grown far north of their natural range on southern slopes, and far south of their natural range on northern slopes. Larsen (20) found in his studies in Idaho that the moisture content of the southwest slope during the summer was dangerously low as compared to that of the northeast slope.

Auten (2) in his work with yellow poplar in the Central States, found the aspect of a site in its influence on moisture to be of great importance. This influence was clearly apparent in the changes of forest types or composition which occur on every forested area. He also found aspect, in its relation to moisture, to have a marked influence on the average annual height growth. He included the north slopes, east slopes and bottoms as moist sites favoring a high growth rate, and the south slopes, west slopes and ridge tops as dry sites causing a slower growth rate.

Degree of Slope.

Russell (26) reports that slope influences the temperature in that cool air tends to drain to the bottomlands below. [Weaver and Clements (32) state that the steepness of slope influences water content. The principal effect of slope is in controlling run-off and drainage.] Toumey (29) writes that trees on a steep hillside tend to have a greater radial growth on the downhill side, and the pith is nearer the bark on the uphill side. In his explanation for this phenomenum he infers that the compression of the tissue on the downhill side is a stimulus for accelerated diameter growth on that side. Bauer (6) asserts that slope is a condition producing eccentric growth to an extent that is proportional to its steepness.

2. Chemical Properties of the soil.

Nitrogen Content.

Holman and Robbins (18) write that next to hydrogen and oxygen, nitrogen is needed in the largest quantities. Auten (3), however, says that due to the small amount of nitrogen required, he could find no correlation between growth of black locust and black walnut and total nitrogen content of the soil. Nemec and Kvapil (23) report no relationship between nitrogen and soil type. They also found that pine stands with an undergrowth of beech have a higher nitrogen content than those without.

Toumey (29) says that the decomposition of forest litter returns from twenty-seven to forty-five pounds of organic nitrogen per acre per year. Auten (4) states that Zon found that black locust seed in pure sand increased the nitrogen content from .0024 grams to .092 grams (38 times) between May 1 and September 10.

Jenny (19) found that a correlation exists between the mean annual temperature and the average total nitrogen content of upland prairie and timber soils, and of the terrace and bottomland soils. The nitrogen content of the soils was found to decrease exponentially with an increase in temperature. In general, for every 10 degrees centigrade decline in mean annual temperature, the average nitrogen content of the soil was found to increase two or three times. Walker and Brown (31) say that in Iowa the temperature and humidity are more or less uniform; therefore, the differences in phosphorus, nitrogen and carbon are due to topography, texture and type of vegetation.

Soil Organisms.

The soils of the forest are populated by a great variety of micro-organisms. The growth and survival of the forest vegetation are directly related to these organisms and their relative numbers. Toumey (29) writes that the essential conditions for their existence not only include the presence of air and water, suitable temperature and the absence of toxic materials, but also require an adequate supply of energy-producing food. Russell (26) concludes that the organic matter affords energy to numerous micro-organisms.

The most important class of organisms is that which acts indirectly on the forest vegetation. These organisms do not live in contact with the roots, and their relative number determines, to a large measure, the degree of availability of nutrients in the soil. An example given by Toumey (29) is the Azotobacter, which changes the nitrogen from non-available to an available form. Russell (26) states that the number of bacteria fluctuates throughout the year, as the amount of energy material available fluctuates. He found that a pH from 6.8 to 7.0 seemed to be the most favorable for bacteria.

McDougall (21) found that in many plants, including oaks, fungi are habitually associated with the roots. Weaver and Clements (32) write that a mycorrhiza is a structure composed of root and fungus. Ectotrophic mycorrhizas have their mycelium on the outside of the root and between the cells. Endotrophic have their mycelium within the root. Many investigators consider the relationship of the fungus to higher plants one of parasitism, which is true in some cases. On acid soils, where nitrogen exists in the form of organic compounds, coniferous trees with mycorrhiza on the roots show the best growth. The mycorrhiza make the nitrogen readily available to the trees. Toumey (29) says that Melin's experiments showed that mycorrhiza bearing roots were capable of absorbing nitrogenous compounds more readily. Toumey (29) reports that Moller found that mycorrhiza do not appear to have the power to fix free nitrogen. Other investigators found this to be true.

Phosphorus

In a study of the affect of nutrient deficiency on the growth of longleaf pine seedlings, Pessin (24) reports that a shortage of phosphorus did not produce any external evidence of injury. The total dry weight of the plant was reduced, however, and shorter tap roots resulted. Auten (3) found that small amounts of the phosphorus in the soluble form are no indication of low site quality. As little as three pounds per acre were found on the better sites of walnut and black locust. No correlation was noted between phosphorus and growth. In his study of yellow poplar, Auten (2) failed to find any correlation between phosphorus and growth of yellow poplar. Walker and Brown (31) discovered a definite and consistent correlation between texture and phosphorus. Sandy loams had the lowest amount while the amounts increased in order through fine sandy loam, loam, silt loams and silty clay loams.

Potassium.

Auten (2) found no relationship between potassium and growth of yellow poplar. In some cases maximum growth occurred on soils too low in potassium to give a test. Pessin (24) showed that a potassium deficiency resulted in a stunted, sickly plant with poor survival in pine seedling studies.

Calcium.

Pessin (24) found that a deficiency of calcium in seedlings resulted in high mortality, delicate weak needles and very little growth after two months. Auten (2) says that the amount of replaceable calcium in the soil did not seem to influence growth in the least as far as the statistical analysis could disclose. Yellow poplar can grow on an acid soil, gather lime, and deposit it in the litter thus building up the calcium content of the surface soil.

Holman and Robbins (18) report that calcium apparently stimulates root development. A deficiency of calcium retards transportation of carbohydrates and their utilization. Toumey (29) states the calcium improves the physical condition of the soil and neutralizes acidity, thereby improving fertility.

Acidity.

Wilde (33), in a discussion of pH, gave the following ranges of pH and their influence on plant growth.

1. Soils of pH less than 3.7 will not support normally developed forests.

2. pH 3.7 - 4.5 supports acidophilous conifers, birch and aspen.

3. pH 4.5 - 5.5 is adapted to some deciduous trees and most conifers. The low availability of nutrient is the reason for low growth.

4. pH 5.5 - 6.9 is characterized by high activity of microorganisms, energetic humification, friable structure, good aeration and high yield of wood. As it approaches neutrality, some conifers become susceptible to fungous attack.

5. pH 7.1 - 8.0 supports largely the stands of southern hardwoods.

6. pH 8.1 - 8.5 is toxic to forest trees.

7. Over pH 8.5 the soil is unproductive so far as forests are concerned.

Wilde (33) further states that the unfavorable influence of alkaline soils upon the forest trees is due either to toxicity of OH-ions or to an excess of calcium or magnesium carbonates, causing a lack of available iron (chlorosis).

Nemec and Kvapil (22) report that open stands have a lower acidity. In addition, soils of mixed stands usually have a lower acidity than corresponding layers of the closed hardwood and conifer stands. They say that soil acidity increases with decreasing air capacity.

Auten (3) showed no correlation between pH and walnut growth.

In reviewing the literature on soil acidity, Auten (4) found that Breal said that soil acidity prevents the formation of nitrates except in small amounts which were taken up rapidly by the plants; hence no nitrates were found in acid soils.

Russell (26) sums up the ideas of soil acidity with the following points:

1. Soils contain two groups of acids.
    a. Organic acids, mainly humic acid.
    b. Inorganic acids of the clay complex, probably alumino-silic acids.
2. Acid soils are characterized by three properties.
    a. Deficiency of replaceable calcium.
    b. Presence of hydrogen ions.
    c. Tendency to contain soluble aluminum and iron salts.

3. Precipitation and temperature.

Burns (8), in a study of the influence of rainfall on tree growth, found that the moisture content of the soil as influenced by precipitation was one of the chief factors favorable to plant growth. Russell (26) reports that yield rises as the water increases up to a certain point, and then falls off because the excess of water reduces the air supply for the roots. Adams (1) found that the amount and distribution of rainfall had considerable influence on height growth. He also found that higher mean monthly temperatures and greater rainfall in the early part of the growing season gave a much greater diameter growth. Adams discredited the importance of light as a limiting factor in growth on the theory that even under dense canopies a sufficient amount of light is found to carry on photosynthesis. Schubert (27) found, through a statistical analysis of his data, that about half the area increment of pine was due to precipitation during the dry summer months.

Weaver and Clements (32) state that the temperature has more or less to do with nearly every function of the plant. With a decrease in temperature to a certain minimum, growth is retarded; at a lower temperature, cell division and photosynthesis are checked; and, at a still lower temperature, respiration ceases and death ensues.

III. EXPERIMENTAL

A. Methods of Procedure

1. Field methods.

The data which are presented in this thesis were gathered on the recently acquired state forest lands in Lee, Lucas and Monroe Counties in Iowa. Nineteen plots were taken in all, and these were so located that each represented typical southern Iowa pole stands of white oak (*Quercus alba* L.), duplicate sample plots being selected to represent each distinct site condition such as aspect, slope, soil texture, pH, precipitation and other climatic and edaphic factors. After some difficulty at the start, satisfactory duplicate representative plots were eventually secured which it was hoped would express influences of the more important or perhaps the controlling or limiting site factors.

In selecting the plots it was, at first, necessary to exercise personal judgment, especially in trying to find the duplicates. In the final analysis, however, the selection of these duplicates resulted not from personal judgment but from the mechanically measured factors as they were found in the field.

These plots were chosen and located more for the express purpose of finding causes among the site factors contributing toward better growth, more satisfactory tree form and healthy forest development rather than to determine actual growth, form and yield. For these reasons a statistical method was of no consequence in their selection. Furthermore, pole stands were chosen because these represent the oldest age classes of timber which now occur in unbroken more or less normal forest conditions. Old virgin stands have long since been removed, so that only individual trees or broken remnants now remain. Another reason for choosing the pole stands for this study is that these now represent the most important commercial forests in the region.

The Lee County plots, nine in number, were established on an eighty acre tract supporting a well-stocked second growth white oak pole stand. The topography of this area is a slightly rolling upland dissected by several narrow, but deep, drainage-ways that formed dendritic patterns throughout the area. The tract had been lightly grazed, but an abundance of reproduction indicated that little damage had been done. Ground fires had occurred from time to time throughout the area, but very few trees bore any severe fire scars.

In Lucas County, an effort was made to locate five plots in a stand of timber having site conditions similar to those found on the Lee County tract. The forest chosen consisted of a well-stocked seventy-two acres of second-growth white oak poles. A rolling upland dissected by several large drainage-ways characterized the topography. Little damage by grazing or fire was found on the area.

The Monroe County plots were chosen to represent the influence of heavy grazing and fire on form and growth. With this in mind, the samples were situated on the Curtis Tract of the State Forest land located in the northwest corner of Monroe County, twenty-five miles northeast of the Lucas County plots. During the past few years this area had been heavily grazed and frequently burned. Four of the plots were located on heavily burned or grazed sites while the fifth plot was established as a check on a site neither heavily burned or grazed. In laying out the individual plots, the first step was to establish a corner and then run the boundaries out from that point. For this purpose the Forest Service staff compass, the abney hand-level and the trailer tape were used in plots which were either square or rectangular, thus simplifying the taking of measurements on the sample area. The plots varied in size from one-tenth to one-quarter of an acre depending upon the topography and density of stocking. When obtaining the plot boundaries, the trees that fell just outside were marked in order to prevent the possibility of measuring trees not on the plots.

The next step in the procedure was to measure and record the species and diameters at breast height with a steel diameter tape. Diameter measurements were recorded to the nearest inch.

From the above measurements the average diameter of the trees was then determined and three trees were chosen for samples. The trees selected were dominant, single stems, healthy appearing, of about average diameter and of average height of the dominant trees. The average height of the main body trees was checked from time to time by measuring the height of ten dominant trees and obtaining the mean.

The three sample trees chosen were then felled, leaving a stump height of six inches in each case. Individual measurements of each tree were then taken of the width of the crown and the crown length to the closest tenth of an inch by means of a fifty foot steel tape. The tree was then limbed and the stem marked off in four-foot sections starting at stump height and extending to a point on the tree where no more sections could be cut without going under two and a half inches. In a similar manner, the tree was then measured to determine its total height. The mid point, located at one-half the tree height plus two and a quarter feet, was then located and marked for cutting. After the stem was thus marked off, the tree was bucked into four-foot lengths. The mid point on the stem was also cut so that a measurement could be made at that point. Measurements of the end sections were then taken, starting at stump height and repeating at the top of each section until the tip was reached. The first measurements taken on the cross section were the diameters inside and outside bark*, obtained with a steel ruler graduated in hundredths of an inch. Perpendicular diameters averaged gave the true diameter. In taking these diameter measurements the ruler was placed to measure the widest and the narrowest parts of the cross section in order to obtain a better average. After the mean diameter was determined, the zero point of the ruler was held on the

* Hereafter diameter inside bark and diameter outside bark will be designated by D.i.b. and D.o.b., respectively. All diameter measurements referred to were taken at 4.5 feet above the ground level.

pith and the other end of the ruler was swung around until the average radius was found. A line was then drawn from the center to the bark along this average radius. Starting at the center, every ten years growth was marked off by pencil marks. The total number of rings at the section was determined at the same time. With the growth marked off, the next step was to measure the distance of each of these marks from the pith. In other words, the growth in ten years, twenty years, thirty years, etc. was recorded.

The age of the tree was considered to be equal to the number of annual rings at stump height plus one year necessary to grow the six inches. The form quotient of each tree was determined by dividing the diameter inside bark at the mid point by the D.i.b.

After completing the detailed investigations of the three trees, other important factors of site were then measured. Slope measurements were obtained by means of the abney hand-level, and converted to per cent slope at 100 feet.

The aspect was determined by the use of a Forest Service staff compass, and recorded to the closest of the eight common points of the compass such as north, northeast, east, etc.

Observations on the soil type and on the different horizons were made by digging a pit twenty inches deep and observing the character of the different horizons. The depth of humus and litter was also observed and measured with the steel ruler at the same time.

Soil samples were taken for the A horizon of each plot. In addition

B horizon samples were taken on about half the plots, with at least one for each site. The reason that B horizon samples were not taken for each plot was that there was little difference between the subsoil in similar plots on the same soil type. A variation was expected between different sites on the same soil type, so samples were taken for such cases. The A horizon sample taken was a composite of five samples from the center and the four corner sections of the plot. The subsoil was taken at the center of the plot by digging a pit in order that a sample could be taken at twenty inches. The samples, as gathered, were placed in two-quart Mason jars and promptly sealed. Each jar was appropriately marked to prevent any mixing of the samples.

The topography of the plot was limited to its relative position on the slope, such as ridge top, upper slope, mid slope, lower slope and bottom.

From the tally of the trees on the plot by species, records were obtained of the forest composition as well as the density. The latter factor was expressed by the total number of trees per acre and their average D.o.b.

The origin of the sample trees, whether seedling or sprout, was determined by observing the condition of the stem at ground level. If this was rounded and somewhat bulged, it indicated a sprout. Stumps were cut open occasionally to check this observation. All of the sample trees proved to be of sprout origin.

Grazing damage was studied by means of the condition of forest reproduction and the state of the vegetation present. A knowledge of the approximate number of stock grazing the area was also obtained from the local farmers.

The fire damage was estimated by observing the extent of fire scars on the trees. The character of the vegetation was also indicative of the amount of fire damage.

Total heights of standing trees were determined by use of a trailer tape and an Abney hand-level.

2. Laboratory methods.

The first determination in the study of the physical and chemical characteristics of the soil was the mechanical analysis. This was carried on by means of the standard Bouyoucos hydrometer method.

In finding the moisture equivalent, the centrifuge method was used.

The hygroscopic coefficient was determined by placing about five grams of oven dry soil in a clamp watch glass and placing both in a saturated atmosphere for forty-eight hours. At the end of the time the sample was removed and weighed to determine the amount of moisture absorbed. This moisture which is equal to the hygroscopic coefficient of the particular soil was recorded in terms of per cent of its dry weight. The chamber used to produce a saturated atmosphere in this method was a desiccator using water instead of a drying agent. Before placing the sample in the chamber, the dessicator was allowed to stand in an incubator at constant room temperature for twenty-four hours so that the atmosphere would have sufficient time to become saturated. This method was checked by running triplicates in the same chamber, and by placing similar soil samples in different chambers. In all cases a good check was obtained. In addition, samples were weighed every twelve hours for over two hundred hours to get the trend of the amount absorbed. It was found that during the whole period the sample continued to absorb more and more water, but that after forty-eight hours a plateau was always reached (on the curve) indicating an almost negligible subsequent gain. From these results, it was concluded that forty-eight hours was the most satisfactory and most accurate time to make the measurements.

The wilting per cent of the soil was measured by planting a sunflower seed in a given quantity of soil and watering it until it become a healthy plant about fifteen inches high. At that time the watering was stopped and the plant allowed to wilt. When the plant wilted, the soil from around the roots was removed and examined for its moisture content at permanent wilting. Permanent wilting is that wilting from which the plant cannot recover by being placed in a saturated atmosphere.

The water-holding capacity for each sample was measured by filling a twelve inch cylinder of known weight to a depth of eight inches with soil. Glass wool was placed over the perforations in the bottom of the cylinder to prevent the soil from going through, and yet permit the free passage of water. The cylinder and soil were then weighed together to get the weight of the soil, which was determined by subtracting the cylinder weight from the total weight.

The cylinder was then placed in a crock of water to completely saturate the soil. The water in the crock was kept at about the same level as the soil. After twenty-four hours, the cylinders were removed and allowed to drain for one hundred and twenty-five hours, at which time it was removed and weighed. The difference in the weight of the dry soil and the wet soil indicated the amount of water the soil could hold against gravity. The amount of water held was expressed in terms of per cent of the weight of the dry soil. This per cent was known as the water-holding capacity.

The volume-weight ratio was measured by determining the weight of 500 c.c. of 20 mesh soil. This was done by filling a 500 c.c. graduate with 20 mesh soil and then determining the weight of the soil.

The chemical properties were measured in the following manner:

1. The pH was determined electrometrically by the quinhydrone electrode.

2. Total nitrogen was measured by the Kjeldahl method.

3. Total carbon was determined by the dry combustion method and multiplied by the factor .27 and 1.724 to get the organic matter in the soil.

4. Total phosphorus was calculated by means of the modified magnesium nitrate method.

3. <u>Office methods.</u>

The average annual height growth of the trees was determined by dividing the total height growth of each tree by the age. The mean height growth for each plot was determined by totaling the average annual height growths of the three trees and dividing by three.

The mean annual diameter growth was determined by dividing the D.i.b. by the age of the tree. The average for the plot was then determined in a manner similar to height growth.

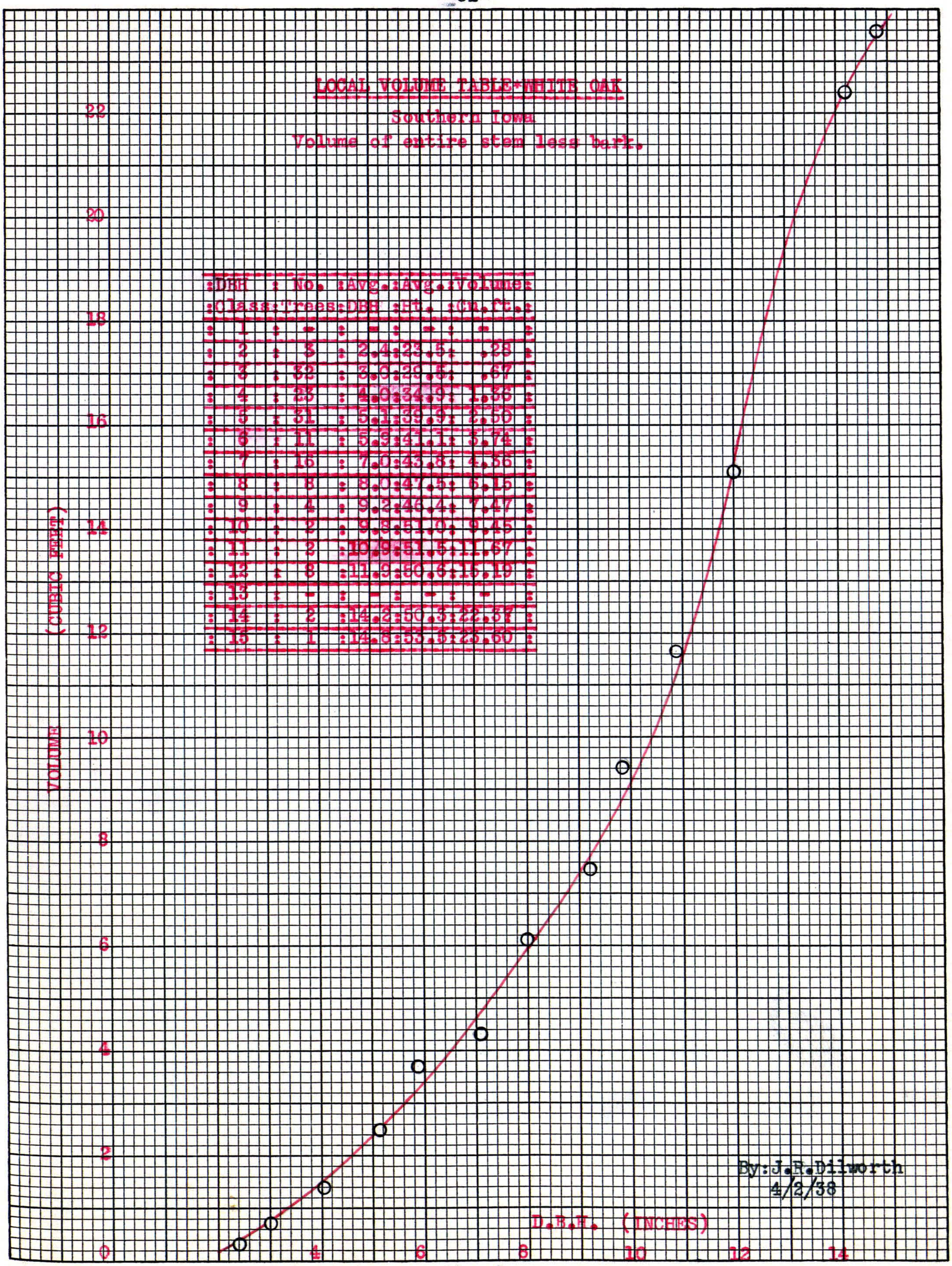
The average annual cubic foot volume growth was determined by plotting the values on form 558A and determining the mean volume of sample trees on the plot. The average volume was then divided by the average age to determine the mean annual cubic foot volume growth.

The average annual height growth during the last ten years was determined from a curve of height over age. The height growth during the past ten years was determined from the curve and divided by ten to get the average annual height growth for that period. The average annual height growth for the last twenty years was determined in the same way except twenty years was considered instead of ten.

The average annual diameter growth was obtained by determining the growth for the last ten years from the stem analysis data and dividing by ten.

Taper curves were drawn with average height plotted over the average radius to give a picture of how the average form of the trees appeared on a given plot.

The volume per acre for each plot was determined by constructing a local volume table, indicated by figure 1, from tree data taken throughout the region. Part of these data were obtained from Professor C. M. Genaux



LOCAL VOLUME TABLE-WHITE OAK

Southern Iowa

Volume of entire stem less bark.

DBH Class	No. Trees	Avg. DBH	Avg. Ht.	Volume Cu.ft.
1	-	-	-	-
2	3	2.4	23.5	.28
3	32	3.0	28.8	.67
4	23	4.0	34.9	1.36
5	31	5.1	38.9	2.50
6	11	5.9	41.1	3.74
7	16	7.0	43.8	4.36
8	8	8.0	47.5	6.15
9	4	9.2	46.4	7.47
10	2	9.8	51.0	9.45
11	2	10.9	51.5	11.67
12	8	11.9	50.6	15.19
13	-	-	-	-
14	2	14.2	50.3	22.37
15	1	14.8	53.5	23.60

Fig. 1

and Mr. J. G. Kuenzel, who were making a forest study on the same area. After the volume table was constructed, the total volume of all the trees on each plot was calculated and converted to a per acre basis.

IV. RESULTS

A. Presentation of Data

The results of this study fall into four distinct groups: first, the conditions of the trees, commonly known as the stand conditions; second, the physical characteristics of the site; third, the chemical properties of the soil; fourth, the climatic conditions of the area. In the following discussion, each group is considered separately and is followed by the correlation of the various site conditions with the characteristics of the stand.

1. Stand conditions.

The forests of southern Iowa have suffered greatly due to mismanagement during the past seventy-five years. Heavy cutting and uncontrolled burning have reduced extensive virgin forests to scattered patches of inferior second-growth timber. It was in these scattered patches of second-growth that this investigation was carried on.

The plots used in this study and their location are indicated by the sampling roster in Table I. The detailed stand conditions found in the white oak pole stands of southern Iowa are recorded in Tables II and III. Table II shows the average conditions by plots while Table III gives the averages found for each of the three counties studied. The growth rates

TABLE I

Sample Plot Roster

Plot	County	Location
2	Monroe	NW/NE Sec. 30; T 73N, R 19W
3	Monroe	SW/NW Sec. 20; T 73N, R 19W
4	Monroe	NW/SW Sec. 20; T 73N, R 19W
5	Monroe	SW/NW Sec. 19; T 73N, R 19W
6	Monroe	SW/NW sec. 19; T 73N, R 19W
7	Lee	SE/NE Sec. 16; T 67N; R 7W
8	Lee	SE/NE Sec. 16; T 67N; R 7W
9	Lee	SW/NW Sec. 15; T 67N; R 7W
10	Lee	SW/NW Sec. 15; T 67N; R 7W
11	Lee	SW/NW Sec. 15; T 67N; R 7W
12	Lee	SW/NW Sec. 15; T 67N; R 7W
13	Lee	SW/NW Sec. 15; T 67N; R 7W
14	Lee	SW/NW Sec. 15; T 67N; R 7W
15	Lee	SW/NW Sec. 15; T 67N; R 7W
16	Lucas	SE/NE Sec. 6; T 71N; R 23W
17	Lucas	SE/NW Sec. 6; T 71N; R 23W
18	Lucas	SW/NE Sec. 6; T 71N; R 23W
19	Lucas	SE/NW Sec. 6; T 71N; R 23W
20	Lucas	SE/NW Sec. 6; T 71N; R 23W

TABLE II
Stand Conditions of Sample Plots

PLOT NUMBER	2	3	4	5	6	7	8	9	10	11
Avg. Age	58	62	44	48	40	34	59	39	43	40
Avg. D.B.H.(inches)	5.87	7.19	5.18	5.96	5.16	5.30	6.03	4.87	5.80	5.50
Avg. Height (feet)	34.5	35.0	33.0	34.5	37.6	36.7	43.2	40.0	42.8	45.2
Avg.Vol. per A.(cu.ft)	968.4	2141.6	776.8	1103.5	1289.5	1096.8	1400.8	1360.4	1782.4	1568.7
Avg.No. trees per A.	424	1008	664	532	496	884	864	968	913	1146
Species by %:										
White Oak	87.7	84.1	81.0	75.1	42.7	59.7	81.0	78.5	75.9	68.0
Red Oak	7.5	3.1	15.3	0.0	5.7	7.7	10.1	1.3	7.2	4.6
Hickory	4.8	12.8	3.8	24.9	51.6	14.9	2.5	11.1	10.9	21.6
Misc.	0.0	0.0	0.0	0.0	0.0	17.6	6.4	9.1	6.0	5.8
Avg.Ann.Hgt. Growth	.59	.57	.78	.73	.92	1.16	.78	1.01	.99	1.13
Avg.Ann.D.i.b.Growth	.095	.110	.125	.124	.128	.162	.106	.115	.125	.126
Avg.Ann.Vol. Growth	.052	.064	.064	.070	.073	.088	.076	.086	.084	.081
Avg. Form Quotient	.616	.619	.719	.652	.815	.755	.774	.765	.662	.709

PLOT NUMBER	12	13	14	15	16	17	18	19	20
Avg. Age	39	39	37	29	62	68	57	62	66
Avg. D.B.H.(inches)	5.40	5.83	5.07	5.12	5.72	5.13	5.80	5.70	6.20
Avg. Height (feet)	42.6	39.9	42.3	40.2	37.0	37.2	40.2	41.8	43.6
Avg.Vol.per A.(cu.ft.)	1360.7	1458.5	1442.9	1555.1	1229.1	1282.0	1292.6	1414.6	1558.0
Avg.No. trees per A.	620	1320	915	1286	750	570	550	520	555
Species by %:									
White Oak	36.5	74.0	62.2	55.4	74.6	65.0	50.9	57.6	45.9
Red Oak	4.5	0.9	12.5	5.1	4.1	17.5	3.6	15.5	13.6
Hickory	39.7	23.7	19.1	11.3	21.3	17.5	43.6	26.9	40.5
Misc.	19.3	1.4	6.2	28.2	0.0	0.0	1.9	0.0	0.0
Avg.Ann.Hgt. Growth	1.10	1.03	1.14	1.42	.59	.56	.73	.69	.69
Avg.Ann. D.i.b. Growth	.128	.140	.130	.175	.092	.079	.097	.085	.088
Avg.Ann.Vol. Growth	.081	.084	.073	.099	.056	.044	.064	.055	.074
Avg. Form Quotient	.701	.673	.685	.652	.670	.769	.639	.619	.733

TABLE III

Average Stand Conditions found in Lee, Lucas and Monroe Counties

Tract	Avg. Age	Avg. Dbh	Avg Ht. (feet)	Avg. F. Q.	Avg. Vol. Cu. Ft.	Avg. Ann. Vol. Gr. (cuft)	Avg. Ann. Ht. Gr.	Avg. Ann. D.ib. Gr.	Avg. Composition of Stand W.O.	R.O.	H.	Misc
Lee	40.0	5.42	41.4	.71	1447.4	.082	1.045'	.129"	67.0	8.0	25.0	—
Lucas	62.0	5.71	39.9	.69	1355.3	.059	.650'	.088"	57.1	10.5	32.0	—
Monroe	50.4	5.87	34.9	.68	1255.9	.064	.716'	.116"	84.9	3.8	11.3	—

Ann-Annual; Gr.-Growth; Vol.-Volume; Ht.-Height; W.O.-White Oak; R.O.-Red Oak; H.-Hickory; F.Q.-Form Quotient.

of the various stands are illustrated graphically by figures 2 through 7.

In view of the extensive data on stand conditions, only a few of the more significant characteristics warrant further consideration. Perhaps one of the best indicators of past mismanagement of the forests is the low cubic volume per acre. Stands with volumes as low as 776.8 cubic feet per acre indicate poor treatment, while other stands running as high as 2,141.6 cubic feet per acre are indicative of a more desirable land management.

It will be observed in Table II that most of the plots have a high percentage of white oak in respect to the other species. This is because the plots were located purposely in white oak stands. The high proportion of white oak is therefore not truly representative of all hardwood stands in this region. Three of the plots contain less than fifty per cent white oak. In these, the white oak makes up most of the main body of the stand and the bulk of the volume, but a large number of saplings and small trees of other species naturally reduces the proportion of the white oak in relation to the other species.

2. Physical characteristics of the site.

The physical characteristics of site are numerous, hence the following discussion will be limited to the presentation of the data. The significance of the data will be discussed later in the paper.

A physical characteristic that Auten (2) found important in his

Fig. 2 - AVERAGE ANNUAL
HEIGHT GROWTH OF ALL PLOTS

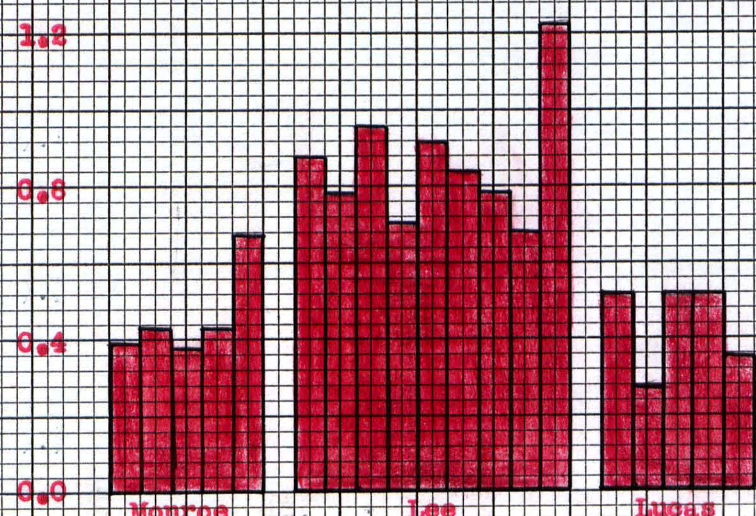


Fig. 3 - AVERAGE ANNUAL
HEIGHT GROWTH LAST 10 YEARS

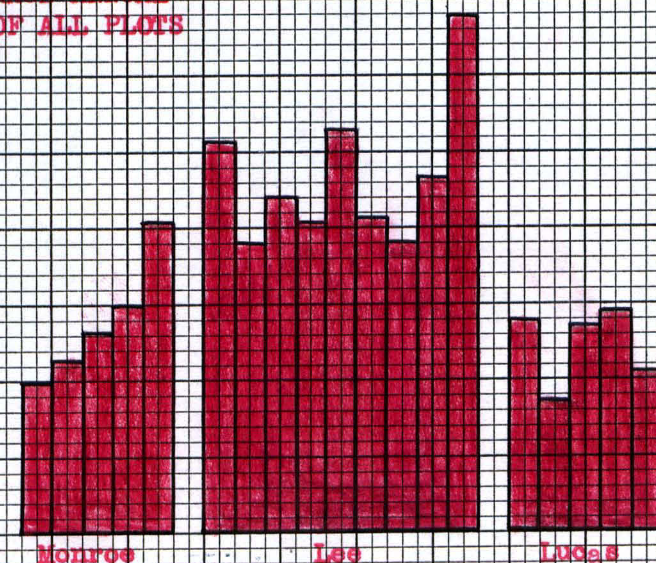


Fig. 4 - AVERAGE ANNUAL
HEIGHT GROWTH LAST 20 YEARS

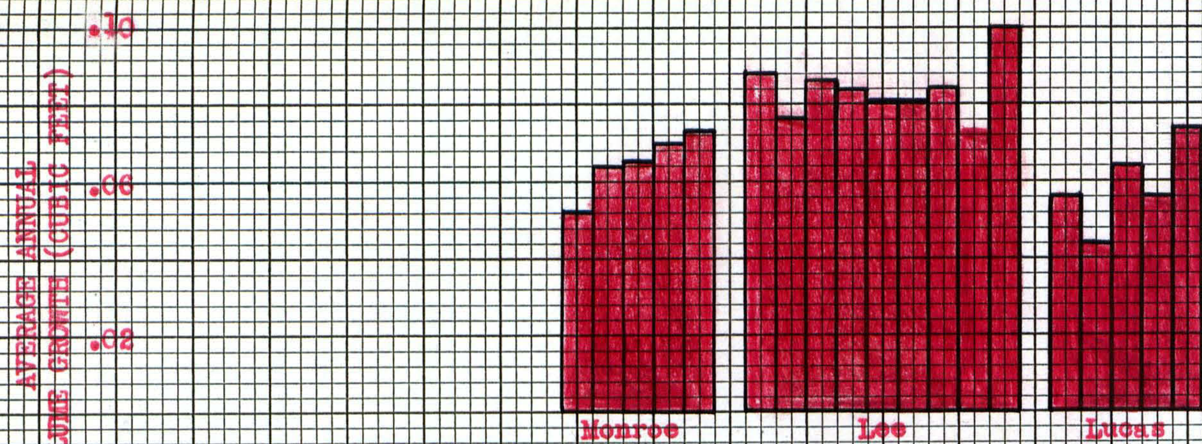


Fig. 5 - AVERAGE ANNUAL
VOLUME GROWTH OF ALL PLOTS

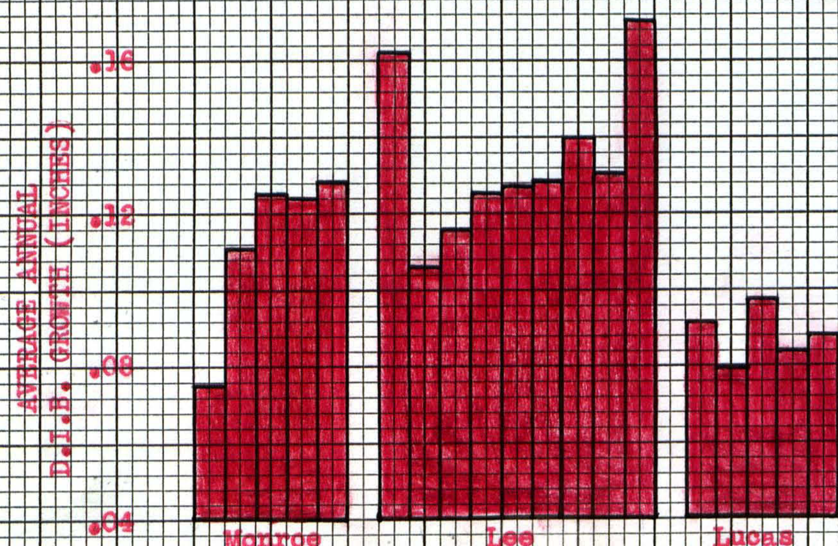


Fig. 6 - AVERAGE ANNUAL
D.I.B. GROWTH ALL PLOTS

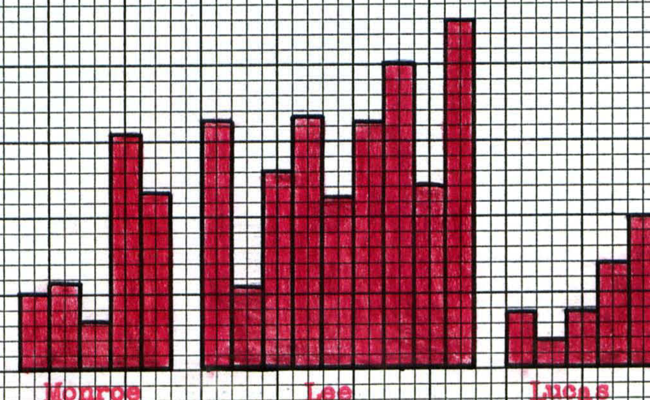


Fig. 7 - AVERAGE ANNUAL
D.I.B. GROWTH LAST 10 YEARS

study of yellow poplar is the aspect as indicated in Table IV. Aspect, as previously defined, is the relation of the slope of the land to the points of the compass. In locating the plots, an effort was made to have each aspect represented by at least two plots. The influence of aspect is ohly indirect through its effect on moisture content of the soil.

It is observed in Table IV that the degree of slope of the plots varies from thirty-four per cent to a draw with practically no grade whatsoever, and that the Lee County plots are characterized by steeper slopes than those located on the other areas. Lee County plots average out to a 15 per cent slope. Those in Lucas County average 11 per cent and those in Monroe County 10 per cent.

All forest soils of southern Iowa, as a rule, have a relatively thin surface soil ranging from one-half to three inches in depth. This is shown in Table V. In addition, the depth to the tight clay horizon, which varies from seven to eighteen inches, is much less under forest than under open conditions. There have been many theories as to the cause of this condition, but there has never been advanced sufficient evidence to explain the phenomena satisfactorily.

A study of the texture of the soils brings out the rather interesting fact that a large amount of clay occurs in many of the samples of the A horizon, as indicated in Table VI. The results of this analysis indicate many of the Lindley and Clarion soils have clay percentages varying from 17.3 to 41.8 in the A horizon. Many of these are over 30 per cent, making

TABLE IV

Aspect, Slope Per Cent and Position on Slope

Plot	Aspect	Slope Per Cent	Location on Slope
2	South	5	Ridge Top
3	East	6	Ridge Top
4	East	16	Upper Slope
5	North	10	Upper Slope
6	North	15	Middle Slope
7	Northeast	7	Upper Slope
8	West	34	Middle Slope
9	South	5	Ridge Top
10	South	21	Middle Slope
11	East	18	Middle Slope
12	North	2	Ridge Top
13	South	13	Middle Slope
14	North	24	Upper Slope
15	Bottom of Draw	0	Bottom of Draw
16	West	9	Upper Slope
17	West	15	Middle Slope
18	South	6	Middle Slope
19	North	16	Ridge Top
20	East	10	Upper Slope

TABLE V

Depth of Litter, A Horizon, B Horizon and Volume Weight

Plot	Volume Wt. (Grams per 500 cc)	Litter (inches)	A Horizon (inches)	B Horizon (inches)
2	417	.25	.75	15.0
3	519	.75	1.50	10.0
4	451	.75	.50	18.0
5	582	.50	3.00	6.0
6	586	.25	1.00	7.0
7	452	1.00	3.00	17.0
8	512	1.00	1.00	5.0
9	411	1.00	2.00	10.0
10	457	.75	2.00	10.0
11	465	1.50	3.00	6.0
12	399	1.00	2.00	17.0
13	444	1.00	1.00	11.0
14	419	2.00	1.50	8.0
15	438	2.00	1.50	18.0
16	410	1.00	.75	7.0
17	469	.75	2.00	10.0
18	375	1.00	1.10	6.5
19	430	1.00	1.50	10.0
20	462	1.50	2.00	12.0

TABLE VI
Mechanical Analysis, Texture and Soil Series

Plot	Horizon	Sand (%)	Silt (%)	Clay (%)	Texture Class	Soil Series
2	A	28.1	41.4	30.5	Clay	Clinton
	B	--	--	--		
3	A	26.2	42.3	31.5	Clay	Clinton
	B	24.2	5.0	70.8	Clay	
4	A	42.2	29.6	28.2	Clay loam	Clinton
	B	80.3	4.0	15.7	Sand	
5	A	24.5	36.3	39.2	Clay	Lindley
	B	24.5	25.3	50.2	Clay	
6	A	54.5	17.4	28.1	Sandy loam	Lindley
	B	--	--	--		
7	A	43.3	25.2	31.5	Clay	Marion
	B	45.5	19.0	35.5	Clay	
8	A	55.5	27.2	17.3	Sandy loam	Lindley
	B	--	--	--		
9	A	23.5	36.0	40.5	Clay	Lindley
	B	--	--	--		
10	A	53.5	19.0	27.5	Sandy loam	Lindley
	B	--	--	--		
11	A	51.5	18.0	30.5	Sandy loam	Lindley
	B	--	--	--		
12	A	23.5	35.5	41.0	Clay	Lindley
	B	--	--	--		
13	A	31.5	34.0	34.5	Clay	Lindley
	B	--	--	--		
14	A	34.8	30.0	35.2	Clay	Lindley
	B	34.5	18.0	47.5	Clay	
15	A	51.5	20.0	28.5	Sandy loam	Lindley
	B	56.2	16.0	27.8	Sandy loam	
16	A	22.2	36.0	41.8	Clay	Lindley
	B	--	--	--		
17	A	52.2	19.6	28.2	Sandy loam	Lindley
	B	35.2	10.0	54.8	Clay	
18	A	36.2	32.0	31.8	Clay	Lindley
	B	--	--	--		
19	A	32.2	34.0	33.8	Clay	Lindley
	B	35.2	12.0	52.8	Clay	
20	A	49.2	23.0	27.8	Clay loam	Lindley
	B	49.6	10.0	40.4	Clay	

the soil class a clay. This is an unusual type for Iowa, because Lindley and Clinton clay soil have never been reported in any part of the state in large enough quantities to be mapped. It is apparent, therefore, that the plots high in clay in the A horizon are exceptional rather than the usual cases. This high clay content of the A horizon is the most significant part of this texture data and indicates that under forest conditions there is a tendency toward a higher clay content. Almost all of the subsoil samples are high in clay due to the accumulation of colloidal materials through leaching of the finer particles from the horizons above.

Table VII, illustrating the moisture relationships of the soil, shows somewhat of a correlation between the water-holding capacity and the clay content of the soil. An increase in clay and silt usually results in increased water-holding capacity. Plot 16, with a clay content of 41.8 per cent, has a water-holding capacity of 56.4 as compared to plot 8 with a clay content of 17.3 per cent and a water-holding capacity of 39.3. This relationship has exceptions, but in general such is found to be the case. A further study shows a relationship between the wilting point and the sand content. Plot 8, with a sand content of 55.5 per cent, has a wilting point of 4.87, while plot 16 has a wilting point of 7.59 with a sand content of 22.2 per cent. This indicates that as the amount of sand increases, the wilting point is lowered. Briggs and Shantz and other workers have found definite relationships between the moisture equivalent, hygroscopic coefficient and wilting point. Whereas the relationship between the hygroscopic coefficient and the wilting point approaches the accepted ratio of .68,

TABLE VII

Moisture Relationships

Plot	Water-holding (%)	Moisture Equivalent (%)	Hygroscopic Coefficient (%)	Wilting Point (%)
2	54.2	20.17	5.96	8.49
3	51.6	23.16	6.24	11.16
4	44.8	18.65	5.02	8.01
5	46.9	19.78	5.14	7.67
6	37.9	15.47	5.21	8.52
7	49.3	16.38	3.83	6.83
8	39.3	13.22	3.57	4.87
9	54.2	19.50	5.48	8.85
10	46.2	17.57	5.83	7.71
11	46.4	23.16	5.18	9.78
12	64.1	16.88	6.45	7.06
13	51.8	23.29	5.72	7.43
14	55.6	22.14	5.50	6.98
15	59.8	16.33	5.75	5.50
16	56.4	20.39	6.88	7.59
17	49.4	14.57	5.47	6.07
18	75.0	22.40	6.69	8.28
19	62.4	17.58	5.51	--
20	48.8	14.27	4.81	4.47

the relationship between moisture equivalent and wilting point is over 2.00 as compared with the generally accepted 1.84. The difference is due perhaps to the fact that the accepted values apply only to agricultural soils, while in this study forest soils are involved.

The total organic matter for all the plots is recorded in Table VIII. A study of these data for each area reveals that the Monroe plots have a mean of 8.92 per cent, the Lucas plots a mean of 5.95 per cent, and the Lee plots an average of 5.80 per cent. The cause of the low content of organic matter in the soils of the Lee County plots, which have the most favorable stand conditions, warrants further consideration. The average thickness of the litter layer for each of the areas, as indicated in Table V, is 1.25 inches, 1.05 inches and .50 inches for Lee, Lucas and Monroe Counties, respectively. This situation is just reverse to that of the amount of organic matter as mentioned above. It is apparent, therefore, that the higher percentage of organic matter in the Monroe plots is due to a more rapid decomposition of the accumulated leaf litter on the surface. An explanation of the differences found on the Lee and Monroe areas might be partially made by the fact that the Lee stands have 991 trees per acre, while only 625 trees to the acre are found in the Monroe stands. This greater density of the former stands undoubtedly plays a large part in the rate of decomposition of the litter. This layer under the Monroe stands is more exposed to the sun, to the wind and other factors that in-

TABLE VIII

Total Organic Matter

Plot	Per Cent	Pounds per Acre (2,000,000 lbs.)
2	6.07	121,400
3	6.20	124,000
4	10.90	238,000
5	9.53	190,600
6	11.93	238,600
7	5.36	107,200
8	4.58	91,600
9	5.01	100,200
10	6.58	131,600
11	6.08	121,600
12	6.74	134,800
13	5.16	103,200
14	7.36	147,200
15	5.34	106,800
16	4.95	99,000
17	4.69	93,800
18	8.44	168,800
19	5.20	104,000
20	6.37	127,400

Average by Counties

Monroe	8.92 %
Lucas	5.93 %
Lee	5.80 %

fluence the rate of decomposition of organic matter. The fact that four of the five Monroe plots have been subjected to heavy grazing, while all of the Lee stands have been but lightly grazed, might indicate another reason why the former plots have a thin layer of litter but a high content of organic matter in the soil. The trampling action of the stock on the litter might well aid in a more rapid disintegration of the leaves and twigs of which the layer consists. The differences between the Lucas and Monroe areas are probably due to the heavier grazing on the later stands. The Lee and Lucas plots show a difference in trees per acre of 591 trees in Lucas County and 991 trees in Lee County. This great difference in stand density is undoubtedly a major factor explaining the more rapid decomposition of the litter on the former area.

3. <u>Chemical properties of the soil.</u>

Chemical properties of the various soils are essential to the growth and development of the trees. Every cell is a composite of many chemical substances which are absorbed from the soil and the air. The chemical properties considered in the following discussion are nitrogen and phosphorus content of the soil and the hydrogen-ion concentration. Other properties not mentioned in this study are also essential to tree growth, but time did not permit a detailed study of these factors.

The nitrogen content of the soil is considered one of the more important chemical properties in plant growth. Holman and Robbins (18) write that nitrogen is one of the chemical substances needed in abundance in plant growth. Table IX shows that under the forest conditions studied, the nitrogen content is very high. An average of all the plots reveals a total nitrogen of 5,580 pounds per acre in the surface soil. A further analysis of the data shows that the Lee, Lucas and Monroe plots have an average nitrogen content of .2774 per cent, .2795 per cent and .2814 per cent respectively. Referring back to the average organic matter content of the three areas in Table VIII, it is interesting to note that a definite relationship exists between the nitrogen and organic matter content of the soil. The Monroe County plots show the highest nitrogen as well as the highest organic matter content in the soil. It is apparent from these observations that the presence of nitrogen in the soil is due, partially at least, to the organic matter in the soil. Organic matter aids the production of nitrogen indirectly by furnishing food to the nitrogen-fixing micro-organisms, and directly through the action of the leaves in fixing nitrogen. Auten (4) asserts that rainfall is another source of nitrogen in the soil. The amount of nitrogen in the soil is important in determining its affect on plant form and growth. If there is a deficiency or excess, the growth and form will be inferior to those sites having optimum amounts. It is not expected that the sited studied will show the effect of too much or too little nitrogen.

The total phosphorus content of the soil, recorded in Table X, is also important in influencing tree growth. It is not found in as large amounts as nitrogen since the average phosphorus content is only about 20 per cent

TABLE IX

Total Nitrogen

Plot	Per Cent	Pounds per Acre (2,000,000 lbs)
2	.2996	5,882
3	.3556	7,112
4	.2497	4,994
5	.2522	5,044
6	.2499	4,998
7	.2461	4,922
8	.1878	3,756
9	.2279	4,558
10	.2751	5,502
11	.2551	5,102
12	.3421	6,842
13	.3281	6,436
14	.3578	7,156
15	.2831	5,662
16	.2816	5,632
17	.2189	4,378
18	.3971	7,942
19	.2673	5,346
20	.2326	4,652

Average by Counties

Monroe	.2814 %
Lucas	.2785 %
Lee	.2774 %

TABLE X

Total Phosphorus

Plot	Per Cent	Pounds per Acre (2,000,000 lbs.)
2	.0588	1,176
3	.0722	1,444
4	.0556	1,112
5	.0489	978
6	.0596	1,192
7	.0537	1,074
8	.0508	1,116
9	.0455	910
10	.0487	974
11	.0447	894
12	.0537	1,074
13	.0591	1,182
14	.0572	1,144
15	.0556	1,112
16	.0517	1,034
17	.0517	1,034
18	.0492	984
19	.0517	1,034
20	.0426	852

Average by Counties

Monroe	.0590 %
Lee	.0521 %
Lucas	.0494 %

of the nitrogen found. This relationship does not indicate a depleted phosphorus supply, or a limiting condition for plant growth. Auten (2), in his study of yellow poplar, found that a high phosphorus content did not indicate a faster growth rate, but his results did convince him that a good growth could not take place on a soil exceedingly low in phosphorus. Averages for the three areas reveal that again the Monroe plots have the greatest amount of the chemical substance under consideration. These plots have an average phosphorus content of .0590 per cent, while the Lee and Lucas plots have .0521 and .0494 per cent respectively. Since all of these percentages are favorable to tree growth and form, a close correlation between the phosphorus content and these two characteristics of tree development will not be so evident.

The hydrogen-ion concentration of all the soil samples is recorded in Table XI. The data reveal that the soils of the forests studied are definitely acid. This is particularly true in the B horizon which ranges in pH from 4.27 to 5.07. The A horizon, however, shows a more favorable condition. This horizon is characterized by pH values varying from 5.5 to 6.7, which are generally considered highly favorable to the growth of deciduous trees. Wilde (33) asserts that a pH of 5.5 to 6.9 is characterized by high activity of micro-organisms, energetic humification, friable structure, good aeration and a high yield of wood. The low pH of the B horizon, and the slightly higher pH of the A horizon in forest soils, is a condition that prevails throughout this region. In view of the fact that agricultural soils usually have a slightly acid A horizon and more

TABLE XI

Hydrogen-ion Concentration

Plot	A Horizon pH	B Horizon pH
2	5.95	--
3	5.75	4.27
4	5.85	4.80
5	5.60	4.57
6	5.54	4.57
7	5.49	4.50
8	5.89	--
9	5.59	--
10	6.03	--
11	6.74	--
12	6.42	--
13	5.32	--
14	6.69	4.85
15	5.77	5.07
16	6.29	--
17	5.92	4.49
18	5.68	--
19	6.40	4.43
20	6.02	4.54

Average by Counties

Lee	6.1 %
Lucas	6.1 %
Monroe	5.7 %

alkaline subsurface and subsoils, the question sometimes arises as to whether the acid condition resulted in a forest cover or the forest cover caused the acid condition. The investigator has found virgin forest and prairie sites on the same soil type which are similar to the cases mentioned above. The virgin forest soil had an almost neutral pH in the A horizon, but became very acid in the B and C horizons. The virgin prairie site, however, was almost neutral in the A horizon and became more alkaline in the lower horizons. These observations lead the investigator to believe that the forests are at least indirectly responsible for the acid condition of the soil on which they grow. The acidity itself is due, at least in part, to the adsorption of the bases by the colloids, and the accumulation of organic acids. The significant fact about acidity in this study is that the pH values of the A horizons fall within the range most favorable to deciduous tree growth.

4. Climatic conditions.

The climatic conditions of the areas, as indicated by Table XII, were measured at United States Weather Bureau Stations located at Bonaparte, Chariton and Indianola. The climatic conditions for Lucas and Monroe County plots were taken from the same station since they were both within twenty-five miles of each other and about the same distance from the weather station at Indianola. The Chariton station was about 17 miles from both areas, but only incomplete data on precipitation could be obtained from this source. The Lee plots were within 18 miles of the Bonaparte

TABLE XII

Climatic Conditions

Tract	#Avg.Ann. Precip.	*Avg.Mean Ann.Temp.	*Avg.Ann. Snowfall	*Avg.Length Gr. Season
Lee	33.52"	51.0 F.	18.9"	168 days
Lucas	32.40"	50.0 F.	28.0"	165 days
Monroe	32.40"	50.0 F.	28.0"	165 days

Data from Bonaparte and Chariton Weather Stations.

* Data from Bonaparte and Indianola Weather Stations.

station. The table shows that a noticeable difference is found in the amount of snowfall on the three areas. The Lee area had but 18.9 inches of snowfall per year as compared with 28.0 inches for the other tracts. A further analysis of the data reveals that total precipitation in Lee County exceeds that of the other counties by 1.1 inches. This amount is not significant in itself, but when the amount of snowfall in Lee County is considered, it is apparent that a greater percentage of the total precipitation falls as rain. The average length of the growing season of the areas varies only three days which is hardly enough difference to have marked influence on plant growth.

B. Correlation of Site Factors with Stand Conditions

To evaluate the influence of individual site factors on form and growth of white oak would require an extensive study for each of the factors found. Extremes and means for each factor would have to be studied carefully before any exact evaluation could be made. In such a study, pH, for example, would have to be considered throughout its entire range. Since this would necessitate years of study, and since most site factors in southern Iowa are present in neither too small nor too large amounts to be limiting, no effort was made toward a true evaluation of each factor. Rather, correlations were obtained between characteristics of site and stand and expressed statistically by means of the correlation index squared, graphically by means of curves and mathematically by the use of tables.

1. <u>Correlation of physical characteristics of the site with stand conditions.</u>

It has been said that in tree growth the physical characteristics of the soil are more important than the chemical properties. (29) The truth or fallacy of such a statement should be partially determined by the discussion that follows.

In view of the findings of Auten (2) which disclose that aspect was closely correlated with height growth of yellow poplar in the Central States Region, an attempt was made to establish this correlation with white oak. A study of Table XIII and the graph in figure 8, shows an excellent correlation between aspect and the average annual height growth. It is generally accepted that the north and east slopes are cooler and more moist than the south and west slopes because of the desiccating action of the sun and prevailing summer winds on the latter two slopes. For this reason, it has been said that increased growth can be expected on the more moist slopes. In this study, only Lee County plots were used so that as many limiting factors as possible might be eliminated. It is true, however, that where particular factors such as grazing and fire damage are not too severe, a correlation with aspect is found on the other areas studied, as well as on the Lee Tracts. The data disclose that the north and east slopes have about the same growth with average annual height growths of 1.133 feet and 1.130 respectively, while the south slopes have an average growth of 1.010 feet and the west slopes .780 feet.

TABLE XIII

Influence of Aspect on Average Annual Height Growth

Plot	Avg. Ann. Ht. Growth	Aspect
7	1.16'	NE*
14	1.14'	N
11	1.13'	E
12	1.10'	N
13	1.03'	S
9	1.01'	S
10	.99'	S
8	.78'	W

Averages of Aspects

North	1.133
East	1.130
South	1.010
West	0.780

* NE Aspect is included in averages as N Aspect.

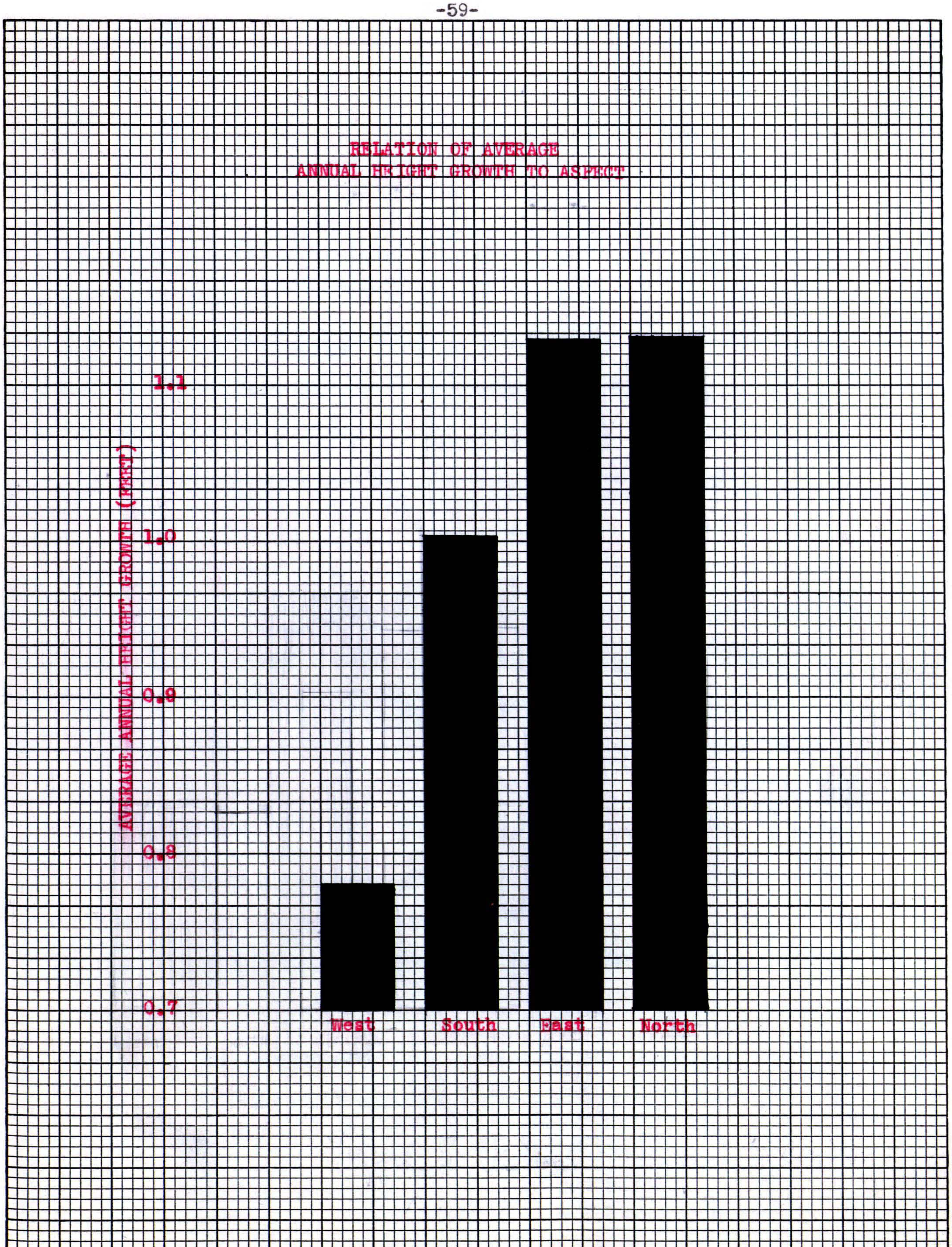

RELATION OF AVERAGE
ANNUAL HEIGHT GROWTH TO ASPECT
AVERAGE ANNUAL HEIGHT GROWTH (FEET)
1.1
1.0
0.9
0.8
0.7
West
South
East
North

Fig. 8

Although slope is generally considered to influence both form and growth, no correlation could be found on the plots studied. Tables II and IV present data which indicate that some plots with steep slopes have a better growth than other plots with a more moderate grade. Plots 9 and 14 reveal this relationship. The former plot, with a slope of 5 per cent has an average annual height growth of 1.01, while the latter sample has a slope of 24 per cent and a growth rate of 1.14 feet. The reverse is also found in plots 8 and 15, which disclose a slope of 34 per cent and 0 per cent and an average annual height growth of .78 feet and 1.42 feet respectively. It is apparent that while degree of slope may influence the stand somewhat, the other factors overshadow its effect. A similar situation is true when the slope is compared with tree form, as is evidenced by the data for the same plots in Tables II and IV.

A high correlation is noted between age and the average annual height growth of the stands. Table XIV shows but one exception to this in a study of the Lee County plots, plot 11, which, due to its more favorable eastern aspect and the fact that it is but one year older than the plots it surpasses, has a higher growth rate. One year of difference is not sufficient to expect much difference in the growth rate. Figures 9, 10 and 11 show graphically the definite correlation between age and growth. A statistical analysis of this same data reveals a 50.16 per cent correlation between the average annual volume growth in cubic feet and age, a correlation of 87.96 per cent between age and the average annual D.i.b. growth and a 91.41 per

TABLE XIV

Age in Relation to Average Annual Height Growth

Plot	Avg. Ann. Ht. Growth	Age
	Lee County Plots	
15	1.42"	29
7	1.16"	34
14	1.14"	37
11	1.13"	40
12	1.10"	39
13	1.03"	39
9	1.01"	39
10	.99"	43
8	.78"	59
	Monroe County Plots	
6	.92 "	40
4	.775 "	44
5	.725 "	48
2	.590 "	58
3	.570 "	62

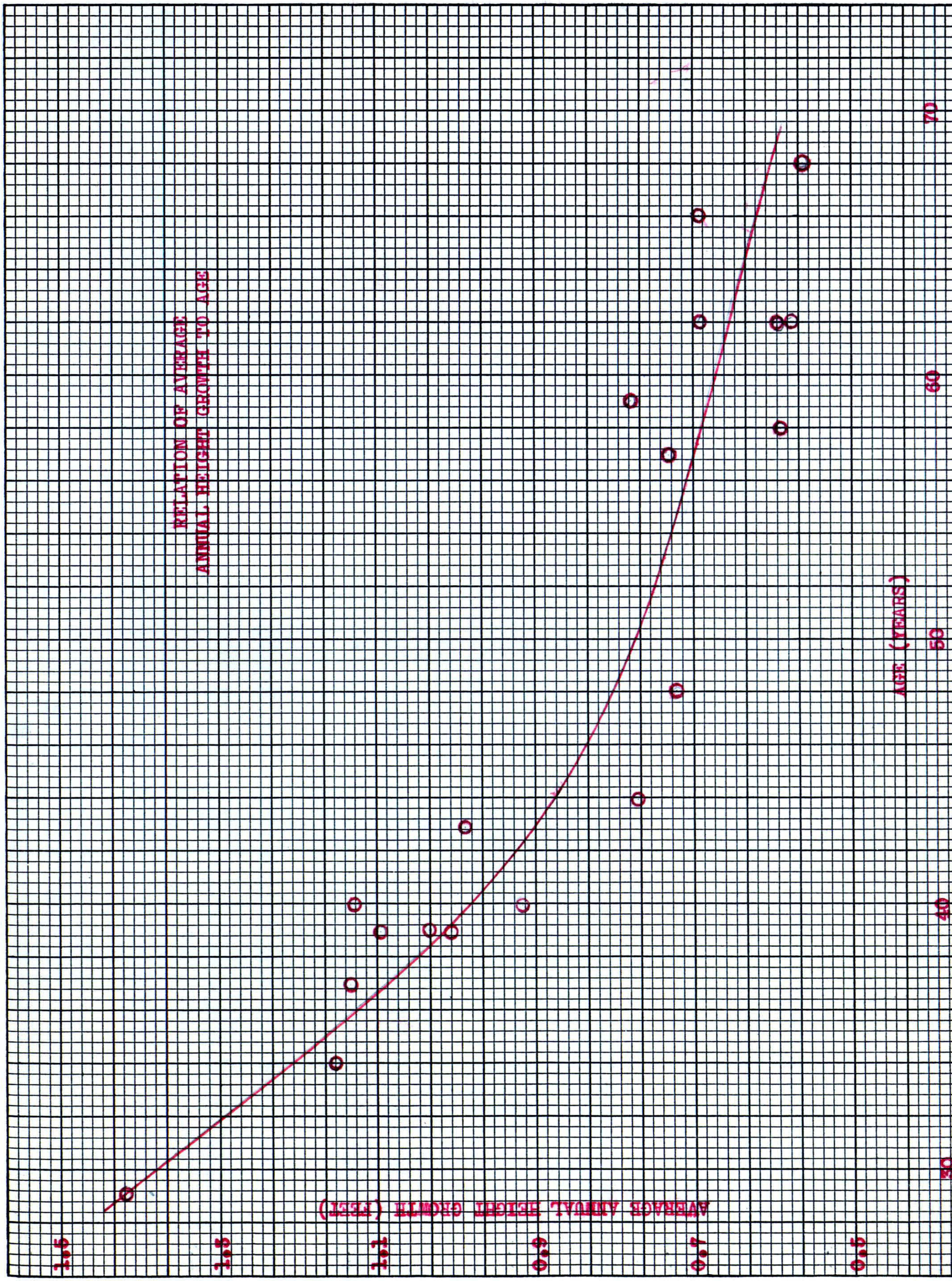

RELATION OF AVERAGE
ANNUAL HEIGHT GROWTH TO AGE
AVERAGE ANNUAL HEIGHT GROWTH (FEET)
1.5
1.3
1.1
0.9
0.7
0.5
AGE (YEARS)
30
40
50
60
70

Fig. 9

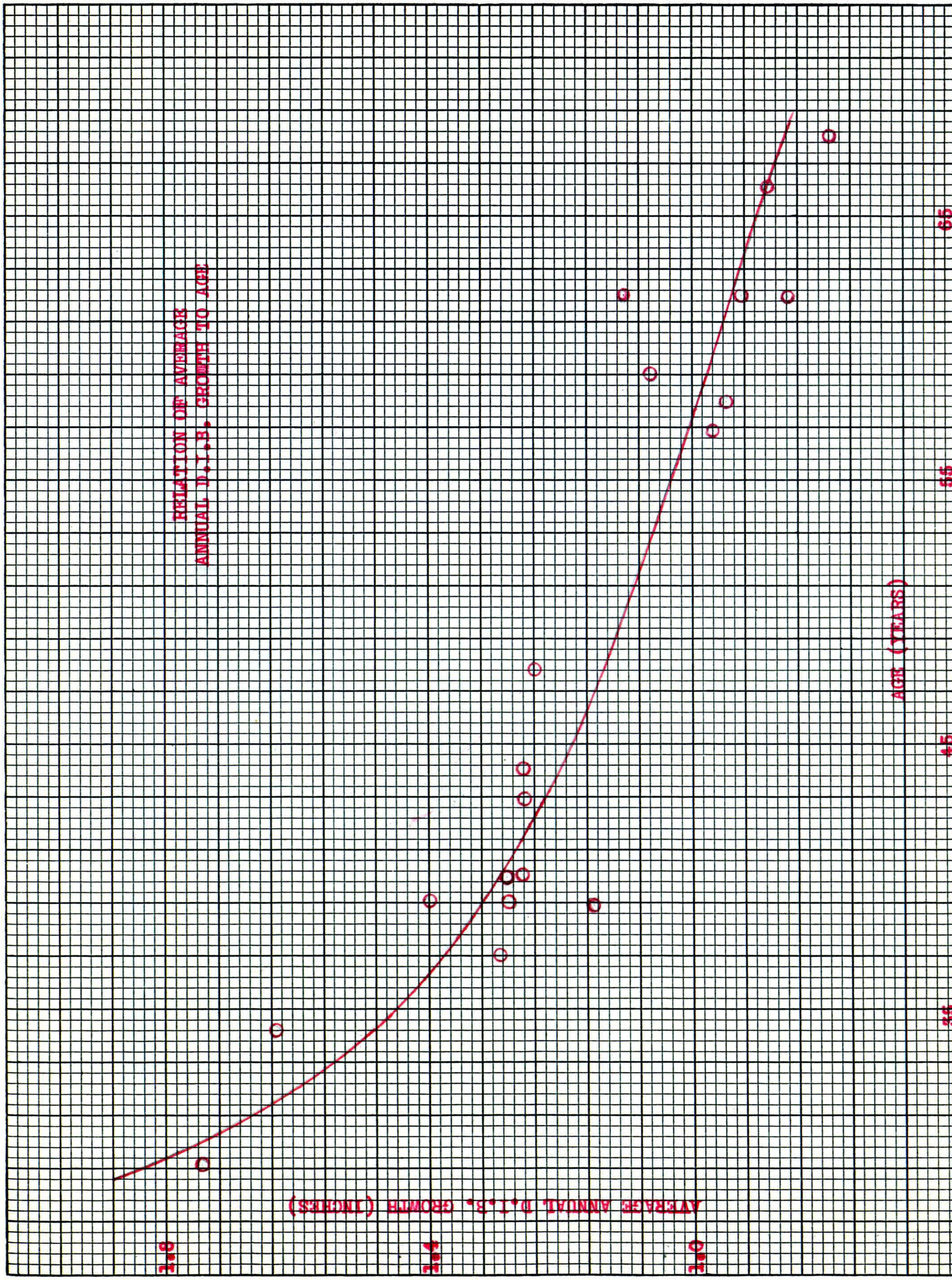

RELATION OF AVERAGE
ANNUAL D.I.B. GROWTH TO AGE
AGE (YEARS)
35
45
55
65
AVERAGE ANNUAL D.I.B. GROWTH (INCHES)
1.8
1.4
1.0

Fig. 10

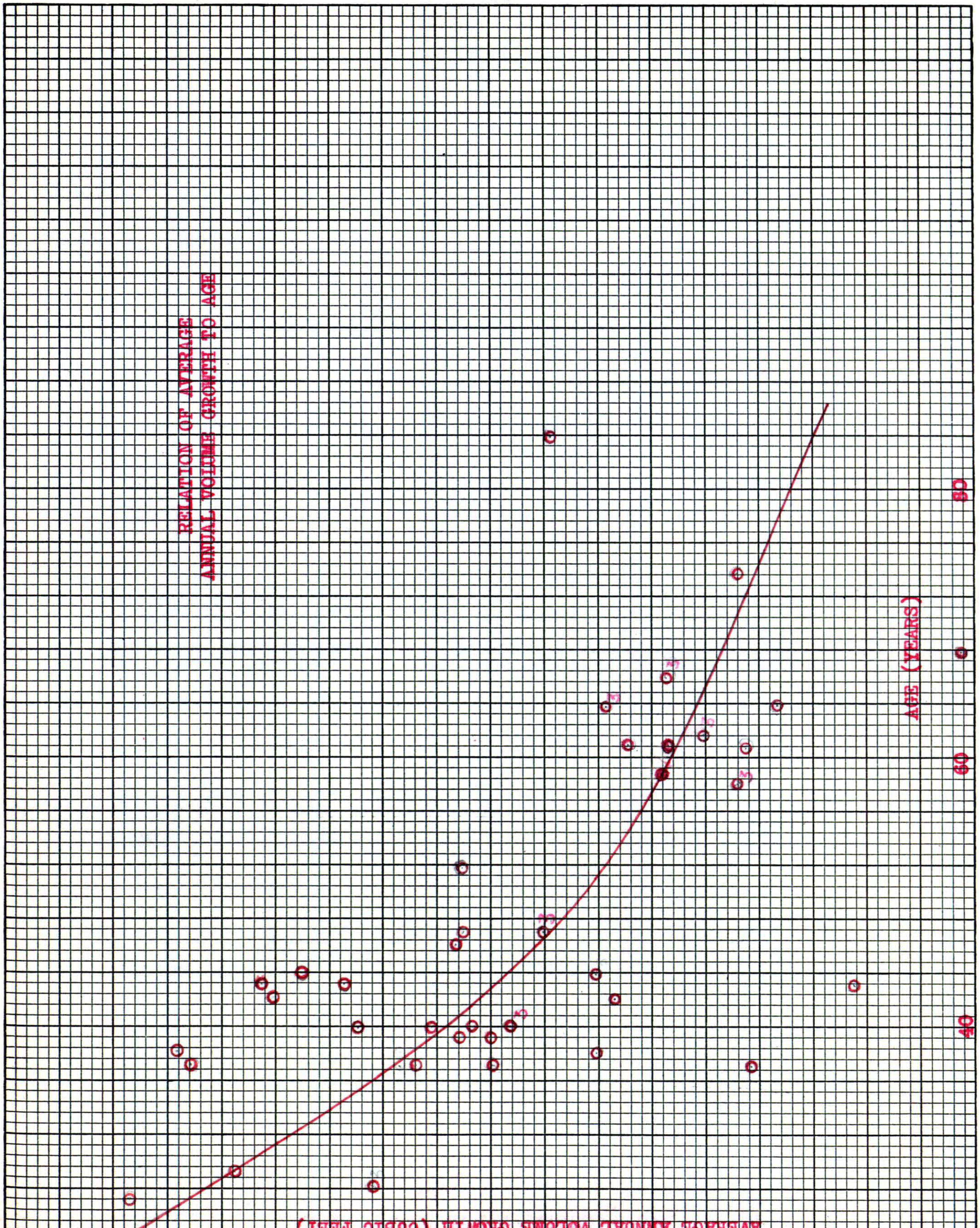

RELATION OF AVERAGE
ANNUAL VOLUME GROWTH TO AGE
AVERAGE ANNUAL VOLUME GROWTH (CUBIC FEET)
.10
.08
.06
.04
AGE (YEARS)
40
60
80

Fig. 11

cent correlation with the average annual height growth. Age has a 30.42 per cent correlation with form quotient. Such correlations are indicative that age plays an important part in both form and growth of the stands.

The influence of the position of the stands on the slope in regard to form and growth of white oak is disclosed in Table XV by plots 12, 14 and 15 of Lee County. A study of the three plots, located within a few hundred yards of each other, indicates that the ridge top location gives the slowest growth rate and the bottom the fastest. The ridge top plot revealed an average annual height growth of 1.10 feet as compared with 1.14 on the upper slope and 1.42 on the bottom. Plots 5, located on the upper slope and plot 6, 150 feet below on the middle slope in Monroe County, indicate further that the middle slope gives a faster growth rate than the upper, thus completing the correlation. Plot 5, as recorded in Table XV, has an average annual height growth of .73 feet in contrast to .92 feet for plot 6. The explanation of this relationship can be confined to the more favorable moisture conditions and the better protection from the adverse weather conditions that exist on the lower sites. In regard to form, plots 12, 14 and 15 with form quotients of .701, .685 and .652 respectively, would indicate that the bottom had the poorest form while the ridge top had the best. This is just reverse to the productivity of the site. Such a relationship does not always hold true since plot 5 on an upper slope had a form quotient of .652, while plot 6 on the same hillside, but on the middle of the slope, had a form quotient of .815.

TABLE XV

Influence of the Location of the Plots on the Slope on Form and Average Annual Height Growth

Plot	County	Location on Slope	Avg. Ann. Ht. Growth (feet)	Form Quotient
12	Lee	Ridge top	1.10	.701
14	Lee	Upper slope	1.14	.685
15	Lee	Bottom	1.42	.652
5	Monroe	Upper slope	.725	.652
6	Monroe	Middle of slope	.920	.815

Various investigations by Coile (12), Auten (3) and others have been made in correlating the depths of the various horizons with growth. A study of the horizons in this investigation reveals no correlation between the depth of the A horizon and form or growth of white oak, and only a small correlation of 5.74 per cent between the average annual height growth and the depth of the B.horizon. No correlation is discovered between the depth of the horizons and tree form. Any correlation that exists, other than that mentioned, is so small that it is overshadowed by other factors.

A study of the moisture relationships of the soil shows no correlation between water-holding capacity and form or growth. In some cases, plots with a high water-holding capacity, as indicated by Table XVI, show a much slower growth rate than other plots with a lower moisture-holding capacity, while in other cases the reverse is true. For example, plot 12 with a water-holding capacity of 64.1 has an average annual height growth of 1.10 feet, while plot 7, with a water-holding capacity of 49.3, has a height growth of 1.16 feet. In contrast, plot 15, with a height growth of 1.42 feet, has a water-holding capacity of 59.8, while plot 8, with a growth of .78 feet, has a water-holding capacity of 39.3. An analysis of the moisture equivalent, which is often referred to as the best expression of water relationships, discloses a 28.17 per cent correlation with the annual height growth, and a 3.37 per cent correlation with the form quotient. A further study of the data in Table XVI shows no close correlation between form or growth and the hygroscopic coefficient or wilting point of the soil. Plot 12 with a hygroscopic coefficient of 6.45 has about the same

TABLE XVI

The Influence of Moisture Relationships on Growth and Form

Plot	Avg. Ann. Ht. Growth	Form Quotient	Water Holding Capacity	Wilting Point	Hygroscopic Coefficient	Moisture Equivalent
15	1.42'	.652	59.8%	5.50	5.75	16.33
7	1.16'	.755	49.3%	6.83	3.83	16.38
14	1.14'	.685	55.6%	6.98	5.50	22.14
11	1.13'	.709	46.4%	9.78	5.18	23.16
12	1.10'	.701	64.1%	7.06	6.45	16.88
13	1.03'	.673	51.5%	7.43	5.72	23.29
9	1.01'	.765	54.2%	8.85	5.48	19.50
10	.99'	.662	46.2%	7.71	5.83	17.57
8	.78'	.774	39.3%	4.87	3.57	13.22

growth rate as plot 7, with a hygroscopic coefficient of 3.83. The wilting point shows a similar relationship with growth.

The question often arises as to whether grazing is harmful, beneficial or neutral in its affect on forest stand and site conditions. The general opinion held by most investigators is that heavy grazing has a decided detrimental affect on the stand and site while light grazing does but little damage. To test this claim, two plots were so located in Monroe County as to have one plot heavily grazed and the other lightly grazed. These samples are represented by plots 2 and 3, recorded in Table XVII. The two plots were situated on the same soil type and the same ridge about one-half mile apart. It is noted that plot 2 has a southern aspect while that of plot 3 is eastern. Although it is to be expected that the east slope should produce the fastest growth rate, the small slope percentages found should limit the resulting differences to a relatively small amount. From Table XVII it is evident that number 3, the lightly grazed plot, has a greater average annual volume growth and a more fertile soil than plot 2. This latter factor illustrates that heavy grazing depletes the total nitrogen in the soil 16 per cent and the total phosphorus 18.5 per cent through the reduction of organic matter and leaf litter. Although the average annual height growth, as well as the average annual diameter growth, appears to be higher on the heavily grazed plot, a study of the average annual height growth for the past ten years, as indicated in figure 2, reflects the influence of the grazing damage that has occurred during this same ten year period. Figure 2 reveals the height growth on

TABLE XVII

Influence of Heavy Grazing on Forest Stands

Stand Conditions

Plot No.	Grazing	Age (Years)	Avg. D.B.H. (inches)	Avg. Ht (Ft)	Avg.Ann. Di.b.Gr. (inches)	Avg.Ann. Ht. Gr. (feet)	Avg.Ann.Ht. Gr.-Last 10 Yrs (feet)	Vol. per A. (cuft)	Avg.Ann. Vol. Gr. (cu. ft.)	Trees per ¼ A.	Avg. Form Quotient
2	Heavy	58	5.87	34.5	.095	.59	.39	968	.052	106	.616
3	Light	62	7.19	35.0	.110	.57	.43	2142	.064	252	.619

Site Conditions

Plot No.	Soil Series	Texture	Depth: Litter	Depth: A Hor.	Depth: B Hor.	Aspect	Slope Per Cent	Moisture Equivalent	Hygroscopic Coef.	Wilting Point	Water holding capacity
2	Clinton	Clay	.25"	.75"	15"	South	5	20.11%	5.96%	8.49%	54.2%
3	Clinton	Clay	.75"	1.50"	10"	East	6	23.16%	6.24%	11.20%	51.6%

Plot No.	pH	Organic Matter (%)	Total Nitrogen (%)	Total Phosphorus (%)
2	5.95	6.07	.2996	.0588
3	6.20	6.20	.3556	.0722

plot 2 to be lower than that of plot 3 for the past ten years. It is further noted that the number of trees and the volume per acre is greatly reduced on the grazed plot. This is due to the inability of reproduction to become established, and for saplings to develop normally.

A study of the influence of heavy burning on growth and form of white oak, as made by a comparison of plots 3 and 4 recorded in Table XVIII, reveals that a situation similar to that found under heavy grazing prevails. Heavy burning has reduced the total nitrogen and phosphorus content of the soil even more than the grazing. It is noted that the burned stand has a slightly faster annual growth rate than that of the check plot. This is undoubtedly due to the fact that plot 4 is located on the upper slope and has an age of 44 years as compared to a ridge top location and an age of 62 years for plot 3. In addition, plot 4 has the more favorable texture and moisture relationship in the soil, but a less fertile soil as measured by chemical properties. Although the data indicate plot 4 to be the better site, a further consideration of the height growth during the past ten years, when heavy burning was most severe, shows that fire damage has reduced the height growth rate to less than that found on the unburned plot, and that the number of trees and volume per acre are also greatly diminished. The average annual increment of 34.5 cu. ft. in unburned plot 3 in comparison with 17.7 cu. ft. in plot 4, is, perhaps, the best measure of how heavy burning has influenced the stands. It should be further noted that the burned plot has a nitrogen and phosphorus content of .2497 per cent and .0556 per cent, while the check plot has a nitrogen content of .3556 per

TABLE XVIII
Influence of Heavy Burning on Forest Stands

Stand Conditions

Plot No.	Fire Damage	Age (Yrs)	Avg. D.B.H. (inches)	Avg. Ht. (ft)	Avg. Ann. Ht. Gr. (feet)	Avg. Ann. Ht. Gr.-Last 10 Yrs. (feet)	Avg. Ann. D.i.b. Gr. (inches)	Avg. Ann. Vol. Gr. (cu. ft.)	Vol. per A. (cu. ft.)	Avg. Ann. Increment per A (cu ft)	Trees per ¼ A.	Avg. Form Quotient
3	Light	62	7.19	~~3.50~~ 35.0 ?	.570	.43	.110	.064	2142	34.5	252	.619
4	Heavy	44	5.18	33.0	.775	.37	.125	.065	777	17.7	166	.719

Site Conditions

Plot No.	Aspect	Slope %	Slope Position	Soil Series	Texture	Depth Litter	Depth A. Hor.	Depth B Hor.	Moisture Equivalent	Hygroscopic Coef.	Wilting Point	Water Holding Capacity
3	East	6	Ridge top	Clinton	Clay	.75	1.50	10	23.16%	6.24%	11.2%	51.6%
4	East	16	Upper slope	Clinton	Clay loam	.75	.50	18	18.65%	5.02%	8.01%	44.8%

Plot No.	pH	Organic Matter (%)	Total Nitrogen (%)	Total Phosphorus (%)
3	5.8	6.2	.3556	.0722
4	5.9	10.9	.2497	.0556

cent and a phosphorus content of .0722 per cent. These data indicate that heavy burning reduces the number of trees in the stand, the growth rate, and the nitrogen and phosphorus content of the soil.

2. Correlation of chemical properties of the soil with stand conditions.

In the following discussion it will be noted that little correlation is found between chemical properties and growth or form. This situation, as previously mentioned, is not due to the fact that chemical properties are non-essential, but rather that in all cases studied they were present in sufficient quantities as to have little limiting affect on stand conditions.

A statistical analysis of the chemical properties of the A horizon, recorded in Tables IX, X and XI, was made through the use of the correlation index squared. This analysis reveals the following correlations:

1. A zero correlation is found between pH and both average annual height growth and the form quotient.

2. A zero correlation is disclosed between total nitrogen content and the average annual height growth. No correlation is found between form quotient and total nitrogen.

3. A 3.37 per cent correlation is noted between the average annual height growth and total phosphorus content, but phosphorus and form quotient show no correlation.

4. The total organic matter shows a 4.7 per cent correlation with the average annual height growth, and no correlation with the form quotient.

From this discussion, therefore, it is obvious that in this study the physical characteristics of the soil show a much better correlation with growth than do the chemical properties.

3. <u>Correlation of climatic conditions with stand conditions.</u>

The study had been under way but a short time when it was observed that a distinct difference in growth existed between the Lee and Lucas County plots. It was found that the Lee County plots had, in general, a much faster growth rate. This relationship is presented in Table III and in figures 2 through 7. Plot 8 in Lee County and plot 17 in Lucas were chosen to explain this difference because of the high degree of similarity evidenced between the two. The comparative conditions of the two plots are presented in Table XIX, where it is shown that the Lee County plot has a much faster growth rate, but little difference in form and site conditions. Differences in soil conditions relate only to slope and the moisture relationships of the soil, both of which are unfavorable to the Lee County plots. The increased growth rate must therefore be due to causes other than soil conditions. A study of the climatic conditions for both sites, as found in Table XII, indicates a greater amount of precipitation, a higher mean annual temperature, less snowfall and a slightly longer growing season than is found on the other areas. The slight differences of one degree in the temperature and three days in the length of growing season are hardly enough to explain the differences in growth. Although the Lee County plot has only 1.1 inches more precipitation than the Lucas

TABLE XIX

Site and Stand Conditions in plots 8 and 17

Stand Conditions

Tract	Avg. D.B.H. (inches)	Avg. Ht. (feet)	Vol. per A.	Avg.Ann. Vol. Gr. (cu.ft.)	Avg.Ann. Ht. Gr. (feet)	Avg.Ann. D.i.b. Gr.	Form Quotient	Age
Lucas 17	5.13	37.2	1282	.044	.56	.179"	.769	68
Lee 8	6.03	43.2	1400	.076	.78	.106"	.774	59

Site Conditions

Tract	Aspect	Slope (%)	Soil Type	Water Holding Capacity	Moisture Equivalent (%)	Hygroscopic Coef. (%)	Wilting Point (%)	Avg. Temp. (°)	Average length of growing season (days)
Lucas 17	West	15	Lindley silt loam	49.4	14.57	3.57	4.87	50.0	165
Lee 8	West	34	Lindley silt loam	39.3	13.22	5.47	6.07	51.0	168

Tract	Avg. Total Precipitation (inches)	Avg. Ann. Snowfall (inches)	pH	Organic Matter (%)	Nitrogen in A. Hor. (%)	Phosphorus in A Hor. (%)
Lucas 17	32.4	28.0	5.92	4.7	.2189	.0517
Lee 8	33.5	18.9	5.89	4.6	.1878	.0508

plot, the fact that only 18.9 inches falls as snow as compared to 28.0 inches in Lucas County makes it significant because a greater percentage of the precipitation falls as rain throughout the growing season. It is apparent, therefore, that a definite correlation between precipitation during the growing season and the rate of growth is found in southern Iowa. To say that precipitation is the only factor causing the difference in growth rate would be incorrect, but it can be said that it is one of the important factors influencing growth in that region. No correlation could be found, however, between precipitation and tree form of the stand.

V. SUMMARY AND CONCLUSIONS

Several investigations, sponsored by the Forestry Department of Iowa State College in cooperation with the Iowa Agricultural Experiment Station, were carried on during the summer of 1937 on recently acquired State Forest lands in south central and southeastern Iowa. These studies, of which this was one, were carried on to supply a need for more detailed information of the forest conditions of southern Iowa. The object of this particular investigation was to trace the influence of site conditions on tree form and growth of white oak. This naturally included a detailed study of the physical and chemical characteristics of the soil from the various sites, and the collection of data on form and growth. In securing this information, the investigator, with the aid of three members of the Civilian Conservation Corps, went into the forests and located and measured sample plots. Soil samples taken were analyzed by standard methods in the soils laboratory of Iowa State College.

The conclusions drawn from this study are arranged in the order of their importance to tree form and growth, and are discussed as follows:

1. The forests of south central and southeastern Iowa in general have suffered greatly from exploitation, heavy burning, excessive grazing and mismanagement. The stands have been cut so heavily with little regard for a future stand that only a sound forestry program, faithfully carried

out, will ever return these forests to a normal condition.

2. The growth and tree form of the white oak pole stands in southern Iowa are affected by the interaction of many variable factors. The influence of each of these factors is not always apparent, however, as little correlation can be expected unless a factor is deficient or in excess of the needs of the forest. Nevertheless, certain correlations are possible in this study.

3. The highest correlations found in this investigation exist between the age of the stand and the average annual height and diameter growth. Statistical studies of the data reveal a 91.4 per cent correlation between age and height growth, and a correlation of 87.96 per cent with diameter growth. A correlation of 30.47 per cent is further revealed between age and form quotient of the trees.

4. A high correlation exists between aspect and tree growth. Apparently the moist north and east slopes support a much faster growth rate than the drier south and west slopes.

5. The amount of precipitation during the growing season shows a definite influence on the growth rate of white oak in southern Iowa.

6. In general, it is found that moisture relationships do not correlate closely with form or growth, however, an analysis of the data reveals a good correlation between the height growth and moisture equivalent.

7. It is apparent from the data presented that the ridge tops

are the least productive, the bottoms most productive, and the upper slopes slower in growth than the middle slopes. This situation is due mainly to the relative moisture conditions of the soil of the four positions.

8. Although no correlation is found between the total organic matter of the soil and the form quotient of the tree, a 4.7 per cent correlation exists between the organic matter and the average annual height growth.

9. A small correlation is indicated between the total phosphorus content and the average annual height, however, none is found with form quotient.

10. A slight correlation is traced between the thickness of the B horizon and the average annual height growth.

11. The favorable pH and nitrogen content of the surface soils are responsible for the fact that both show a zero correlation with tree form and growth.

12. It is obvious from the above conclusions that the physical properties show a much better correlation with tree form and growth than do the chemical properties of the site.

13. Further results indicate that heavy grazing and burning on forest sites deplete the nitrogen and phosphorus content of the soil, and the volume, the number of trees and the average annual increment per acre.

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VIII. APPENDIX

Plate I

Sprout stand of mixed oaks in southern Iowa showing thrifty character of stand relatively free from fire scars and branch stub decay.

Plate II

Typical white oak pole stand of southeastern Iowa. The Lee County plots were located in stands such as these.

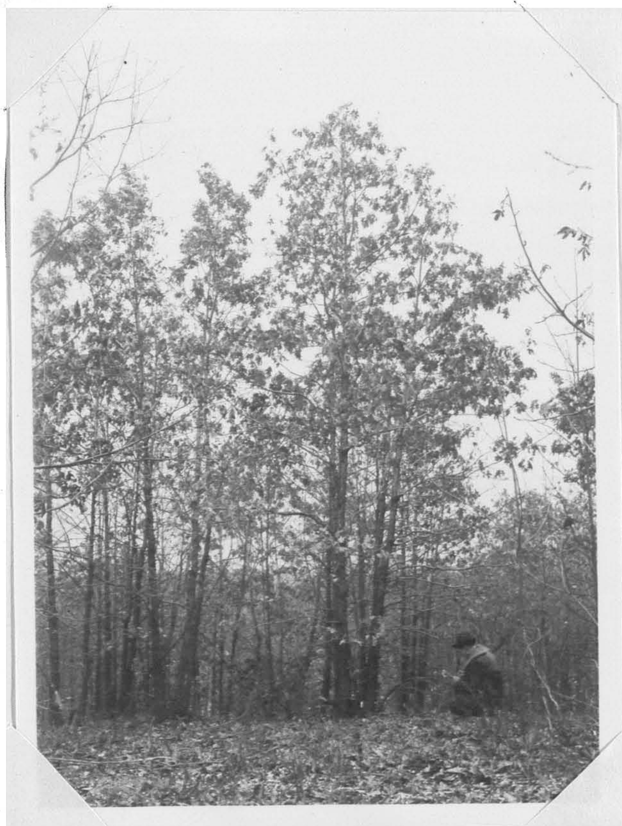

Plate III

A clump of 14 year old white oak sprouts in southeastern Iowa

Plate IV

Characteristic ridge top stand of mixed oaks in southeastern Iowa.