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SEASONAL RADIAL GROWTH OF SUGAR MAPLE (*ACER SACCHARUM* MARSH) AS RELATED TO CERTAIN ENVIRONMENTAL FACTORS

By

CHARLES WILSON REIMER

A DISSERTATION

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SEASONAL RADIAL GROWTH OF SUGAR MAPLE (ACER SACCHARUM MARSH) AS RELATED TO CERTAIN ENVIRONMENTAL FACTORS

By

Charles W. Reimer

AN ABSTRACT

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ABSTRACT

The study was undertaken to learn more about the activity of the cambium of sugar maple (Acer saccharum Marsh), and also to determine what effect environmental factors might have on trees growing in a relatively undisturbed climax-type forest.

One hundred sugar maple trees were selected for radial growth studies in Ingham County, Michigan. Measurements covered a period of two growing seasons and were taken weekly with a dial gauge dendrometer. Three size classes were chosen; viz., 10- to 15-inch DBH (diameter at breast height), 15- to 20-inch DBH, and over-20-inch DBH.

Soil moisture at various stations in the woodlot was measured with an electrical resistance unit. Blocks were buried at the twelve-inch and thirty-six-inch levels. Soil temperature was taken at these same stations with a soil thermometer. Other environmental data were secured from a weather station located just outside of the woodlot.

All three size classes showed the same general pattern of growth. Growth began the week ending May 5, 1949, and again the week ending May 11, 1950. It appeared that the

temperature of the soil and air was important in determining the time of initiation of radial growth at breast height. Since solar radiation and total hours of sunlight also increased considerably at the same time when first radial increases were recorded, it is possible that some component of light might also have had an important threshhold value controlling to some extent the initiation of cambial activity.

Two periods of marked recession of the growth rate were recorded, both in 1949 and 1950. Of the environmental data considered, the indication was that, in terms of "extrinsic" control of the growth rate, total hours of sunshine were possibly both directly, and in part indirectly, responsible for the occurrence of these recessions. It is also possible, however, that "intrinsic" factors controlled more directly the character of the growth pattern. In this investigation it was not possible to determine which of these two factor complexes was more important or what their interrelation might have been.

There was no definite time of cessation of cambial activity. In general, there was very little enlargement recorded after the first week in September.

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Trees exposed to various borders of the forest were measured along four radii. There was no consistent pattern of eccentric growth demonstrated by trees exposed to any one border.

Total growth for 1950 was less than for 1949. This was attributed to one or a combination of three major factors: (1) seed production in 1950, no seed production of consequence in 1949; (2) fewer hours of sunshine in 1950; (3) cooler air and soil temperatures in 1950.

Soil moisture within the woodlot was, apparently, not critical at any time during the growing seasons under consideration. Available moisture near the south and west edges of the woodlot dropped to a critical level during the last few weeks of the enlargement period for all trees.

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INTRODUCTION

The cambium of deciduous trees in this area is active at best only about one-half of the calendar year and many times over a much shorter period. During this time the rate of enlargement of the stem varies considerably during different parts of the growing season, indicating an uneven production and maturation of cells.

Since the development of the "Zuwachsuhr" (Pfister, 1880), it has been possible to measure this increase in thickness in the living tree and also the fluctuations in the rate of increase. The increases obtained from such measurements are due mostly to the activity of the cambium and should be some indication of the way in which the entire tree is reacting to its environment. Previous investigations have shown this to be the case for certain trees affected by certain environmental factors.

Unfortunately, most investigations of this type have been carried out on coniferous species and until quite recently there were but few major contributions to the subject of growth and enlargement of deciduous woody stems. There have also been

but few studies of stem enlargement of trees growing in an undisturbed climax-type forest. Observations have usually been limited to trees situated in parks, on campuses, yards, or those not within their natural range of distribution.

In the present study, specimens of sugar maple were selected which were growing in a relatively undisturbed stand of beech (Fagus grandifolia) and maple. It was possible to find only three other growth studies on this species involving enlargement of the stem. These investigations dealt with individual trees and environmental conditions at the site itself were not considered.

It seemed desirable not only to know more of the character and magnitude of growth but also some of the environmental factors at the site which might influence this growth pattern. Therefore, in addition to radial-growth measurements, several environmental factors were measured in an attempt to determine any possible correlative relationships. The ultimate purpose of this investigation, then, is to add something to our present knowledge of factors which influence growth of this forest species.

REVIEW OF PREVIOUS WORK ON TREE GROWTH

Earlier Investigations and Techniques

It is most difficult to move backward through history in an attempt to find the exact beginning of man's interest in the phenomenon of periodic growth in woody stems. The original stimulus probably stemmed from observations of the ends of cut or wind-thrown trees. McMurrick (1930) in his account of Leonardo daVinci stated that he (daVinci) was not only aware of tree rings but went so far as to give interpretations regarding their presence and relative thickness. It is also said of Carl von Linné (from Erlandsson, 1936) that he too was quite aware of tree rings and also suggested relationships between them and climatic factors.

From the literature available it would seem that most of the early interest in this subject was confined to the European continent. Erlandsson (1936) has presented one of the best accounts of this early work in Europe.

By the 19th century interest in tree growth had increased considerably. The main area of inquiry was still in Europe but

work began to come from botanists in the United States. Glock (1941) reviewed some of the work of these American investigators, in addition to that of the more important investigators in Europe. He said:

> Actually dozens of references could be cited to early work on growth layers but they would quickly become repetitious and wearisome. All in all, the publications contain a curious mixture of inference and interpretation, and here and there a thread of sound botanical investigation.

It does seem clear, however, that even before the invention of instruments for measuring radial increase in the living tree and even before special techniques were devised for making very careful measurements of tree rings from cut sections, scientists were aware of the possibilities of relationship between the deposition of woody material and the external environment. Rainfall was usually the factor suggested as being of prime importance.

Toward the end of the 19th century, instruments were devised for measuring the periodic increase in living tree trunks. In 1879, according to MacDougal (1936), Kaiser constructed a special type of caliper which was claimed to be capable of measurements down to 0.01 mm. At about the same time another instrument (Zuwachsuhr) was constructed by

Pfister (Boehmerle, 1883) which consisted of a metal band encircling the tree having one end attached to a compound lever pointing to a scale. All sorts of modifications were made following this principle. Friedrich (1905) elaborated on the instrument made by Pfister, constructing what he termed a "Zuwachsautograph." A revolving drum was employed to which was attached a marking device. This allowed for continuous readings over periods of several days. Friedrich even went so far as to assemble a radial growth instrument connected to a bell in his office. The bell would ring when tension was put on the connector as a result of increase of the circumference of the attached tree. An apparatus for measuring increase in stem size which makes use of induced electrical currents is mentioned by MacDougal (1938). Polansky (1930) has presented a good review of the types of instruments used up to 1930.

One of the great pioneers of growth studies by use of instruments is D. T. MacDougal. In 1918 MacDougal produced a precision instrument mounted on a "floating frame" which was termed a dendrograph. By use of special materials with a low coefficient of expansion errors due to such expansion or contraction were minimized. One of the serious objections to

the use of the German instruments was that this factor was not taken into consideration. MacDougal also designed a second type of measuring apparatus. This one, called a dendrometer, measures the increase in radius of a stem in contrast to diametral measurements obtained by use of the dendrograph. The dendrometer is likewise mounted to the tree but has no arrangement for a recording drum (although modifications are possible for such use). Measurements must be made at desirable intervals from a pointer moving over a scale. Both instruments are described and illustrated by MacDougal (1936, 1938). Friesner (1941, 1942, 1946) made use of these instruments in his original investigations in Indiana and Maine.

In 1932 Reinike described a precision dendrometer apparatus in which measurements are made with a micrometer. Byram and Doolittle (1950) gave an illustration of this instrument, which they also used. This instrument has found rather wide acceptance among foresters interested in radial growth. Recently, still another type of measuring device has been presented by Daubenmire (1945). This is also referred to as a dendrometer. It is not necessary to attach the instrument itself to the tree. Being of such a size that it fits easily in one hand,

it can thus be used in measuring several trees in a matter of minutes. The dendrometer has been used with considerable success and represents one of the best methods yet devised to measure radial increases in the field, especially when a quantity of measurements are desirable. Daubenmire and Deters (1947), and Daubenmire (1949, 1950), have studied the radial enlargement of several different types of trees, using this instrument.

Although measurement of radial increase was greatly aided by the use of instruments attached to the living tree, their invention and use by no means replaced techniques which involved direct measurements of rings and tissues within each ring. In general, all of the techniques for measuring cambial activity are mutually complimentary, and in some cases it would seem profitable to measure radial increase both by instrument and by observation of histological sections.

Observations and correlations of radial increase with environmental conditions falls into two categories: (1) long-term, and (2) short-term correlations. In the former, growth is compared from year to year with similar groupings of climatic components. The method usually employed is that of

measuring tree-ring widths from cut slabs, cut wedges or cores taken by an increment borer. Douglass (1936) gives an excellent review of these methods. Sometimes calipers or a measuring tape are used for determining yearly stem size increase.

Short-term correlations deal primarily with the cambial activity during the course of a single season. Several methods are possible, only two of which need be mentioned here. A series of cores can be taken from different parts of the same tree or from other trees at selected intervals of the growing season. The tissues are then prepared for observation and measurement according to the nature of the study. The difficulties of correlation become apparent upon realization that the sections for comparison have come from different trees. Even when taken from the same tree it must be recognized that the growth pattern and rate quite possibly varies in different parts of the stem (Jost, 1892; Friesner, 1940; Harmon, 1942). Within limits, however, this method can be very useful. Jost (1892), and Hanson and Brenke (1926), used such a technique.

The dendrometer and dendrograph are also used for short-time observations although they are by no means

restricted to such use. With the exception of the extensive work of MacDougal (1936), who did maintain his dendrographs in operation for several years, most other studies have been for periods of 1 or 2 seasons of growth.

Concepts

Long-term Correlations

About 1860, Keuchler and Furras (Glock, 1941) published results of tree-ring analyses done in the southwestern part of the United States. The former (Keuchler) maintained that "broad rings indicate wet years and thin rings that can scarcely be distinguished with the naked eye denote dry years" (Glock, 1941, p. 650). Furras' work contradicted this in that it presented proof that rings in that part of the country are not necessarily annual. Bogue (Lodewick, 1930) showed a relationship between rainfall and ring width of oak in Michigan, especially when there was an abnormally heavy or light annual precipitation. According to Robbins (1921), the ring width of oaks in Missouri varied inversely as the sum of mean temperatures for May and June. There was a direct correlation with the growth and March-to-June rainfall. Antevs (1928) found rainfall

correlations best (75% agreement) when it comes at a time when available water is on the "dry limit." Lyon (1936) found highest rainfall-growth correlations in New England with suppressed trees of hemlock and next highest with codominant trees. The general trend of correlation was greater when rainfall for the period from April to August was used.

Diller (1936) reported on the growth rings of beech in northern Indiana. He concluded that growth usually varies inversely with the June temperature, and in most cases directly with June precipitation. Kleine, Potzger and Friesner (1936) stated: "Precipitation plays the primary role of limiting factor in annual ring growth." They found direct correlation between annual-ring width of oak and the average rainfall of June, July and August; an inverse correlation with temperature for the same period. Fuller (1938) reported correlation between annual-ring widths of red oak and rainfall in Illinois for 44 out of 66 years. He cited examples of certain trees which seem to show no correlation with rainfall in any combination of months taken. In many cases, however, rainfall correlations were very good, especially in dry years. Somewhat the same results were

reported by Hansen (1941) for conifers in arid habitats of Washington.

Douglass (1936) correlated the occurrence of sun spots with tree-growth cycles. He said: "The possibility must not be overlooked, however, that under certain conditions there may be a direct relation between solar activity and tree growth rather than an indirect relation through rainfall or some other climatic factor as intermediary." Lodewick (1930) had stated that the effect of sun spots appear to be through their influence on rainfall.

Avery and co-workers (1940) in New England made observations on hemlock trees felled by the hurricane of 1938 and found little or no correlation between growth and either rainfall or temperature. They found annual-ring widths decreased with increasing distance from the center, but state that this does not indicate that less wood is formed; the greater circumference more than compensates for the narrow rings, they say. Lyon (1943) made a similar study on hemlock and white pine. He reported very good correlation between rainfall and ring width using years of maximum and minimum growth rates for correlation. Evidences of lag and cumulative effects

were also noticed. Importance of microclimate is noted by reference to the impossibility of cross dating of trees from Boston with those of New Hampshire. Of this he said, ". . . each area has its own dates for local drouth and abundance effects . . ."

From time to time voices were raised against this general trend of correlation of tree growth with but few factors, especially against those papers in which rainfall alone was isolated as the correlating factor of prime importance. Sampson (1940) wrote a brief article on "The Dendrochronology Enigma" in which he minimized the importance of tree-ring studies and the importance placed on interpretations thereof. In the same journal and appended to his article is one by Chapman (1940) in rebuttal to the conclusions of Sampson.

Then, in 1941, a review of the entire subject of "Growth Rings and Climate" was presented by Glock (1941). He expressed surprise at such correlations involving only rainfall in relation to tree-ring widths by saying:

> A careful reading of the work having to do strictly with the comparison of width of growth layers and rainfall is apt to convey the impression that the fundamentals of plant anatomy and physiology either have been neglected or have not been investigated.

> . . . studies simply emphasize what very few students will deny; the great importance of water to plant life. To go farther than this at present is to lose sight of the fact that the deposition of cellulose is a complicated process.

Some of the many factors involved in the growth process are then listed by him. Just how studies could be made to include this myriad of factors is not clear from this review. As a conclusion to the review (covering 203 references) Glock suggested:

> It seems abundantly clear first, that rainfall and temperature are of great importance to tree growth, second, that under a certain combination of interacting factors . . . rainfall and temperature have such an influence on physiological processes as to bring about a degree of similarity at times in the fluctuations of tree growth and rainfall or temperature, and third, that correlations even if they were of a high degree, do not permit the derivation of past or future rainfall.
>
> An understanding of plant physiology and anatomy brought about by judicious experimentation under the strict discipline of the botanist may ultimately reveal the criteria by which growth layers and their cellular structure will yield a picture of the soil moisture regime and perhaps thereby indirectly, a picture of rainfall type.

In speaking of the "factor complex" Friesner (1941) explained: "Of the environmental factors, light, temperature, and available water are perhaps the most important. In our area . . . temperature and light are more often adequate with available water becoming the limiting factor." Thus, reason

is given by him for greater attention to one factor in the complex.

Correlations seem most satisfactory from semiarid regions and from sites well drained and with light soil, although recently Lyon (1949) published the results of an investigation on rings of white pine growing in a bog. He concluded: "White pine trees growing in a bog that is subject to rise and fall of water level in response to local rainfall and temperature factors, are found to show, during years of unsuppressed growth, essentially the same sequences of narrow and wide rings as trees growing on nearby upland soil."

A great amount of work on tree rings has come from the Tree Ring Laboratory in Tucson, Arizona. Their work indicates that when carefully applied, tree rings can be an index of time lapse and can also show correlations with rainfall for certain periods. Schulman (1940) recorded 412 references on tree-ring analysis and suggested sources for more than 2,000 more references on the general subject. His paper appeared in the Tree Ring Bulletin, a publication organ for the Tree Ring Laboratory. For other references and review of concepts of tree rings and their analysis, the reader is referred

to Kleine, Potzger and Friesner (1936), Glock (1941, 1950), Douglass (1936, 1937), and Friesner and Friesner (1941).

From the work done in this connection it would seem that most long-term analyses have been made correlating rainfall and temperature with tree-ring widths. The growth-rainfall correlations seem not to fit any particular pattern except in localized areas and on certain selected sites where water relationships are not continuously favorable. The specimens most frequently chosen were those which were deemed particularly "sensitive" to availability of water (viz., oaks, hemlock, and pine). Temperature correlations seem to vary also with the locality. Some workers found no correlation between growth and increase or decrease in temperature for certain selected periods. Others found an inverse correlation with temperature during certain parts of the year. Still others found periods of direct correlation. In the light of these findings the importance of the plants' microecology becomes more apparent.

Short-term Correlations

In this type of correlation emphasis has been placed on the factors which might influence the growth in width of a woody

stem over periods of hours or days in a growing season. Results of such studies should throw some light on results of long-term correlations. Problems of primary concern to the investigators in this field are: (1) factors influencing the inception of growth, (2) factors influencing the amount, character and length of growth, (3) factors influencing the cessation of growth.

One of the very early investigators into the subject of seasonal radial growth in woody plants was Hartig (1885). This investigator found in the Norway spruce and European larch that 50 to 75 percent of the growth for the season was completed (at a height of 27 meters) on June 9, whereas only 18 to 35 percent of the total growth for the season was completed at a height of 1.5 meters from the ground. In isolated trees the percentage appeared about the same throughout. As far as the course of growth is concerned he reported that the European larch began growth on April 25 and terminated growth on July 1. The awakening of cambial activity, he said, is dependent upon temperature, and that soil temperature, insolation, and thickness of the bark were influencing factors.

Jost (1892) studied the course of growth by felling trees (larch, pine, oak and maple) every 14 days and measuring the

amount of wood accretion. His primary concern was the relationship between axial and radial growth. He found axial growth well under way before radial growth began and that the latter lasted longer than the former. Using calipers (Kluppen) Böhmerle (1905) showed that artificially watering a stand of Scotch pine (in Austria) increases the amount of "Zuwachs." The same year Friedrich (1905), using a "Zuwachsautograph," found: ". . . es steht wohl erst recht ausser Zweifel dasz die jeweilige Frühjahrs-und Sommerwitterung auf das Wachstum der Bäume Einflusz übt"; showing again the importance of rainfall on growth.

In the United States Brown (1912) described results of anatomical observations on Pinus rigida specimens. He found no appreciable difference in awakening of the cambium on the north and south sides of trees studied. He stated:

> . . . a number of peculiarities already noted by others are prevalent in mature specimens [of P. rigida]. These are: (a) lessened density on the south side of trees, (b) irregularity of cambial awakening in closely neighboring parts of the same section, (c) successive formation of new elements before previous ones have reached their maximum size, and (d) double rings . . . .

In anatomical measurements of the cambium Knudson (1913) said that the resting cambium of larch included 6 rows

of cells, the entire section measuring 34 microns. Brown (1915) also reported on minute observations of stem sections made on white pine. He recorded two optimal-growth periods within a single season; one in the spring, which he associated with the utilization of the stored food in the trunk; the other in July and August, which he said is due to the utilization of photosynthetic products of the current season. Brown noted that Mischke recorded two similar optima in pine but sought to correlate them with specific rainfall conditions during the period in which his material was collected. Jost is also cited by Brown as having found two such periods in all but three specimens examined; further that maximal growth occurred at very different times in different species although growing under "similar" climatic and soil conditions. Brown's conclusion to this was:

> Undoubtedly this periodicity of growth is connected with the periodic change in the type of wood formed, the well known transition from spring to summer or autumn wood. The spring wood has the wide lumen and thin wall which is associated with rapid extension.

About the initiation of cambial activity Brown said that the displacement of intercellular air spaces in the rays in the neighborhood of the ring by water may bear a causal relationship to this renewal of activity. As far as cessation of activity

is concerned he advanced the possibility that an accumulation of excess foods may be the cause ". . . but the fact that, with a wet and warm summer, both longitudinal and radial growth may be restarted, adds support to the view that the governing factor is, rather, a lack of moisture." Whether this "lack of moisture" refers to the actual lack in the soil or to a possible lack of ability of the plant to take in water is not stated.

Describing the character of growth of the box elder in Utah, Korstian (1920) found that growth began in the trunk on May 19, about three weeks after the leaves unfolded. At a later date MacDougal (1936, 1938), Friesner (1941, 1943), and Reimer (1949) found the same relationship between the unfolding of leaves and cambial initiation to be true in other deciduous species. This is not true, however, for all deciduous species (e.g., ash) (MacDougal, 1936). Korstian found no direct correlation between the "march of diametral growth" and current temperatures; this in contrast to the findings of Hartig (1896).

Using a MacDougal-type dendrograph, Lodewick (1925) found that cambial activity in Fraxinus americana began first on the south side of observed trees, but after all the cambium was activated ". . . growth progresses more rapidly on the

north side." A rest period of about ten days was recorded from June 9 to 19. Several days of precipitation immediately preceded this cessation of cambial activity so that the causative factor could not have been soil moisture. He concluded that it probably was temperature.

Hanson and Brenke (1926) made anatomical studies of the wood of Acer saccharinum (L.) and Fraxinus campestris (Britt.) in Nebraska. Fourteen sections were taken during the season, each from a different tree of the same species, to determine the rate of growth. The width of the cambial layer was used as an index; the wider the layer the more rapidly new cells were being formed. Growth began in the ash about April 15 and in the silver maple between April 20 and 27. Growth ceased in the former by September 14 and in the latter by August 15. There was a slight increase in the maple, resuming about September 14 and terminating about October 14. As for environmental correlations, they found no correlation between cambial activity and precipitation; a direct correlation between cambial activity and temperature increase in the spring until it reached about 60 degrees Fahrenheit, after which there seemed to be an inverse correlation.

Priestly (1930) discussed the character of cambial activity. Of the initiation of growth he said:

> The resumption of cambial activity in each growing season is a somewhat elusive phenomenon, beginning in one region it gradually spreads to others, and similarly its fluctuations and cessations of activity are not simultaneous throughout the whole of the tree.

This brings to mind the differences in percentage of growth completion in various parts of the same tree as reported by Hartig (1885).

Of the phloem Priestly stated: "It is not at all clear that there is any marked cessation of activities of growth and differentiation during the winter." As more recent works (Daubenmire, 1946, 1947, 1950; Friesner, 1941, 1942; MacDougal, 1936, 1938) indicate, evidence points to the possible fact that, at least in areas having a winter season, no activity of enlargement is discernible. In warmer climates this may well be the case.

Lodewick (1930) took cores from specimens of the longleaf pine in Florida. The site was seven miles from the Gulf of Mexico where the annual rainfall is approximately 60 inches, the greater amount coming in July and August. Rainfall data were taken from a ranger station 4-1/2 miles from the site.

He concluded that precipitation from about the middle of June to the middle of October has the greatest effect on the production of summerwood with a qualitative correlation of 91 percent. "Springwood formation is almost a constant irrespective of rainfall. The summer wood, on the other hand, appears to vary more directly with the rainfall." Mention is made of "other factors" which exert, or might exert, influence on springwood production.

As to vigor and radial enlargement, Lodewick said that the departure of the curves of various vigor classes from the general curve is usually in amount rather than in direction. A correlation was attempted between crown volume and average diameter but met with failure. He stated: "So little agreement was found, even among similar crown shapes, that it was deemed unnecessary to make more accurate volume computations."

Pearson (1937), on the other hand, maintained: "Trees with undersized crowns or, more specifically, trees having a small leaf surface, are known to grow at a slower rate than those with large full crowns." Bordoux (1946) maintained that growth of upper-story trees had no direct relation to either

crown space or crown volume but did correlate with surface area of the crown.

MacDougal (1933) reported on the relation of leaf surface to the amount of wood produced. The conclusions were that the amount of wood produced by a unit leaf area in an old and large tree was less than in a young tree. "It seems reasonable to assume that much more energy is used in lifting water and in translocation of photosynthetic products in such trees. No available information gives grounds for any conclusions as to lesser efficiency of leaves on old or large trees."

Kienholz (1934) observed the same phenomenon of two maxima in growth rate, as found by Brown (1915). His work was on conifers. Growth began on May 12 and reached a first maximum on June 2, decreasing slightly, increasing to a second maximum on July 9. Growth ceased on October 1. He found no correlation between the maximum, minimum, or mean air temperatures and the average weekly growth rate nor between relative humidity and the growth rate. From this he further concluded that not environmental factors but internal factors were responsible for the double maximum, thereby agreeing essentially with Priestly (1930), and Brown (1915). The two

maxima are said by him to correspond with the formation of springwood and summerwood, respectively. Kienholz said that Stevens recorded a somewhat similar phenomenon for roots; i.e., a first maximum of enlargement came in roots on June 8 and a second maximum on October 4. A somewhat similar result was recently reported by Morrow (1950) for the roots of sugar maple.

In 1936 results of some very detailed and extensive studies were finally reported on by MacDougal (1936). This worker had attached dendrographs to several kinds of trees both native and introduced into Arizona. He kept records of growth on these species over periods of several years. Complete records of growth of Pinus radiata are presented covering the years between 1918 and 1934. Many other data on both coniferous and deciduous trees are presented covering observations over periods of one to several years. Only some of the pertinent conclusions will be presented here.

MacDougal believed that the initiation of growth in Acer macrophyllum was determined by rising temperature but that the termination of wood formation was due to other factors.

> In this case it is not moisture, as the soil around the roots was "wet" at all times. Cessation of growth

> took place under favorable temperatures and about 20 days before any deterioration of leaf green was visible. It is probable that a chemical analysis of the leaves would uncover the decisive factors.

His results on the Monterey pine showed a termination of diametral growth coincident with a soil-moisture deficiency leading him to the conclusion that this was the causative factor. As a final statement on A. macrophyllum he said: "The annual layers of this maple would, therefore, not constitute a record of precipitation or of soil moisture conditions."

This investigator maintained that radial growth may be continuous throughout all seasons. He presented data from Monterey pine and Monterey cypress to support this. According to him continuous growth was also reported from Africa and Java.

He maintained also that the rhythmic action of trees was imposed by the environment and should not be taken as an inherited condition.

In temperature experiments MacDougal (1936) artificially heated trees for 15 days and they showed no response, but he said this merely shows that other factors are responsible, in addition to correct temperature, for cambial initiation. A statement concerning environmental factors was given by him:

> The balance between water supply and transpiration and temperature of growing cell masses are the dominating conditions in both radial and terminal growth. Conventional meteorological statistics as wind direction and velocity, cloudiness, sunshine, relative humidity, precipitation, evaporation from the soil, air temperature, are of value only as they affect transpiration and the temperature of cell masses.

Two years later MacDougal (1938) presented a book on tree growth in which he described and discussed the growth of numerous deciduous and coniferous trees. Reference up to 1938 pertinent to the growth of these particular trees are included. In the genus Acer he discussed growth data for: A. saccharum, A. saccharinum, A. negundo, A. pseudoplatanus, A. macrophyllum, A. rubrum, and A. campestre.

The A. saccharum described was growing in the New York Botanical Garden. Diametral increase began on May 12, 1920, at about the time when leaves had reached full expansion. It was not until June 4, however, that the increase became "positive and rapid." About July 1 the growth rate was at its highest and around the first of August growth ceased. The only environmental condition measured was the temperature of the cambium. This temperature was between 15 and 20 degrees Centigrade at the time diametral increase became "positive."

Friesner (1941) published the first results of a series of investigations employing a dendrometer. The original study was of Fagus grandifolia in Indiana. Growth in the beech began about the Middle of May and ceased about July 15. The three trees studied all showed the "grand period" of growth. Friesner listed the three "most important factors controlling wood formation which are variable on the same site from season to season and from day to day" as: temperature, evaporation rate, and water. He said light may become a limiting factor "if temperature and available water are at their optimum."

Using the dendrographic method, five species of deciduous trees were studied by the same author (1942b). Representatives of the following species were selected: Fagus grandifolia, Ulmus americana, Ulmus fulva, Acer saccharum, and Quercus alba. The exact environment was not discussed but it appears that these trees were not growing in environmentally undisturbed areas. All four species (F. grandifolia had been previously reported on) were said by him to exhibit the "grand period" of growth. In another of his presentations (1943) he mentioned that U. americana did not exhibit this "grand period" character. A recent communication with Dr. Friesner clears up the point. The idea was correctly stated

in his paper of 1943 when he explained that U. americana showed no resemblance to "grand period" growth. Daubenmire (1947) made no distinction, including this species in with those showing "grand period" curves. In A. saccharum radial increase began on May 12 and was completed by the end of July, according to Friesner (1942b). Two peaks of growth rate were observed (week ending June 9 and week ending June 30), bringing to mind this phenomenon as reported by Brown (1915), Kienholz (1934), and others. Such a pattern was also reported for Ulmus. He stated that external conditions are important in determining initiation, time of peak rate, amount, and cessation of growth, but that the growth rhythms occur independent of definable rhythms in the external environment. The daily rhythm of rate of root elongation also has been attributed to internal causes by Friesner (1919).

In 1946 Friesner and Waldon (1946) published results of five seasons' growth of Pinus strobus in Maine. They found the time of initiation of radial enlargement varied from April 15 to May 26; time of cessation from September 18 to November 1. Temperature, according to them, appeared to be the most important factor in controlling the time of initiation of radial

enlargement, the critical temperature being 50 degrees Fahrenheit. Rainfall correlations were "fair" when average annual rainfall data were used. Results by Daubenmire (1949) on the same species in Idaho indicate that temperature might not be the important factor in growth initiation, at least in that area.

Growth of trees at different altitudes was studied by Daubenmire (1946). In this study 32 coniferous trees (four species) were used. Cambial activity was retarded at higher elevations and late summer shrinkage was much less at higher altitudes than at lower. Investigation into the relation of day-length and temperature to the initiation of cambial activity were made by him (Daubenmire, 1949). He concluded that the beginning of diametral growth had no close relationship to maximum or minimum air temperatures, or even to soil temperature at 20 centimeters depth. Further, he said: "In most instances growth begins at a rather well defined period suggestive of photoperiodism." According to him low temperatures cannot stop cambial activity unless the temperature drops to frost levels.

Daubenmire and Deters (1947) made comparative studies of deciduous and evergreen trees in Idaho. The trees selected

were a part of the arboretum on the campus of the University of Idaho. The character of cumulative seasonal growth was compared and contrasted. All of the species began growth at approximately the same time in both years studied (with the exception of Robinia pseudoacacia, which began approximately 2 months before all others). Early in the season the evergreen trees grew more rapidly than the deciduous trees but the situation was reversed later in the season. Their results cast some doubt on the concept that growth begins earlier in ring-porous trees than in diffuse-porous trees (Friesner, 1942). The initiation dates for Ulmus, Quercus and Fagus were practically the same. Cumulative growth curves are presented for each of the 17 species studied. Different trees showed varying responses to the summer drought. The growing season began before the end of the frost season and terminated "well in advance" of the first frost in autumn.

In another paper Daubenmire (1950) found negative correlation between photoperiod and the beginning of cambial activity. He expressed the idea in one publication (1949) that differences in response of cambiums of the same species may possibly be due to genetic differences "among the species and ecotypes"

studied. Daubenmire (1950) published results of such a study on P. ponderosa races. There appeared but "little difference" among the populations despite the fact that there was "considerable variation" within a population. Daylength seemed to have no influence upon the growing season and cambial activity duration was not related to population or race groupings. He said:

> Daylength either does not determine the beginning of cambial activity or on this habitat other conditions masked the influence of daylength. Since the results of earlier studies . . . also furnish negative evidence of photoperiodic control over inception of cambial activity, the former of the two possibilities mentioned above appears to be correct.

Study of a single specimen of shortleaf pine (Pinus echinata) by Byram and Doolittle (1950), using a dendrometer, revealed that the greatest amount of growth came in the spring when there was only a slight amount of correlation with rainfall. A "definitely positive effect" was recorded for these two factors during the summer.

Because no soil-moisture data were taken by them their statements on soil moisture must be taken as hypotheses. They stated it was likely that soil moisture began to be a limiting factor in June; that "for the period July 9 to August 8 . . . the limiting effect of the moisture supply on growth has become

apparent.'' It is difficult to interpret two statements from their paper. They stated:

> During the spring period of rapid growth, the three most important growth factors (light, moisture, and temperature) have their optimum values, and growth is at a maximum.

In summary they said:

> Thus, in spring, temperature, sunshine and certain inherent characteristics of the tree are limiting factors relative to growth.

If the first statement is true then only the ''inherent characteristics'' could be listed as limiting in the spring. If the latter is true, then only moisture is at an optimum during the spring.

Summary of Major Concepts

As a whole these short-term correlations have been very helpful in sorting out some of the major problems involved in the evaluation of cambial activity. The question of initiation of cambial activity seems to be not yet solved. Some investigators say that temperature must be at a certain level for cell division to begin. MacDougal (1936) found 8 degrees Centigrade as a minimum internal temperature for cambial initiation in pine, although he says this may not be a direct correlation at all. Friesner and Waldon (1946) said the critical air temperature

was 50 degrees Fahrenheit for pine in Maine. For ash, Hansen and Brenke (1926) found cambial activity to begin as the temperature rose above 52 degrees Fahrenheit and for maple it began as the temperature of the air reached 60 degrees Fahrenheit. Hartig (1896) correlated "rise in temperature" with initiation of cambial activity in conifers. Daubenmire found no relationship between inception of growth and either air or soil temperature. This study included sugar maple and other deciduous and evergreen trees in Idaho. He suggested that photoperiod was more likely responsible for cambial initiation (1949) but later (1950) gave evidence that it was not.

As for other internal factors Söding (1936) maintained that growth proceeds basipetally by production of hormones in the immature buds which, after translocation to secondary tissues would incite them to activity and production of hormones. This would set up a sequence expressed by the author as: "Wuchstoff-Wachstum-Wuchstoff-Wachstum."

MacDougal (1936) also mentioned the possibility of hormones as being at least partially responsible for cambial

initiation. Söding (1936) and later Fraser (1949) introduced growth-promoting substances into the stem of woody plants and found that cambial growth was incited at a point immediately below the application. Avery et al. (1937) advanced the "probability" that growth hormones in shoots of Aesculus and Malus were instrumental in stimulating cambial activity. The subject of plant growth substances is discussed by Went and Thimann (1937) and by Skoog and others (1950). It is seen that most work has been carried out with herbaceous plants.

Environmental relationships during the growing season are also quite complex. The concepts presented by investigators of this phase of growth reflect results of studies on a few species (notable exceptions are MacDougal [1936, 1938], Daubenmire [1947, 1949a, 1949b]), few specimens and localized areas. Even so, it is doubtful if over-all concepts could be formulated which would hold for all species in all habitats. Whatever the case may be, some of these ideas are presented in summary.

There is some agreement that rainfall exerts an influence on the latter part of the seasons' growth (Lodewick, 1930 [conifers]; Friesner, 1942 [deciduous trees]; Byram and Doolittle, 1950 [conifer]). This agreement is usually assumed to operate

through the influence of rainfall on soil moisture, with the assumption that, with lessened rainfall, soil moisture will go down to the critical level. No work correlating soil moisture with radial growth at a particular site has been found which will either substantiate or deny this. Hanson and Brenke (1926), on the other hand, found no relationship between precipitation and seasonal radial increases. MacDougal and Shreve (1924) said that for P. radiata, growth over short periods of time showed negative correlation with rainfall.

Air temperature is said to be directly correlated with the early course of growth (MacDougal, 1936; Hanson and Brenke, 1926) and inversely correlated with later growth (Hanson and Brenke, 1926). However, Kienholz (1934) found no correlation between maximum, minimum or mean air temperature and weekly growth rate of pine.

Atansiu (1949) presented an interesting hypothesis, which, even though it was gleaned from study of herbaceous plants, could operate in relation to the woody plant. He said:

> Eine negative klimatische Wasserbilanz im April und Anfang Mai begünstigt den sich stark in Minimum befindlichen Wärmefaktor und dadurch das Wachstum; Ende Mai, Juni ist eine positive klimatische Wasserbilanz für das Pflanzenwachstum günstiger.

This indicates that a negative water balance in spring is desirable as it allows for a higher soil temperature, a more important factor at this time.

Light and atmospheric humidity can be important and limiting to growth (Friesner, 1941). Kienholz (1934) found no relationship between diametral growth of pine and relative humidity.

Cessation of growth has been attributed for certain species to the lack of water (Friesner, 1941; Priestly, 1930; MacDougal, 1936). Mitchell (1936) reports that Pelargonium leaves showed retarded carbon fixation above 30 degrees Centigrade in either moist or dry air. Klebs (1917), Berthold (1904), and Lakon (1912) (see Priestly, 1930) thought that cambial activity might stop because of the excess of organic materials or because of the lack of inorganic salts. The latter could be associated with the lack of moisture in the soil.

Less is known of the internal mechanism involved in the cessation of growth but it seems possible from the results of Söding (1936), Went and Thimann (1937), Skoog et al. (1950), and many other workers in the field of plant hormones, that dwindling hormone production may slow and finally cease

cambial activity. Further studies on radial growth can add much to the concepts already presented, especially as they operate in the same species in their various microhabitats.

Asymmetric Growth

Two papers written in the 19th century are worthy of mention in this connection. Mer (1889) formulated two causes for eccentric growth, viz.: (1) factors affecting the manufacture of organic products (slope, proximity to other trees, exposure, fertility of the soil), (2) factors influencing cambial activity (mechanical stress caused by wind, gravity, "traumatism"). He said that trees growing on a slope exhibit greater growth of the trunk on the uphill side, and that competition on some one side of a tree means that radial increase will be "shorter" on that side. Hartig (1896) studied eccentric growth by the somewhat unique method of observing the distribution of "red wood" in the spruce (Fichte). "Red wood," according to the author, is usually formed only when some stress or strain is put on the stem. One tree observed growing along the west edge of the forest showed greatest "red wood" on

the east side. His conclusion was that the mechanical or swaying effects of the wind caused eccentric growth.

Grossenbacher (1915) mentioned that the real cause of "zonation" is thought to be inherent, though the environment induces its manifestation. In the semi-arid areas of the southwest, Douglass (1936) shows that slope is important to eccentric growth in western pine, the uphill side being favored because the moisture reaches that side first. This is in agreement with Mer (1889).

Lodewick (1930) took cores from four cardinal points of several pine trees growing on essentially level sites. The object of the investigation was to determine whether the south and west sides showed greater growth than the north and east sides because of longer periods of insolation. He found ". . . growth along the north and west radii was greater than the other two radii . . . though examination of 12 trees that had recently been cut . . . gave no evidence of consistent elongation of any one axis." As to crown and number of branches arising from one side, he said:

> **Whether or not exposure at breast height directly under the greatest photosynthetic area will show [these] xylem increments depends upon the straightness of the grain through the intervening bole.**

> In trees studied there is no consistent decrease in diameter on the side of least crown development when measurements are made at breast height, in fact according to the data . . . an increase in diameter was more often the case.

Friesner (1940) studied asymmetrical growth of Quercus velutina and, in disagreement with Mer (1889), said that competition "exerts no demonstrable independent effect" on eccentric growth as long as it is only "a part of a complex of other variable factors." He found average growth immediately above main roots always greater than above areas where there are no roots. From his data there is at least some indication that the uphill side of the tree is favored, although half of the trees showing this response were also those having the greatest number of roots on the uphill side.

Harmon (1942) found that the "gentle" slope had but little effect on asymmetrical growth, but that on "steep" slopes growth was greater on the uphill side. In disagreeing with Friesner (1940) he stated: "Competition, when not offset by other factors, exerts a demonstrable influence on asymmetrical growth in that growth on the competition side is less . . . ."

It is thus seen that five factors are discussed as being at least partially responsible for asymmetrical growth. They

are: (1) slope, (2) position of main roots, (3) competition, (4) wind action, and (5) character of the grain.

Obviously many other environmental factors are operative in radial growth of trees. To review the work on these factors alone would be to go beyond the scope of this paper. For the person interested in literature on such factors the author suggests material and bibliographies presented by the following authors: Meyer and Anderson (1939), Curtis and Clark (1949), Miller (1938), Weaver and Clements (1938), Oosting (1948), Daubenmire (1947). For a review of soil water relationships the reader is referred to Kramer (1949 [over 650 ref.]).

METHODS AND MATERIALS

Description of the Area

Site Location

The specimens under consideration in this study are situated in Toumey Woodlot located on the campus of Michigan State College in East Lansing, Michigan. In the northwestern part of Ingham County, the woodlot lies approximately 2 miles southeast of the Natural Science Building, midway between Mt. Hope and Bennett Roads. The eastern edge of the area borders on Hagadorn Road.

Vegetation and Land Use Data

At the time of settlement in Ingham County (approximately 100 years ago) the area was covered almost exclusively by hardwood forest. Species listed as being a part of this coverage included: Quercus rubra var. borealis (red oak), Q. alba (white oak), Q. velutina (black oak), Carya sp. (hickory), Fagus grandifolia (beech), Acer saccharum (sugar maple), Fraxinus sp. (ash), Tilia americana (American linden or basswood), Ulmus

sp. (elm), Acer rubrum (red maple), Acer saccharinum (silver maple), Q. bicolor (swamp white oak), Juglans nigra (walnut), Juglans cinerea (butternut), Prunus serotina (black cherry), Platanus occidentalis (sycamore), Populus deltoides (cottonwood), Celtis occidentalis (hackberry), and Liriodendron tulipifera (tulip tree). The list does not include those species characteristic of wet peaty swamps. Such areas were very infrequent throughout the county.

As a result of settlement the present hardwood coverage has been reduced to about 15 percent (Veatch, 1941). Most of the area included in this 15 percent has been cut over, pastured or otherwise disturbed by man. Much of the remaining area (85%) is utilized in cultivation of various cereal crops, vegetables and forage crops (timothy hay, alfalfa, clover). Orchards are also to be found throughout the area, and in a few areas intensive muck farming is practiced. Dairying represents one of the greatest sources of income from farms in the county.

The State Capitol of Michigan, Lansing, occupies a considerable part of the northwest corner of the county. Other larger cities in the county include East Lansing, Mason and Williamston.

Climatic Features

The climate of Ingham County is characterized as "rather mild" in summer and "fairly cold" in winter. Precipitation during the year is fairly evenly distributed, with an annual fall of about 31 inches. Veatch (1941), in a discussion of the rainfall, said:

> Although the rainfall shows considerable annual and seasonal variation and marked differences exist in the moisture holding capacity of the soils receiving the same amount of precipitation, general crop failures due to a deficiency or an excess of water have never occurred.

The average frost-free season is about 160 days, from about May 3 to October 10. The longest growing season recorded was in 1932, when it extended 194 days. The shortest was in 1929, when the growing season lasted but 122 days. Frost has been recorded as early as September 8 in the fall (1883) and as late as May 28 in the spring (1902).

The county has a mean annual temperature of 46.9 degrees Fahrenheit, a mean winter temperature of 24.2 degrees Fahrenheit and a mean summer temperature of 68.6 degrees Fahrenheit.

Winds are westerly and are seldom of such force as to cause any widespread crop or property damage.

Primary local differences in climate are only those governed by slope and depression. Since there is little difference in altitude throughout the county and there are no large bodies of water immediately present, wide variation would not be expected.

Physical Features (Ingham County)

Physiography

Of the physiography of Ingham County, Veatch (1941) said:

> The relief as a whole is smooth or gently undulating, although some parts are choppy and comparatively hilly. The secondary topographic features are those common to the moraines, till plains, outwash plains, and old glacial drainage valleys of this section. . . . As streams are not numerous, stream dissection is comparatively slight. The extreme difference in elevation between the highest and lowest points in the county is less than 300 feet and local differences between the levels of swamps, lakes or stream valleys and the adjacent higher land generally do not exceed 100 feet. Most of the slopes are short, smooth and rounded, rather than angular. They are related to constructional features of glacial origin rather than to subsequent stream dissection or geological erosion.

Drainage

Most of the county drainage is controlled by the Grand River Drainage Basin, which empties into Lake Michigan at

Grand Haven, Michigan. The immediate area of the college campus and surrounding territory is drained by the Red Cedar River, a tributary of the Grand River.

Both the physiography and the drainage in the county represent features resulting primarily from the action of glacial ice. During the Cary substange of the Wisconsin glaciation, the Saginaw lobe, by readvances and retreats, formed a series of L-shaped moraine features spreading north and east through the central part of the Lower Peninsula. Some of these moraines (Kalamazoo, Charlotte, Lansing, Grand Ledge) are present, in part, throughout the county and are primarily responsible for its present relief. These features are not always sharply defined and it is sometimes difficult to mark the exact boundaries of a single moraine.

Soils

Soils in Ingham County are of several kinds. Veatch (1941) divided them on the basis of drainage and texture into seven groups. They are: (1) well-drained clayey soils, (2) imperfectly and poorly drained clayey soils, (3) well-drained loamy and sandy soils, (4) well-drained very sandy soils, (5)

poorly drained sandy soils, (6) alluvial soils, and (7) organic soils. Under these categories he listed and described 34 soil types.

Physical Features (Site)

Toumey Woodlot is situated on a part of one of the previously mentioned L-shaped moraines, the Lansing Moraine. Approaches to the area, highest in the immediate vicinity, are very gradual (B slopes) on all sides but the southeast (Figures 1, 2, and 3). Here the approach is dissected in a southeast-northwest direction into one or two rolling mounds dropping off about twenty feet on either side (Figures 4 and 5).

Within the woods there are three areas which could be classified as "physiographically different." These will be called: (1) lowland, (2) slope, and (3) upland. The much larger portion of the woodlot lies on the upland where the amount of slope never exceeds 2 to 3-1/2 percent. The study was conducted on this upland area. At its widest points the woodlot measures about 1,200 feet by 700 feet.

In this forested upland area the soil type encountered was Hillsdale sandy loam, characteristic of category 3 of the

Figure 1. View of Toumey Woodlot taken from the north looking south. Disturbed area is to the extreme right.

Figure 2. View of Toumey Woodlot taken from the northwest looking southeast. Disturbed area is right of center.

Figure 3. View of Toumey Woodlot taken from the south looking north.

Figure 4. View of southeast edge of Toumey Woodlot looking northwest.

Figure 5. View of east-southeast edge of Toumey Woodlot looking west-northwest.

Veatch (1941) classification. He described this type as follows:

> A representative area of this soil consists of a plow layer of grayish-brown sandy loam or light loam, underlain by a 10- to 20-inch layer of pale yellow friable sandy loam, which grades into a layer of yellow or yellowish-brown sandy fine-granular friable clay loam ranging from 18 to 24 inches in thickness. The substratum consists either of pervious sandy clay, which is moderately stoney and gravelly in places, or of separate layers and pockets of sand, clay, and gravel.
>
> The content of humus is not high, in either the virgin or the cultivated soil but is sufficient to impart a light-brown color. Although the subsurface layer contains sufficient fine material to make it moderately retentive of moisture, it is permeable and penetrable to a depth of several feet. In most places the reaction is medium or strongly acid from the surface to a depth ranging from 36 to 48 inches. The material below this depth gives an alkaline reaction but either contains more sandstone fragments and less limestone or contains less calcareous clay than the associated Miami and Bellefontaine soils.
>
> Hillsdale sandy loam has the common textural variations of practically all of the soils in the county. The texture is sandier and the underlying material more pervious in places where this soil grades into the Coloma and Bellefontaine soils, and the content of clay is higher where it grades into Miami loam. Clay spots appear on some eroded slopes. In many places the surface soil is fine sandy loam; and small spots, in which the soil consists of a covering of sand or sandy loam over clay, as heavy as that underlying Miami loam, are also included with the Hillsdale soil. The distinction between the Hillsdale soil and the less gravelly areas of the Bellefontaine soils is not sharp, and this distinction probably is of small practical importance, as the smoother and less gravelly areas of both soils have similar agricultural value.

Analysis of Vegetation (Site)

The brief description of the woodlot which follows is based on quantitative data obtained from a 1/8-acre-quadrat study (made in the upland portion) and on observations of the woodlot flora made over the period covered by the study. A more complete report of the quantitative aspects of this woodlot is to appear in a publication of the Forestry Department, Michigan State College, in the near future.

The crown cover of the trees in this area is approximately 90 to 95 feet from the forest floor and, with the exception of a few "blowdown" exposures (Figure 7), is essentially a continuous canopy.

Of the woody species tabulated in the 1/8-acre-quadrat study, two stand out as being the most important as regards both basal area and number of stems present. They are Acer saccharum and Fagus grandifolia. The overwhelming predominance of Acer and Fagus over the other woody species recorded is evident from the figures in Table I. The total number of stems for these two species represents over 97 percent of all stems (over one inch) encountered in the 1/8-acre plot. Figures 6 and 7 show the general area in which the quadrat study was made.

Figure 6. View of Toumey Woodlot in the undisturbed section. Picture taken facing south.

Figure 7. View of Toumey Woodlot in the undisturbed section showing increased number of small stems in the vicinity of a "blowdown." Picture taken facing north.

TABLE I. Quantitative data from a 1/8-acre plot located in the upland area of Toumey Woodlot.

Species	Stems 1 to 3 Inches	Stems 4 to 10 Inches	Stems 10 to 20 Inches	Stems Over 20 Inches	Total No. Stems	Basal Area (sq. ft.)
Acer saccharum	227	25	10	5	267	35.472
Fagus grandifolia	33	17	5	7	62	31.427
Tilia americana			1	1	2	4.587
Ulmus americana	3	1	1		5	1.644
Prunus virginiana	1				1	.022
Ostrya virginiana	1				1	.067

Quercus rubra var. borealis has been observed in various parts of the woodlot but did not occur in the area selected for quantitative study. Shrubs seen in the woodlot included: Sambucus pubens and, in the west end, Zanthoxylum americanum.

Herbaceous plants found in the spring include: Erythronium americanum, Claytonia virginiana, Uvularia grandiflora, Trillium grandiflorum, T. recurvatum, Dentaria laciniata, Ranunculus abortivas, Arisaema triphyllum, and Galium sp. Various species of Viola were also present.

In the early part of the summer Phlox divaricata appeared at the extreme south edge of the woodlot. Two species were found in fairly great abundance in the early fall. They are Viola canadensis and Epifagus virginiana.

Again it must be emphasized that this list is not complete, being based on the 1/8-acre-quadrat study and on observations and identifications made in the field. It is seen, however, that on the basis of the features mentioned, the woodlot could be characterized generally as a beech-maple-type forest (Weaver and Clements, 1938, pp. 510-512).

Trees Selected for Study

One hundred specimens of sugar maple (A. saccharum) were selected in the upland portion of Toumey Woodlot (Figure 8). Selection was on the basis of size (DBH) and, as much as possible, on the basis of being free from disease, having a clean straight bole and a healthy crown not excessively suppressed.

Results of a population study on these same trees (Reimer, 1950) indicate that there are very few "hybridization" forms (Dansereau and Desmarais, 1947). Only one tree studied (No. 46) had characteristics "typical" of the black maple (A. nigrum Michx). The remaining specimens from which leaf collections could be made all possessed more or less "typical" sugar maple features. A subsequent investigation (Reimer, 1951b) substantiates this conclusion for the upland specimens.

Three arbitrary size classes were established. They are: (a) Size Class I - trees with a DBH from 10 to 15 inches, (b) Size Class II - trees with a DBH of from 15 to 20 inches, and (c) Size Class III - trees with a DBH of over 20 inches. Nearly all of Size Class III included trees having DBH measurements between 20 and 25 inches, however, a few had a larger DBH (Table II).

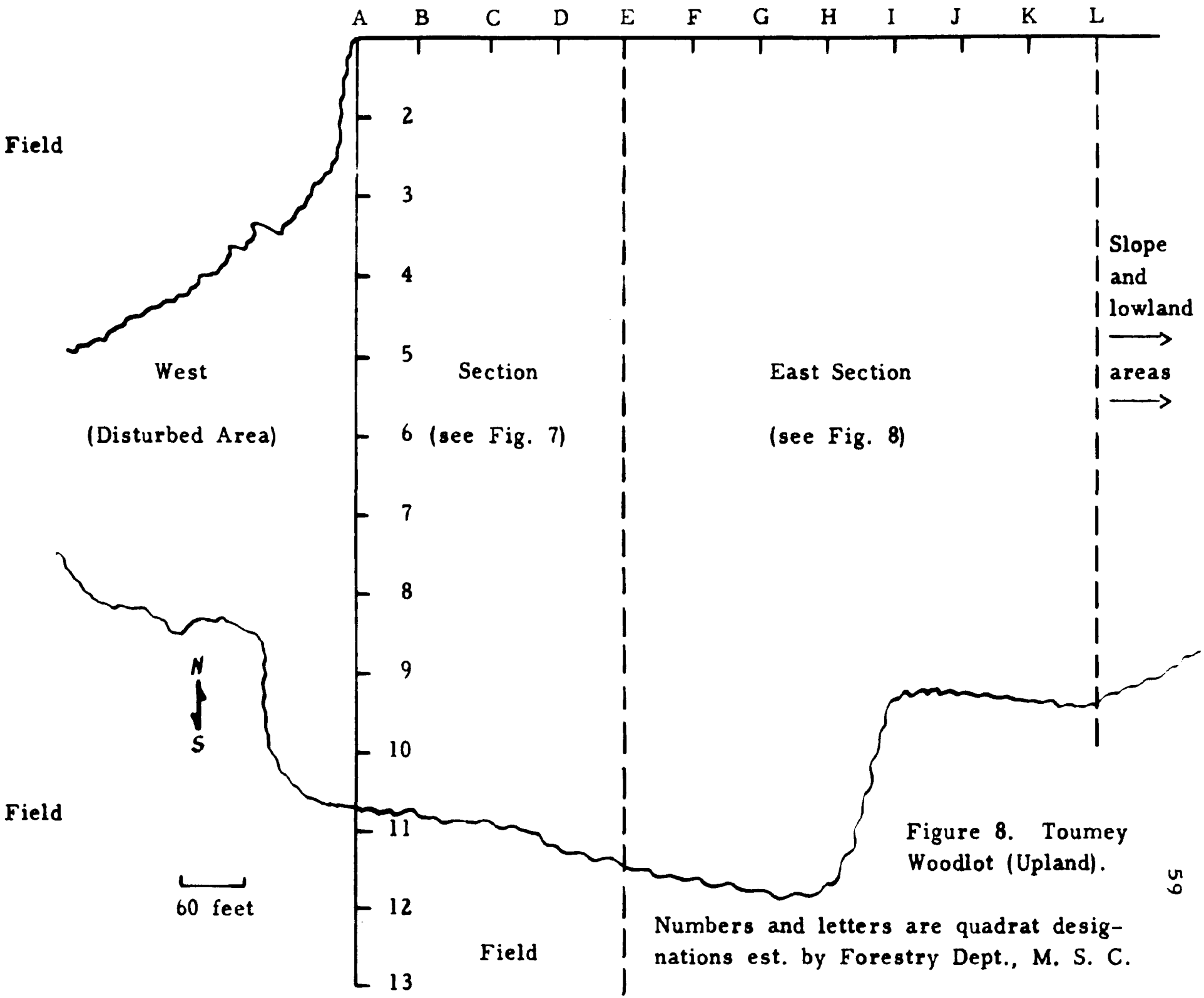

Figure 8. Toumey Woodlot (Upland).

Numbers and letters are quadrat designations est. by Forestry Dept., M. S. C.

TABLE II. Approximate tree diameters for 1949 before growth began (measurements in inches with calipers at breast height).

Tree No.	N-S	E-W	Tree No.	N-S	E-W
1	10	10-1/2	18	10	12
2	11	12	19	9-3/4	12
3	9-3/4	10-1/4	20	11	12-1/4
4	11-3/4	12-3/4	21	12-3/4	13-1/2
5	13-3/4	13	22	12-1/2	13
6	13-1/4	13	23	13	13-1/2
7	10	10-3/4	24	13-1/4	14
8	14-1/2	14-1/2	25	12	12-1/2
9	13-1/4	13-1/2	26	10-3/4	10
10	12	12-1/4	27	12-1/2	11-1/2
11	13-1/2	13-1/2	28	10	9-3/4
12	10-1/2	11	29	8-1/2	9-1/4
13	13-1/2	13-3/4	30	9-1/2	10
14	11-1/2	11	31	21-3/4	22
15	12-3/4	12-1/2	32	19-1/4	20
16	12-1/2	12-1/2	33	17	18
17	13	11-3/4	34	19	19

TABLE II (Continued)

Tree No.	N-S	E-W	Tree No.	N-S	E-W
35	19-1/2	21	53	21	21
36	14	15	54	22-1/2	21
37	22-1/4	22-3/4	55	19	21
38	18-3/4	19	56	24	22
39	16	17-1/4	57	18	17-1/4
40	18-3/4	18-1/2	58	14	13-1/4
41	18-3/4	18-3/4	59	13-1/4	14-1/4
42	21-1/2	24	60	19	18-1/2
43	19-3/4	20	61	24	23-1/4
44	18	17	62	25	26-1/2
45	13	14	63	25	26-1/2
46	17-1/4	16	64	27	26
47	22	22	65	30	31
48	19-3/4	19-1/2	66	33	32-1/2
49	22	20-1/4	67	24	23
50	22-1/4	23-1/4	68	16-1/2	15
51	22	25	69	30-1/2	33-1/2
52	21	19-1/2	70	32	35

TABLE II (Continued)

Tree No.	N-S	E-W	Tree No.	N-S	E-W
71	19	15-1/2	86	16	17
72	15-1/2	17	87	17	16-1/2
73	24	27	88	18	18
74	25	25	89	14-1/2	14-1/2
75	27	28	90	17-1/2	17
76	24	23	91	24-1/2	25
77	25	21-1/2	92	26	25
78	21-1/2	20	93	24-1/2	25
79	22-1/2	22	94	17	19
80	19-1/2	18-1/2	95	10-1/2	11-1/2
81	16-3/4	17	96	30	26
82	16	18	97	32	32
83	15-1/2	15	98	20	19-3/4
84	18	17-1/2	99	10-3/4	13
85	14	12-1/2	100	22-1/4	22-1/2

The restrictions placed on the trees selected did not leave much choice as to location. Nevertheless, a fairly good coverage of the upland area was possible (Figures 9 and 10). Twelve of these 100 trees are growing in the extreme western part of the upland area. This part had been previously partially cut and grazed and is only now beginning to show some signs of understory development. Here the forest floor is composed mostly of grasses with the exception of the section immediately adjacent to the undisturbed part. The remaining 88 trees are to be considered as a part of this undisturbed upland forest.

Ninety of the 100 trees were measured along one radius (west). Measurement of any one cardinal point would be open to some criticism so this choice was more or less arbitrary. If any reasons need be given for this selection, they might be the following: (1) Readings were taken in all cases, except on rainy days, in the morning hours when the few penetrating rays of the sun entered the canopy from an easterly direction. In this manner the screws mounted to the trees had a minimum chance for possible expansion due to radiation from the sun. (2) It was more convenient to enter the woodlot from the

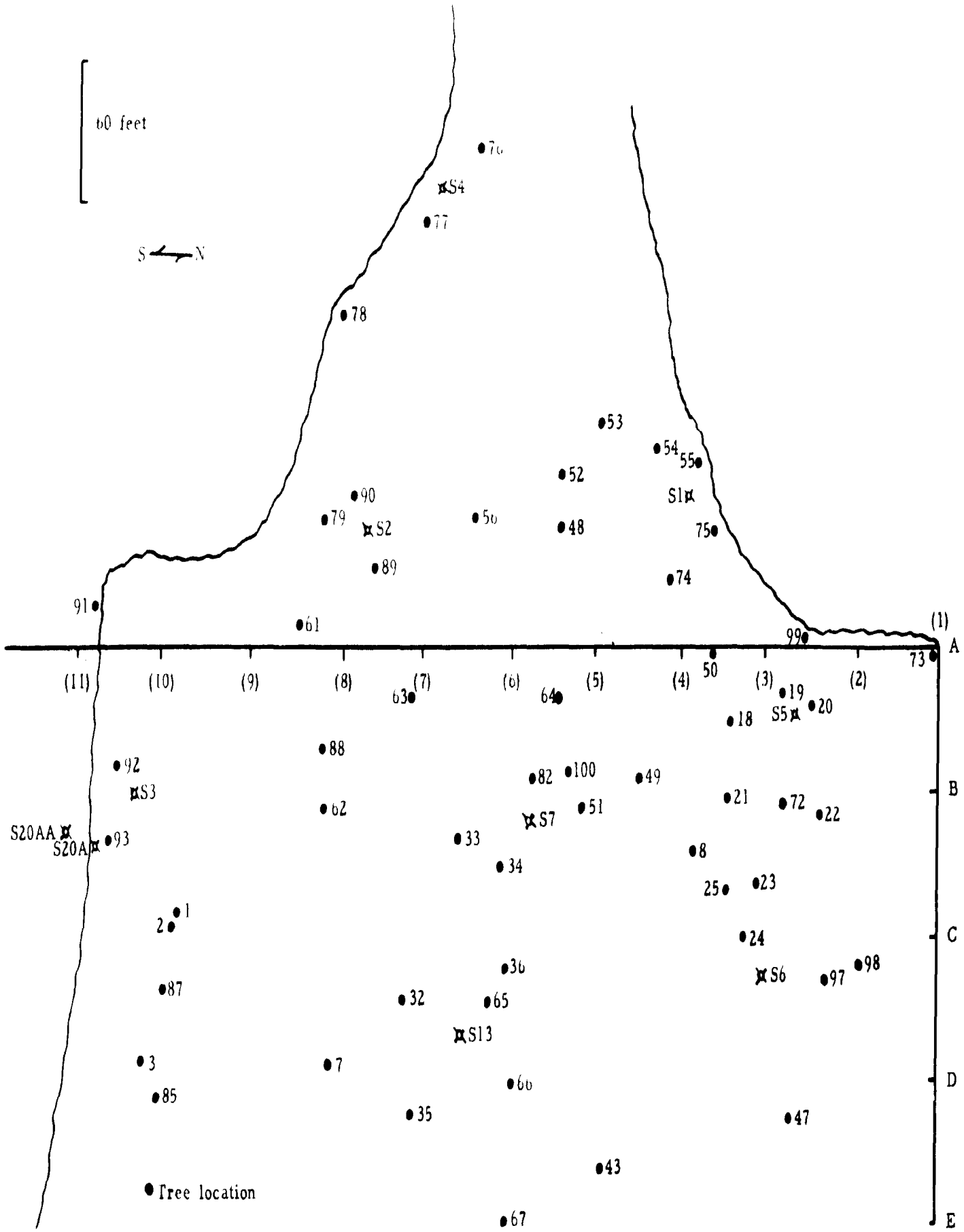

Figure 9. Taumoy Woodlot (west section)

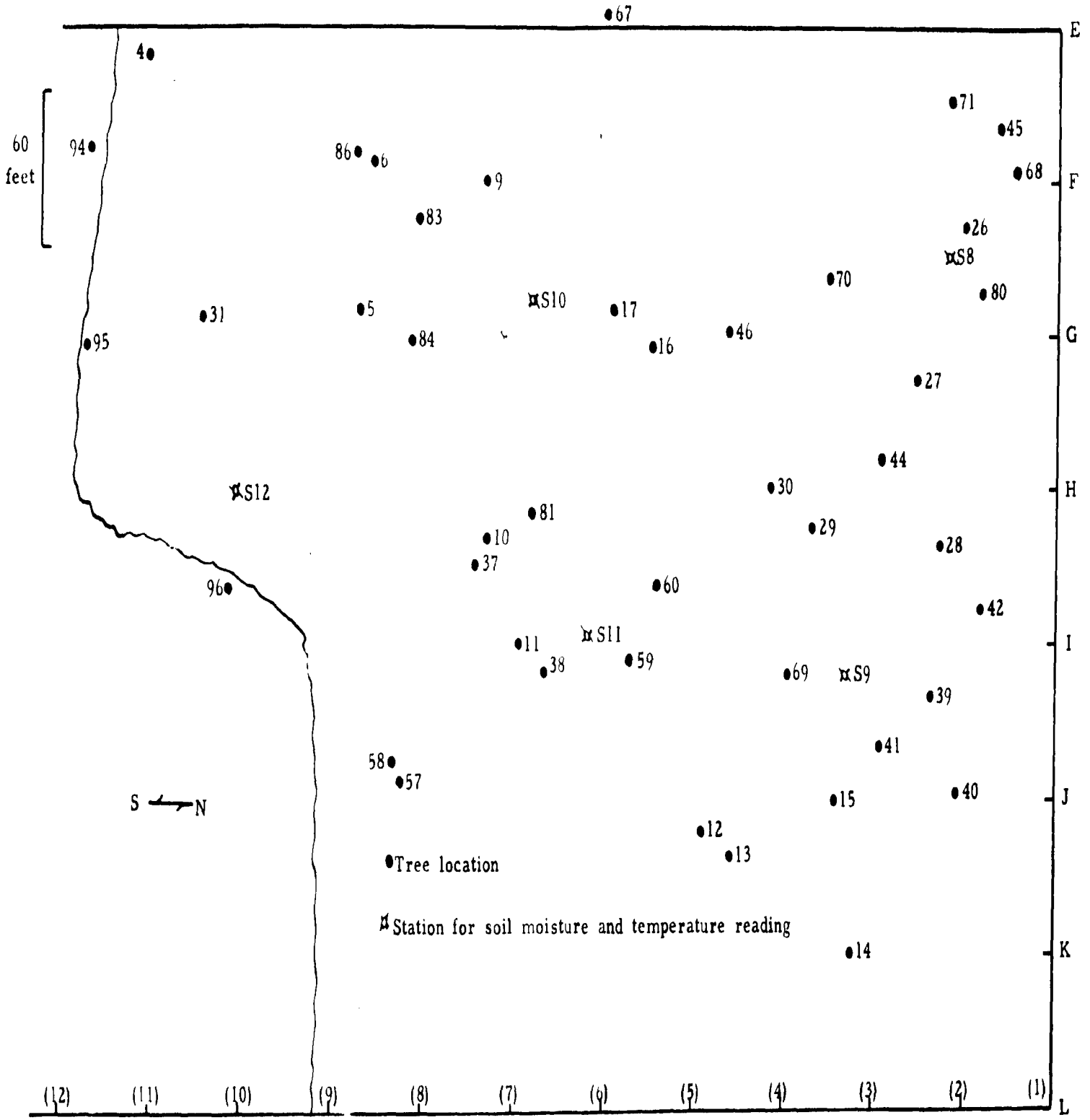

Figure 10. Toumey Woodlot (east section).

west side. This meant that by having the screws and tags on the west side, location was facilitated during the first few weeks of recording.

Ten trees were measured along four radii. Trees 91 (Figure 11), 92 (Figures 12 and 14), 93 (Figures 13 and 14), 94 (Figures 15a and 15b), and 95 (Figure 16) had crowns forming a part of the south edge of the stand. These trees were used for observation of any possible "edge" effect on radial increase. For the same reason trees 96 (Figures 17a and 17b), with an east exposure, and 99 (Figure 19), with a west exposure, were selected. Trees 97 and 98 (Figure 18) are growing immediately adjacent to a "blowdown" and have parts of their crowns exposed to direct afternoon sunlight. It was the object in this case to determine if there be any effects on radial growth of the "partial release" from competition (Stevens and Spurr, 1949). The crown of tree 100 is a part of the closed canopy and this tree was selected in order to determine the radial-growth pattern in a situation where no particular exposure was evidenced. Figure 20 shows the location of this tree.

Figure 11. Tree 91. Picture taken facing east.

Figure 12. North side of tree 92.

Figure 13. North side of tree 93.

Figure 14. Trees 92 and 93 as seen from west. Picture taken facing east.

Figure 15a. Tree 94 as seen from southwest. Picture taken facing northeast.

Figure 15b. Tree 94 as seen from northwest. Picture taken facing southeast.

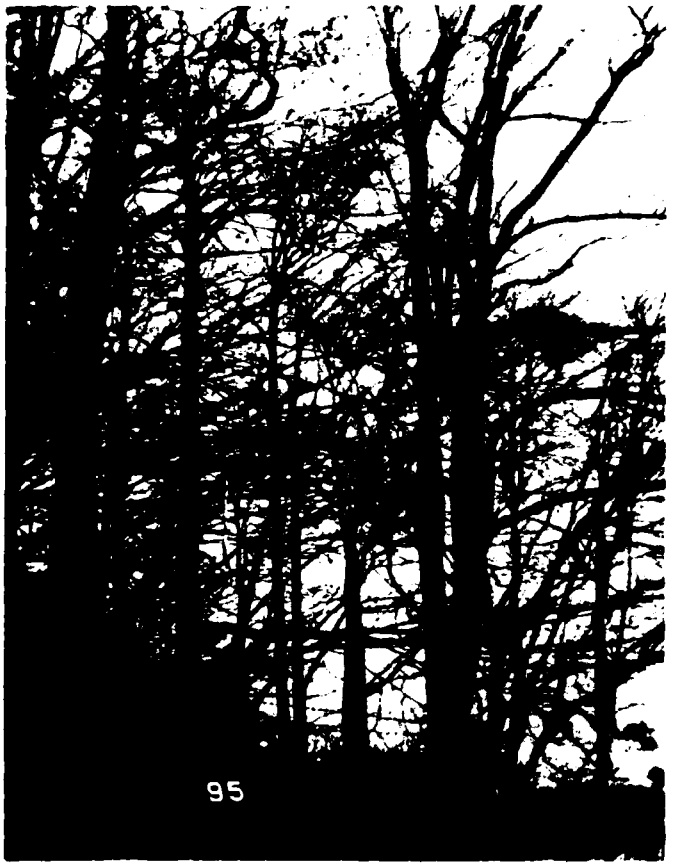

Figure 16. Tree 95 as seen from southwest. Picture taken facing northeast.

Figure 17a. West side of tree 96.

Figure 17b. West side of tree 96 showing upper branches.

Figure 18. Trees 97 and 98 as seen from south. Picture taken facing north. Blowdown is just left of center.

Figure 19. South side of tree 99.

Figure 20. Tree 100 as seen from southwest. Picture taken facing northeast.

Measurement of Radial Increase

A precision dendrometer of the type described (Daubenmire, 1945) and used by Daubenmire (1946, 1947, 1949, 1950) was employed in this investigation. The advantages of this instrument over the one described by Reinike (1932) are discussed by Daubenmire (1945, 1949).

One modification in technique was made by this investigator. Instead of using a thin, flat piece of metal glued or otherwise affixed to the bark, a small 3/8-inch screw was secured into the bark just far enough to present a firm base for the arm of the dial gauge. In the opinion of the writer, the thickness of bark in the specimens studied was more than adequate to allow for anchorage of the "recording screw" and at the same time to separate it from the secondary meristematic tissues.

The instrument itself records increases down to 0.001 inch and it is even possible to interpolate down to 0.0005 inch with reasonable success (Daubenmire, 1945). This, ordinarily, is not necessary unless most precise data are desired. When data are taken weekly or biweekly, accuracy down to 0.001 inch

is all that is required. Even at this level of measurement the error is quite small.

On March 27 and 28, 1949, three brass wood screws and one 3/8-inch "recording" screw were placed in each of 90 trees on the west side. Twelve brass wood screws and four "recording" screws were placed in each of 10 trees, three large and one small, at each of four sides (viz., north, south, east, west). Accordingly, 130 radii were prepared for measurement. The screws were stopped in such a position that the screwdriver slots were vertically displaced. Thus, it was not difficult to determine if any of the screws had been altered. In a few cases squirrels and other arborescents in climbing the tree would dislocate the recording screw. This would have to be reset and the reading for that week was lost.

Initial recordings were not made until the week ending April 4, 1949. Readings were taken every week thereafter during the growing season. The last reading of 1949 was taken October 14. Readings were interrupted during the winter and resumed again the first week of April, 1950. The last reading of 1950 was taken September 16, 1950.

Occasionally it became necessary to reset the instrument as a result of radial increases. This was done by measuring two trees before resetting the gauge and then remeasuring the same trees after the resetting. In all cases the numerical amount to be added to the readings was the same for the two trees checked. As an added check a block of seasoned wood with correctly placed measuring screws was kept in the laboratory under relatively uniform conditions. The instrument was checked periodically with the original reading taken on this block. No discrepancies over 0.0005 were recorded.

Environmental Factors Measured in the Woodlot

Within the woodlot two environmental factors were measured—soil moisture and soil temperature. Soil moisture measurements were made with an electrical resistance unit of the type described by Bouyoucos and Mick (1940, 1947). The instrument operates on the principle of the Wheatstone bridge. Plaster of Paris blocks are buried to desired depths and for recordings, leads from these blocks can be connected to the portable instrument. The particular instrument used was equipped with earphones for determining the "null" point. A later modification

has an "electric eye" for visual readings. Resistances are given in ohms.

An arbitrary limit of 75,000 ohms resistance "has proved practical as an indicator of the maximum forces against which plants can obtain moisture from the soil" (Bouyoucos and Mick, 1947). This, then, represents the lower limits (in resistance units) of permanent wilting. A resistance of 600 ohms, also arbitrarily selected (based on the principle of the fall of the resistance curve to a minimum constant level), represents approximately the point of resistance at which the soil is beginning to lose water in response to gravitational forces. This resistance, then, represents the moisture equivalent of the soil. The entire range of resistances can be conveniently transferred into percentages and these are referred to as percentages of "available water."

There may be some question as to the necessity of calibration of the resistance blocks for the particular soil in which they are placed. Of this Bouyoucos and Mick (1948) have said:

> It is emphasized, however, that calibration is not necessary to the use of the standard block resistance as an indicator of the force with which moisture is held by the soil, or as an indicator of the approximate volume and mass relationships, that is, the amount of available water present in the soil.

The only exception is made in the case of soils with a high soil concentration. For the other soils they maintained that "for any given resistance, different soils hold water with approximately the same force."

Year-around weather conditions seem not to have any great effect on the buried resistance blocks in upland areas. "Under Michigan weather conditions, plaster of Paris blocks have functioned satisfactorily in well drained soil profiles for more than five years" (Bouyoucos and Mick, 1948).

In June, 1949, thirteen soil-moisture stations were established throughout the upland area of Toumey Woodlot. At these stations blocks were buried at 1-foot and 3-foot depths. These depths were suggested by Dr. Bouyoucos of the Soils Department at Michigan State College. They also seemed reasonable in the light of field observations of "blowdown" trees in the woods. Figures 21a, 21b, 21c, 22, and 23a show the exposed roots of these trees. From the position of the roots it appears that most of the smaller ones are concentrated at about the 4- to 14-inch level. Some of the larger roots are seen to penetrate farther down into the soil. Figure 23b also

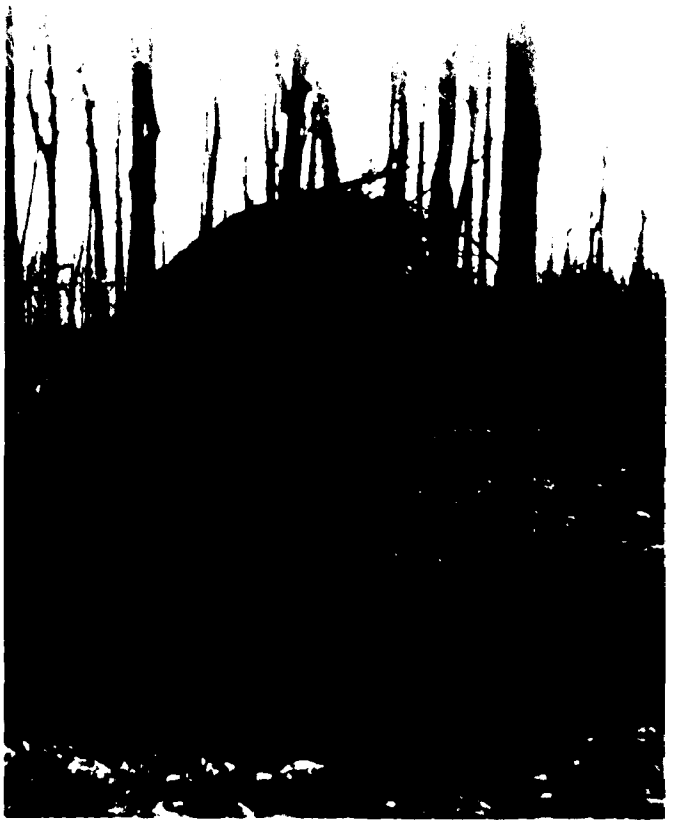

Figure 21a. Blowdown A showing exposed roots. Side view looking south.

Figure 21b. Blowdown A showing exposed roots. View looking northeast.

Figure 21c. Blowdown A showing exposed roots. Side view looking north.

Figure 22. Blowdown B showing exposed roots. Side view looking northeast.

Figure 23a. Blowdown C showing exposed roots. Side view looking east.

Figure 23b. Blowdown C showing depth of hole formed as result of dislodgment of roots.

shows that the depth of the hole from which the roots were dislodged was about 17 to 20 inches.

Biswell (1935) described the root habitat of sugar maple saplings (8, 10 and 16 years old) growing on a gentle slope in the clay soil of Nebraska. He said:

> Although taproots were 1 to 1.8 inches in diameter . . . they at once gave rise to such large laterals that their size was quickly reduced.
>
> Their course was not vertically downward. All grew obliquely downward in part and the greatest depth of penetration was three feet.

He then presented a diagram of the root system which revealed that most of the roots were at about the one-foot level, with a secondary grouping at the two-foot level. He found but sparce development of small rootlets.

Stations 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and 12 had two blocks at each of two depths, one-foot and three-foot. Stations 11 and 13 had but one block at each depth. Along the south edge, two remaining blocks were placed so that one was at the very edge of the woods while the second one was buried about twenty feet outside the woodlot in a grass-covered meadow. Both blocks were buried to a depth of one foot.

A post-hole digger was used to remove the soil to the desired depth. As each bit of soil was removed it was placed on a waterproof canvas next to the previously removed soil. When the three-foot level was reached the moistened block was placed in a recess made in the side of the hole and then surrounded with soil from the adjacent area. In this manner the layers of soil above the block were relatively undisturbed, thus giving a better picture of the water regime at that level. The hole was then filled to the one-foot level and this process of setting the block was repeated.

The top soil layers were replaced, allowing only the wire leaders to extend above the surface of the ground (Figure 24). It would seem from the profiles that the blocks at the one-foot level were situated in the lower portion of the A horizon while the blocks at three feet were in the lower portion of the B horizon.

After a period of about three weeks, readings were begun at these thirteen stations (July 14), so that for the first season's growth only a part of the soil moisture figures for the woodlot itself were available. Data for the entire growing

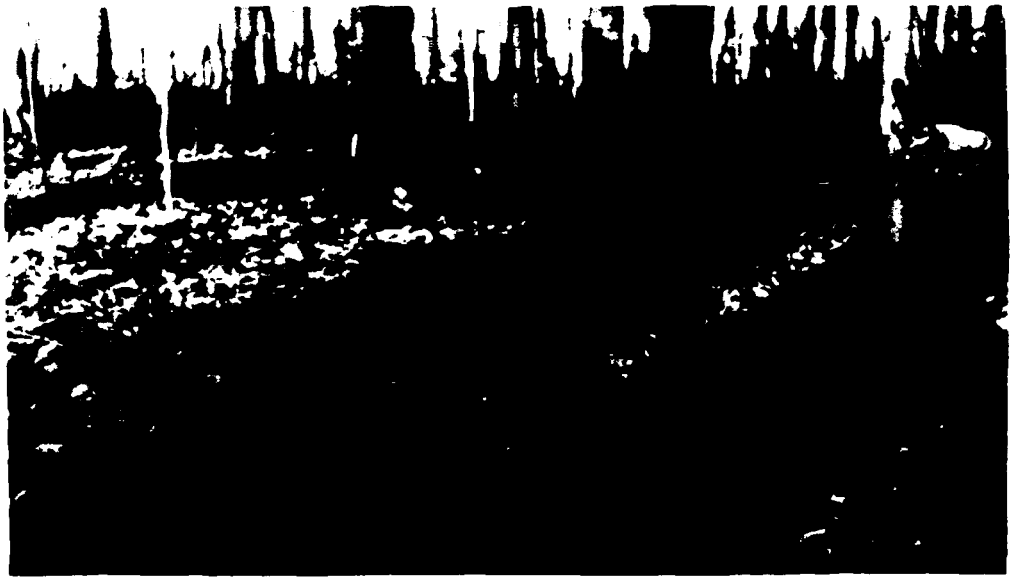

Figure 24. Wire leaders leading to soil moisture blocks. Metal ends plug into recording unit.

season of 1950, however, were obtained. Weekly readings were made at the same time as were the dendrometer readings.

Soil-temperature data were taken weekly at the various stations established for soil-moisture readings. Thus, there were thirteen regular stations. Soil temperature was also recorded in the two areas at the south end of the woodlot. These two areas had but one block each buried at the one-foot level and have been previously located and described.

A soil thermometer, Type No. 1264, manufactured by the Wm. Welch Company, Chicago, Illinois, was used. This type of thermometer allowed for measurements of soil temperature at about the three-inch level. The thermometer was plunged into the ground upon arrival at a particular station. After soil-moisture readings were taken and recorded (about 5 minutes), the reading on the soil thermometer was recorded.

Other Environmental Factors

In addition to soil-moisture and soil-temperature data taken in the woodlot, other climatological data were secured from the hydrologic station located on the campus of Michigan State College about 300 yards to the west of Toumey Woodlot.

The following data were secured from this station: daily soil temperature at the three-inch level (measured with a hygrothermograph), daily soil moisture at the one- and three-foot levels (measured with an electric resistance unit), daily solar radiation (measured with an Eppley pyroheliometer [Crabb, 1950]), daily evaporation (open-pan method), daily precipitation (measured from rain gauge).

Unfortunately it became necessary to utilize climatological data from the Lansing weather bureau. The available figures for air temperature (measured with a thermograph), amount of cloudiness (arbitrary scale 1 to 10; measured with sunshine recorder), and total hours of sunshine, were taken from their reports.

All of these data were converted into weekly figures to facilitate correlation with other measured data taken from the woodlot. Permission for the use of the Hydrologic Station data was given by the Michigan Hydrologic Research Station, Soil Conservation Service, USDA, in cooperation with the Michigan Agricultural Experiment Station, under the direction of G. A. Crabb, Jr. For a view of the hydrologic station and for a

discussion of the use of the pyroheliometer, the reader is referred to the publication by Crabb (1950).

OBSERVATIONS AND RESULTS

Introduction

It is appropriate at this time to clarify the author's meaning of the term "radial growth." Throughout the paper reference is made to the "radial growth" of certain specimens or certain groupings of specimens. On a strict basis this term is entirely too general and almost completely incorrect. The objection would lie in the specific use of the term "growth" rather than in the use of the term "radial" which should be fairly definite.

At least three phases are recognized, viz., cell formation, cell enlargement, cell maturation, in the "growing process" of living tissues. Cell rehydration has also been considered as "growth" (MacDougal, 1936). In addition to these various processes peculiar to "growth" in living tissues, shrinkage and distention of nonliving parts would, in the case of the stem, affect any radial measurement taken. With all of these processes occurring simultaneously it would indeed be

most difficult to separate out the effect on enlargement of any one process.

As can be seen, certain aspects of growth are to be associated almost exclusively with the water regime of the plant, others only partly associated with this and partly associated with carbon fixation and subsequent physiochemical processes.

In spite of this it does seem reasonable that increase in any phase, or any combination of phases of growth mentioned (with the exception of swelling of nonliving tissues) is a fairly good index of the rate of metabolism of the tissues at the measured level. The use of the term "growth" for such an increase caused by any or all of the above-mentioned growth "phases" would still not be far from correct, even though in a more general sense.

Students of cambial-activity phenomena determined by the dendrometer, are forced to use the increase figures obtained as an index of the actual formation, distention and maturation of cells, keeping in mind that, at certain times, increases and decreases caused by factors other than the activity of the secondary meristems and adjacent living tissues,

might influence in some way the interpretation of the results.

Radial growth, then, refers here to any increase recordable on the instrument used; the collective result of any one or all of the aspects previously mentioned. It is realized that with present techniques it is impossible to determine the volume changes in nonliving elements during the growing season, but assumed that unless extreme water shortage ensues, their changes will not materially affect the curve of seasonal growth.

Radial Increase in Trees Measured Along One Radius

Early Spring Measurements to Determine the Date of Growth Initiation

At the beginning of measurements in Toumey Woodlot an arbitrary initial or zero point had to be established in order to determine subsequent increases. Because of this, it might be said that some increase in the radius, possibly due to growth, occurred previous to this time. It has been shown, however, that for several species of deciduous trees, radial increase does not become measurable until after the leaves are one-half to three-fourths developed (Friesner, 1941, 1942;

Reimer, 1949). Reimer (1949) also reported that axial growth was practically completed before radial enlargement began. Acer saccharum was one of the five species studied by him. No such leaf and shoot development was apparent in Toumey Woodlot until about the first of May.

The following dates for "inception of growth" have been recorded on a dendrometer for Acer saccharum:

Investigator	Date (week ending)	Location
Stout, A. B.	May 12, 1920	N. Y. Bot. Gard.
Friesner, R. C.	May 12, 1941	Indianapolis, Ind.
Reimer, C. W.	June 10, 1947	Indianapolis, Ind.

Work by Daubenmire (1947) listed the date of "attainment of 10% of net annual increment" for sugar maple as being May 16, 1944, and May 17, 1945 (Moscow, Idaho). Initiation must have preceded these dates by several days. In view of these data it seems safe to assume that radial growth had not begun before the time of the first readings in 1949.

The relative amounts of rehydration and growth occurring the week ending May 5, 1949, could not be determined. But in 1950 (Tables VI-A, VI-B, VI-C) it will be noted that the first week of increase not only brought all figures back to their

highest point reached the previous year, but in most cases the increase was much more than could be accounted for by rehydration of nonliving tissues.

Description of Growth for 1949

Figures 25, 26, and 27 indicate that sometime during the week ending May 5, 1949, radial increases averaging around 0.006 to 0.007 inch occurred. Just how much of this represented activity of living tissues cannot be said but it is probable that cambial activity was at least partially responsible for the increase. All three size classes showed increase during this week.

For a period of three weeks after initial radial increase there was a halting fluctuation in the growth curve for 1949 (Figures 25, 26, and 27), followed by a very sharp surge of growth rate lasting for two weeks. This latter growth could be called the first major peak of increase rate. It does not represent the highest peak of increase.

Growth for the week ending June 16 was considerably less than for the previous week and represents the first major drop in growth rate after growth was well under way.

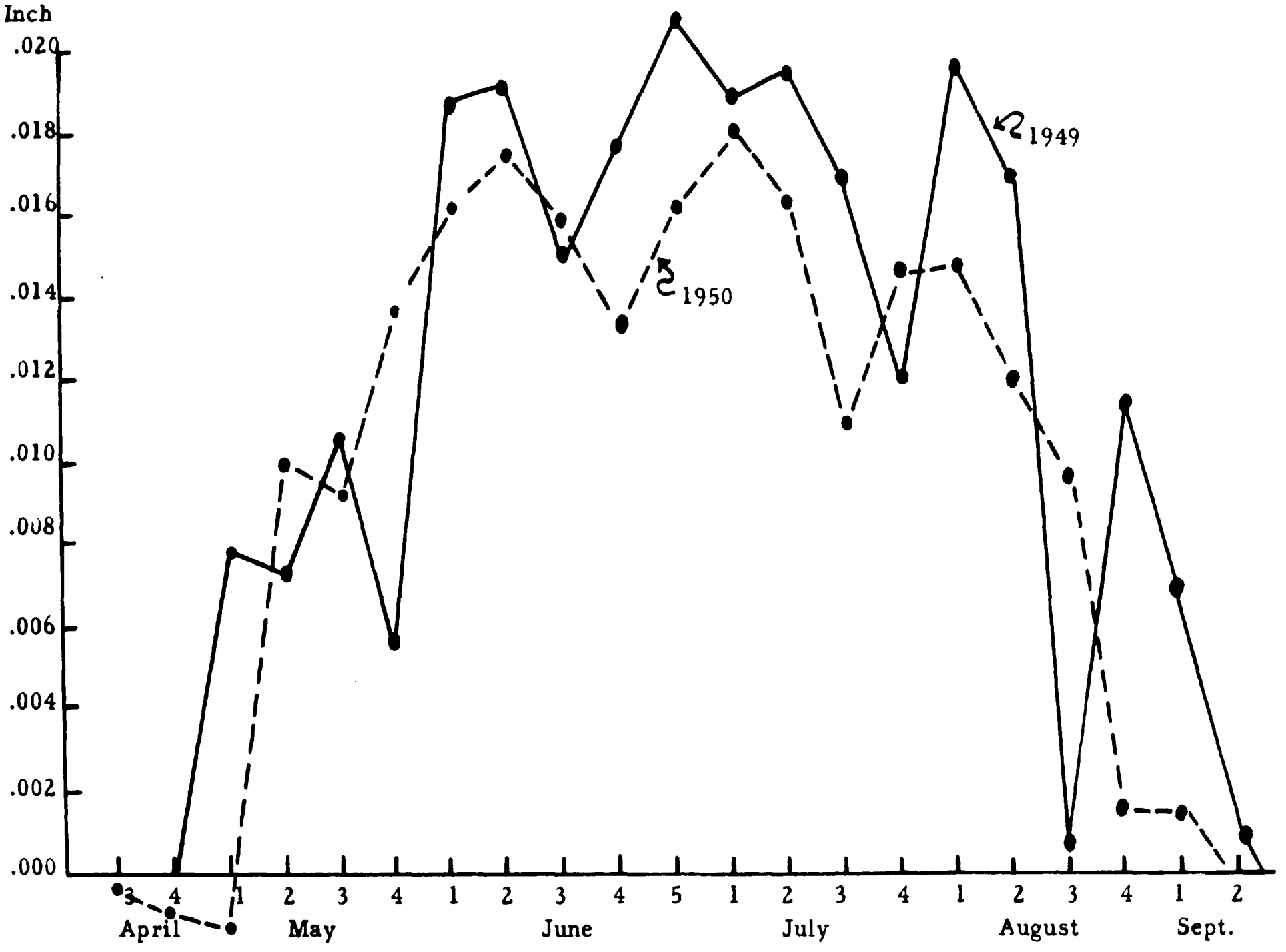

Figure 25. Radial growth of Size Class I trees for 1949 and 1950. Each weekly recording represents the arithmetic mean increase of 30 trees.

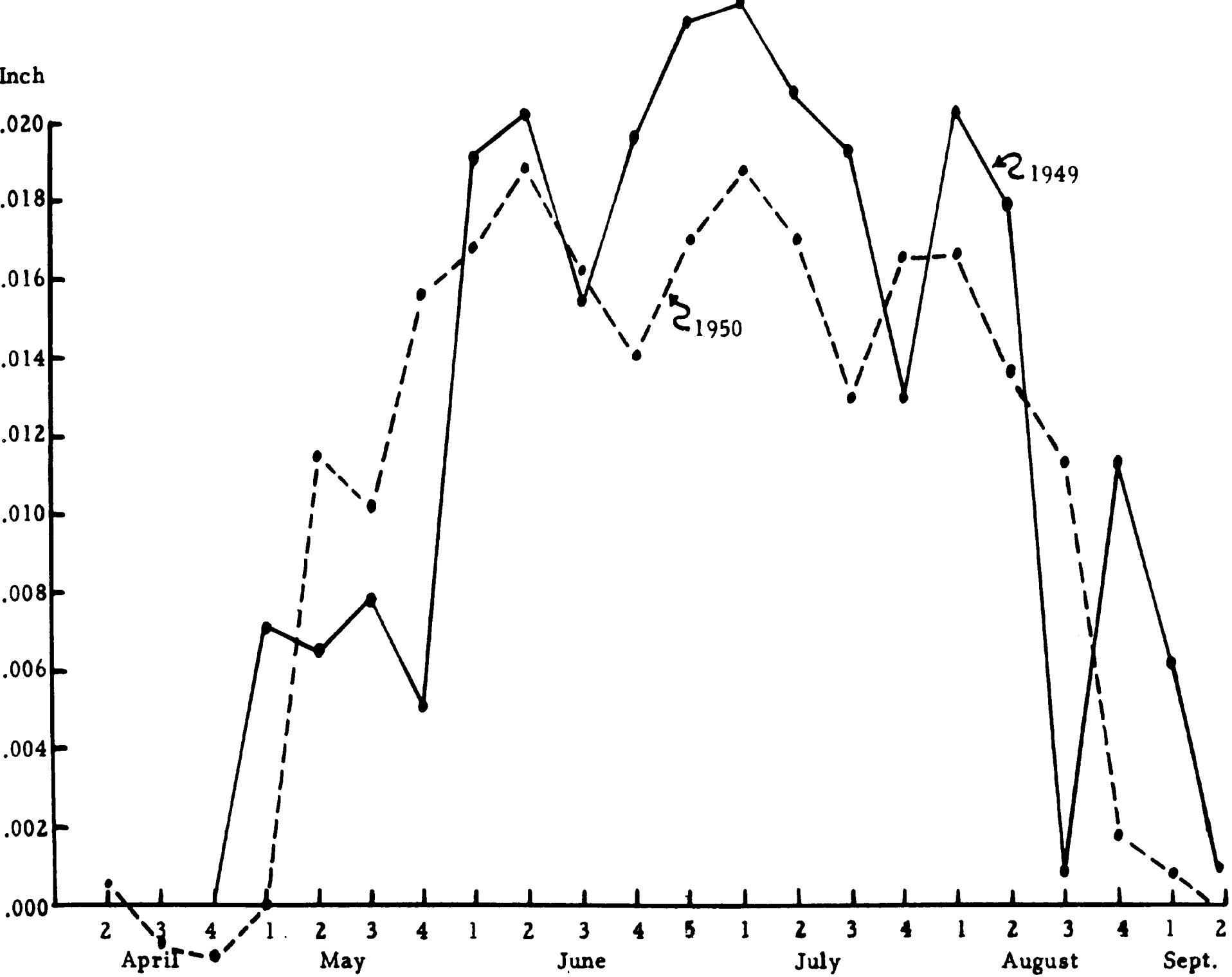

Figure 26. Radial growth of Size Class II trees for 1949 and 1950. Each weekly recording represents the arithmetic mean increase of 30 trees.

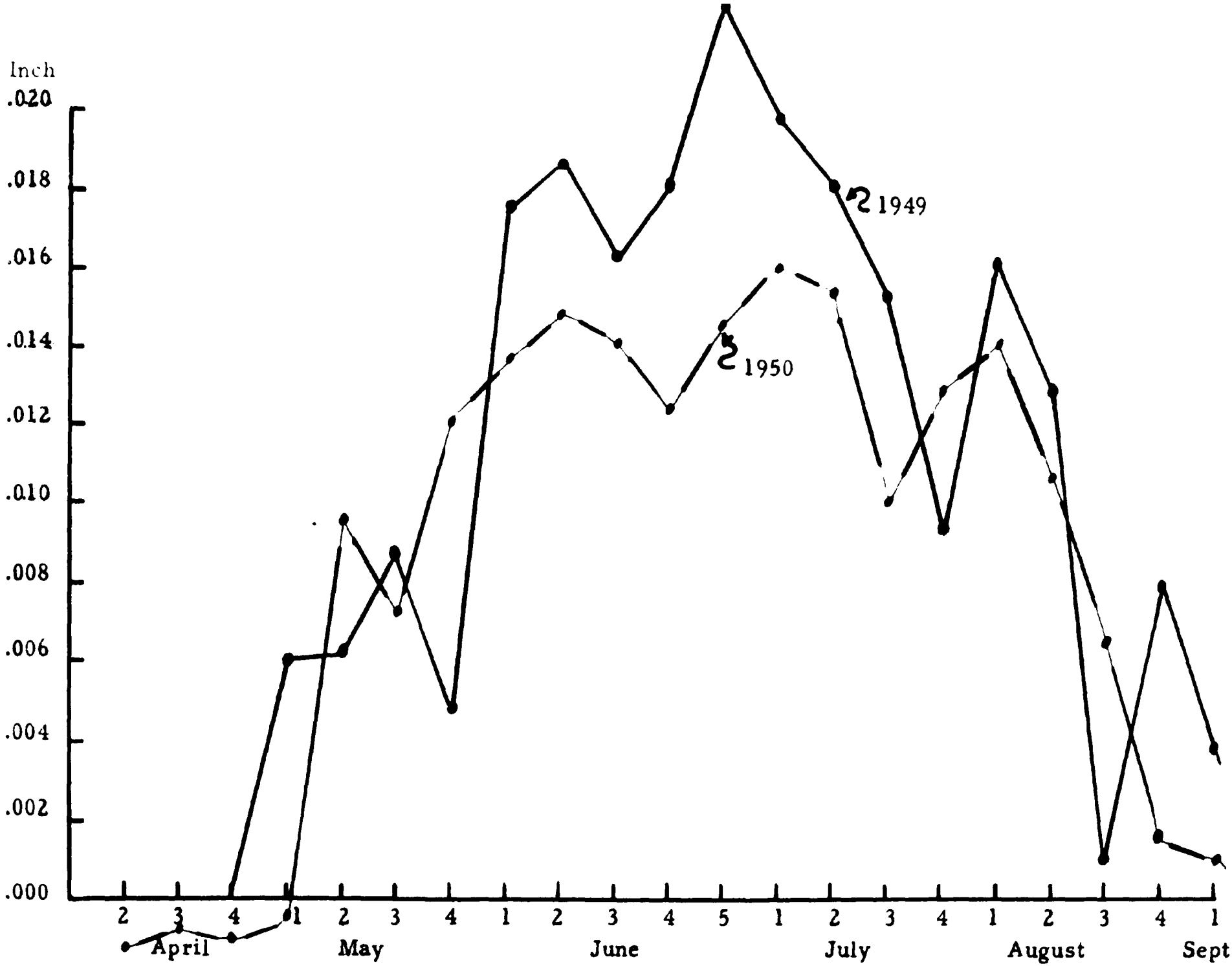

Figure 27. Radial growth of Size Class III trees for 1949 and 1950. Each weekly recording represents the arithmetic mean increase of 30 trees.

A second and more extended peak of growth rate was evident between June 23 and July 21. The following week (ending July 28) the growth rate decreased, marking the second major recession during the greater part of the growing season.

A third recession of growth rate during the week ending August 18 divided the remainder of the growing season into two other periods of greater increase. The first included the weeks ending August 4 and August 11 and the second came during the week ending August 25.

On the basis of the figures recorded it is somewhat difficult to say exactly when growth ceased. The last rather conspicuous increase came the week ending September 2. Two weeks later a slight average increase was recorded and even on September 30 some increase was evident, although it was below 0.001 inch. On October 13 all increases had ceased with the possible exception of one or two trees which still showed small increases. Some trees showed no radial growth beyond the week ending August 25.

In general it can be said that the growing season for sugar maple in 1949 extended from about May 5 to about September 2, a period of 18 weeks. Peak rate of growth came

the week ending July 7 for Size Class II trees and June 30 for Size Class I and III trees.

Description of Growth for 1950

In 1950 a positive increase which could be interpreted as due at least partly to growth was not recorded until the week ending May 11. The increase averaged between 0.009 and 0.011 inch. All three size classes responded during the same week (Figures 25, 26, and 27).

After the first week of increase, the rate of growth, with the exception of one week, climbed steadily up to the week ending June 10. The second week (ending May 18) showed a slightly lesser amount of increase over that of May 11. The first peak rate of growth, then, was reached the week ending June 10. The weeks ending June 17 and June 24 produced successively smaller increases. This marked the first major recession of rate for 1950.

The first three weeks in July increases were again larger, making for a second peak rate of increase. The second major recession in growth rate was recorded the week ending July 22.

This was followed by a third peak rate of cambial activity (weeks ending July 29 and August 5). From this week, rate of increase was steadily less for each succeeding week.

The last increase of any consequence was the one ending August 19, but increases were recorded for various trees up to the time of the last readings on September 16. As in 1949, the time of cessation of radial growth varied considerably with the tree. In one case (tree 44), the last increase was recorded the week ending July 29. Most of the others continued growth enlargement at least until August 19.

Thus, for 1950, radial growth extended generally from about May 11 until about September 2, a total of 17 weeks. The peak rate of increase for all size classes occurred the week ending June 10.

Comparison of Environmental Factors with Increase Measured Along a Single Radius

Initiation

It has been previously mentioned that the first increase which can be interpreted as growth in 1949 came sometime during the week ending May 5. In 1950 the first increase was

apparent for the week ending May 11.[1] In both years at these respective times there was a coincident increase in air temperature above 50 to 51 degrees Fahrenheit (Figures 28 and 29). At no time previous to this was the weekly mean air temperature this high. The increase in mean weekly air temperature for the week ending May 5, 1949, was from 51 to 66 degrees Fahrenheit. During the week ending May 11, 1950, the mean weekly air temperature increased from 48 to 54 degrees Fahrenheit. Soil temperatures also showed a significant increase for these same periods (Figures 30 and 31).

Total solar radiation and total hours of sunshine are plotted in Figures 32, 33, 34, and 35. Solar radiation during the week of first radial increase also increases in both years above 3,000 Langley units. Yet, during the week ending April 14, 1949, solar radiation was considerably above this value and no growth was in evidence. Likewise, total hours of sunshine for the week ending April 14, 1949, was about as great as it was for the week ending May 5, 1949, when radial growth commenced.

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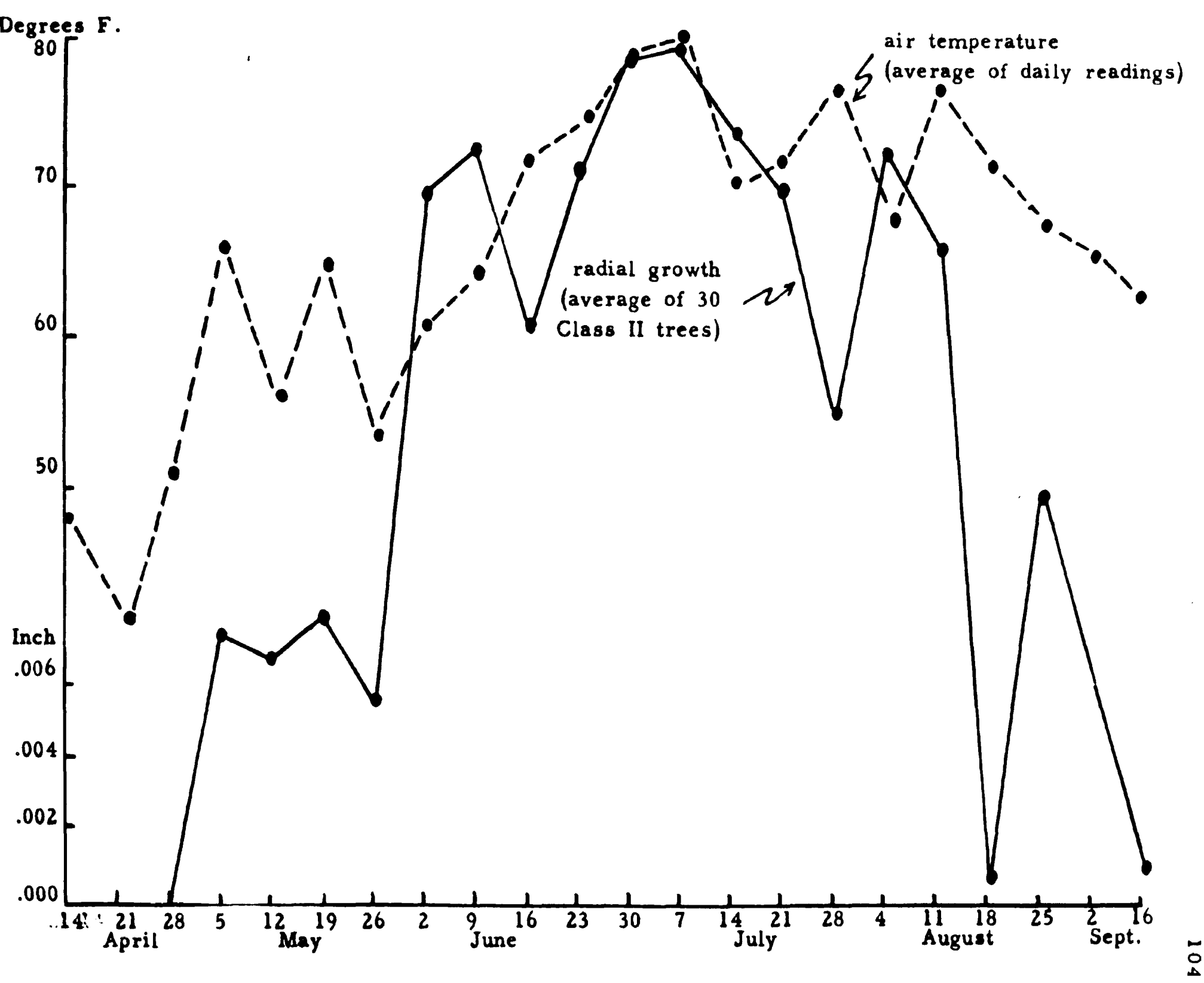
[1] Because of the fact that the curves for all three size classes were quite similar there was no necessity of comparing each of these groups with the environmental data. In all cases of comparison, Size Class II was utilized.


Degrees F.
80
70
60
50
air temperature
(average of daily readings)
radial growth
(average of 30
Class II trees)
Inch
.006
.004
.002
.000
14
21
28
5
12
19
26
2
9
16
23
30
7
14
21
28
4
11
18
25
2
16
April
May
June
July
August
Sept.

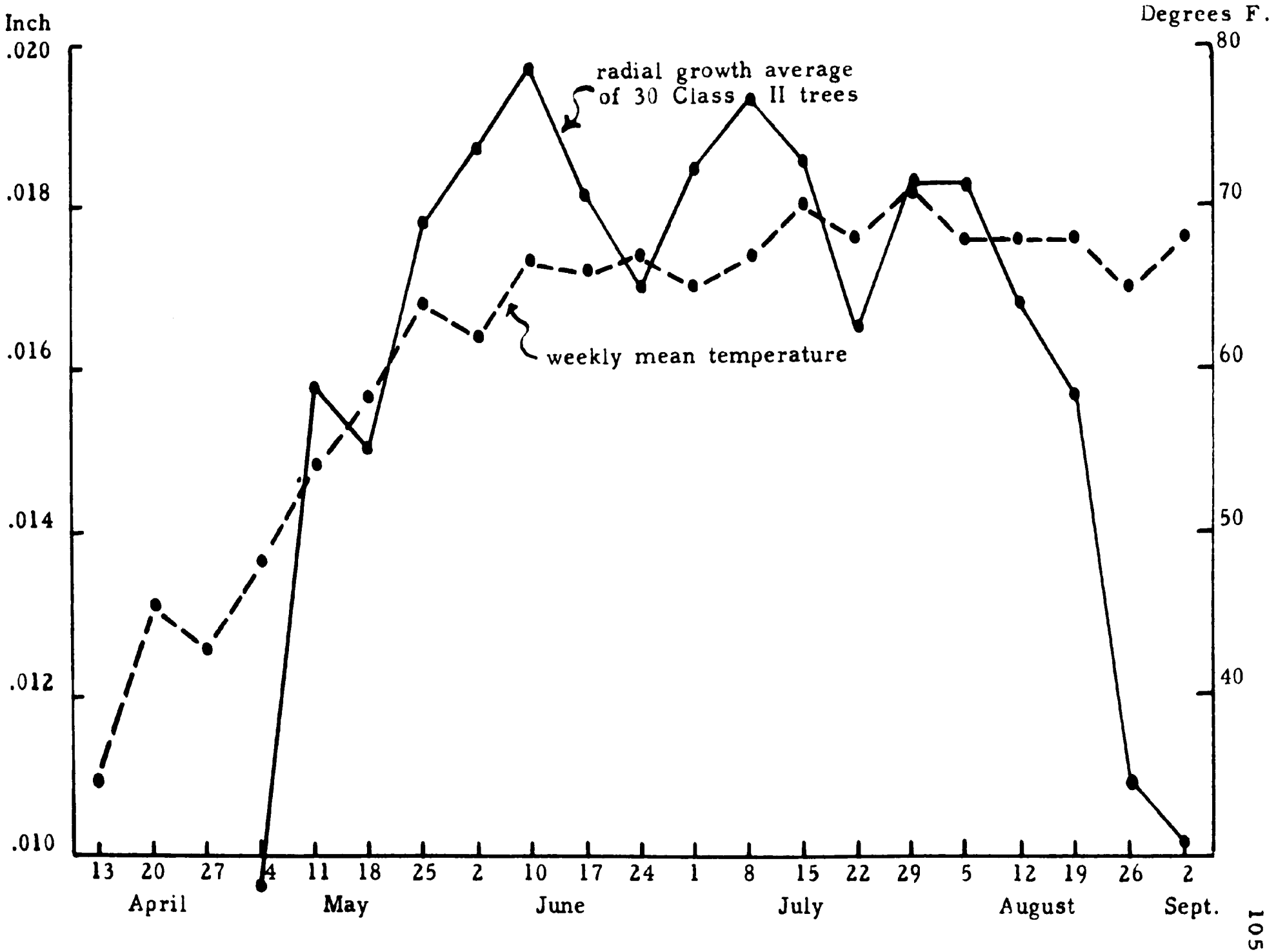


Figure 29. Radial growth - air temperature comparison. 1950.

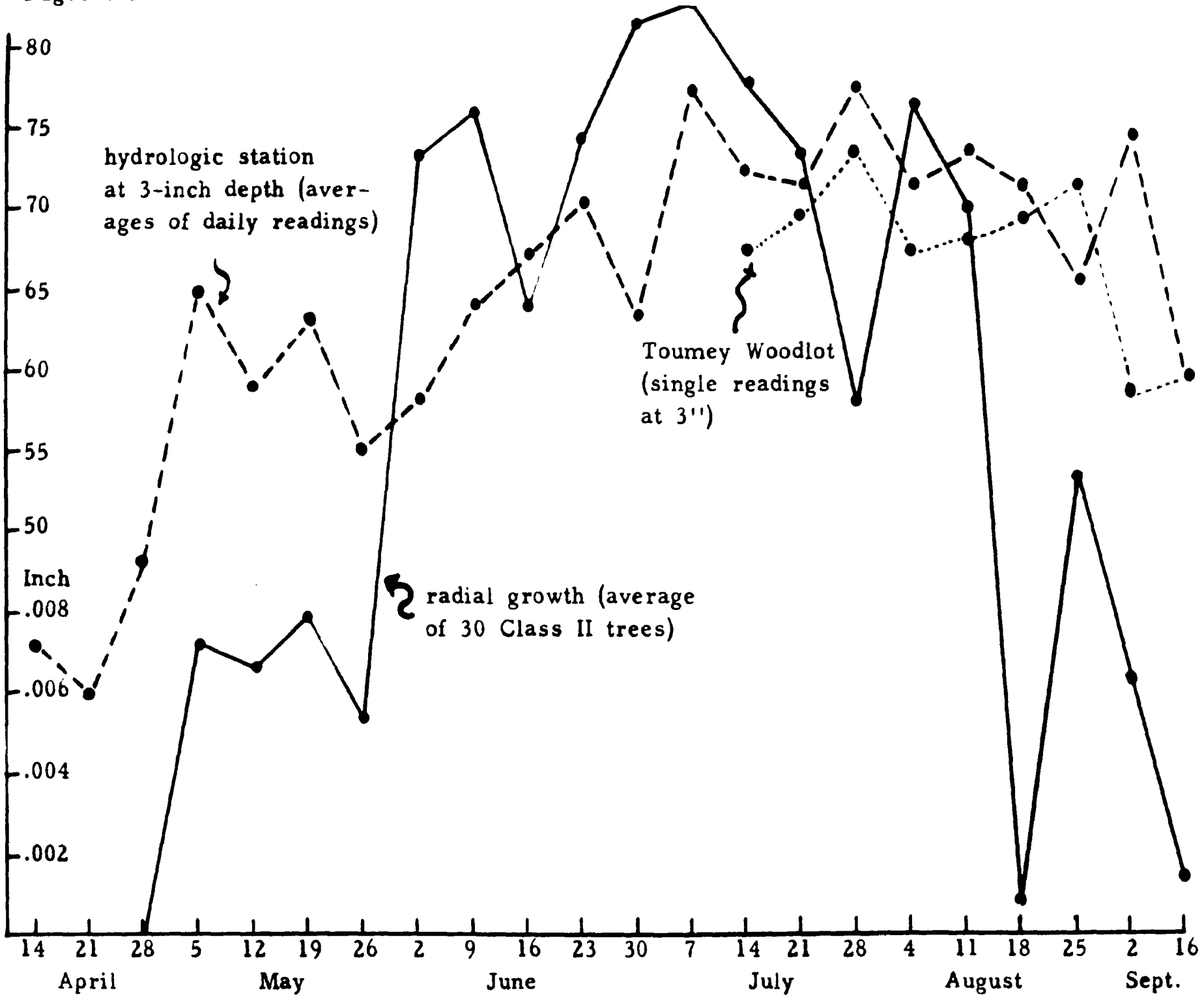


Figure 30. Radial growth - soil temperature comparison. 1949.

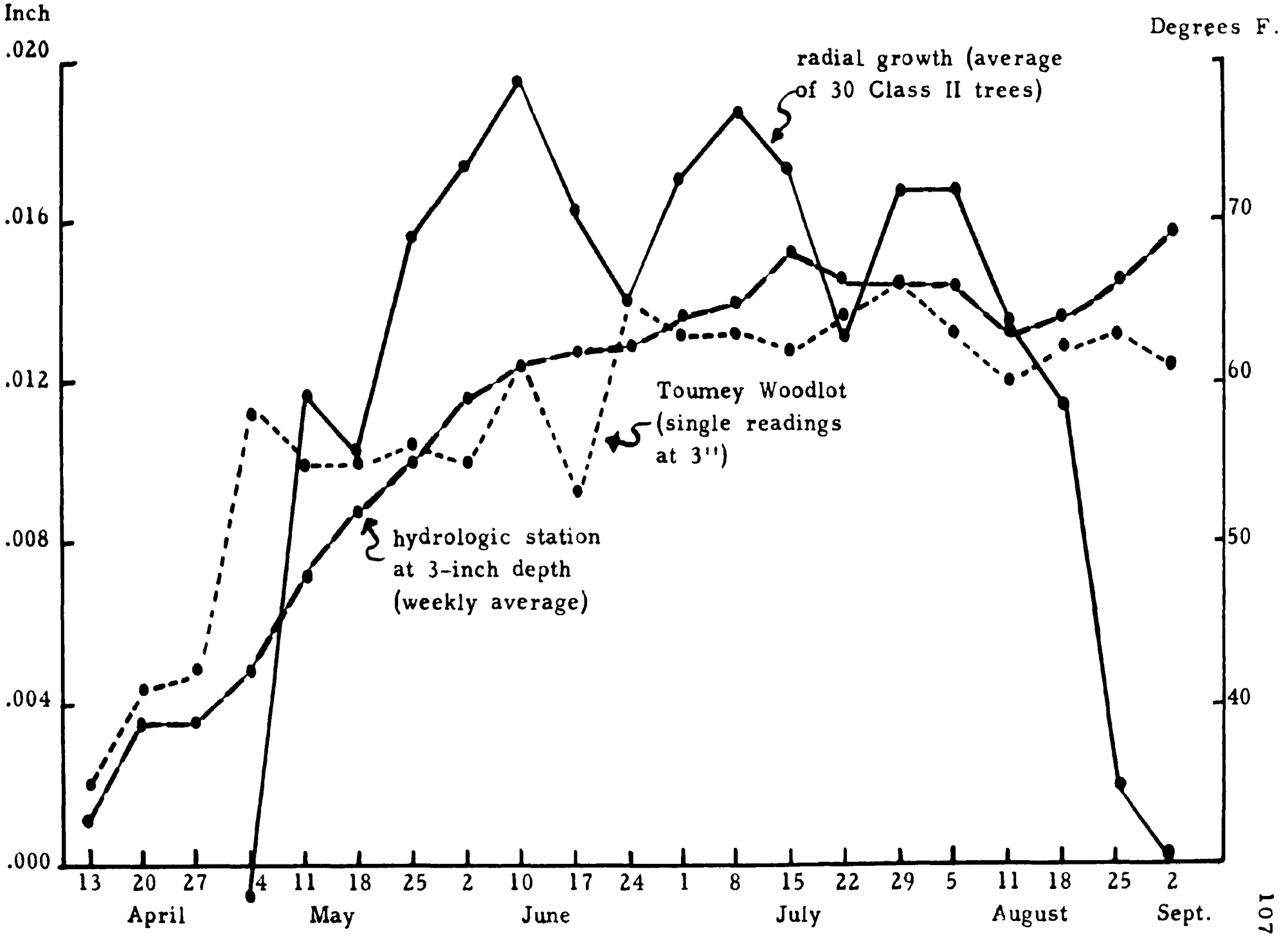


Figure 31. Radial growth - soil temperature comparison. 1950.

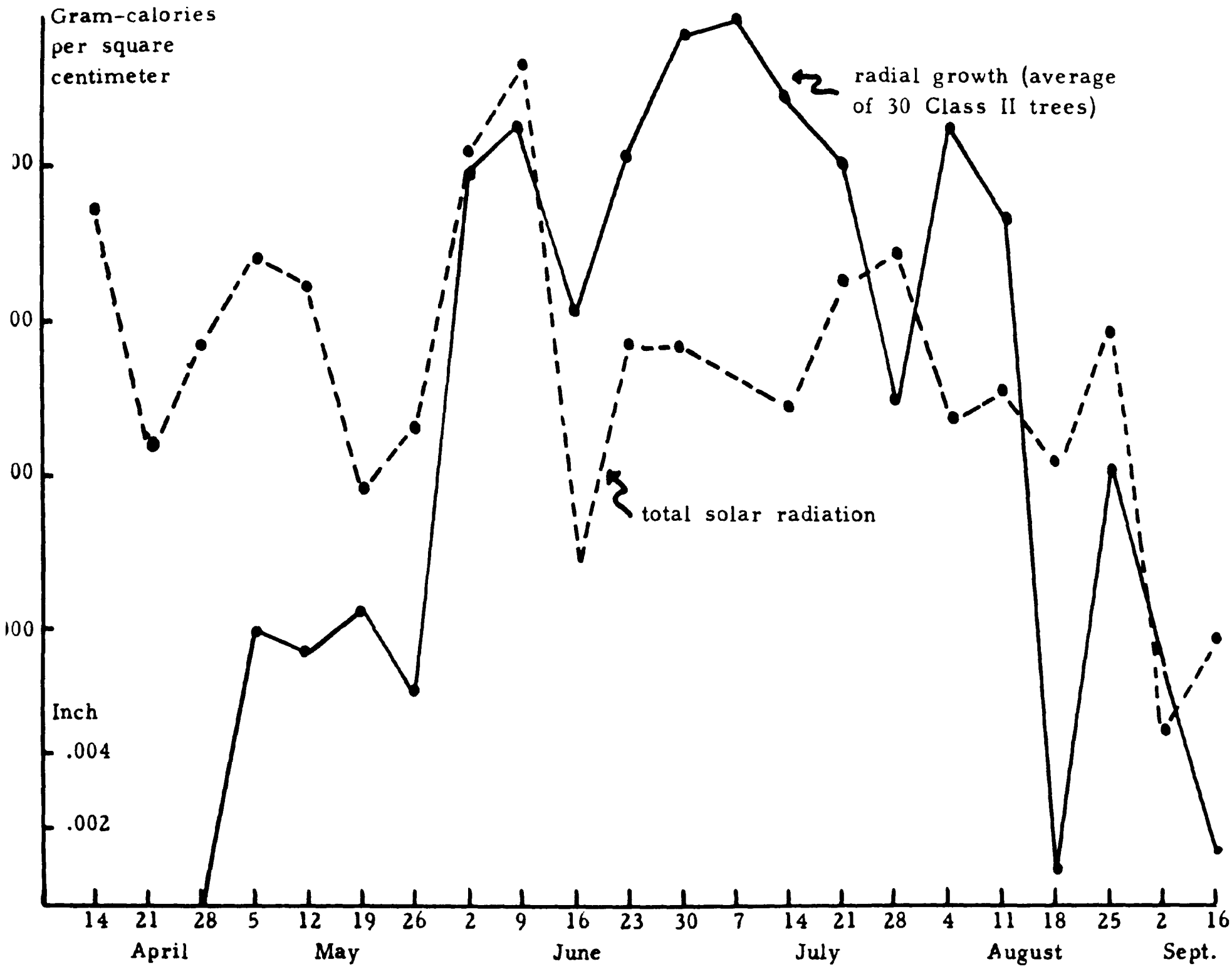
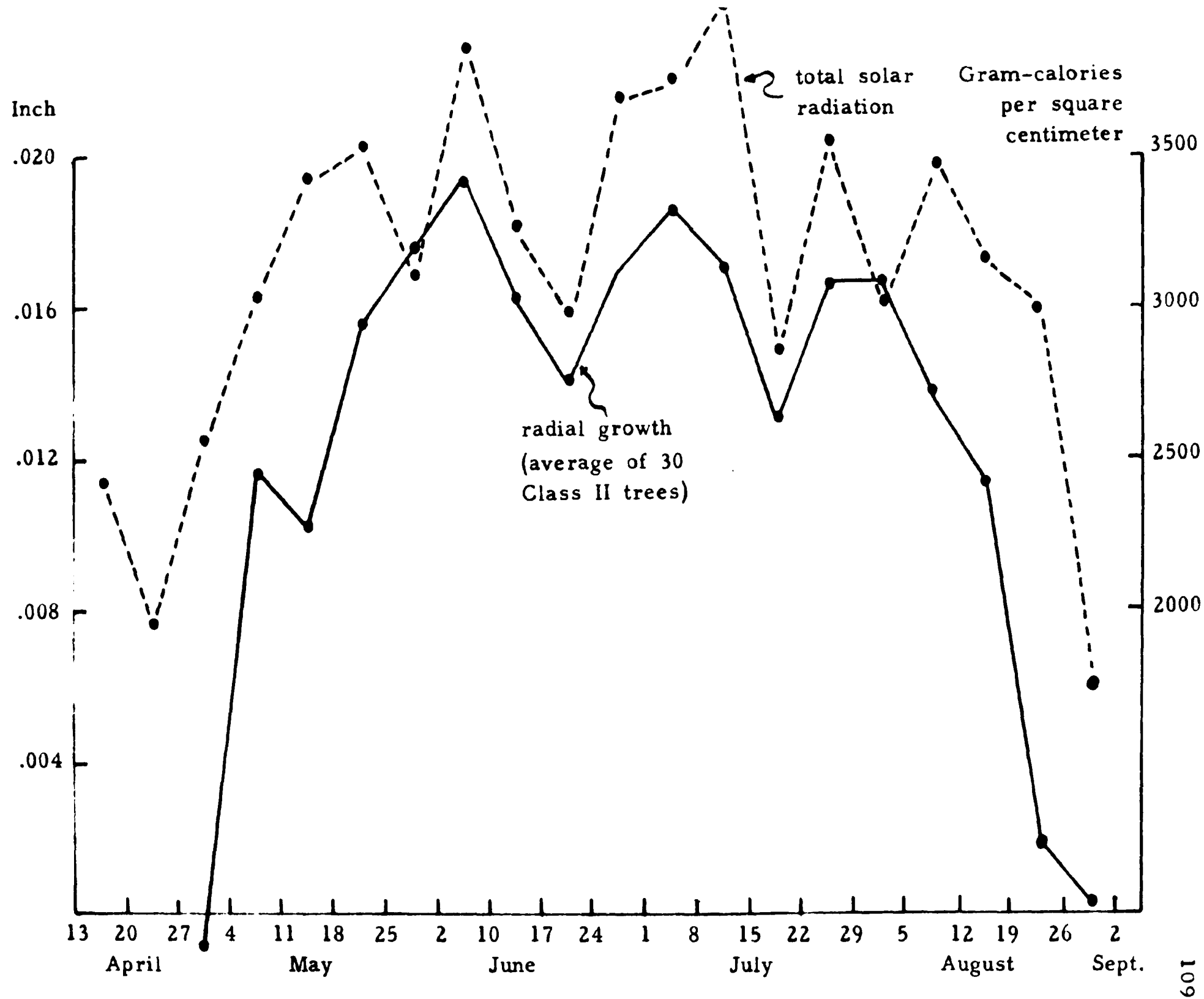
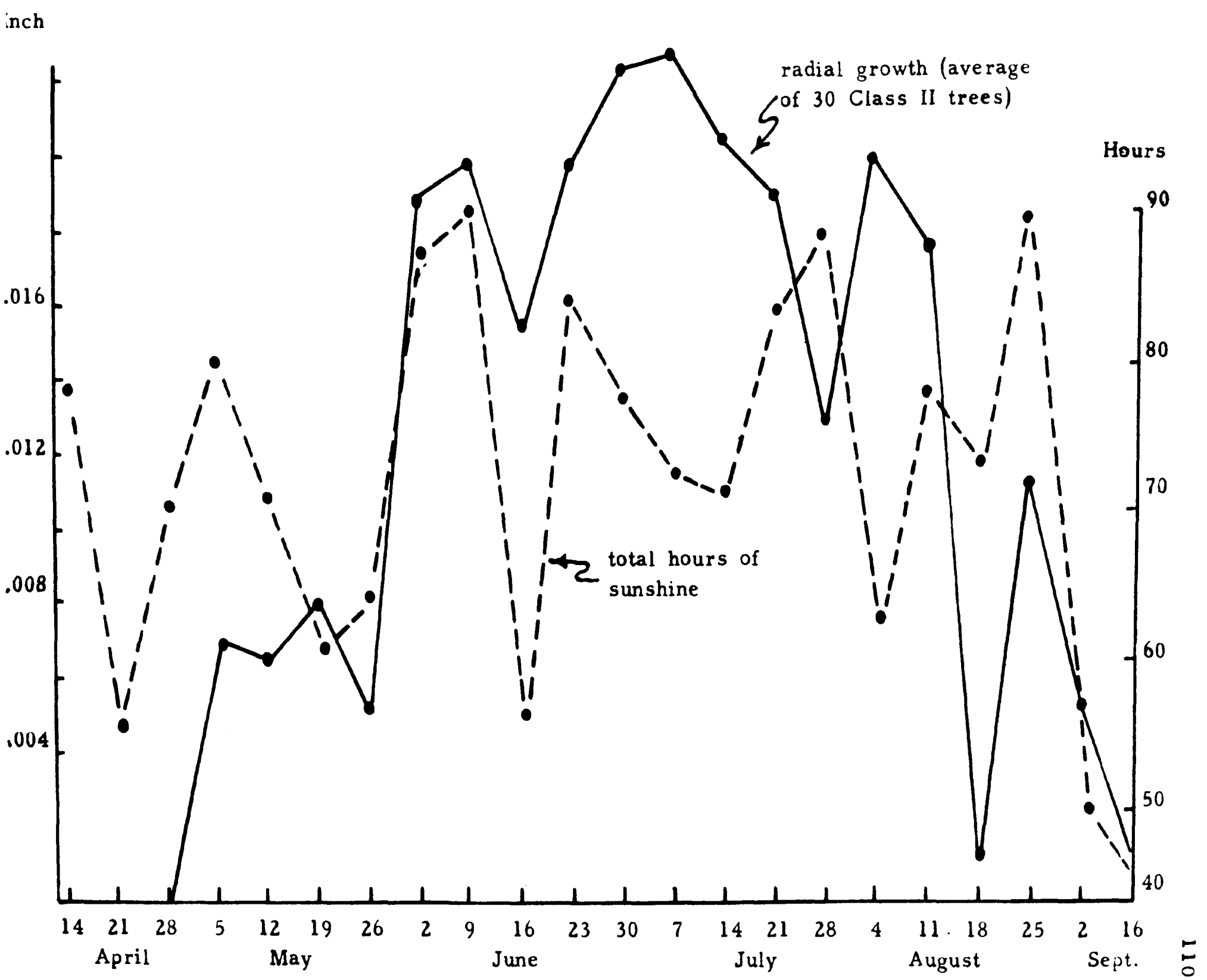


Figure 32. Radial growth - solar radiation comparison. 1949.


Inch
.020
.016
.012
.008
.004
Gram-calories per square centimeter
3500
3000
2500
2000
total solar radiation
radial growth (average of 30 Class II trees)
13 20 27 4 11 18 25 2 10 17 24 1 8 15 22 29 5 12 19 26 2
April
May
June
July
August
Sept.


Inch
radial growth (average of 30 Class II trees)
Hours
.016
.012
.008
.004
90
80
70
60
50
40
total hours of sunshine
14 21 28 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 2 16
April
May
June
July
August
Sept.

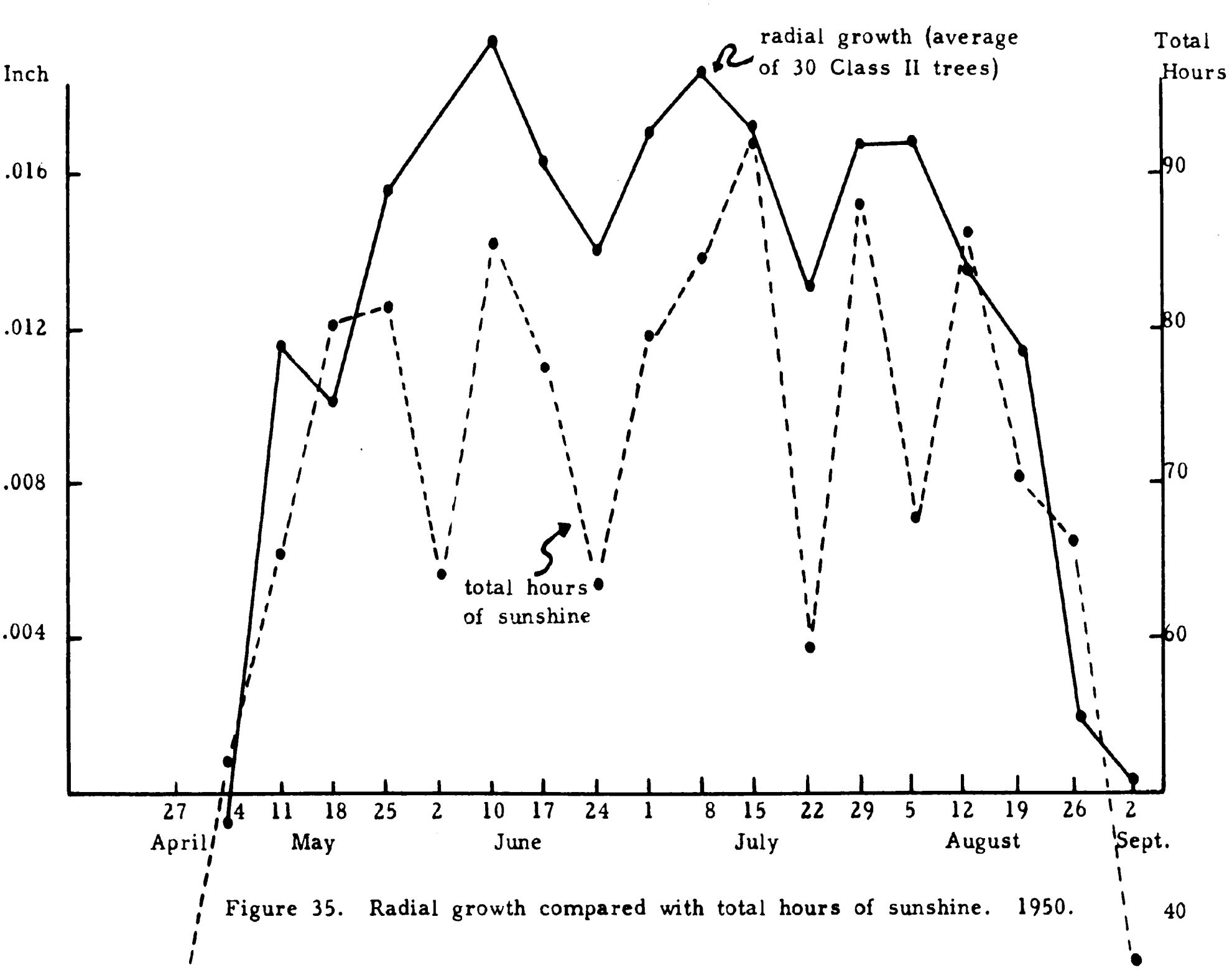


Figure 35. Radial growth compared with total hours of sunshine. 1950.

Period of Increase to First Peak Rate

1949

This season the trend of increase rate was generally upward from the time of growth initiation until the week ending June 9. The exact period under consideration in this section extended from May 12 to June 9.

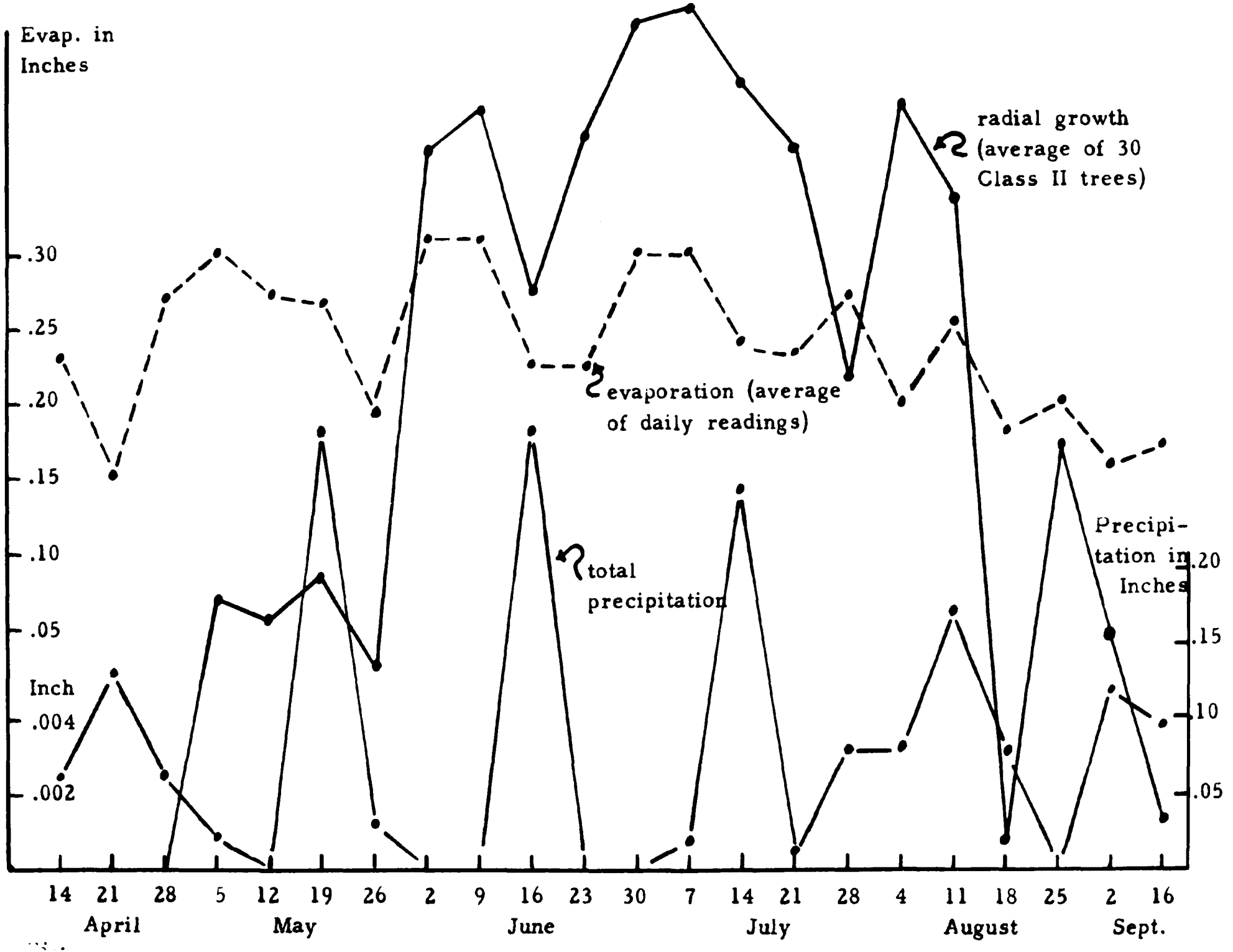
The increases for May 12, May 19, and May 26 marked a definite break or change in direction of growth rate (previously described). It is of importance to note that coincident with this three-week fluctuation which held the rate of increase at a low level, there was also a corresponding change in air and soil temperatures (Figures 28 and 30). The slight increase in growth rate registered the week ending May 19 came at a time when the temperature of the air increased sharply from 55 to 65 degrees Fahrenheit. Soil temperatures at the hydrologic station increased that week from 58 to 62 degrees Fahrenheit.

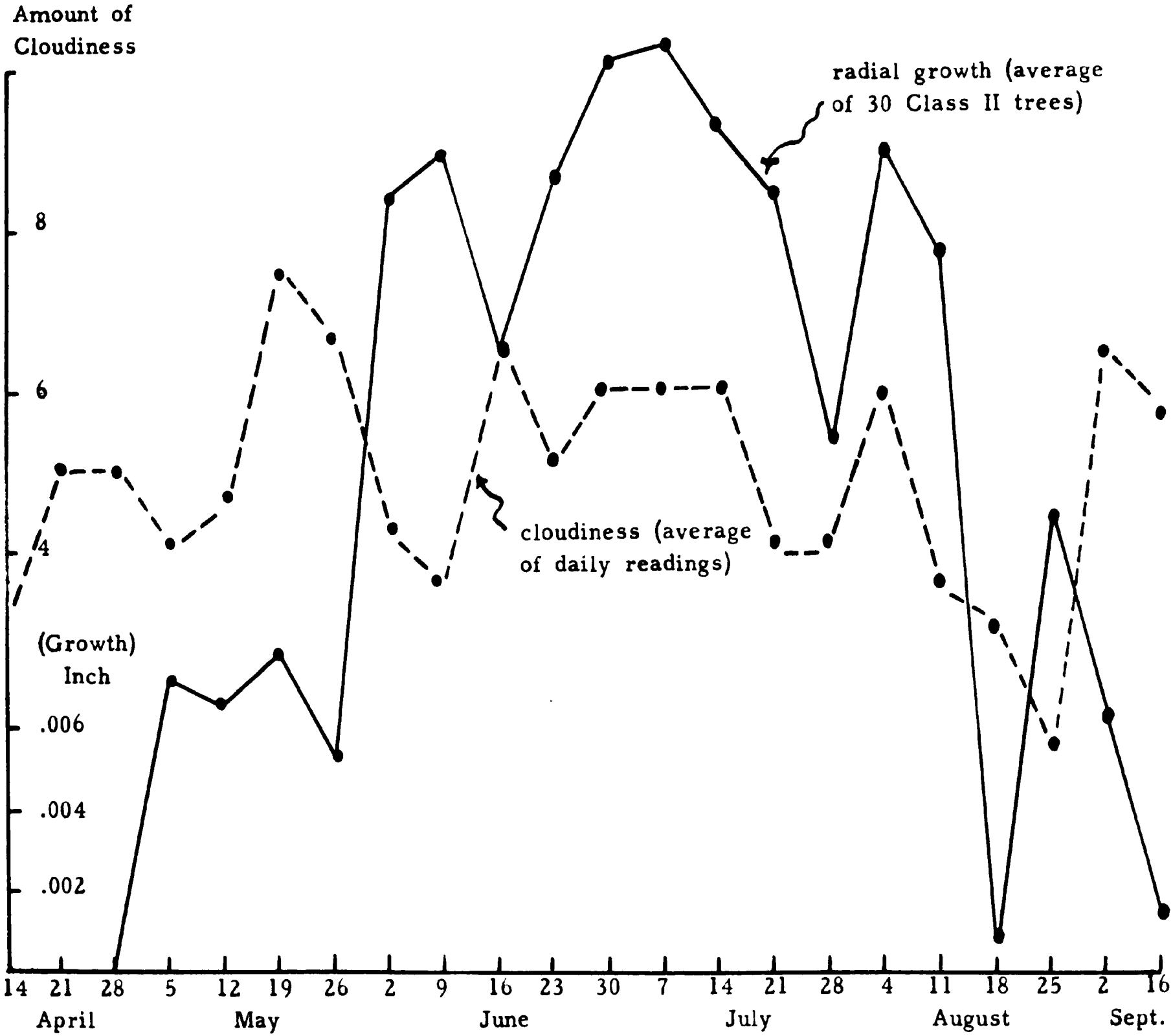
The following week (ending May 26) growth rate decreased rather sharply. Mean weekly air temperature for the same week dropped from 65 to 53 degrees Fahrenheit (Figure

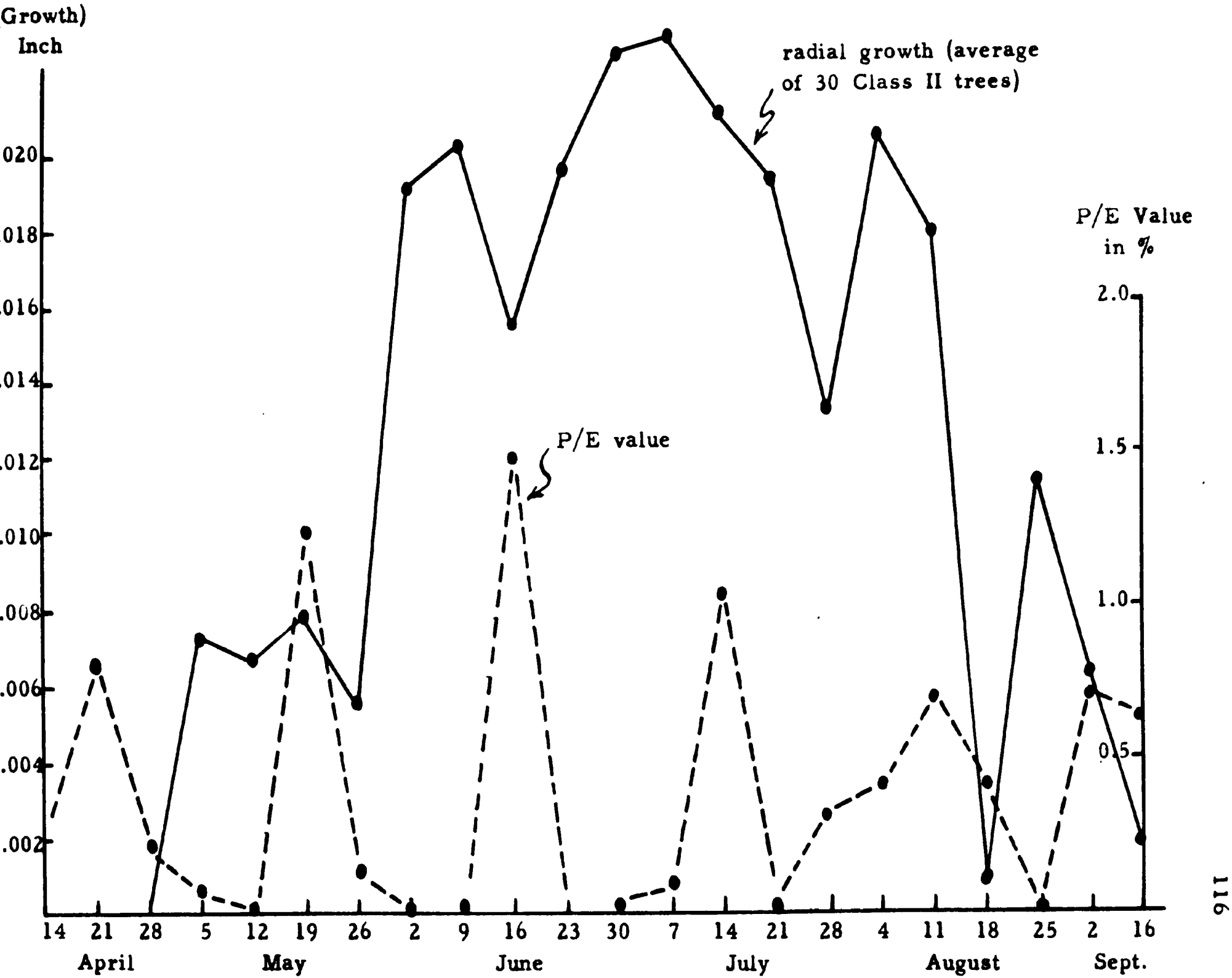
28). Soil temperatures also declined from 62 to 54 degrees Fahrenheit (Figure 30).

During this "plateau period" other factors seem not to show definite correlations. The week ending May 19 was one in which heavy precipitation was recorded (Figure 36), along with a sharp decrease in the number of hours of sunshine (Figure 34), an increase in cloudiness (Figure 37), and a decrease in solar radiation (Figure 32). Under these conditions radial increase rate was greater than either the previous or the succeeding week. Evaporation did decrease the week ending May 26, and was the single factor other than temperature which showed correspondence to the growth fluctuation (Figure 36). Figure 38 shows the P/E value for this same period.

The week ending June 2 showed a very conspicuous increase in rate of radial growth. This was followed by a week (ending June 9) of even greater activity. During these two weeks, the air temperature climbed steadily to 64 degrees Fahrenheit. Both weekly mean averages were above 60 degrees (Figure 28). Soil temperature at the hydrologic station also advanced to 63 degrees Fahrenheit (Figure 30).


Evap. in Inches
.30
.25
.20
.15
.10
.05
Inch
.004
.002
radial growth (average of 30 Class II trees)
evaporation (average of daily readings)
total precipitation
Precipitation in Inches
.20
.15
.10
.05
14 21 28 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 2 16
April
May
June
July
August
Sept.


Amount of Cloudiness
radial growth (average of 30 Class II trees)
8
6
4
cloudiness (average of daily readings)
(Growth) Inch
.006
.004
.002
14 21 28 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 2 16
April
May
June
July
August
Sept.


(Growth)
Inch
.020
.018
.016
.014
.012
.010
.008
.006
.004
.002
radial growth (average
of 30 Class II trees)
P/E value
P/E Value
in %
2.0
1.5
1.0
0.5
14 21 28 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 2 16
April
May
June
July
August
Sept.

Light conditions were also much more favorable at this time, as is seen from Figures 32, 34, and 37. Practically no rainfall was recorded for this period and evaporation increased with the trend of radial increase (Figure 36). Soil moisture at the hydrologic station showed a marked decrease the week ending June 9, the week of a peak growth rate (Figure 29).

1950

The week ending May 11 was the first week of radial increase for 1950. The trend of increase rate from this date was likewise upward and extended until the week ending June 10. This covers a period of five weeks, in comparison with a period of six weeks in 1949.

During this five-week period only one weekly reading was less than the previous week's reading. This was the reading taken the third week of May (ending May 18) (Figures 25, 26, and 27). Appearing the first week after initial increase, it is of doubtful significance.

Air temperatures, which had been increasing steadily, increased again this week from 54 to 58 degrees Fahrenheit (Figure 29). Soil temperature in the woodlot remained constant

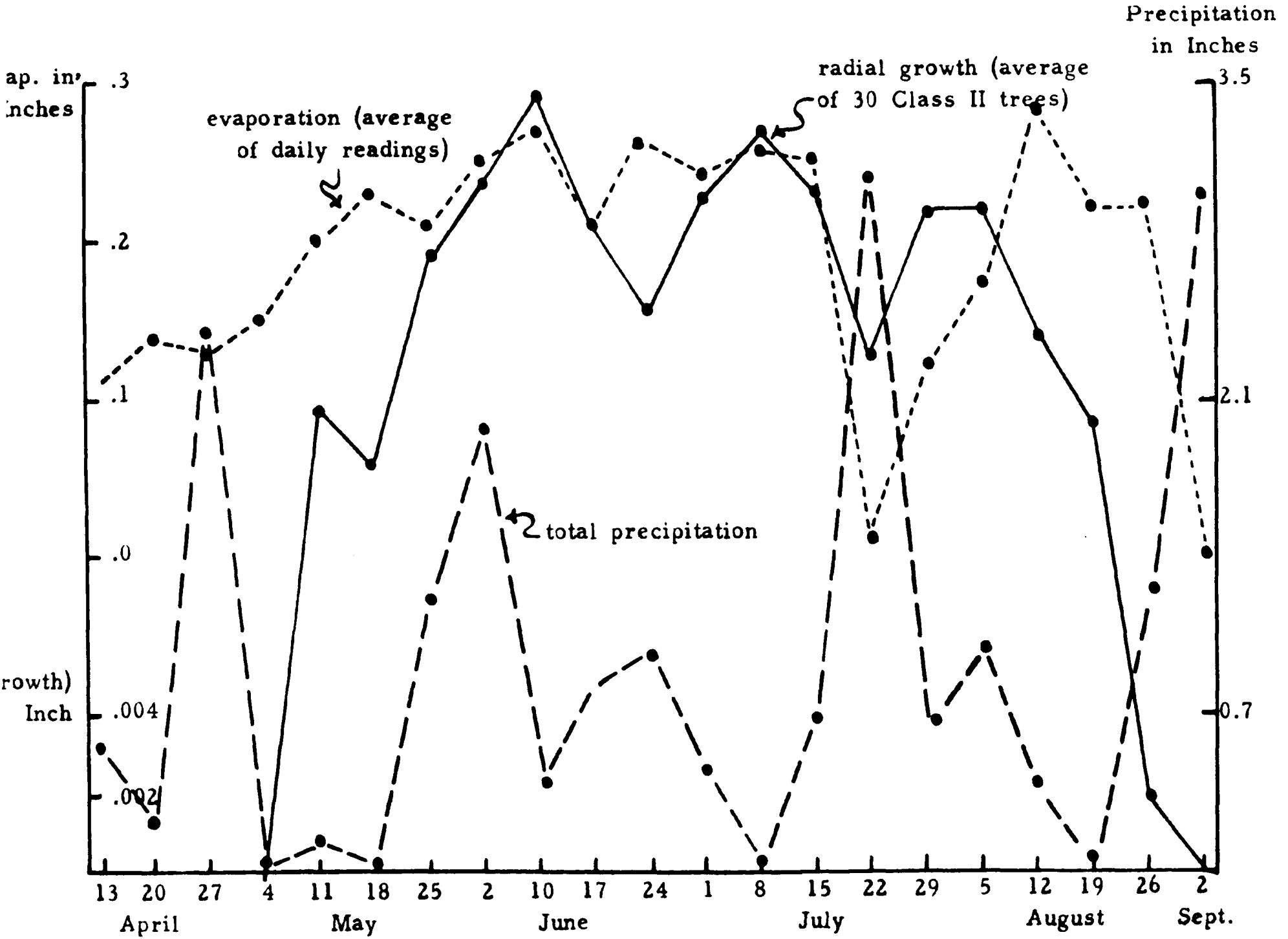
at 55 degrees Fahrenheit (Figure 31). Other factors showed no serious fluctuations of importance. The entire period of increase in growth rate was marked by a general increase in intensity and duration of sunlight (Figures 33 and 35), a steady increase in evaporation (Figure 39) and a moderate amount of precipitation (Figure 39). The precipitation-evaporation ratio is compared with growth in Figure 40. No significant relationship is indicated.

Soil moisture figures were obtained for this period of 1950 in the woodlot, and are thus of greater importance than the figures taken from the hydrologic station. Figure 41 indicates that even though there was a decrease in available moisture at the hydrologic station for the weeks during which the peak rate of growth was noted, the moisture within the woodlot at the 12-inch and 36-inch levels remained fairly constant between 80 and 90 percent available moisture.

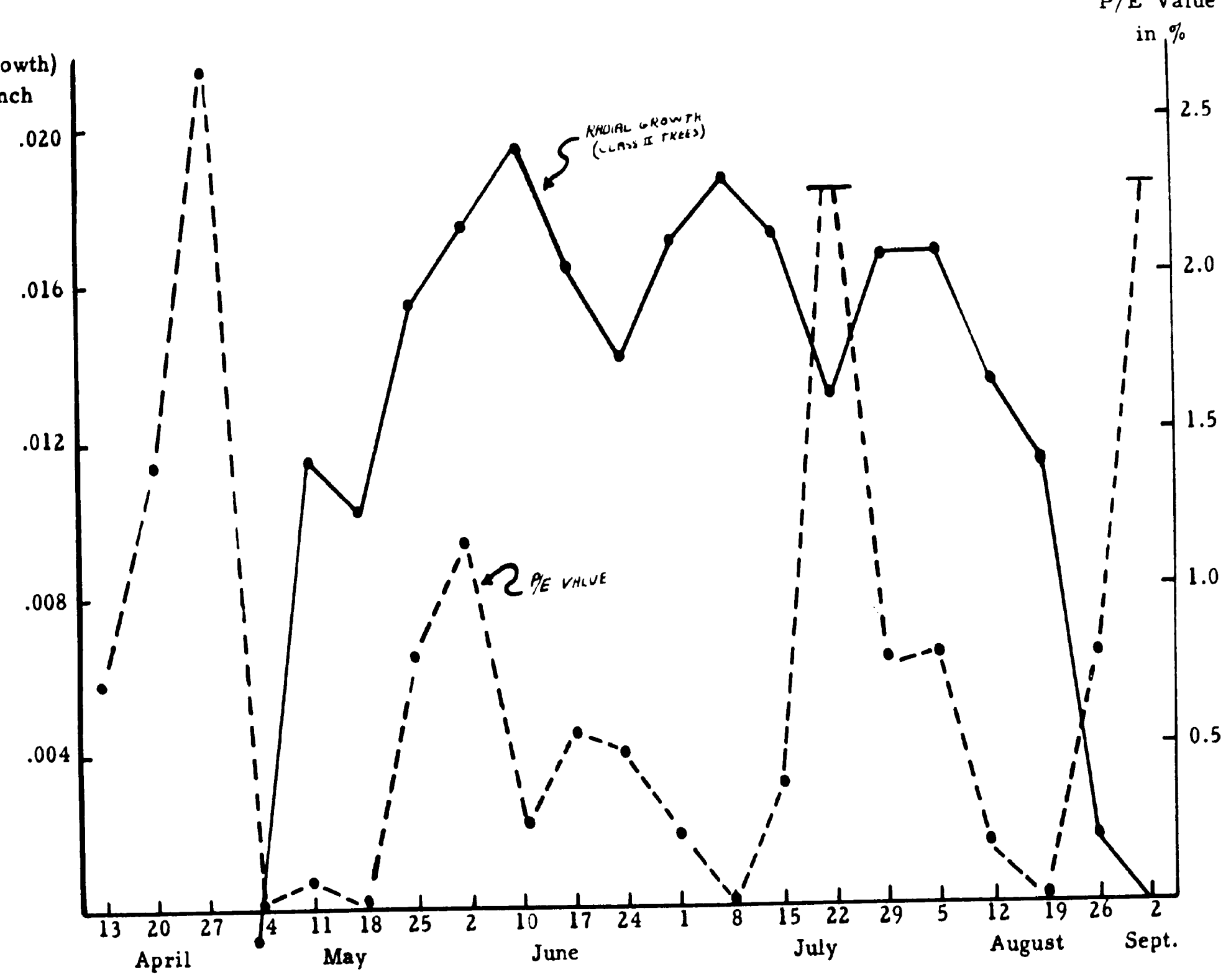
First Major Decline in Growth Rate

1949

This decline is noted the week ending June 16 and is found in all three size classes (Figures 25, 26, and 27). Soil



gure 39. Radial growth - precipitation and evaporation comparison. 1950.


owth)
nch
.020
.016
.012
.008
.004
P/E Value
in %
2.5
2.0
1.5
1.0
0.5
RADIAL GROWTH
(CLASS II TREES)
P/E VALUE
13 20 27 4 11 18 25 2 10 17 24 1 8 15 22 29 5 12 19 26 2
April
May
June
July
August
Sept.

12

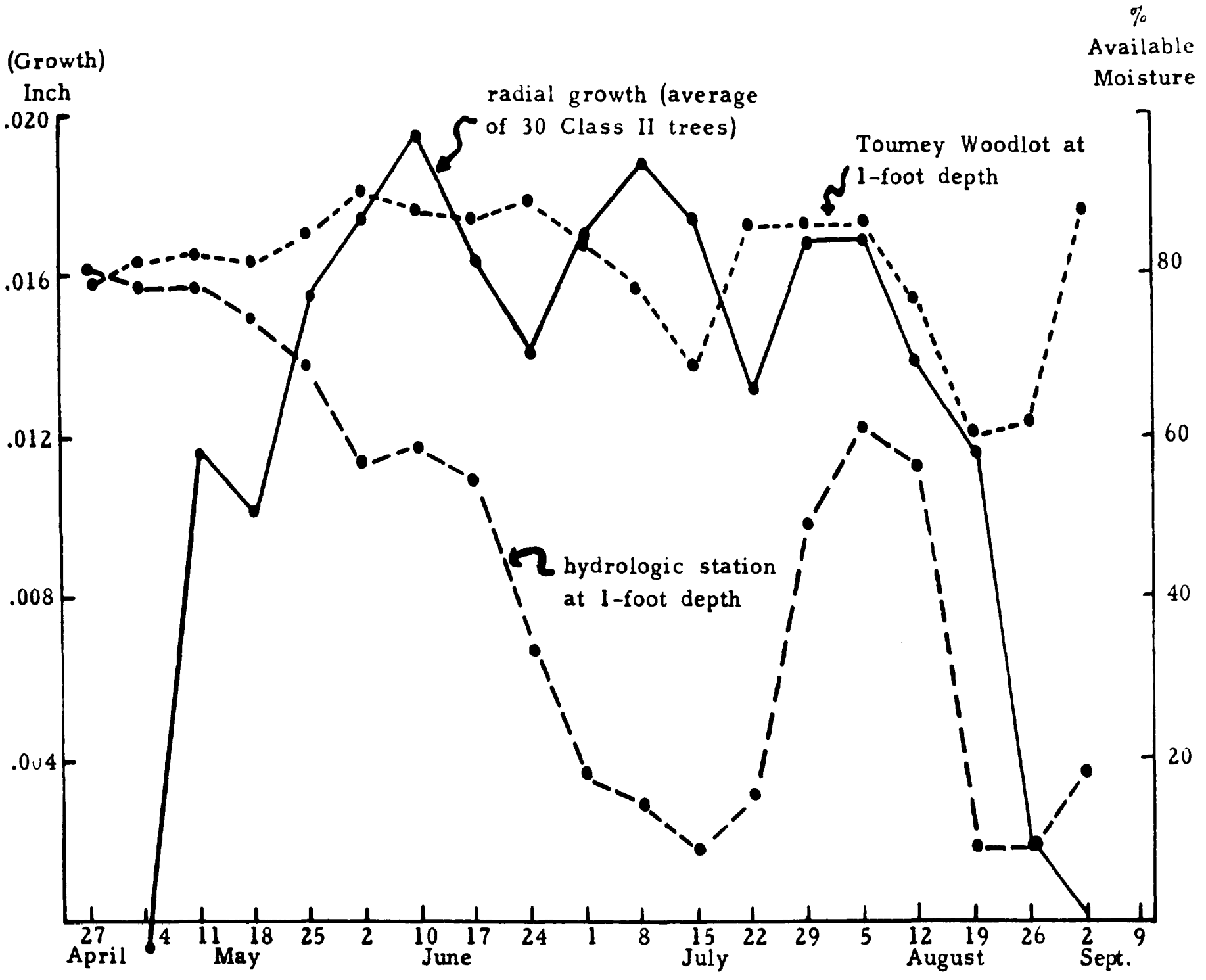


Figure 41. Radial growth - soil moisture comparison. 1950.

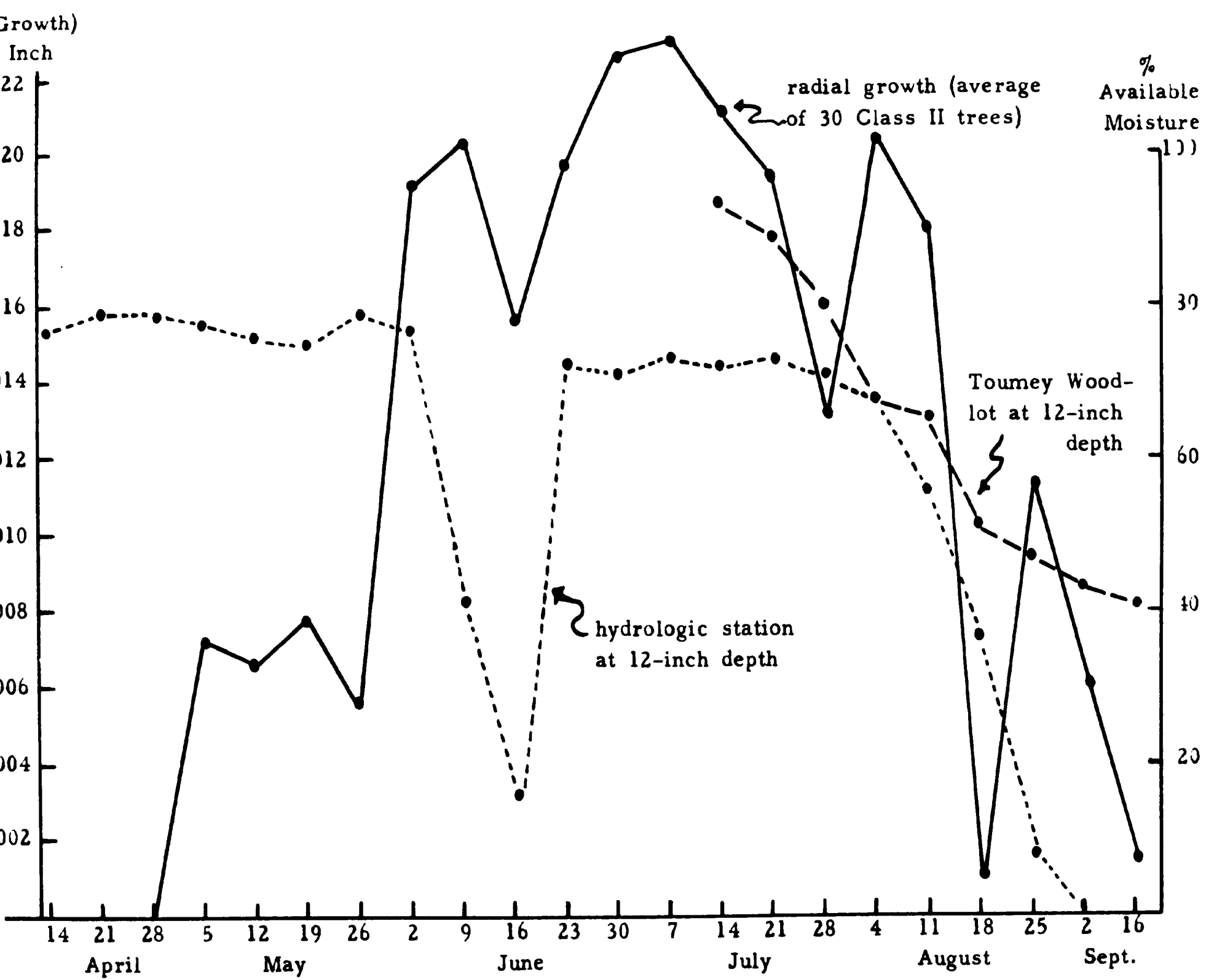
moisture at the hydrologic station fell below 20 percent available moisture at that time (Figure 42), but the comparison of soil moisture in the woodlot for 1950 with that at the hydrologic station (Figure 41) must be kept in mind in any interpretation of this decline in 1949.

This was a week of heavy precipitation (Figure 36) which undoubtedly influenced the light conditions also. Figures 32 and 34 indicate a severe drop in solar radiation and total hours of sunshine. Evaporation also decreased at this time (Figure 36), while air and soil temperatures continued a steady rise (Figures 28 and 30).

1950

The rate of growth showed a two-week period of decline this year, whereas in 1949 it lasted for a single week. Growth rate declined steadily for the weeks ending June 17 and June 23. Both solar radiation (Figure 33) and total hours of sunshine (Figure 35) showed a corresponding two-week steady decline. As would be expected, cloudiness increased (Figure 43).

The first week of decline in growth rate also showed an 8-degree depression of soil temperature in Toumey Woodlot,


Growth)
Inch
22
20
18
16
14
12
10
08
06
04
02
% Available Moisture
100
30
60
40
20
radial growth (average of 30 Class II trees)
Toumey Wood-lot at 12-inch depth
hydrologic station at 12-inch depth
14 21 28 5 12 19 26 2 9 16 23 30 7 14 21 28 4 11 18 25 2 16
April
May
June
July
August
Sept.

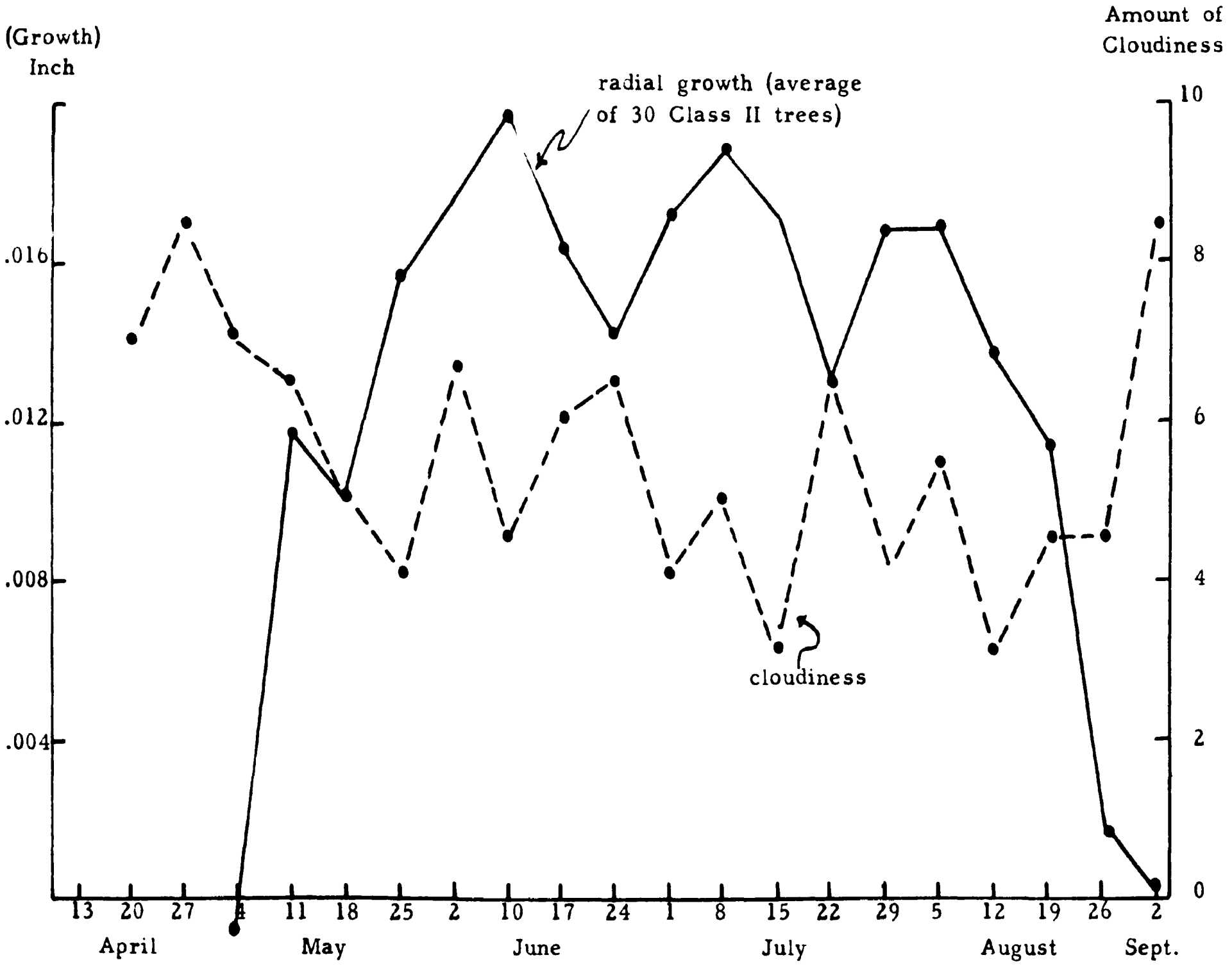


Figure 43. Radial growth - cloudiness comparison, 1950.

followed, however, by a 12-degree-Fahrenheit increase to 65 degrees Fahrenheit (Figure 31). Air temperatures (Figure 29) remained steady and below 70 degrees Fahrenheit for the two-week period. Soil moisture in the woodlot was also relatively unaffected, although the hydrologic station data showed that there was a significant drop in available moisture (Figure 41). Evaporation decreased the week ending June 17 but increased again during the week of growth decline (Figure 39).

Second Period of Increased Cambial Activity

1949

This second period of increased activity extended from the week ending June 23 to the week ending July 21 (Figures 25, 26, and 27). Increase for the week ending July 8 was the largest weekly increase recorded for the season in the case of Size Class II trees. Class I and Class III trees reached the seasonal peak rate one week earlier (June 30). Actually there was very little difference in the magnitude of growth recorded on June 30 and July 7 for Class II trees (Figure 26).

During this entire period air temperature continued to climb steadily until it reached a weekly mean of 80 degrees

Fahrenheit the week of July 1 to July 7 (Figure 28). Evaporation showed an increase up to June 30 and remained the same for the following week (Figure 36). Amount of solar radiation (Figure 32) and hours of sunshine (Figure 34) increased sharply the week ending June 23, and then began a steady decline for three weeks, up to July 14. Cloudiness increased to 6 and remained high for two weeks (Figure 37). Little rainfall was recorded up to the week of peak growth rate (Figure 36).

The two weeks of growth after the week ending July 7 set a gradual rate for evantual decline to zero of the growth rate. Evaporation (Figure 36), air and soil temperatures (Figures 28 and 30), also declined for the week ending July 14, whereas solar radiation (Figure 32) and total hours of sunshine (Figure 34) both had begun a steady decline by July 7.

The week ending July 14 was one of heavy precipitation (Figure 36). Soil temperature in the woodlot for the week reading taken July 14 showed an average temperature of 66 degrees Fahrenheit with an increase by July 22 to 68 degrees Fahrenheit (Figure 30).

Up to July 21, none of the factors considered showed an extreme variation in direction with the exception of air temperature (Figure 28) and soil temperature (Figure 30).

1950

This period of increased growth activity extended but three weeks, from July 1 readings to the week ending July 15. A secondary peak rate was recorded the week ending July 8 for all three size classes. Thus there is a close correspondence with the time of peak rate of increase for 1949, although in 1950 this does not represent the highest weekly recording for the season (Figures 25, 26, and 27).

The light factor seemed to bear a more direct relationship with this period of activity than any of the other factors. Solar radiation (Figure 33) and total hours of sunshine (Figure 35) showed fluctuations in the same direction as the weekly growth pattern. Cloudiness decreased correspondingly (Figure 43). Other factors showed very little fluctuation during this time.

Soil moisture at the hydrologic station began a steep decline from the week ending July 1 through the week ending July 15, but only a slight variation is to be noted in the soil moisture figures taken from stations in the woodlot (Figure 41). Soil moisture at the 12-inch level dropped to 69 percent available

moisture, and at the three-foot level moisture declined to about 80 percent available moisture.

Second Major Decline in Growth Rate

1949

Radial increase for the week ending July 28 was markedly less than for the previous period of growth. This is well marked in all three size classes. For the first time evaporation rate was inverse to the growth rate. Figure 36 shows that there was an increase in evaporation for this week.

Also worthy of note is the rise in mean weekly air temperature to 77 degrees Fahrenheit (Figure 28). Figure 30 shows that soil temperatures also increased noticeably this week. Solar radiation (Figure 32) and total hours of sunshine (Figure 34) increased to relatively high levels. Soil moisture in the woods began a steady decline at this time (Figure 42).

1950

The second sharp decline in growth rate for this season occurred the week ending July 22. Figures 33 and 35 reveal

that solar radiation and total hours of sunlight decreased sharply this same week. Cloudiness increased considerably (Figure 43).

Evaporation dropped to the lowest level for the season at this time, coincident with a heavy precipitation (Figure 39). Other factors were not appreciably different, with the exception of an increase in available moisture at the 12-inch level from 71 to 86 percent (Figure 41).

Third Period of Increased Cambial Activity

1949

For two weeks following the decline recorded for the week ending July 28, radial growth increased again. Both air temperature (Figure 28) and evaporation (Figure 36) dropped appreciably the first of these two weeks. During the second week they both increased about as much as was the decrease of the previous week. A slight decrease in growth rate occurred this second week.

Solar radiation (Figure 32) and total hours of sunshine (Figure 34) decreased considerably for the first of these two weeks. During the week ending August 11 these two factors showed another increase.

1950

Figures 25, 26, and 27 show a two-week period of increase quite similar to the one described for 1949. However, instead of a smaller increase for the second week (which would be the week ending August 12), the rate remained the same as that of August 5.

Solar radiation (Figure 33) and total hours of sunshine (Figure 35) showed the same fluctuation as seen for this corresponding period in 1949. Both of these factors increased the week ending August 5 and decreased the following week (August 12). Cloudiness again showed a reverse fluctuation (Figure 43). It should also be noted that evaporation increased considerably for these two weeks (Figure 39).

Further Decline and Cessation of Growth

1949

Measurements for the third week of August (week ending August 18) (Figures 25, 26, and 27) indicate that radial growth practically stopped that week. This represented a sharp decline over the previous week's increase.

This was the only interruption in a steady decline to zero of the rate of growth. It appeared in all size classes and in practically all of the individual trees.

Mean air temperature for this week (Figure 28) was above 70 degrees Fahrenheit and was even higher the week previous to this. Evaporation (Figure 36) declined considerably this week. Soil moisture, which had been showing a steady decline, decreased further to just slightly above 50 percent available moisture in the woodlot (Figure 42).

The "recovery" from this recess came at a time when evaporation (Figure 36) increased and mean weekly air temperature (Figure 28) decreased to 68 degrees Fahrenheit. Soil moisture in the woodlot (Figure 42) did not decrease appreciably from the previous week.

Cessation of growth varied considerably from tree to tree. Some specimens appeared to have ceased growing a full month sooner than others. No environmental factors showed specific fluctuations to conform with this variation. In general, however, solar radiation (Figure 32) and total hours of sunshine (Figure 34) decreased to a very low level from about the middle of August to the middle of September. Air temperature (Figure

28) and soil temperature (Figure 30) both receded to around the 60-degree-Fahrenheit mark. Soil moisture dropped in some parts of the woodlot to below the wilting coefficient (Figure 42), yet in other parts, the lowest percentage reached was not below 90 percent available moisture (Table VI).

1950

There was a steady uninterrupted decline of growth rate from August 5 until no further appreciable increase was registered (September 16).

Solar radiation (Figure 33) and total hours of sunshine (Figure 35) declined to a very low level over this period. Evaporation also decreased up to the week ending September 2 (Figure 39). From August 5 to August 19, soil moisture in the woodlot at the 12-inch level dropped from 86 to 60 percent available moisture (September 2) (Figure 41).

Again this season the time of cessation varied with the tree and showed no specific tendencies.

Seasonal Aspects

A Comparison of the Two Seasons of Growth

Figures 44 and 45 show the "grand period" nature of the growth curve for sugar maple previously mentioned by Friesner (1942). It is to be noted that the total radial increase of both seasons was less for Size Class III trees and greatest for Size Class II trees. To interpret this it will be necessary to keep in mind the volume relationships, age relationships, vigor and relative position in the crown cover of the trees in these three classes.

One of the important features of the two years of growth is that during the portion of the season when growth was at its greatest rate, the curve for 1950 was conspicuously lower than that for 1949. An examination of totals for the season (Table III) reveals that growth was less for 1950. In terms of linear increase only, the growing season, 1949, produced about 3 inches (2.928 inches) more wood, collectively, from 90 trees, than in 1950, or an average of about 0.033 inch per tree. Such an increase would require from one to two weeks of

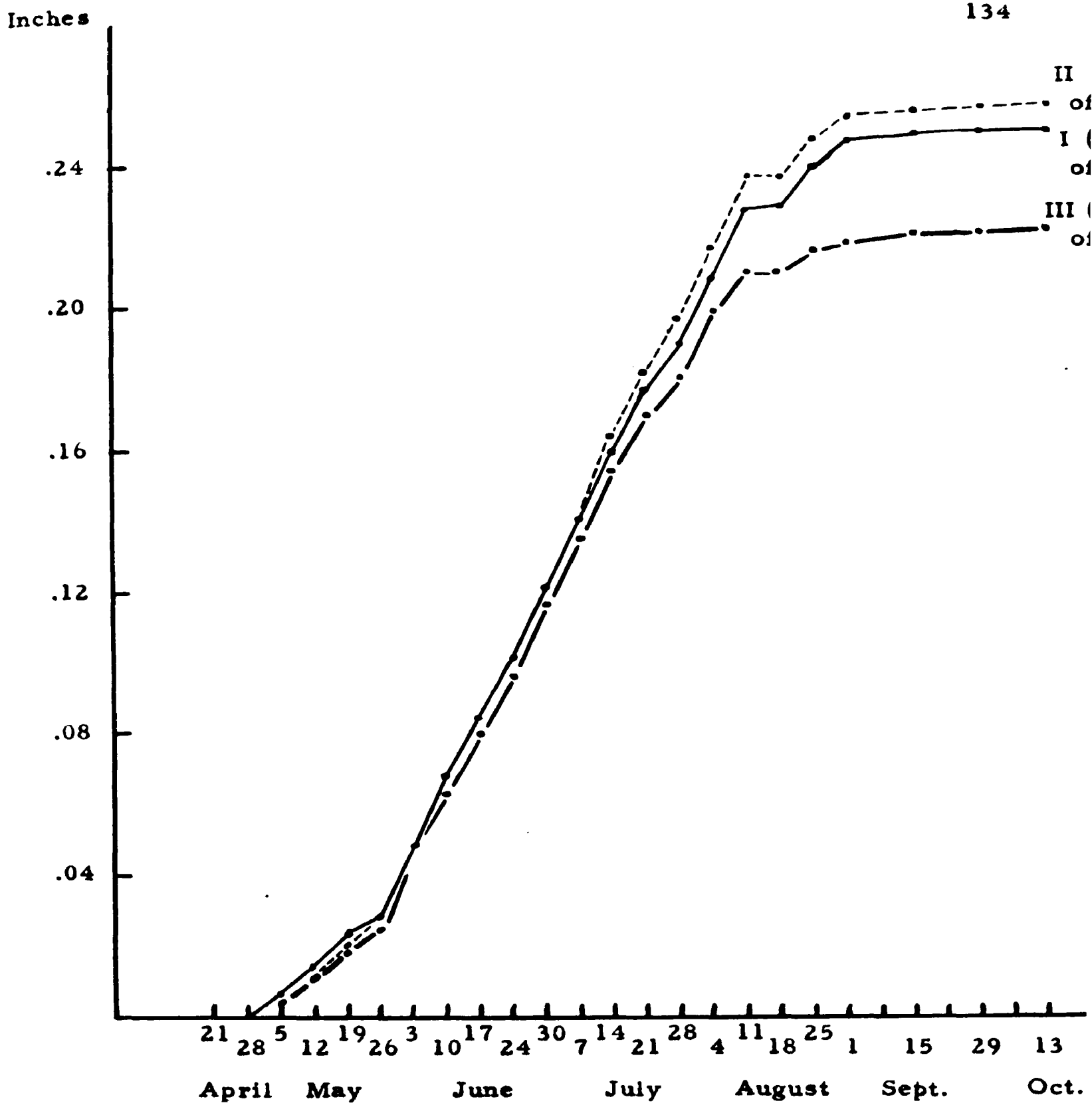


Figure 44. Cumulative radial increase. 1949.

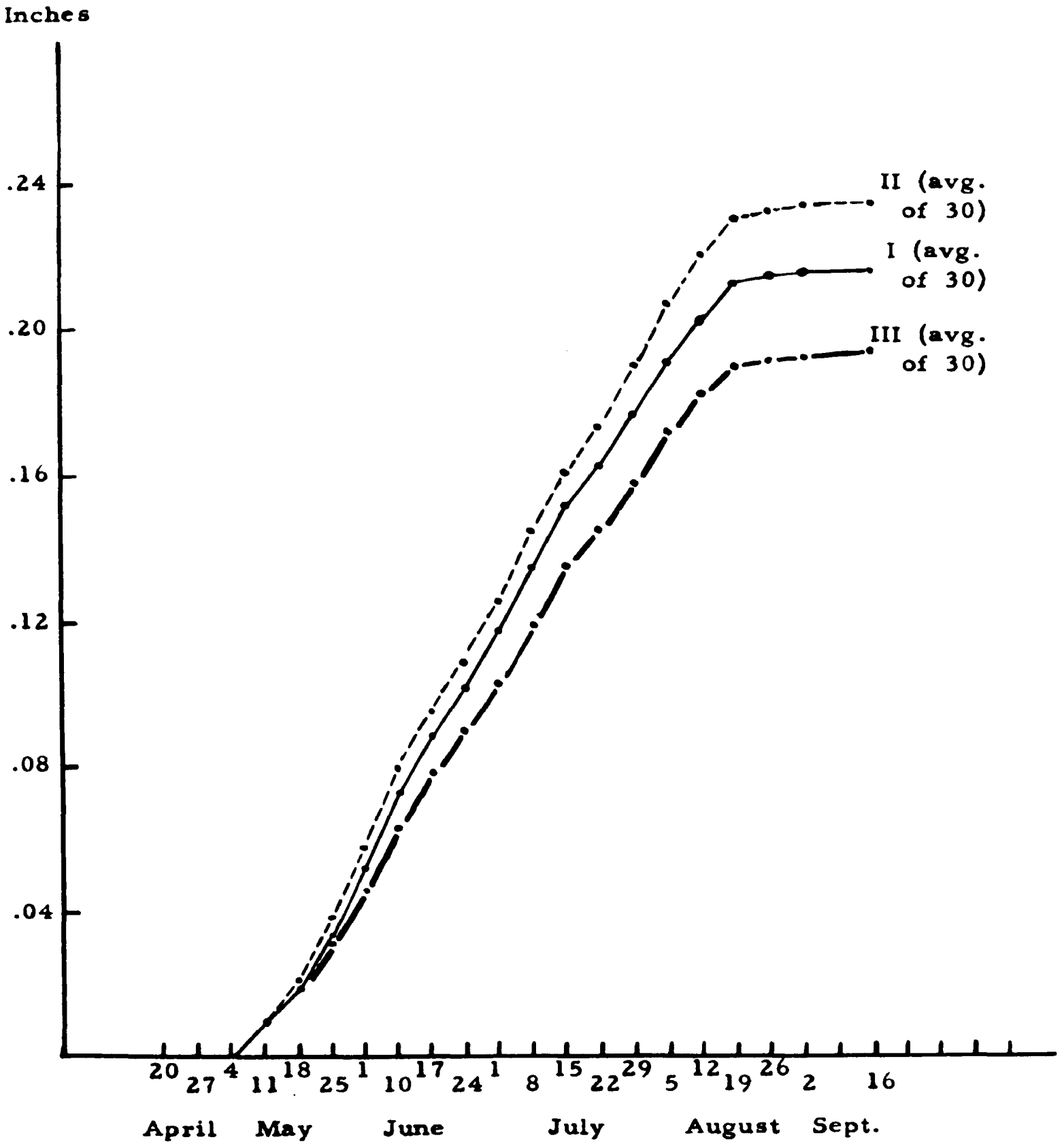


Figure 45. Cumulative radial increase. 1950.

TABLE III. Comparison of environmental and growth data for 1949 and 1950.

Factor	May 5 to Sept. 15, 1949	May 4 to Sept. 15, 1950
Rainfall (inches)	12.03	19.10
Evaporation (inches) (open pan)	33.87	28.27
Solar Radiation (Langley units)	54,985.5	62,751.8
Sunshine (hours and minutes)	1,471:53	1,409:06
Cloudy, 8-10 (days)	42	41
Clear, 0-3 (days)	48	44
Air Temperature (degrees F.) (Max.-sum)	10,493	10,187
Air Temperature (degrees F.) (Min.-sum)	7,561	7,216

Growth of	Total Linear Increase	Total Linear Increase
Size Class I (30 trees) (inches)	7.417	6.412
Size Class II (30 trees) (inches)	7.755	6.893
Size Class III (30 trees) (inches)	6.632	5.571

cambial activity functioning during the height of the growing season.

Another striking feature of these two seasons of growth is that the pattern is quite similar. Both seasons have, during the period of greatest activity, two periods of marked recession in the growth rate (Figures 25, 26 and 27). The trend during the beginning weeks and for the last few weeks was, respectively, toward increased and decreased activity. There were minor fluctuations tending to halt or accelerate these trends. These features were, again, apparent in all three size classes.

Comparison of Environmental Data Totals for 1949 and 1950 with Growth Totals

Table III shows in a comparative manner various of the environmental data for 1949 and 1950. It is significant to note first that there is a great deal of difference between rainfall for the two years. Much more rain fell from May 4 to September 15, 1950, than for a comparable period in 1949. Less growth was recorded, however, in 1950.

Hours of sunshine were less for 1950. If the "deficient" amount were equally distributed throughout the season, it would mean a difference of almost 30 minutes every day.

Solar radiation showed a reverse relationship, that is, during 1949 less radiation was recorded for this period than in 1950.

Maximum and minimum temperatures likewise showed a smaller summation for 1950 than for 1949. If equal portions of this difference were allotted to each day of the growing season, it would mean a difference of nearly 2.5 degrees Fahrenheit for both maximum and minimum temperatures.

With these data it must be added that in 1950 there was a very heavy seed production apparent throughout the woodlot. In 1949 very little flowering was noted; in fact, the author attempted to secure flower specimens in the spring of 1949 and was able to find only 3 trees in flower. In 1950, on the contrary, collections could be made almost at will from any place in the woodlot.

Other Growth Investigations of Sugar Maple Compared with Present Study

Figure 46 compares growth rates of sugar maple obtained in other investigations with the growth rate obtained in the present study. The other two investigations were carried out in Indiana in 1941 and 1947. Growth data presented by

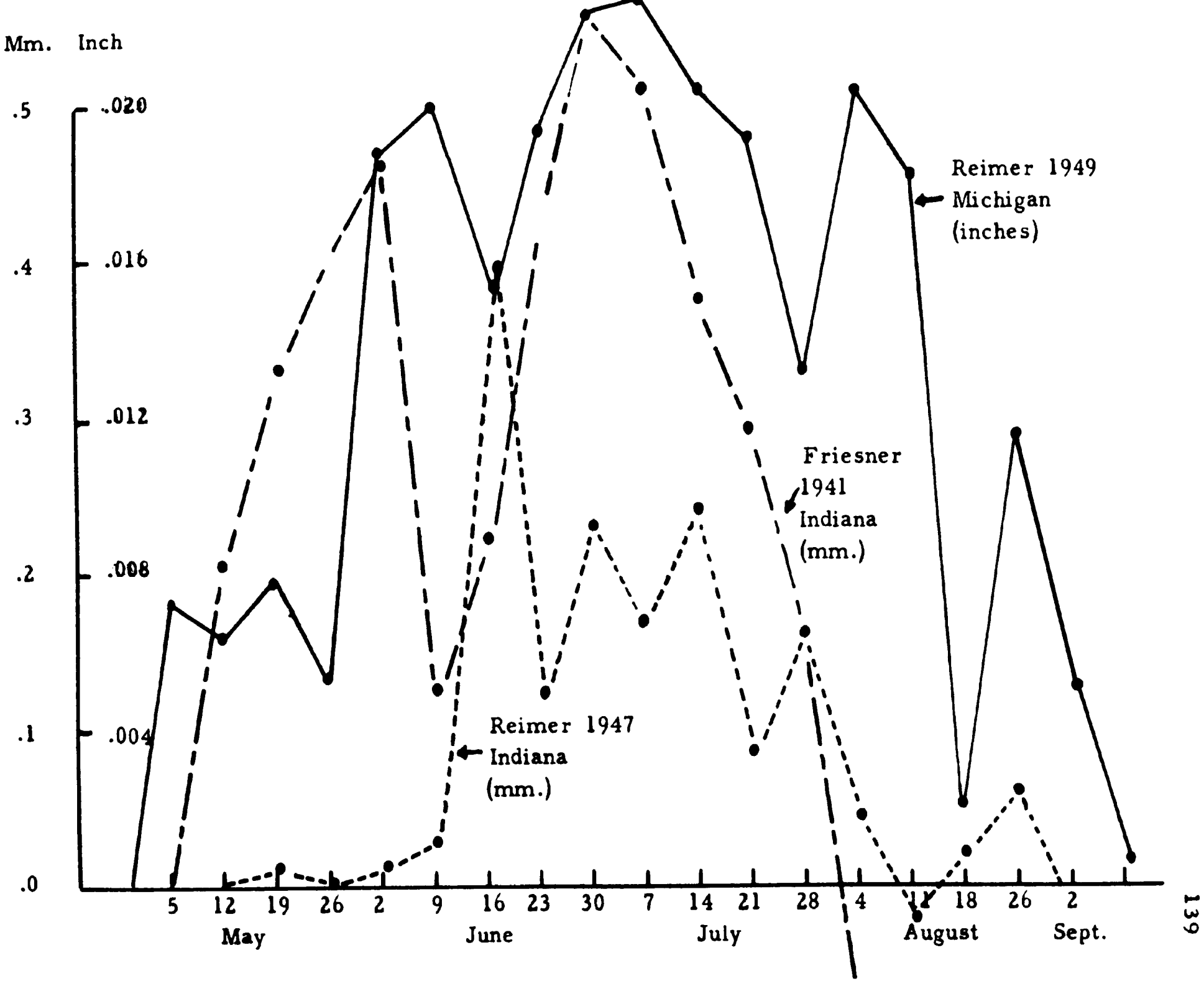


Figure 46. Radial growth of the present study compared with radial growth of the

Friesner (1942) show two sharp recessions dividing the increase rate into two periods. These periods correspond well with the curve obtained in this investigation. The course of increase measured by Reimer (1949) shows an extremely late time of growth initiation and acceleration. In spite of this there is some similarity with the pattern obtained by Friesner. It must be added here that in the studies by Friesner (1942) and Reimer (1949), only one specimen was used. However, the recessions were of such a magnitude as to warrant some comparison with the present study.

Growth ceased in 1941 in the two trees measured by Friesner around the first of August. In 1947 there was a slight period of "postseasonal" activity, if it may be called such, which appeared about the same time as the last period of growth increase for 1949 in Toumey Woodlot.

The publication of MacDougal (1938) cited results of investigations by Dr. A. B. Stout on a sugar maple tree growing in the New York Botanical Garden in 1920:

> Diametral increase became positive and rapid at cambium temperatures of 15–20° C., about June 4th. Enlargement was at an end by July 1.

In the same publication results of microscopic examinations by Lodewick on sugar maple are given:

> The activity of the cambium on the outer face begins at the same time as on the inner face, and took place by May 9. . . . Growth appeared to be at its highest rate about July 1st, and to come to an end about August 1 when the fruits were turning brown, although slight activity could be found in parts of the cambium during the month.

Both of these observations conform in general to the data plotted in Figure 46.

It is also clear from this figure that radial increase in Toumey Woodlot extended over a considerably longer period than reported for the trees studied in Indiana and New York. For 1949, the growing period extended over a period of approximately 18 weeks in the woodlot studied. In 1950, 17 weeks of active growth was recorded. Some trees still registered small increases after 22 weeks, but hydration of previously formed cells might be the factor involved instead of any generative activity on the part of the cambium (Daubenmire, 1947).

Reimer (1949) and Friesner (1942) both reported a growing period of 12 weeks for sugar maple. Daubenmire (1947) presented cumulative growth curves for sugar maple which indicate that the "grand period" extended from sometime in the early part of May to the early part of August. A very gradual

increase is noted in his growth curve for sugar maple extending up through December. This, he said, was to be interpreted partially as a rehydration of shrunken tissues and partially to a belated hydration of cells produced in the summer. If this period is excluded, the season of growth recorded by him would not extend over a period greater than 13 or 14 weeks at the most. Likewise, Lodewick's observations (MacDougal, 1938) would cover a period of about 14 or 15 weeks if the "slight activity" in August were included.

Comparative Results of Tree Growth in Various Parts of the Woodlot

Trees from various parts of the woodlot were selected for comparative examination of growth patterns. The increases were computed using the amount of increase for each individual group during the first week of enlargement as a zero point. For that reason, both curves began on the same point regardless of whether one group showed more or less initial growth than the other. In this manner each group is being compared with its own set "pace," thereby minimizing the error due to differences in diameter of the trees. The only points of

importance are those points where the curves separate, come together, or cross.

Figures 47 and 48 compare growth of groups D and F. Group D is located inside the woods. Group F is located in the west part of the woods between the undisturbed section and the furthermost selected trees in the disturbed section. It is noted that for both seasons one period of growth showed serious differences in fluctuation. This occurred about the first of July in both cases. At that time group D (inside the woodlot) showed an extreme positive fluctuation in growth rate. Group F trees, on the contrary, showed a decrease in growth-rate fluctuation.

Soil-moisture data which were available for that period of 1950 (Table X) showed a decrease of over 40 percent between July 1 and July 15 around group F trees (Station 2). Moisture availability decreased from 100 percent to about 95 percent in the vicinity of group D trees (Table VIII). Soil temperature showed no significant trends for this period (Figure 31).

Other growth fluctuations were noted in this group comparison but were not of an extreme nature. Figures 49 and 50

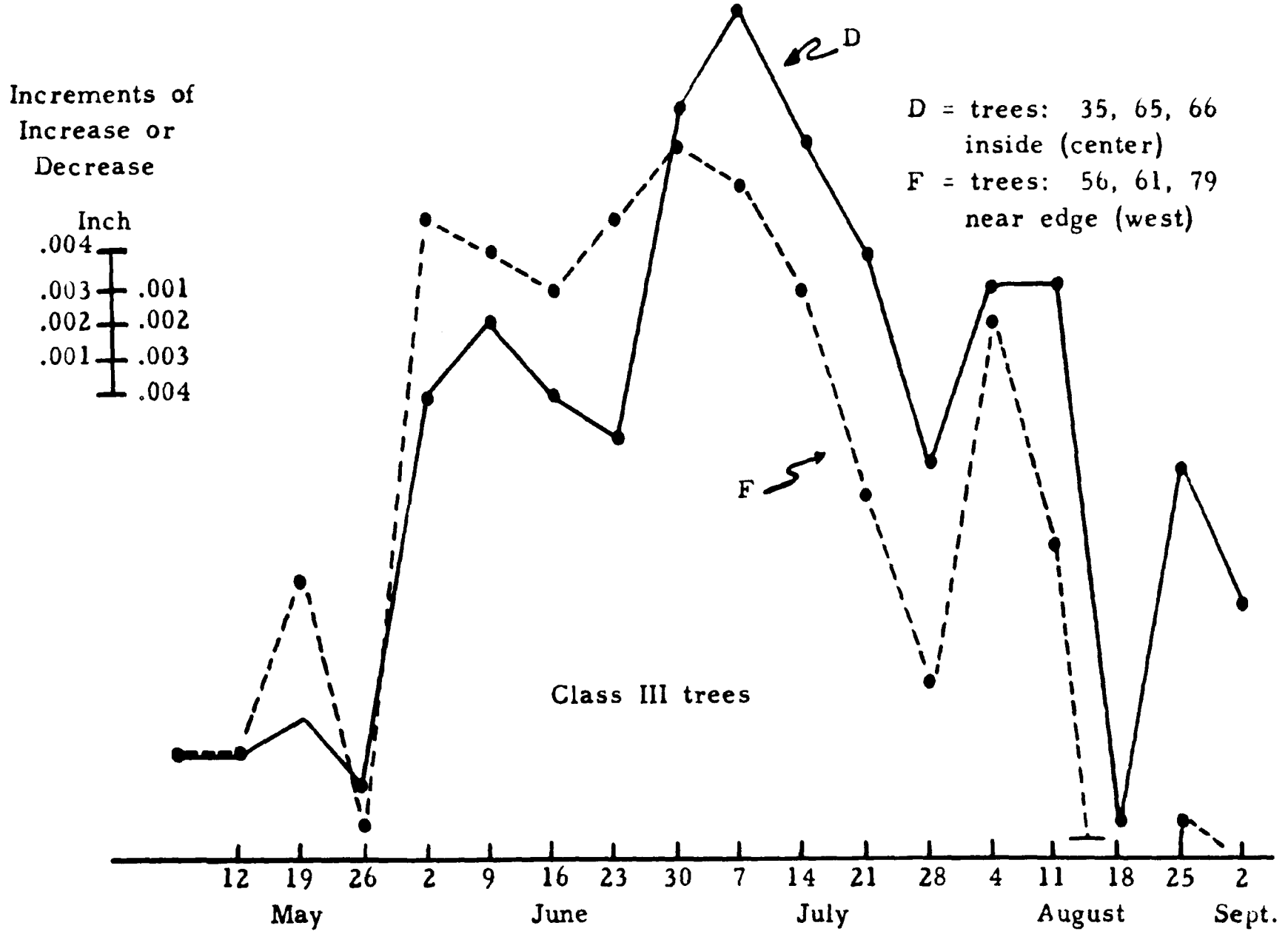


Figure 47. Radial growth differences. Groups D and F compared. 1949.

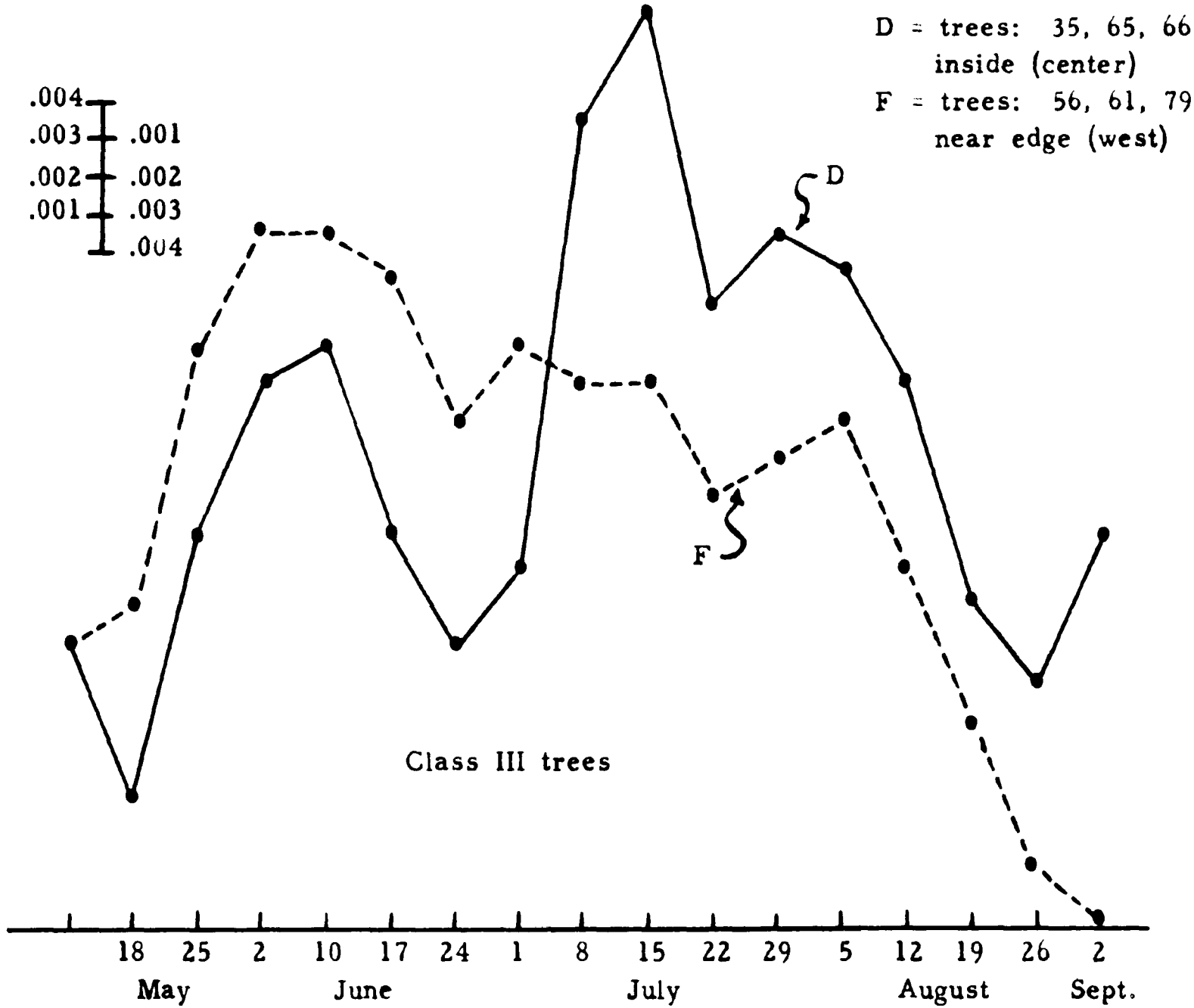


Figure 48. Radial growth differences. Groups D and F compared. 1950.

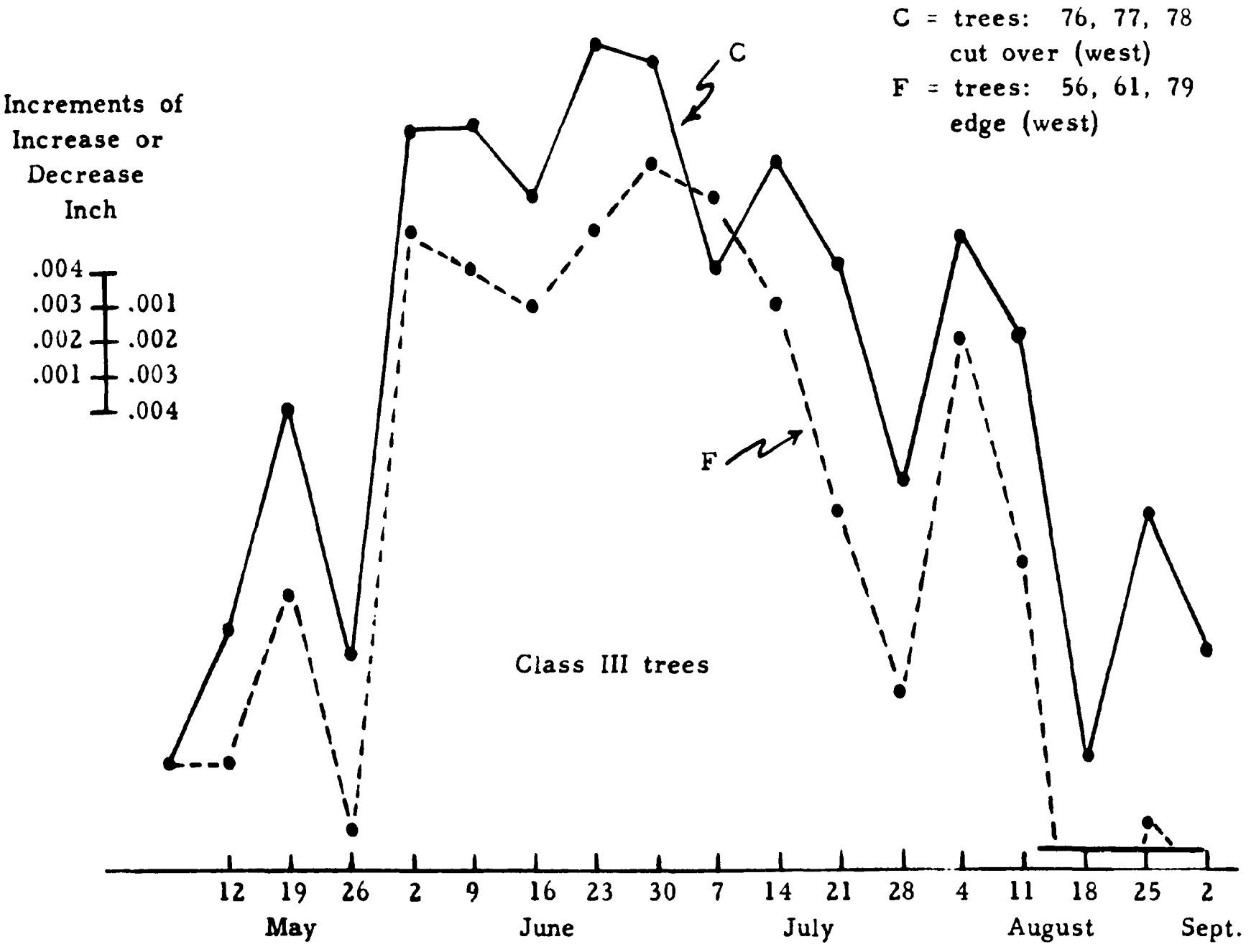


Figure 49. Radial growth differences. Groups C and F compared. 1949.

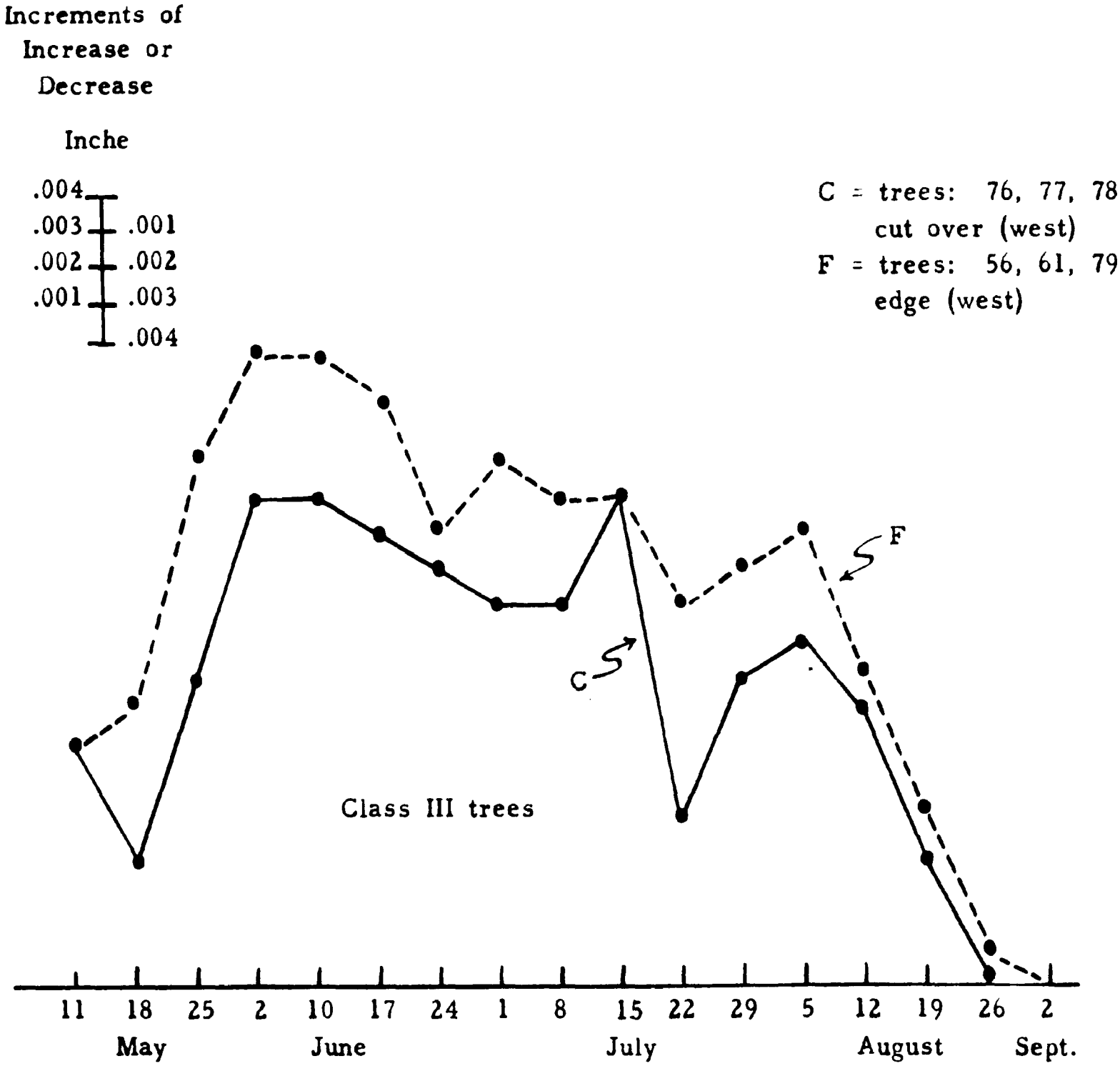


Figure 50. Radial growth differences. Groups C and F compared. 1950.

compare group C trees with group F trees. Group C is in the disturbed area quite close to group F. No such pattern as found in the first comparison is noted here. Actually, these two growth curves are quite similar, and serious differences in fluctuation are not apparent during either season.

Figures 51 and 52 compare groups K and L, both within the main part of the woods. The growth-fluctuation patterns are essentially the same except that the curves separate somewhat about the first of June in both 1949 and 1950. None of the external factors measured correlate with this.

Figures 53 and 54 compare group R with group T. Figures 55 and 56 compare group R with group P, and Figures 57 and 58 introduce group S in comparison with the same group R. Group R is located about 40 feet in from the southwest edge. Groups P, T, and S are inside the woodlot.

In these three groups of comparisons a divergence of curve R appeared the week ending July 7, 1949, and extended to the week ending July 21, 1949. Again, results of soil moisture data (Table VIII) reveal a very considerable drop (to 59% available moisture at the 12-inch level) in the vicinity of group R (Station 3). The drop was not appreciable for the areas

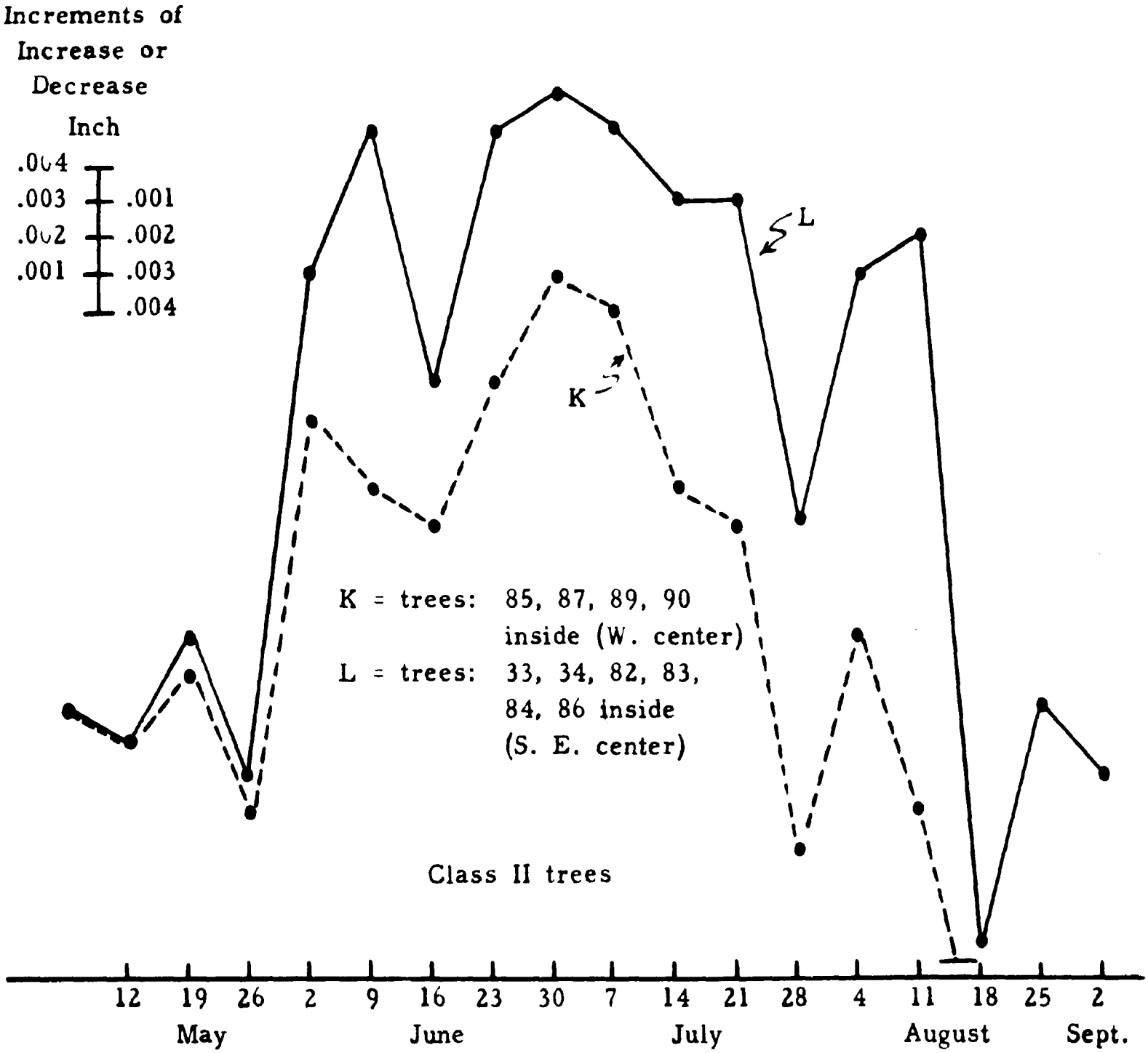


Figure 51. Radial growth differences. Groups K and L compared. 1949.

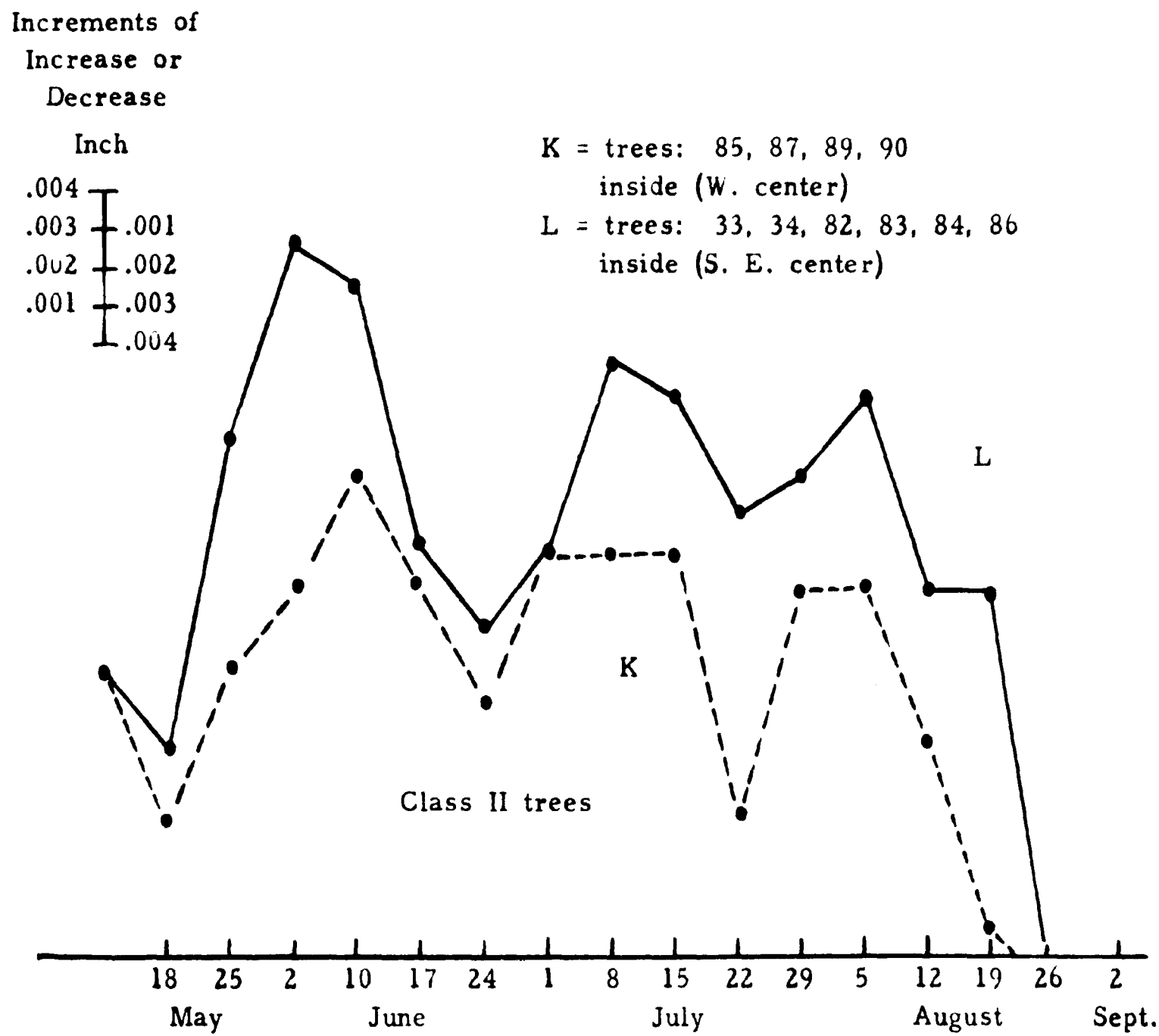


Figure 52. Radial growth differences. Groups K and L compared. 1950.

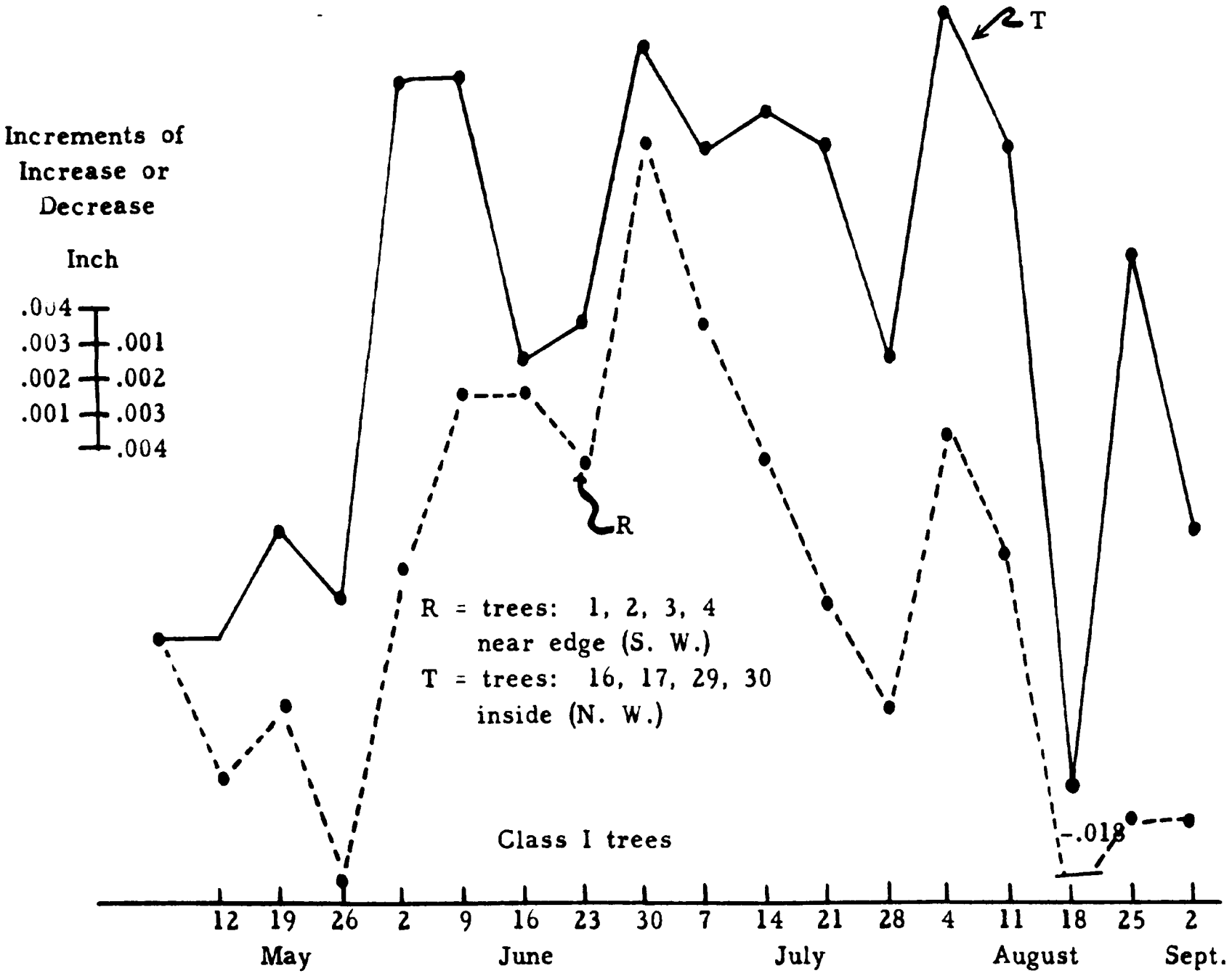


Figure 53. Radial growth differences. Groups R and T compared. 1949.

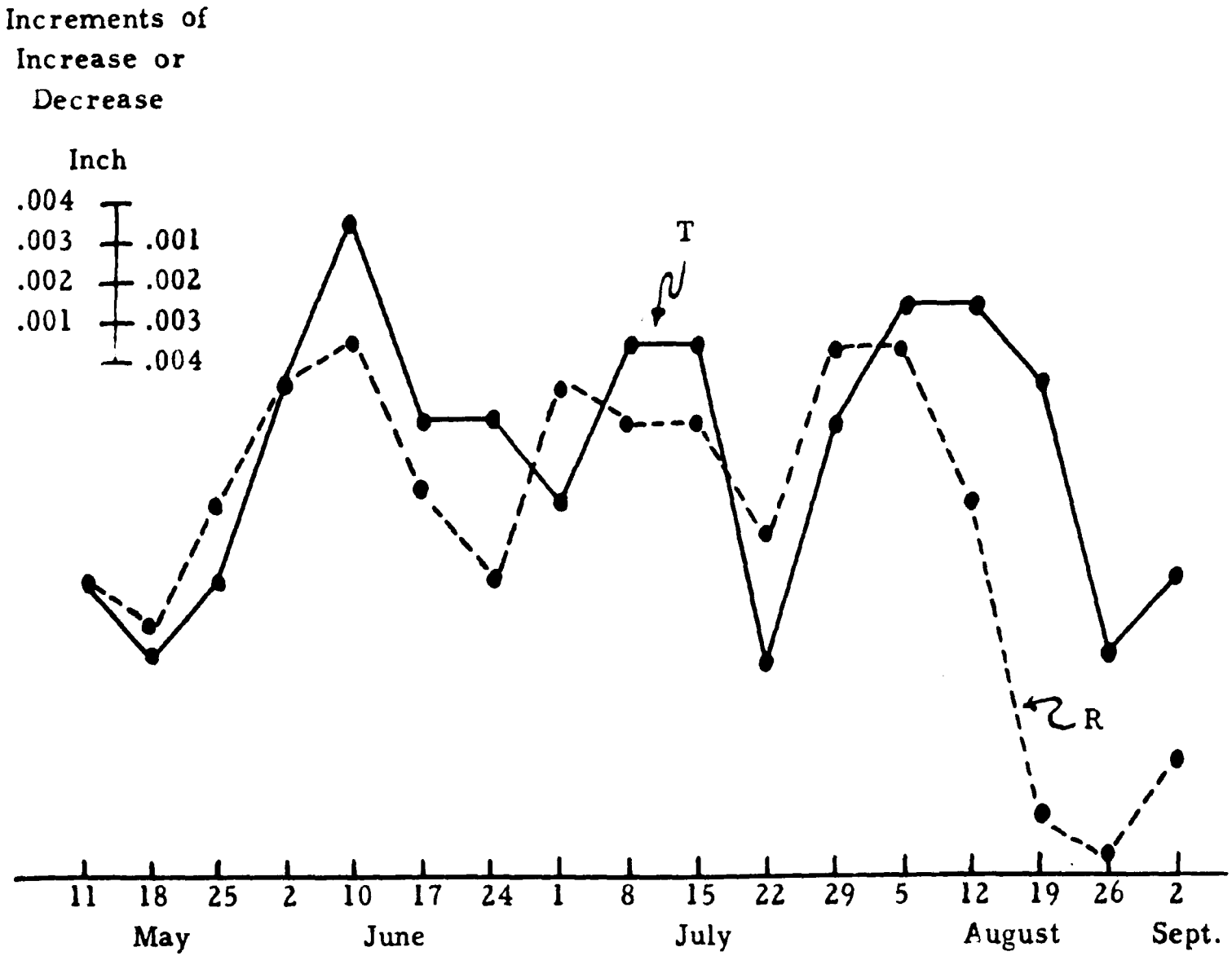


Figure 54. Radial growth differences. Groups R and T compared. 1950.

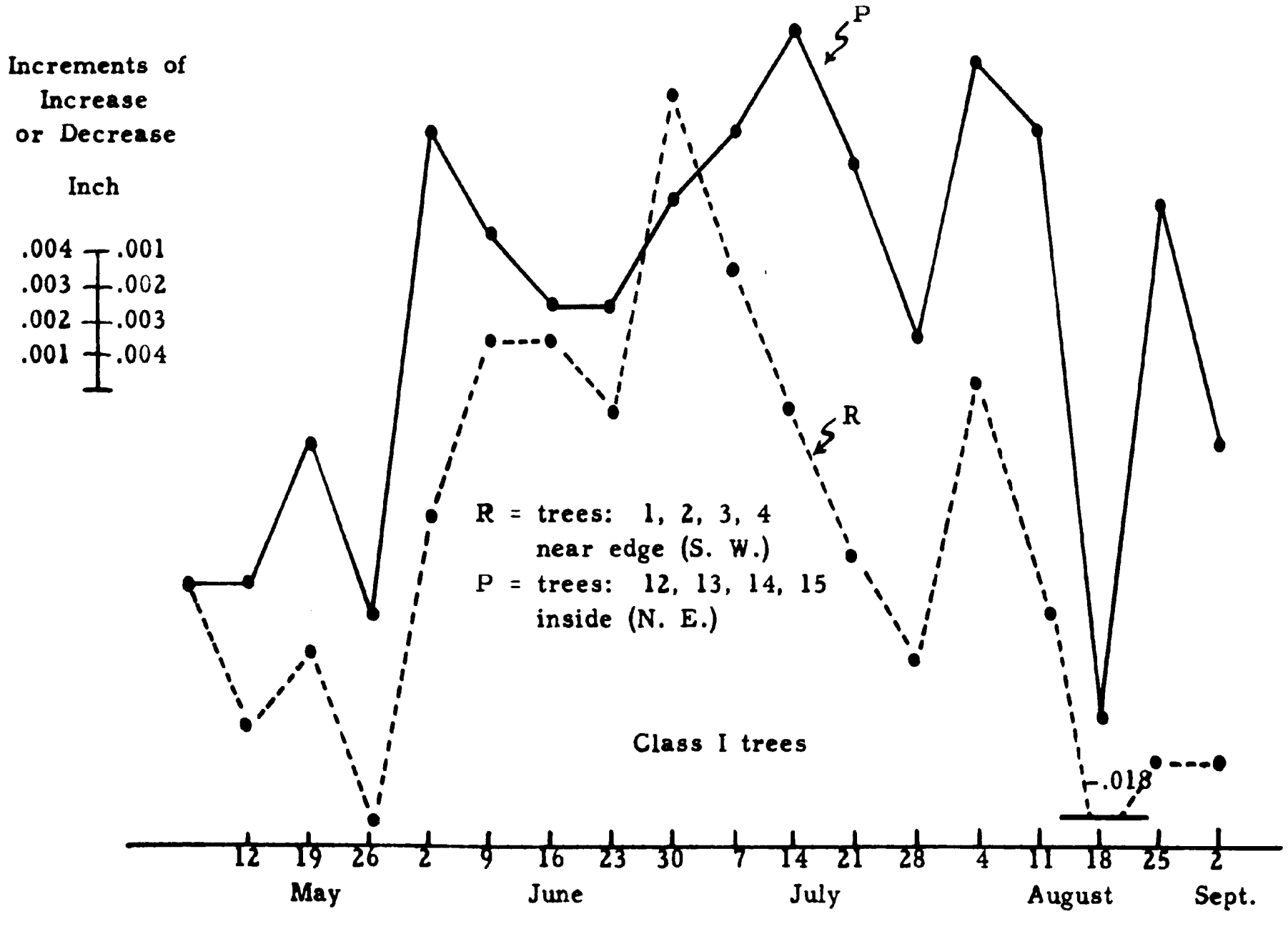


Figure 55. Radial growth differences. Groups P and R compared. 1949.

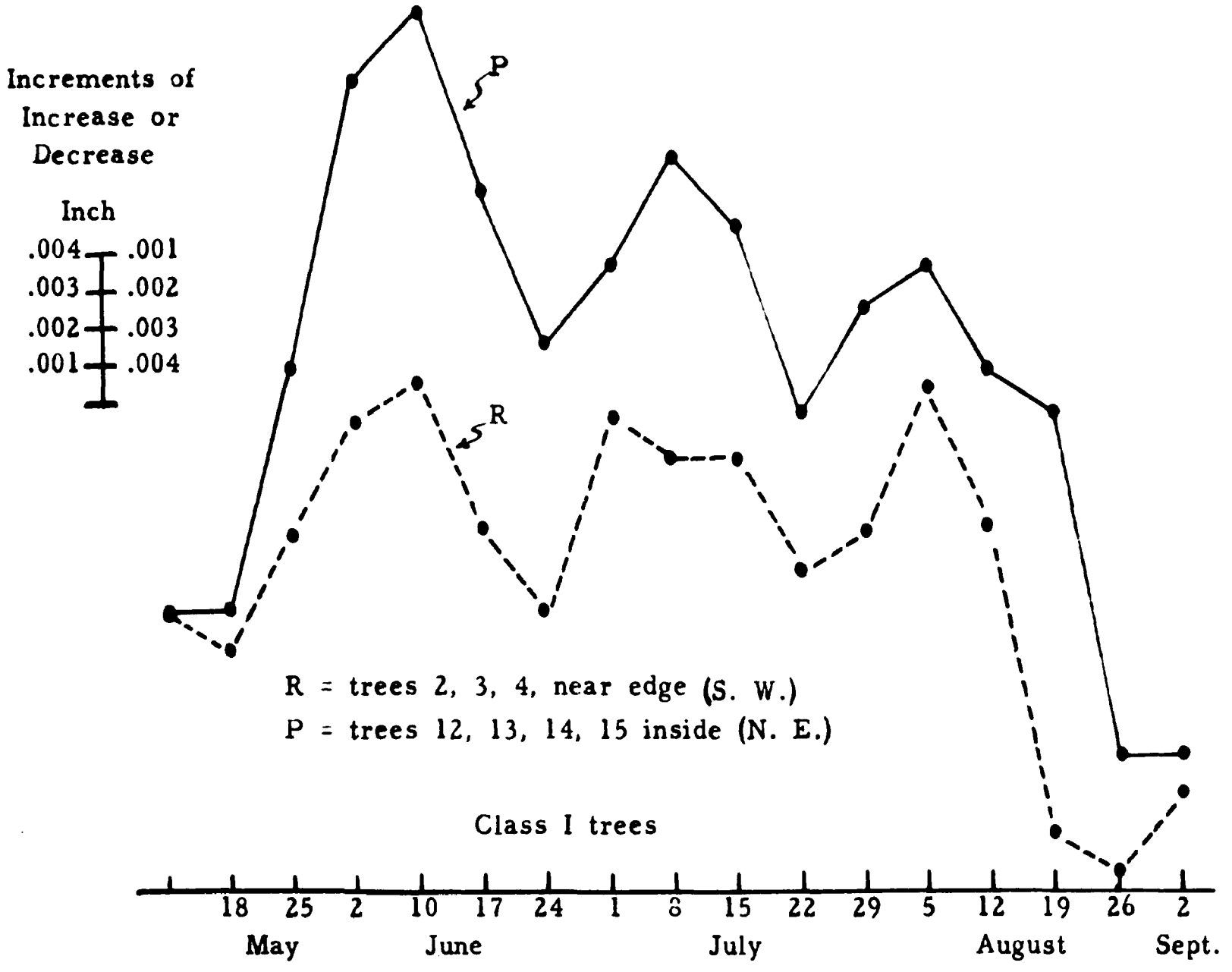


Figure 56. Radial growth differences. Groups P and R compared. 1950.

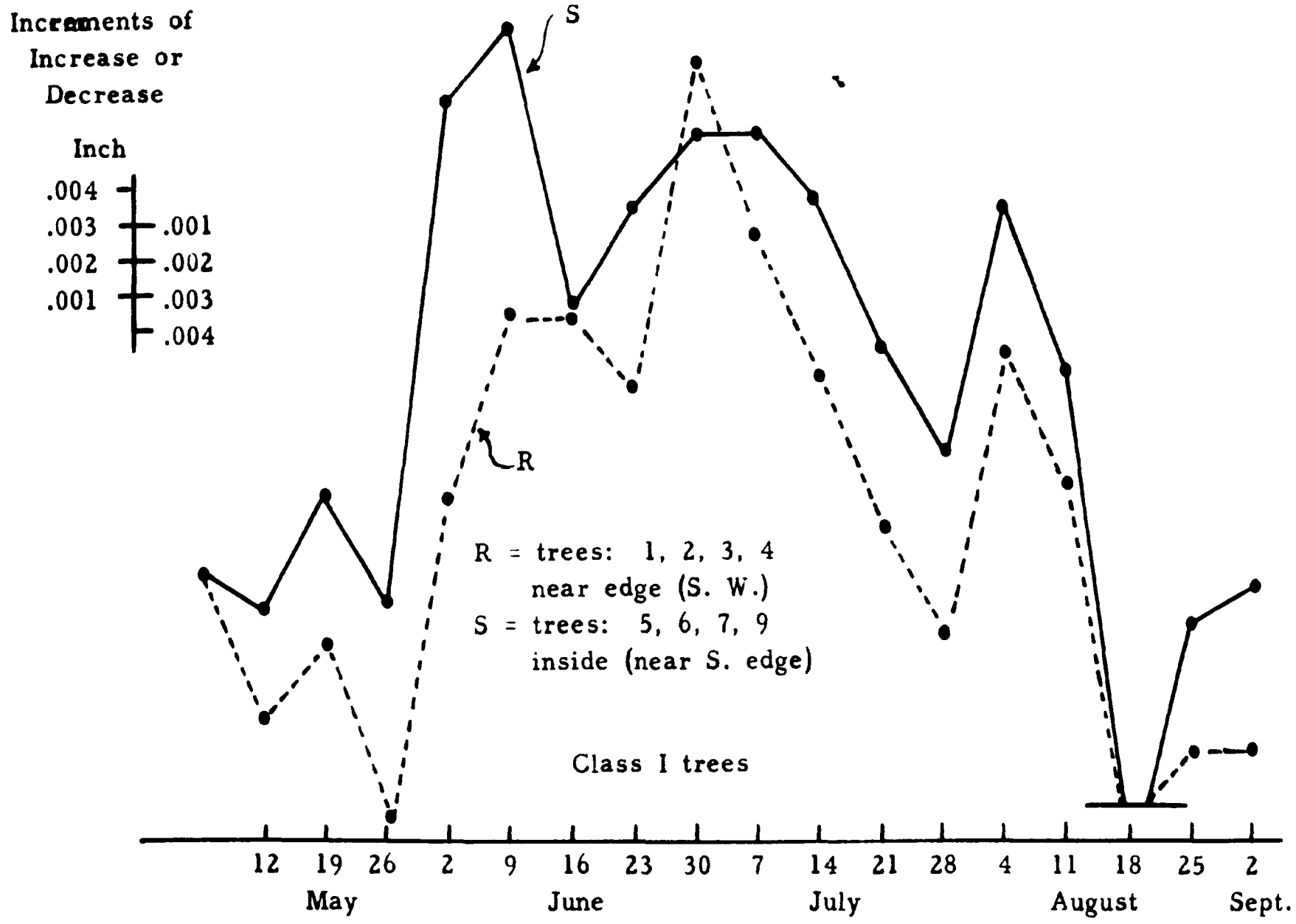


Figure 57. Radial growth differences. Groups R and S compared. 1949.

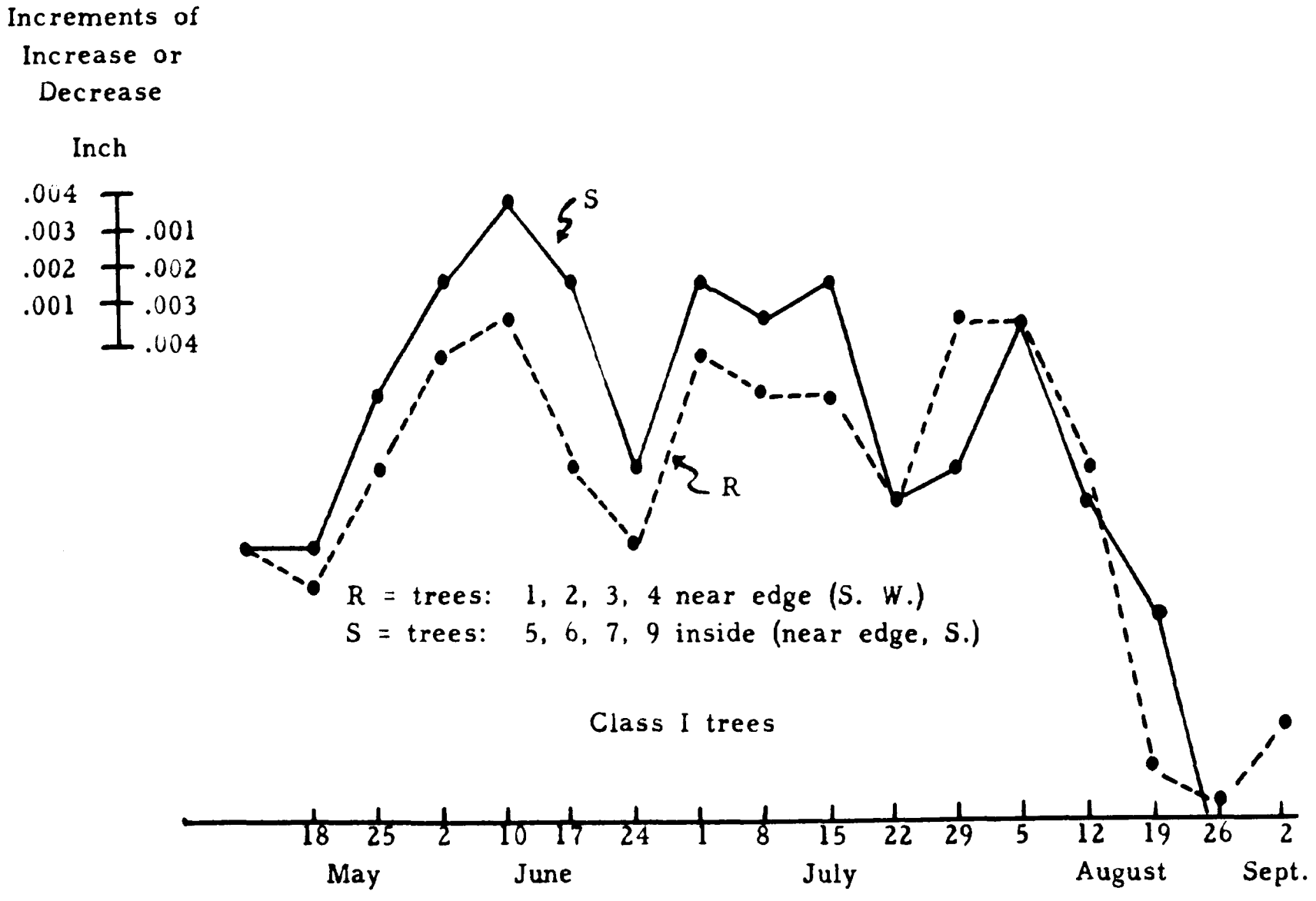


Figure 58. Average weekly increase differences. Groups R and S compared. 1950.

around the other three groups (Stations 9, 10, 11, and 13). The available moisture did decrease at these stations, but did not fall below 80 percent. For 1950 these same groups did not show any serious fluctuation differences. Minor fluctuations did occur but were not of such an extent as to be correlated in this study.

It is of interest to compare these findings as a whole with the information given in Figures 59, 60, and 61, which show the trend of available moisture at the "edge" stations and the stations located well within the woodlot. From about the time of peak rate of growth in July, the two curves of available moisture separate; the curve representing the "edge" stations dropped appreciably each week until it approached the wilting coefficient by the end of August. This was generally true for both years. Some stations in the "edge" area reached the wilting coefficient by the week ending August 25, 1949, and remained there for the remainder of the period during which readings were taken.

At Station 3 (Table VIII), soil moisture on August 4, 1949, at a depth of 12 inches, was about 12 percent available moisture. Although moisture percentages were generally higher

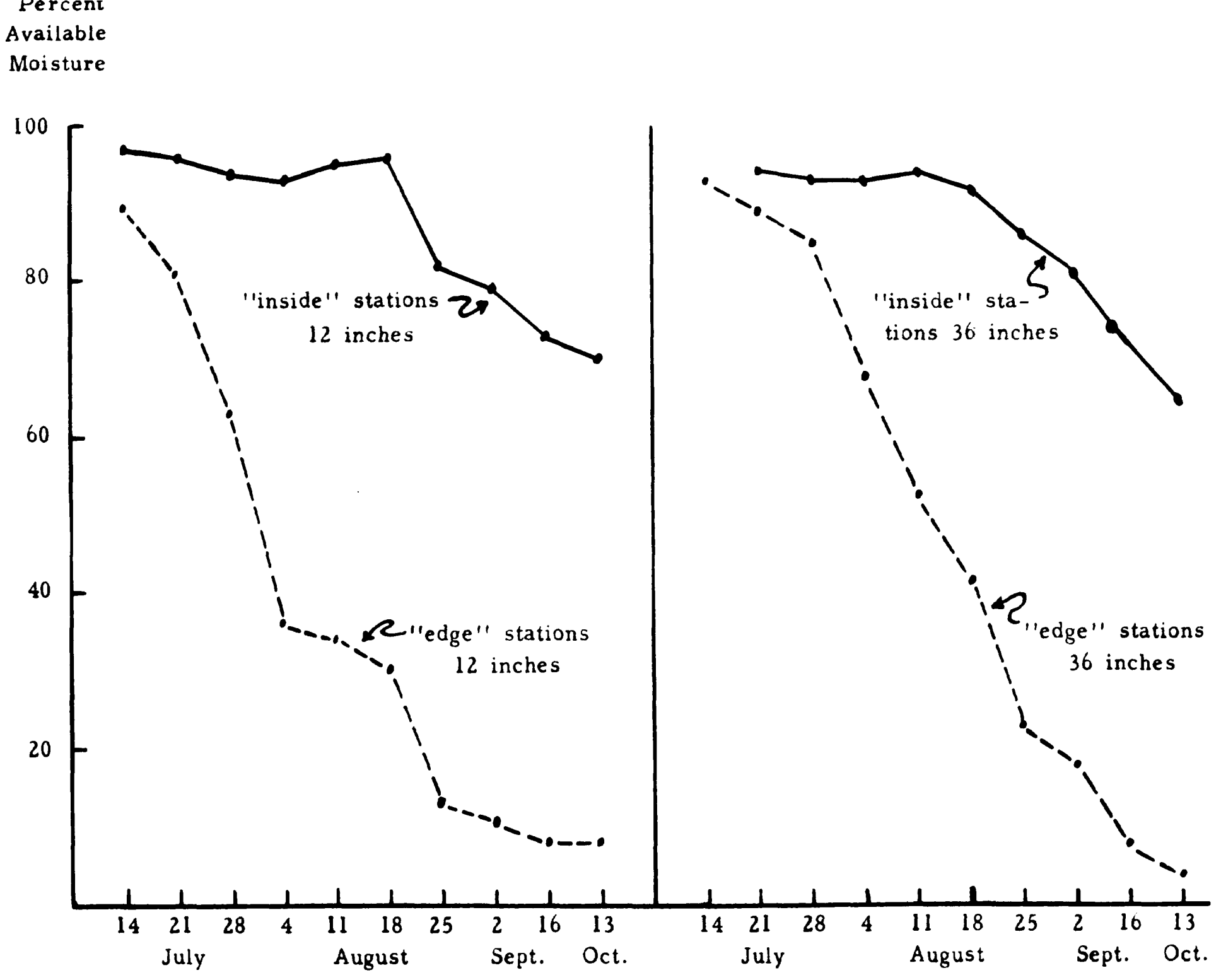


Figure 59a. Soil moisture in Toumey Woodlot

Figure 59b. Soil moisture in Toumey Woodlot

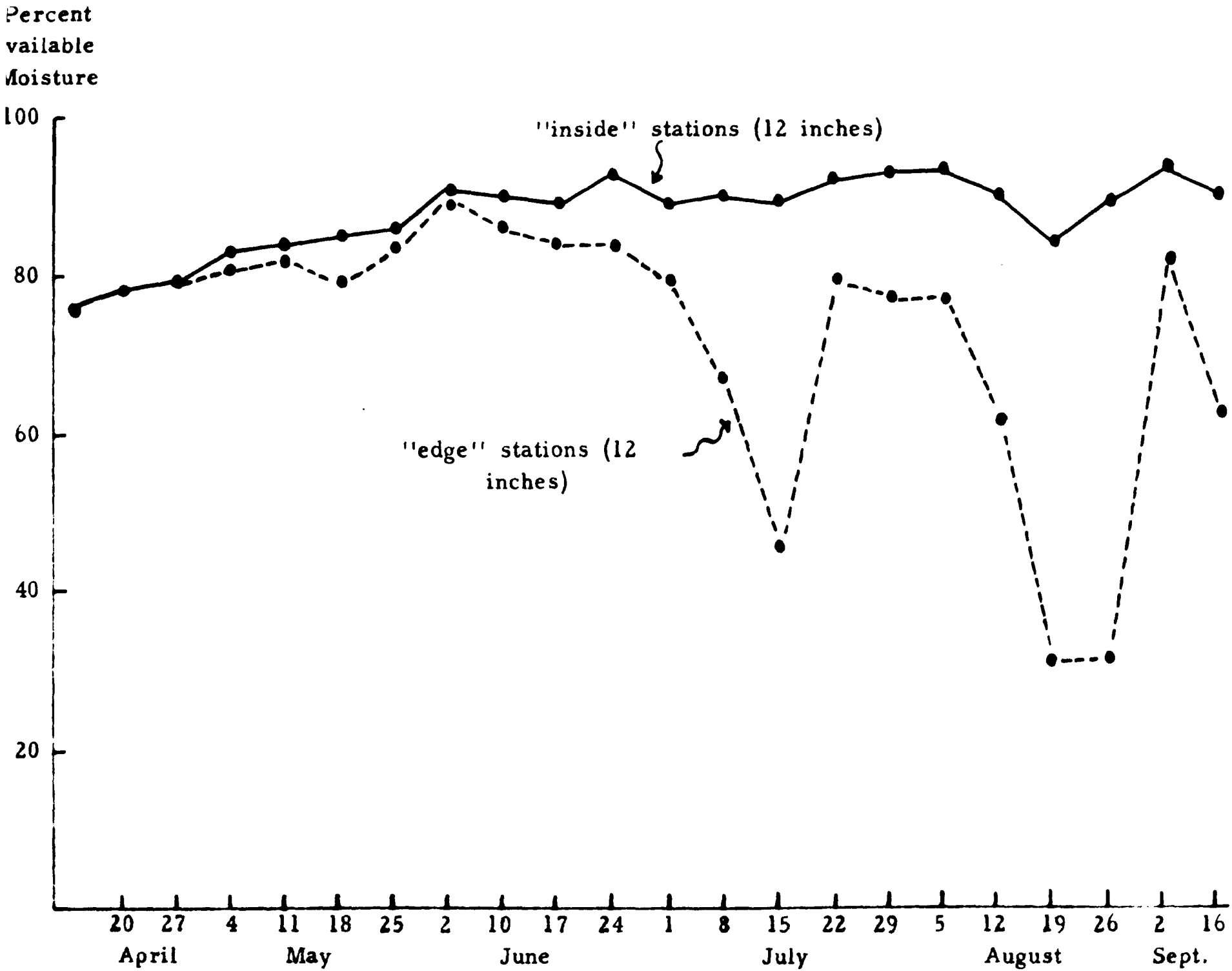
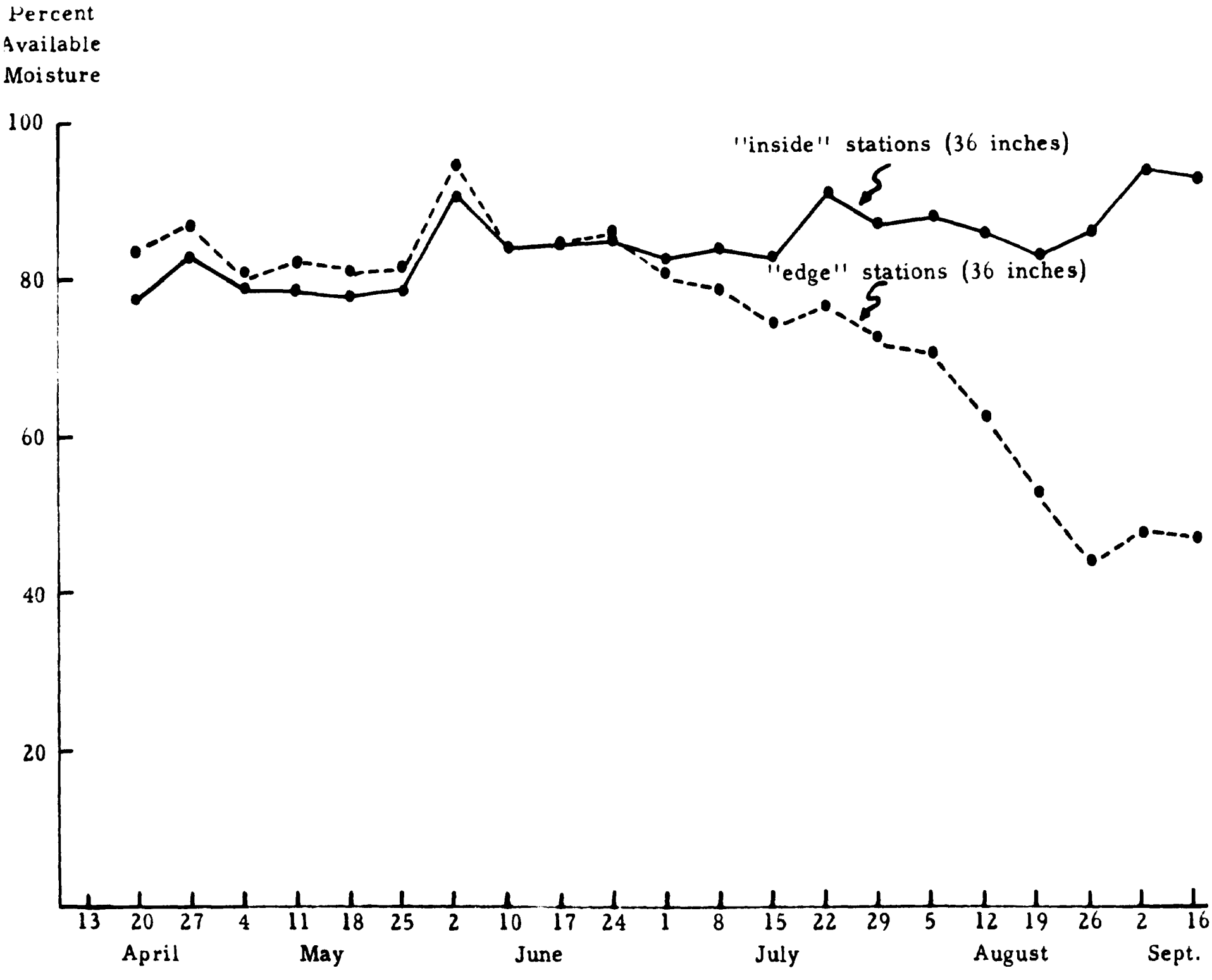


Figure 60. Soil moisture in Toumey Woodlot at the 12-inch level. 1950.


Percent
Available
Moisture
100
80
60
40
20
"inside" stations (36 inches)
"edge" stations (36 inches)
13 20 27 4 11 18 25 2 10 17 24 1 8 15 22 29 5 12 19 26 2 16
April
May
June
July
August
Sept.

160

in 1950, the wilting coefficient was reached by Station 2 and Station 3 on August 26 at a depth of 12 inches (Table X). Soil temperatures were also consistently higher by from 2 to 5 degrees in these stations (Tables XII and XIV). Figures 62 and 63 compare soil temperatures in Toumey Woodlot at the "edge" and at the "inside" stations. It is seen that although the trend of soil temperatures is quite similar, the "edge" stations showed slightly higher temperatures than found on the "inside" of the woodlot.

Increase in Trees Measured Along Four Radii

Tree 91

Figure 64 indicates the total amount of radial growth for 1949 and 1950 in each of four directions (viz., north, south, east, west). This is the case with all trees discussed in this section. Eccentric growth was not much in evidence in this tree, but growth tended to be less on the south side. This is more evident for 1950. In each of the two years there was a slightly greater amount of seasonal growth along the east radius. Figures 65 and 66 show this to be the trend for both seasons. At none of the four periods did the radial increase along the

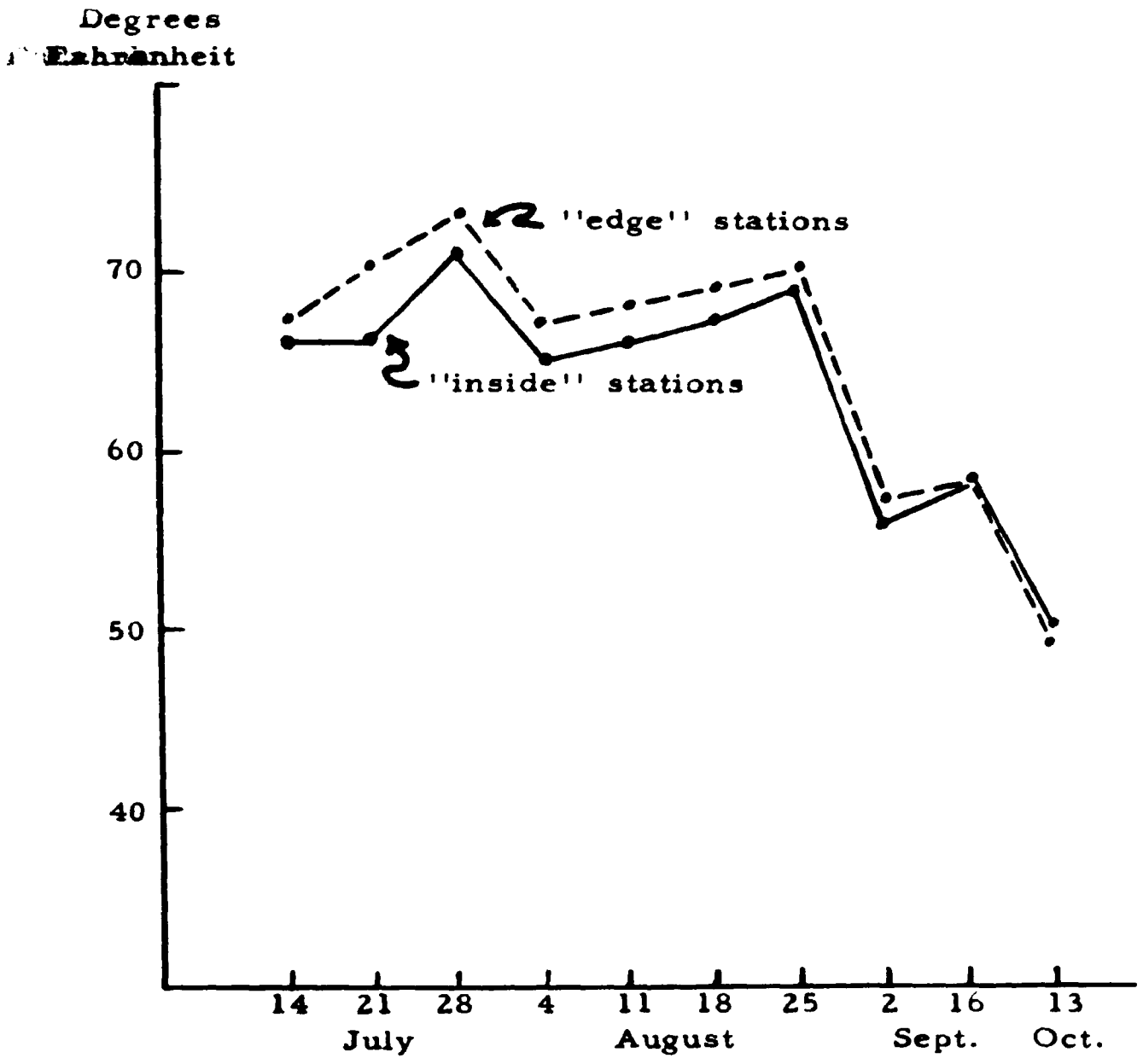


Figure 62. Soil temperature in Tourney Woodlot at a depth of 3 inches. 1949.

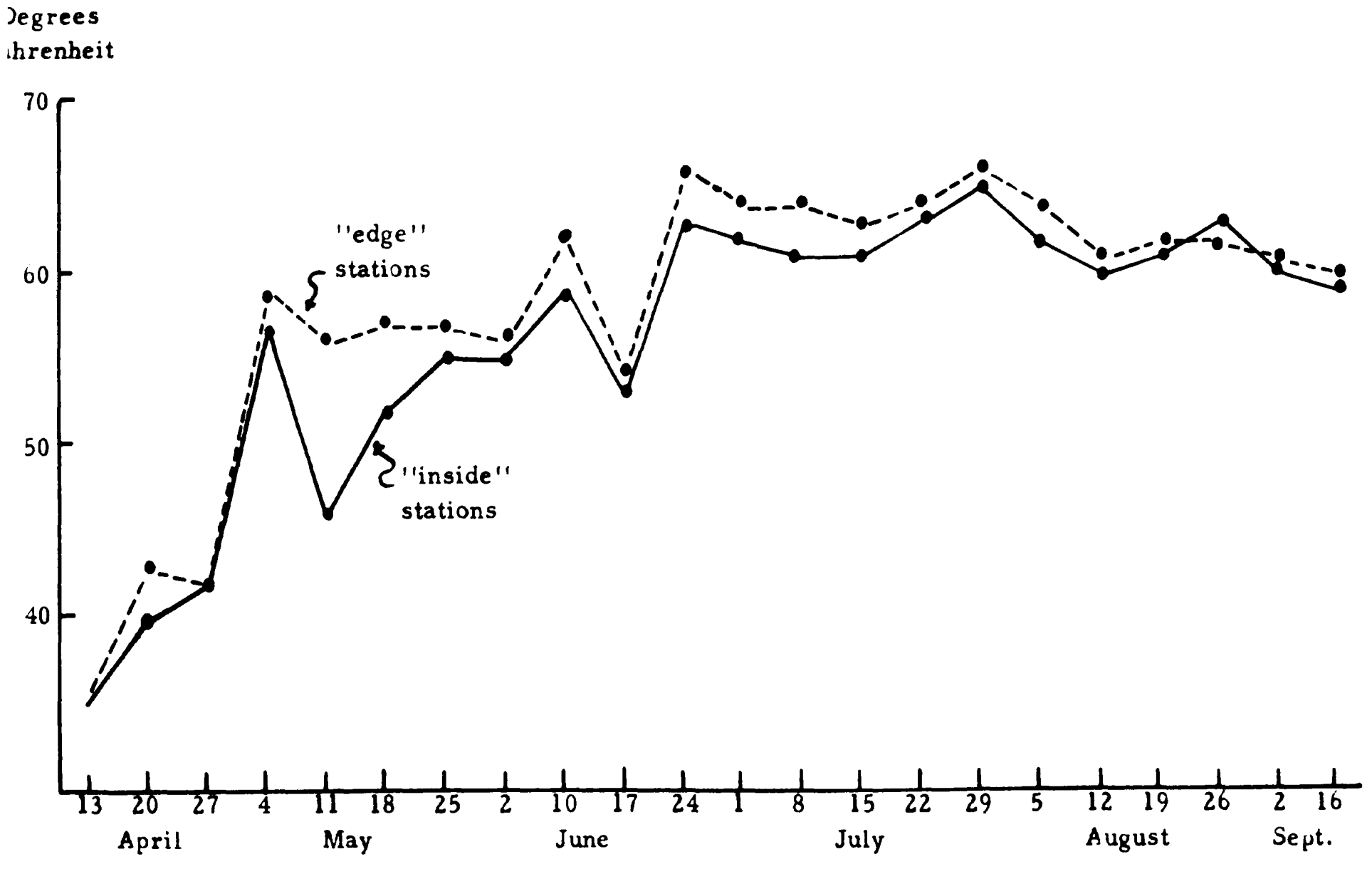


Figure 63. Soil temperature in Toumey Woodlot at a depth of 3 inches. 1950.

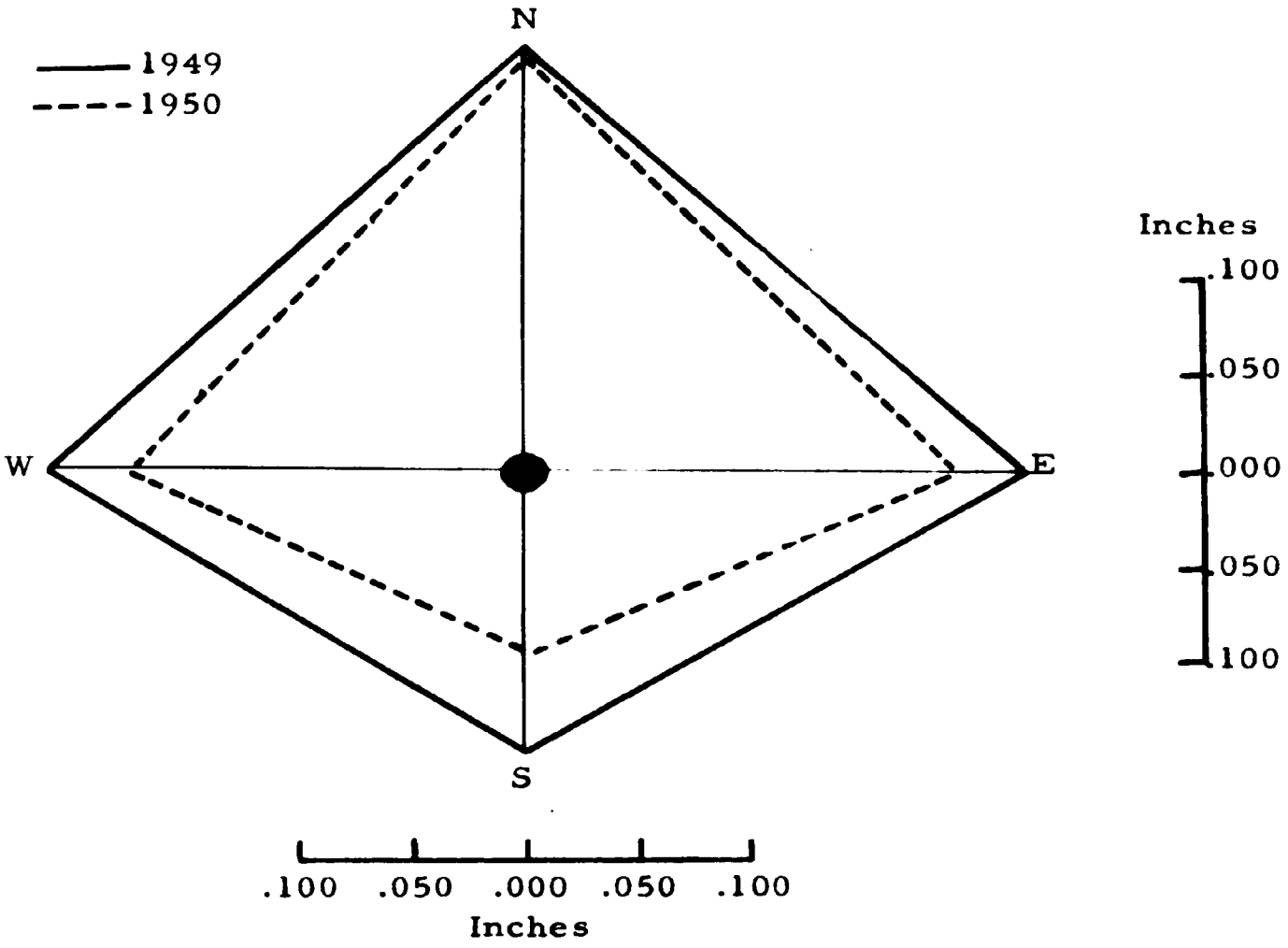


Figure 64. Total seasonal growth as measured along four radii. Tree 91.

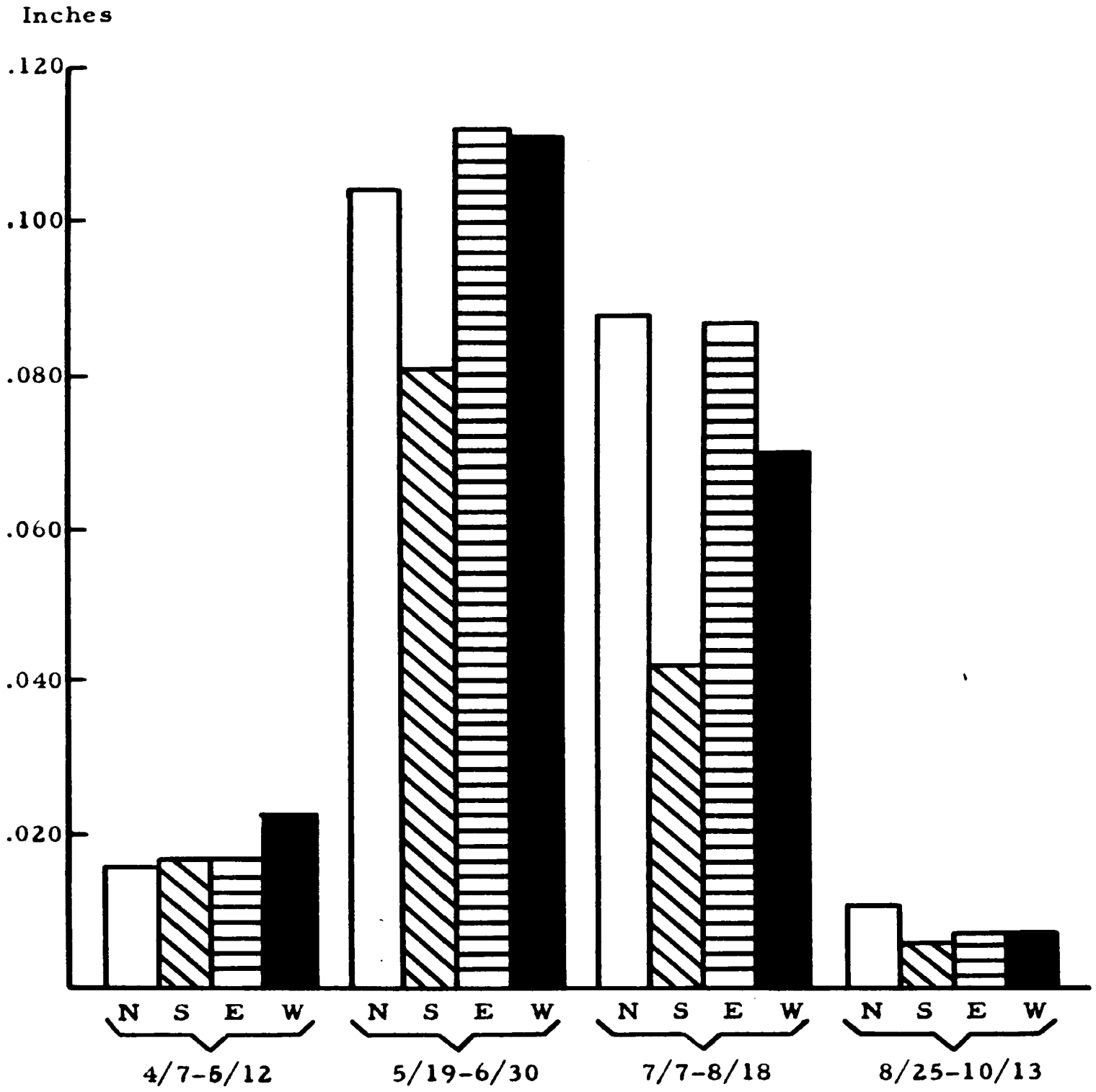


Figure 65. Growth accumulation over specified seasonal periods. Tree 91. 1949.

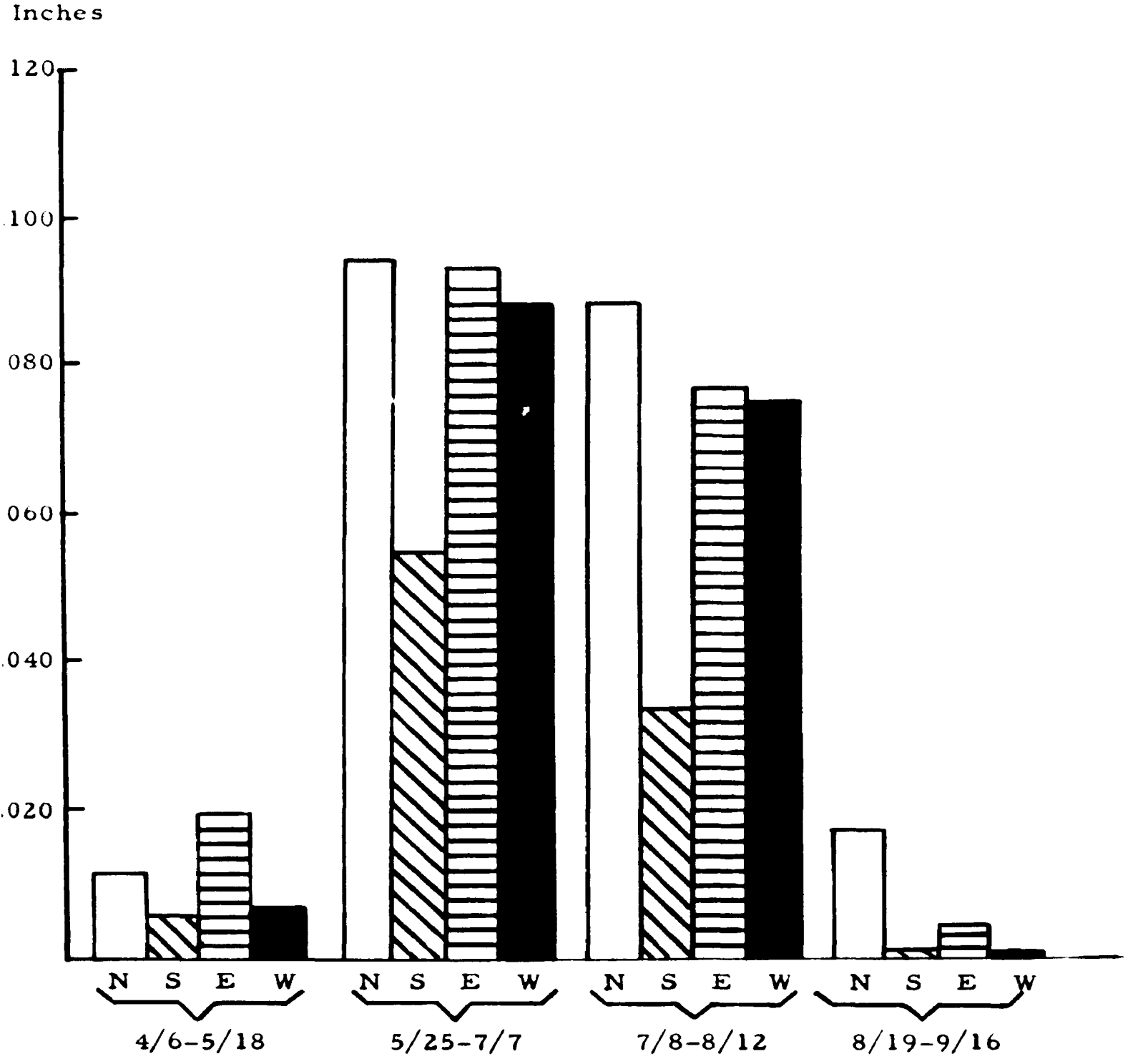


Figure 66. Growth accumulation over specified seasonal periods. Tree 91. 1950.

south radius exceed that of the other radii, with the exception of the first period of 1949, and here the increase along the north radius was but very slightly less.

Tree 92

For both years this tree showed eccentric growth in a north-south direction (Figure 67). This was much more pronounced in 1949, when growth was greater. There was practically no difference in the east-west growth during the two years. Figures 68 and 69 show that there were also few differences in magnitude of growth during four selected periods of each season.

Tree 93

This tree is growing just east of tree 92 (Figure 14) and showed smaller seasonal increases along the north radius than along the other three. Figure 70 indicates that growth on the north side was less during the entire season. During the first few weeks of both seasons the increases along the south and east radii were greater. During the period from May 18 to July 1, increase was greater along the west radius in 1950,

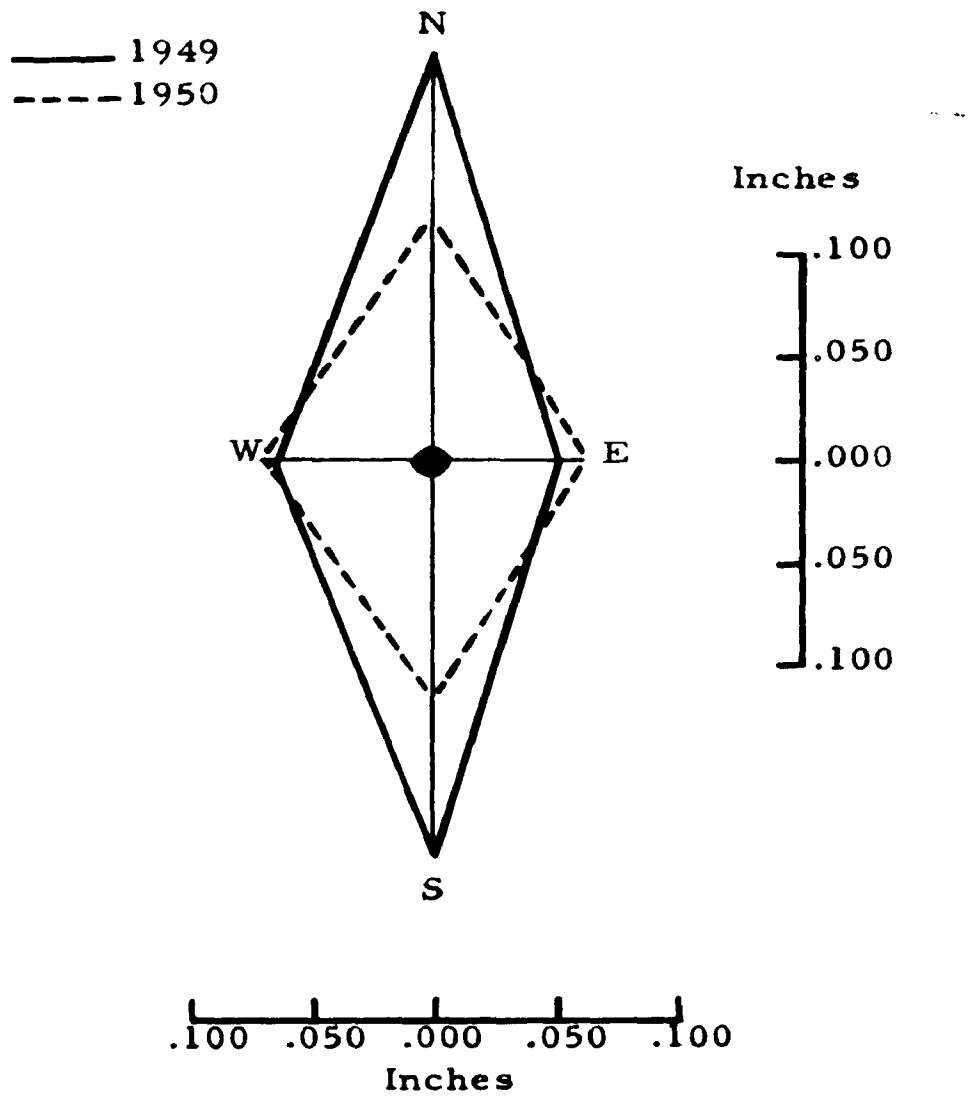


Figure 67. Total seasonal growth as measured along four radii. Tree 92.

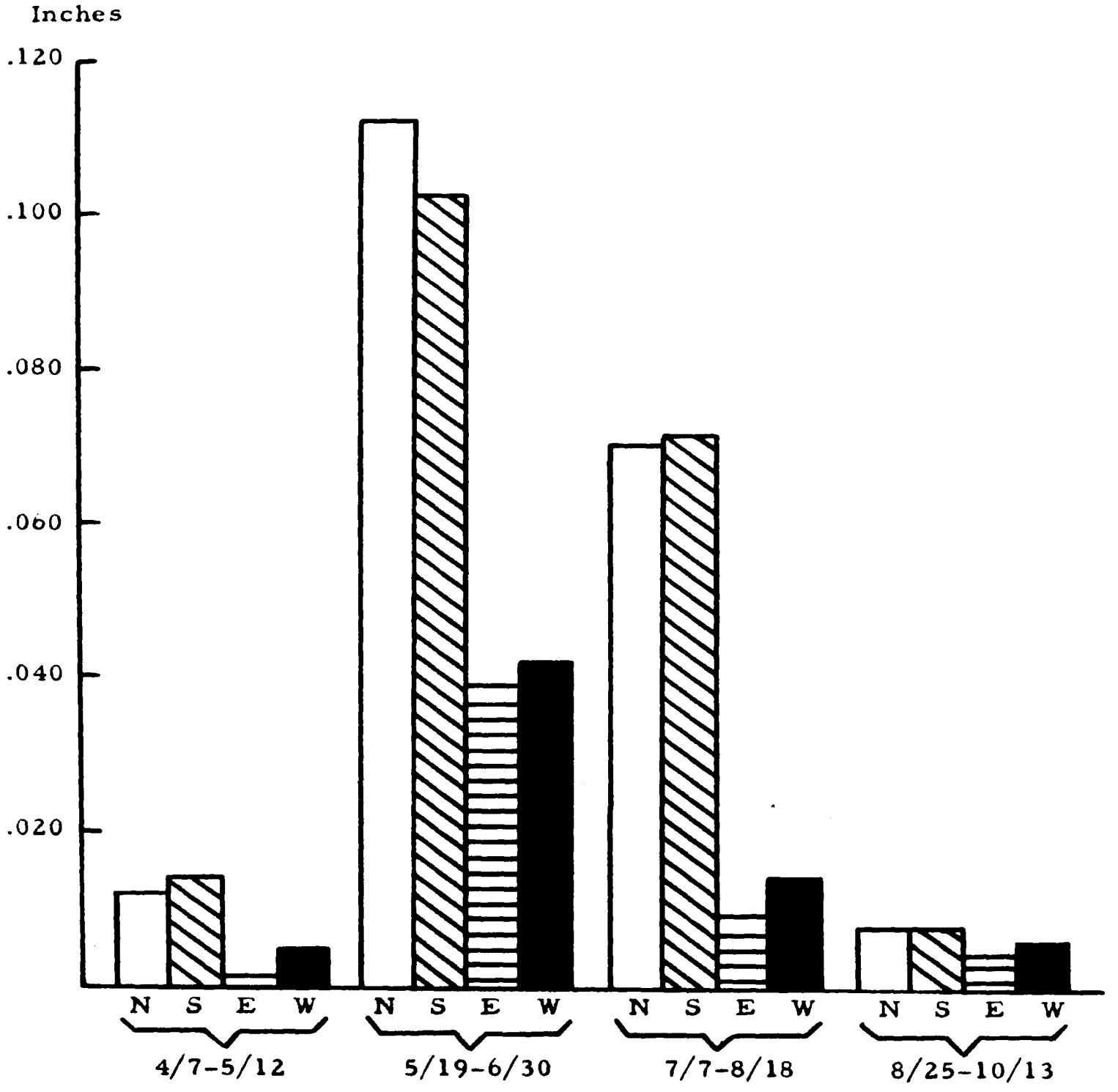


Figure 68. Growth accumulation over specified seasonal periods. Tree 92. 1949.

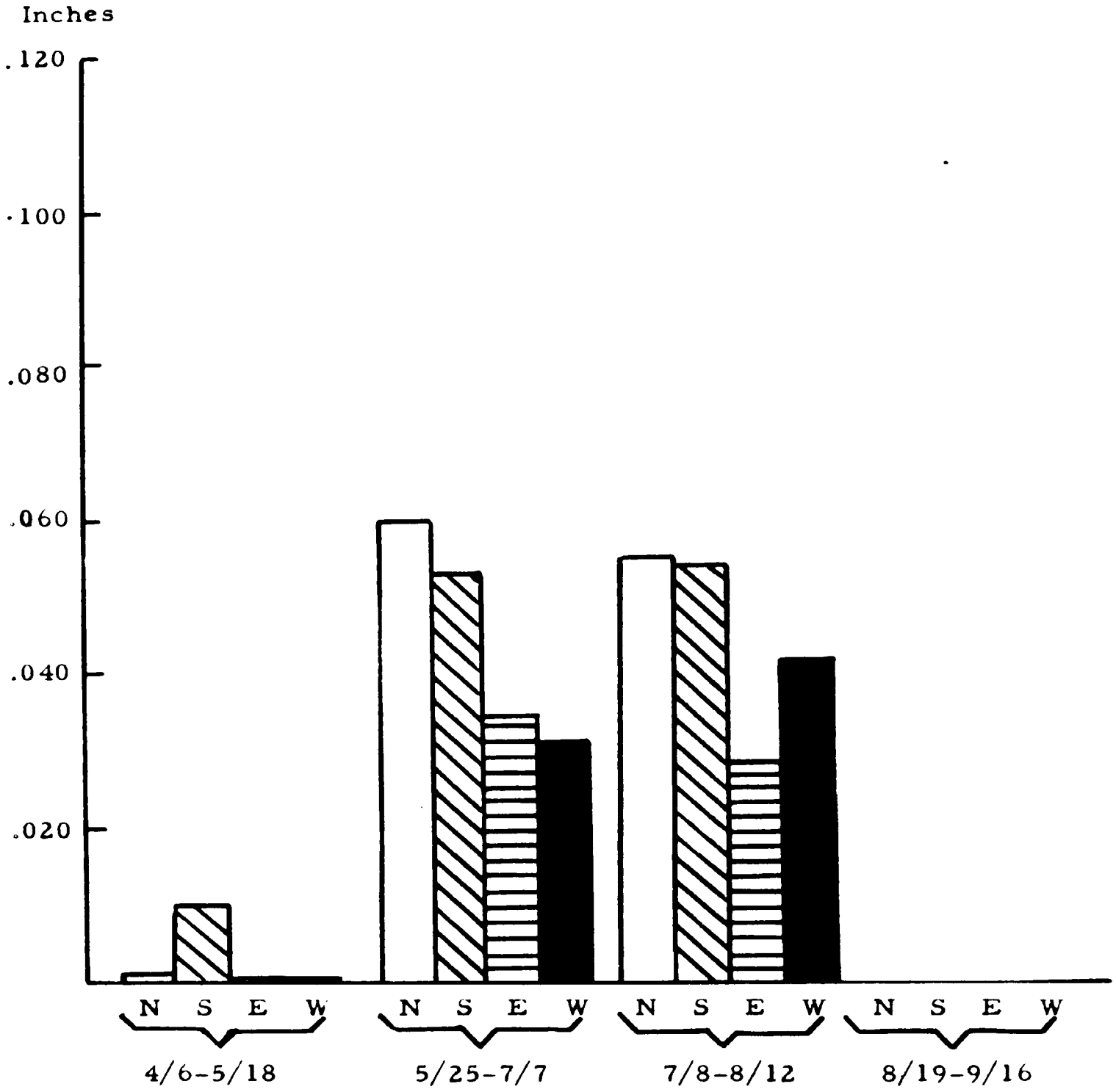


Figure 69. Growth accumulation over specified seasonal periods. Tree 92. 1950.

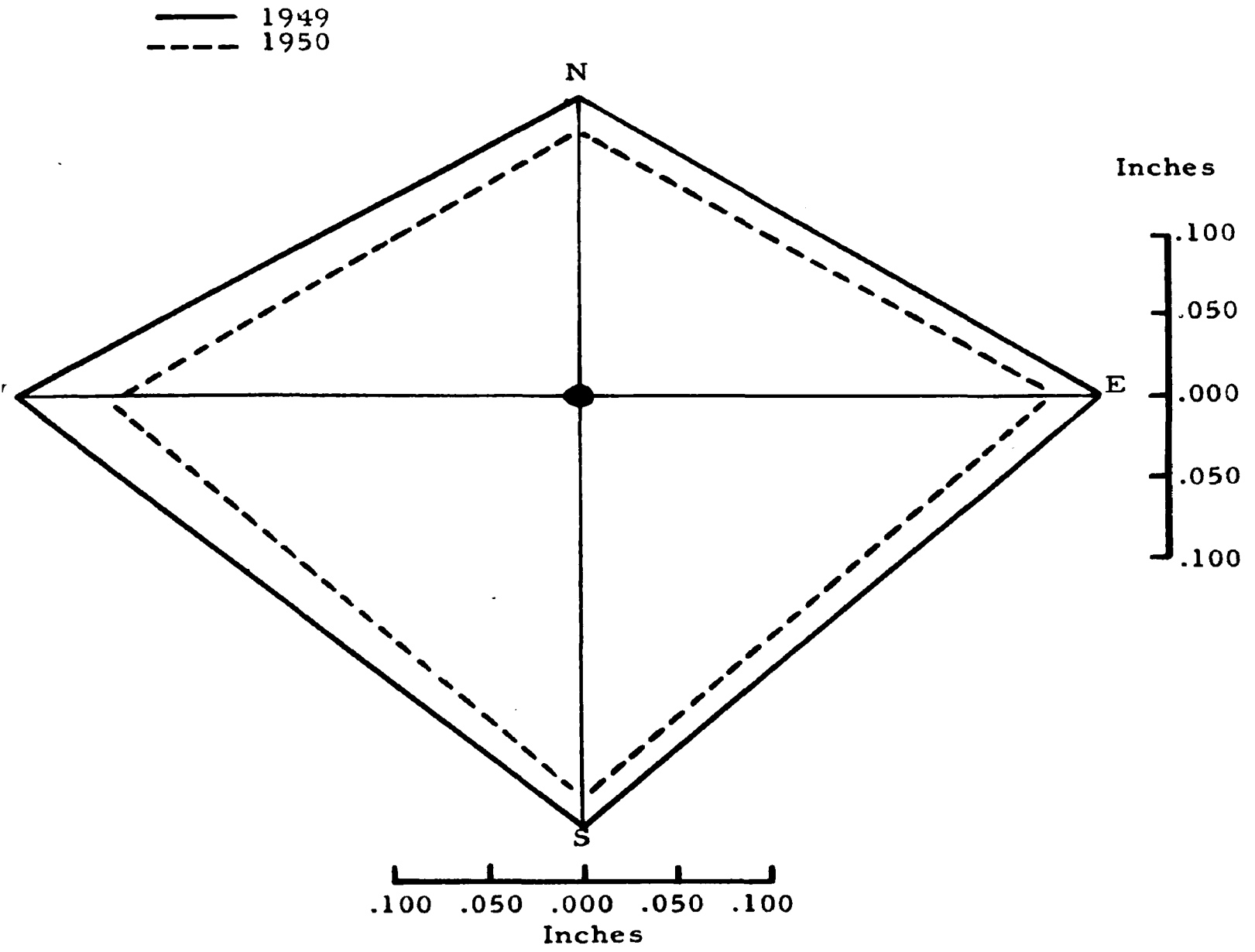


Figure 70. Total seasonal growth as measured along four radii. Tree 93.

but from July 1 to August 12, the south radius exhibited a greater amount. During these same two periods in 1949 the west radius showed greater increases. Figures 71 and 72 show the seasonal distribution of growth for this tree.

Tree 94

Figure 73 shows that practically no eccentric growth was in evidence for this specimen in 1949. In 1950, a considerable decrease along all four radii was noted. There was even a tendency for less growth on the north side. The same situation found for tree 93 is present here. For the period from May 18 to July 1, 1950, greatest increase was recorded along the west radius. From July 1 to August 12, 1950, the south radius showed the greatest amount of increase (Figures 74 and 75). The north radius showed smaller increases over the entire season.

Tree 95

Another south edge tree, this one showed a smaller amount of increase on the north side for both years (Figure 76), with a tendency for greater growth in a south and east

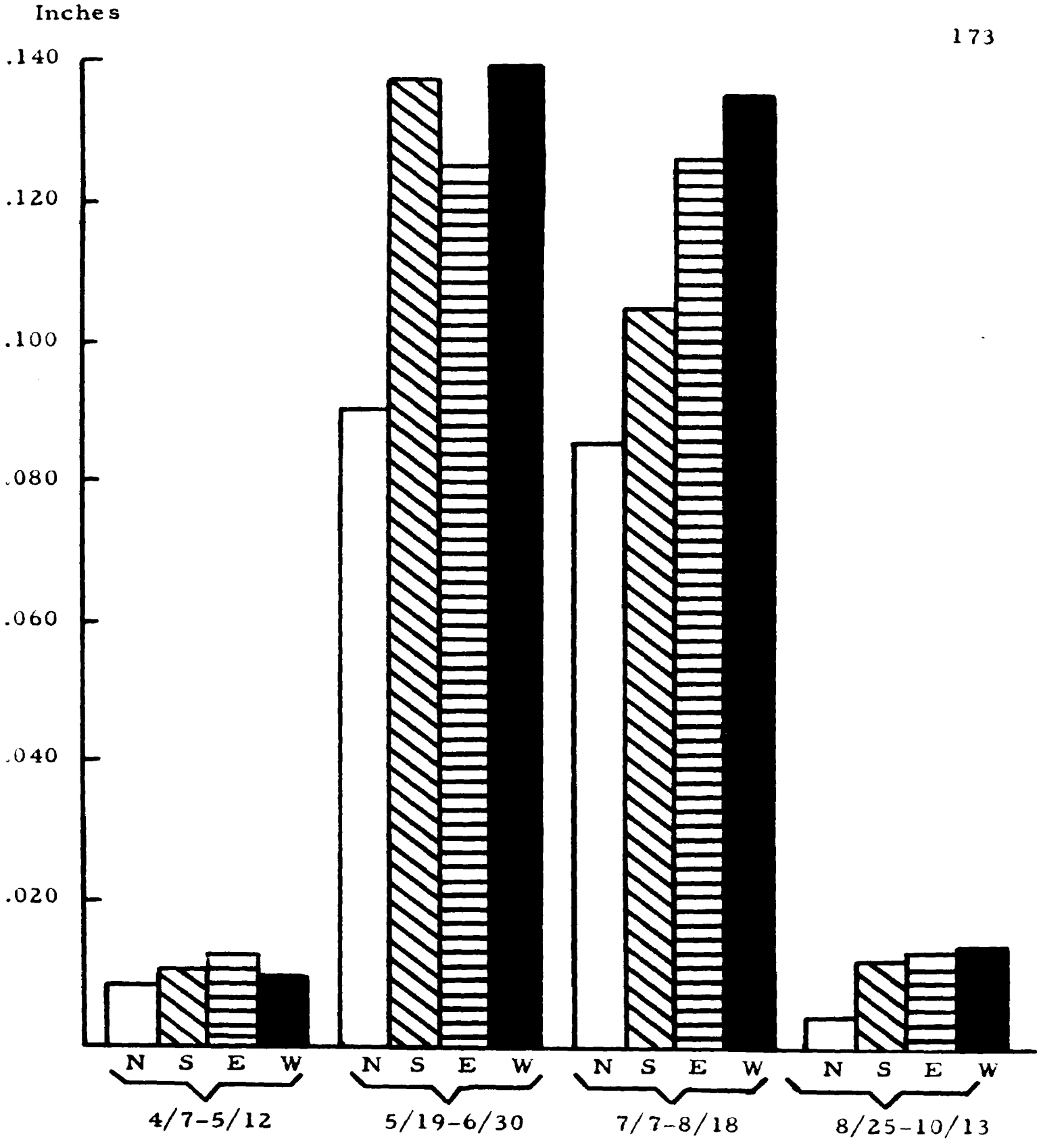


Figure 71. Growth accumulation over specified seasonal periods. Tree 93. 1949.

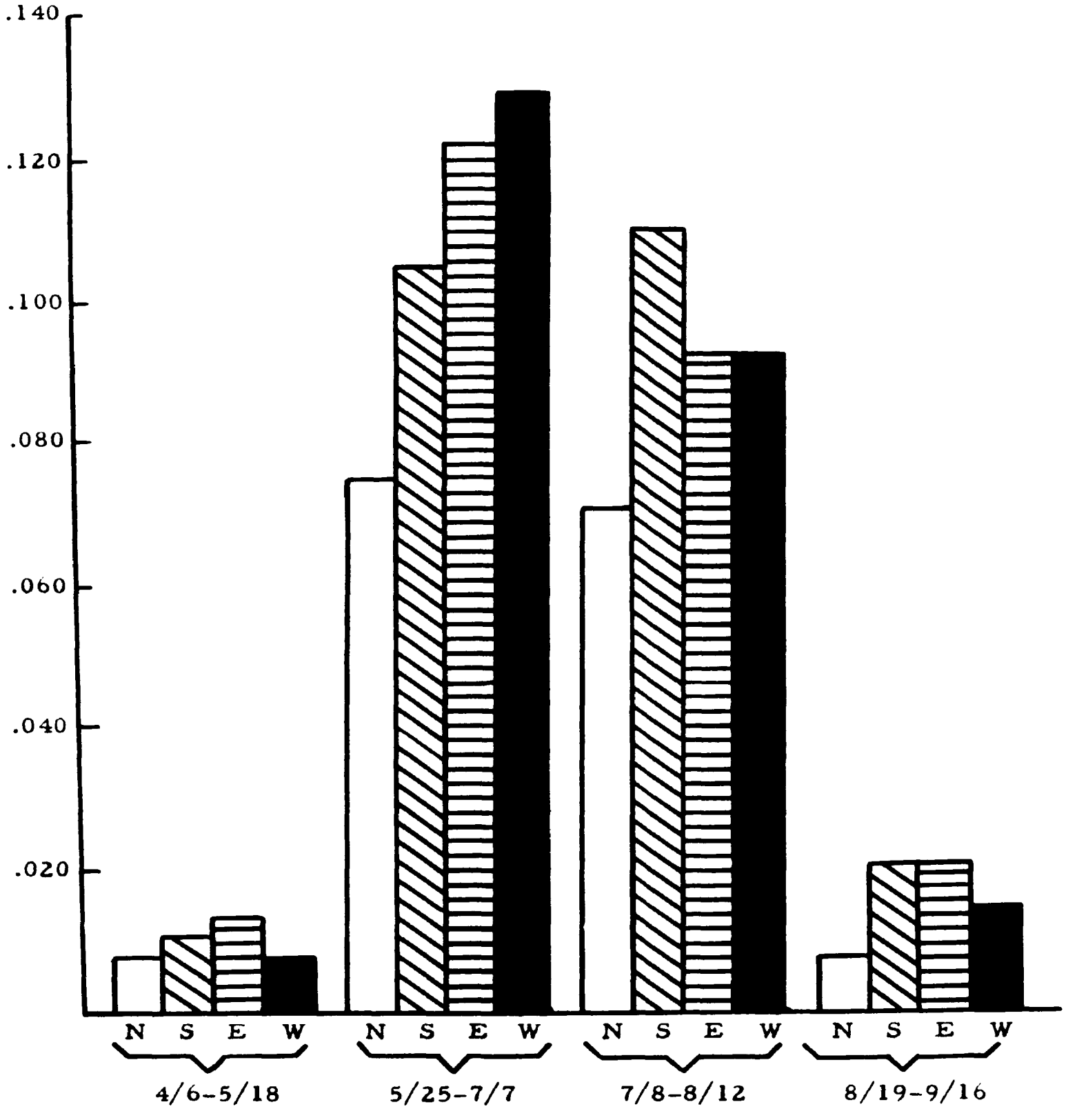


Figure 72. Growth accumulation over specified seasonal periods. Tree 93. 1950.

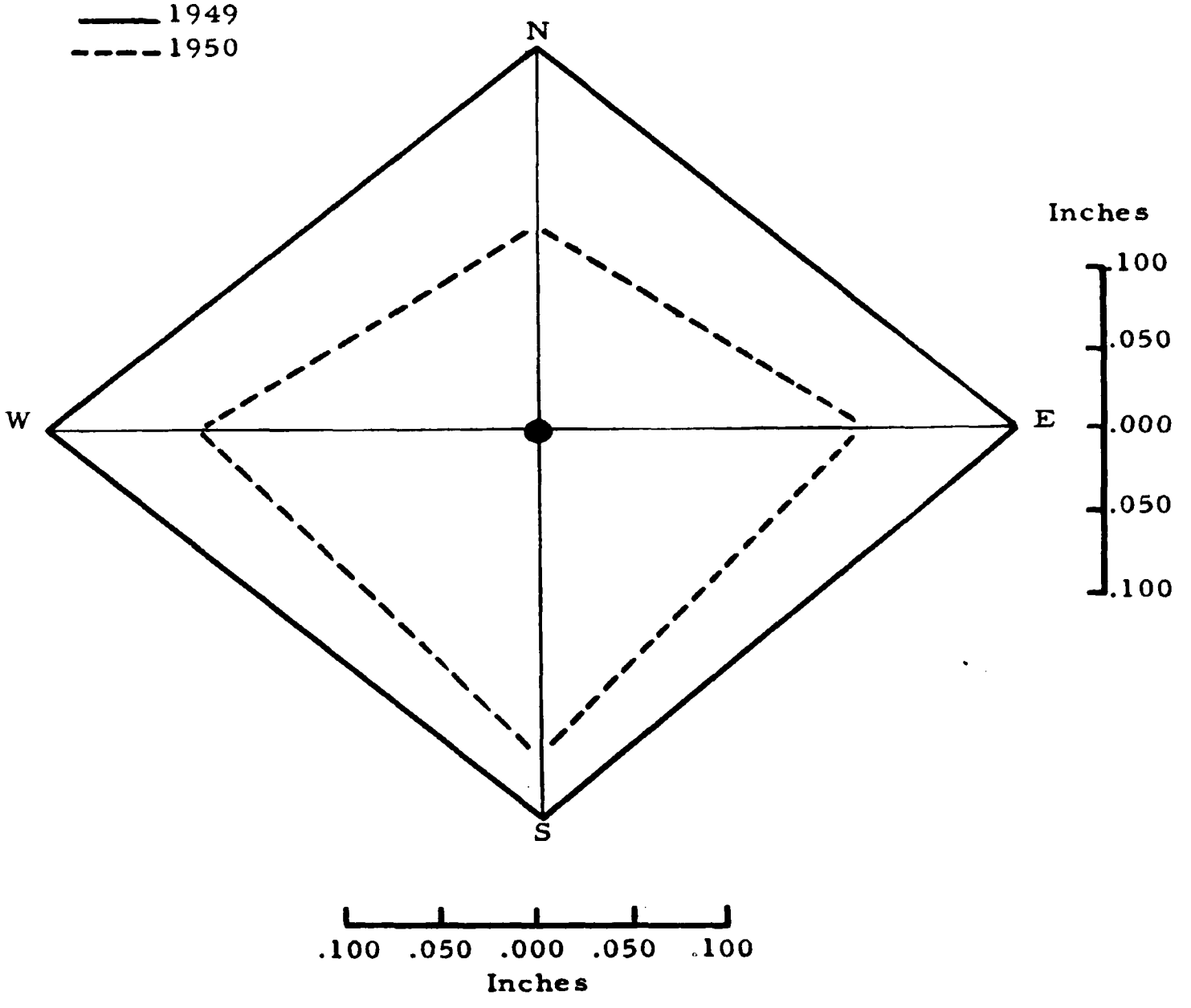


Figure 73. Total seasonal growth as measured along four radii. Tree 94.

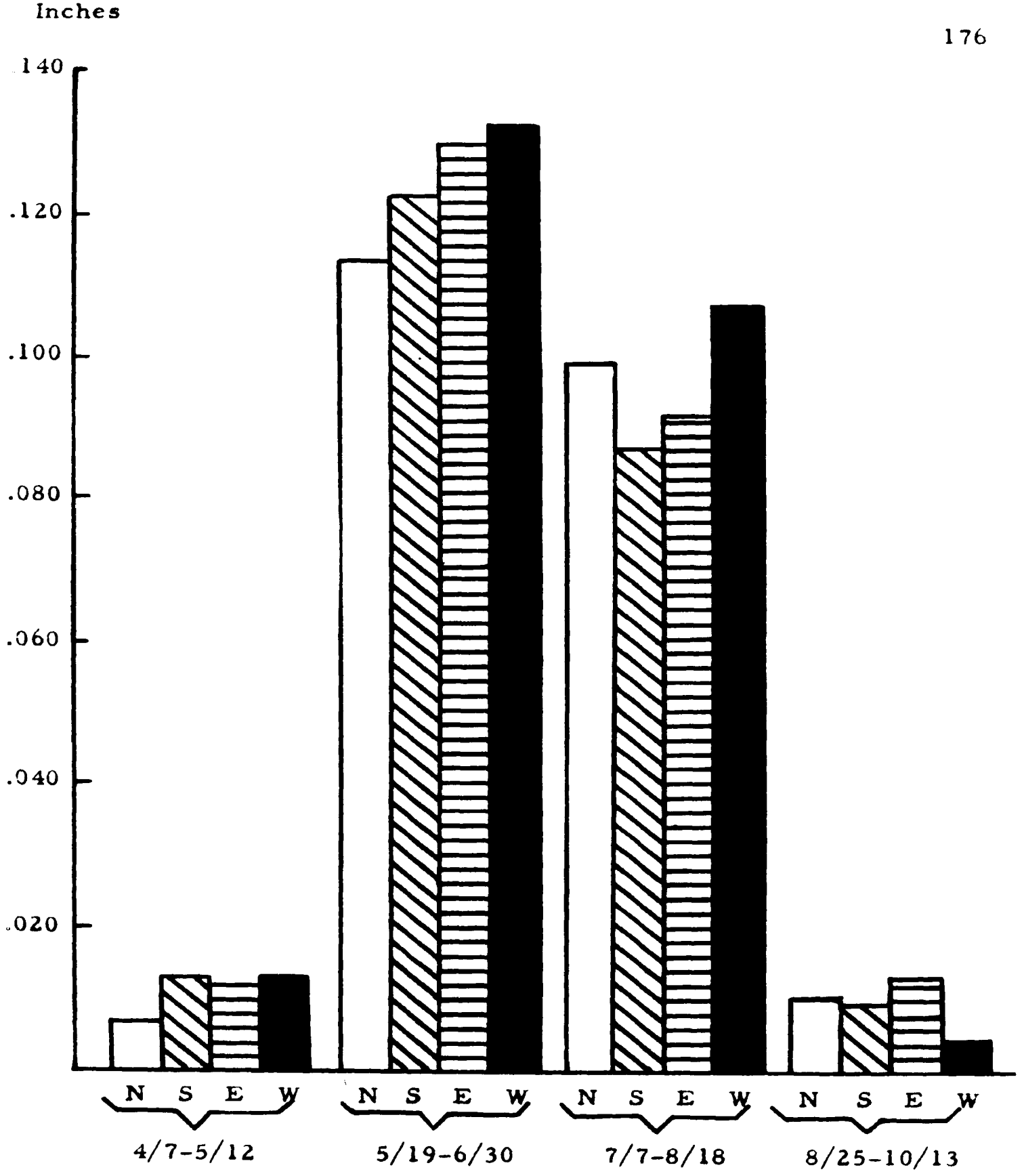


Figure 74. Growth accumulation over specified seasonal periods. Tree 94. 1949.

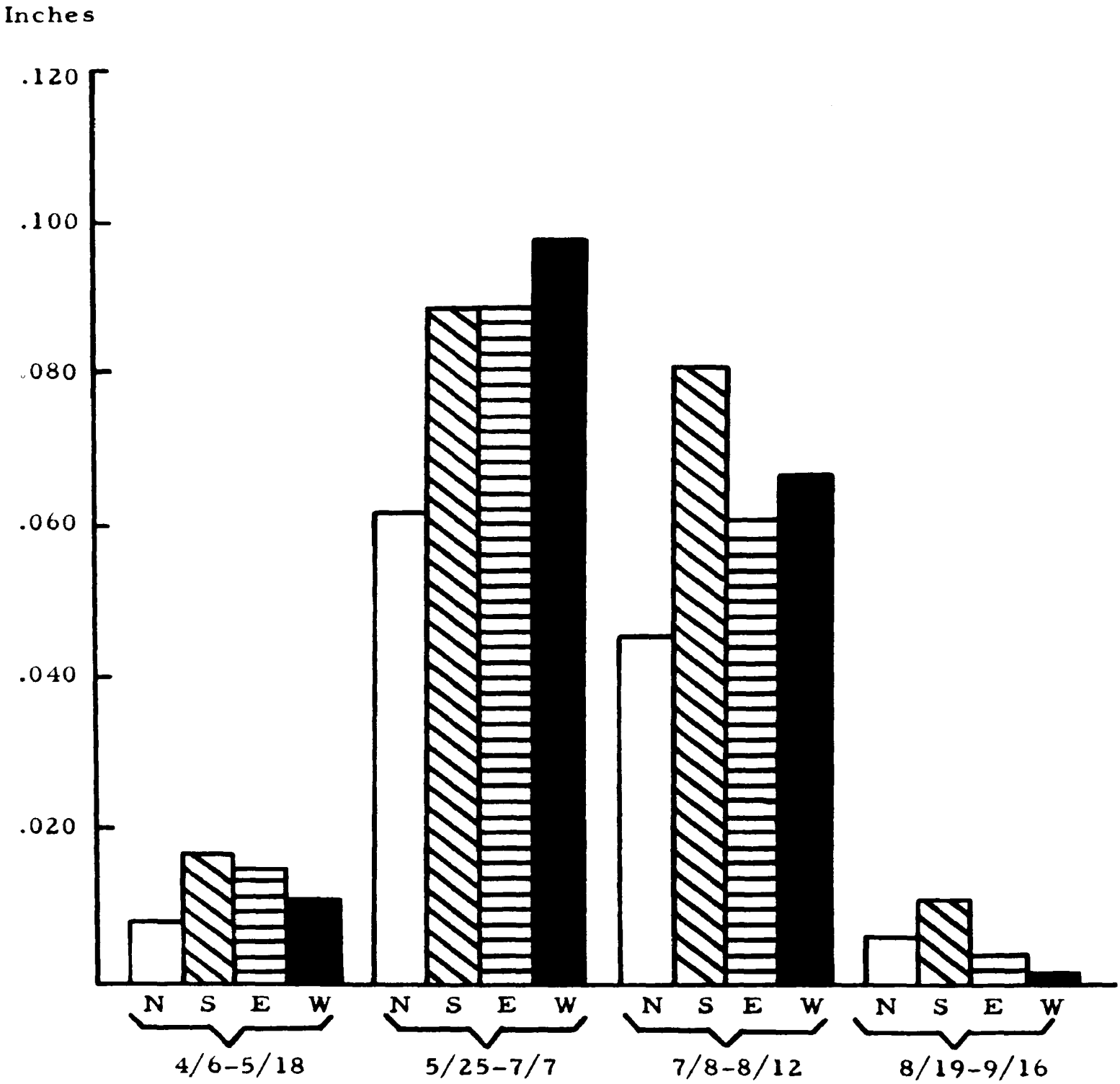


Figure 75. Growth accumulation over specified seasonal periods. Tree 94. 1950.

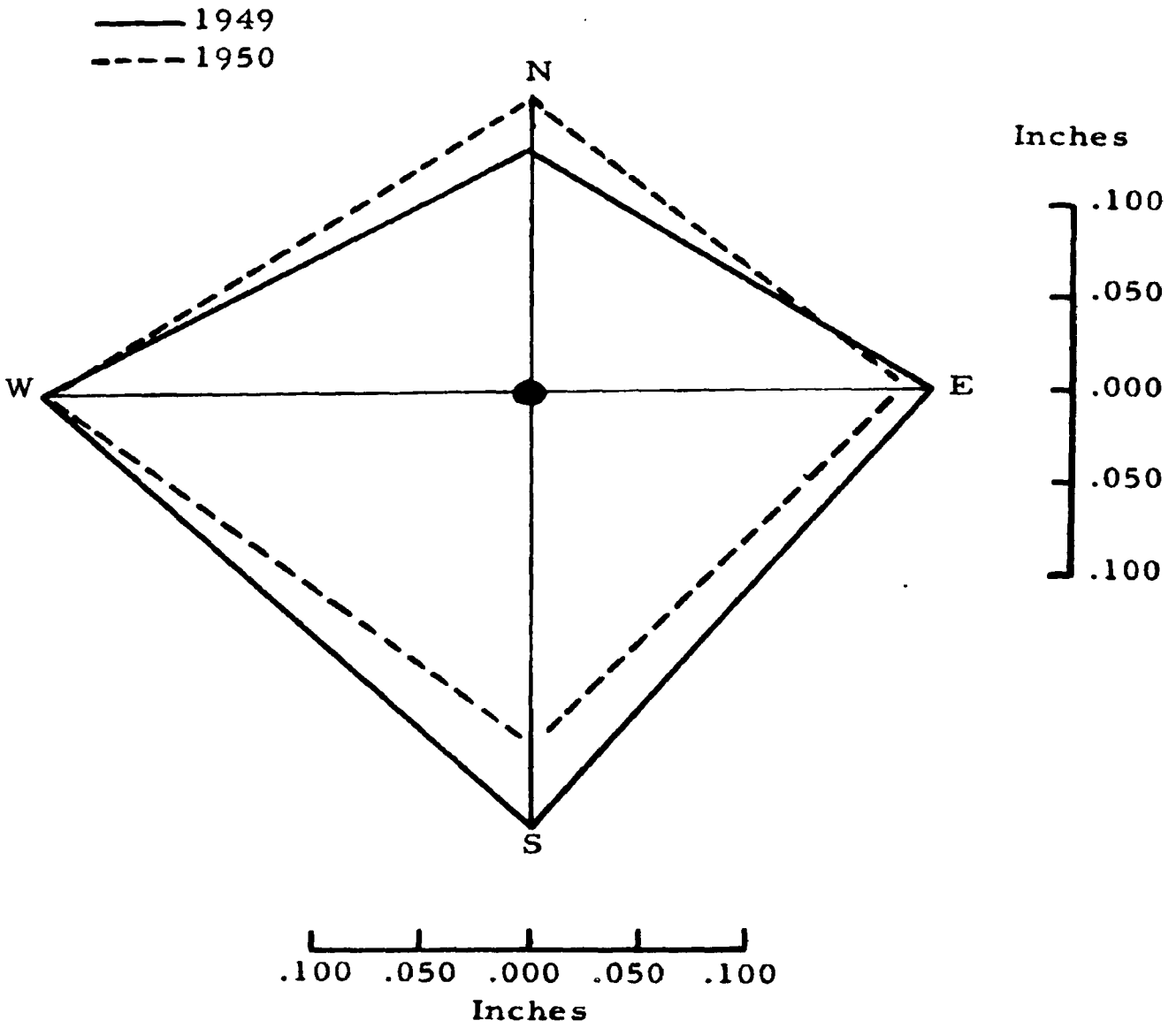


Figure 76. Total seasonal growth as measured along four radii. Tree 95.

direction. The small amount of increase during the period from July 1 to August 12, 1950, on the north side made for less total growth in 1950 (Figure 78). In 1949, the north radius was consistently less than the other three (Figure 77).

Tree 96

Located with an east exposure, this tree exhibited eccentric growth for both years, but not in the same manner. Growth for the year 1949 was greater along the east radius. The least amount was recorded along the west radius. In 1950, however, growth was about the same in every direction except along the south radius, which was the shortest radius of increase for that year (Figure 79). These features appeared throughout their respective seasons as seen from Figures 80 and 81.

Tree 97

This tree is located just east of a "blowdown" area in the north part of the woods. During 1949 an extremely small amount of increase was recorded for the east radius and a large amount of increase was recorded for the west, north and

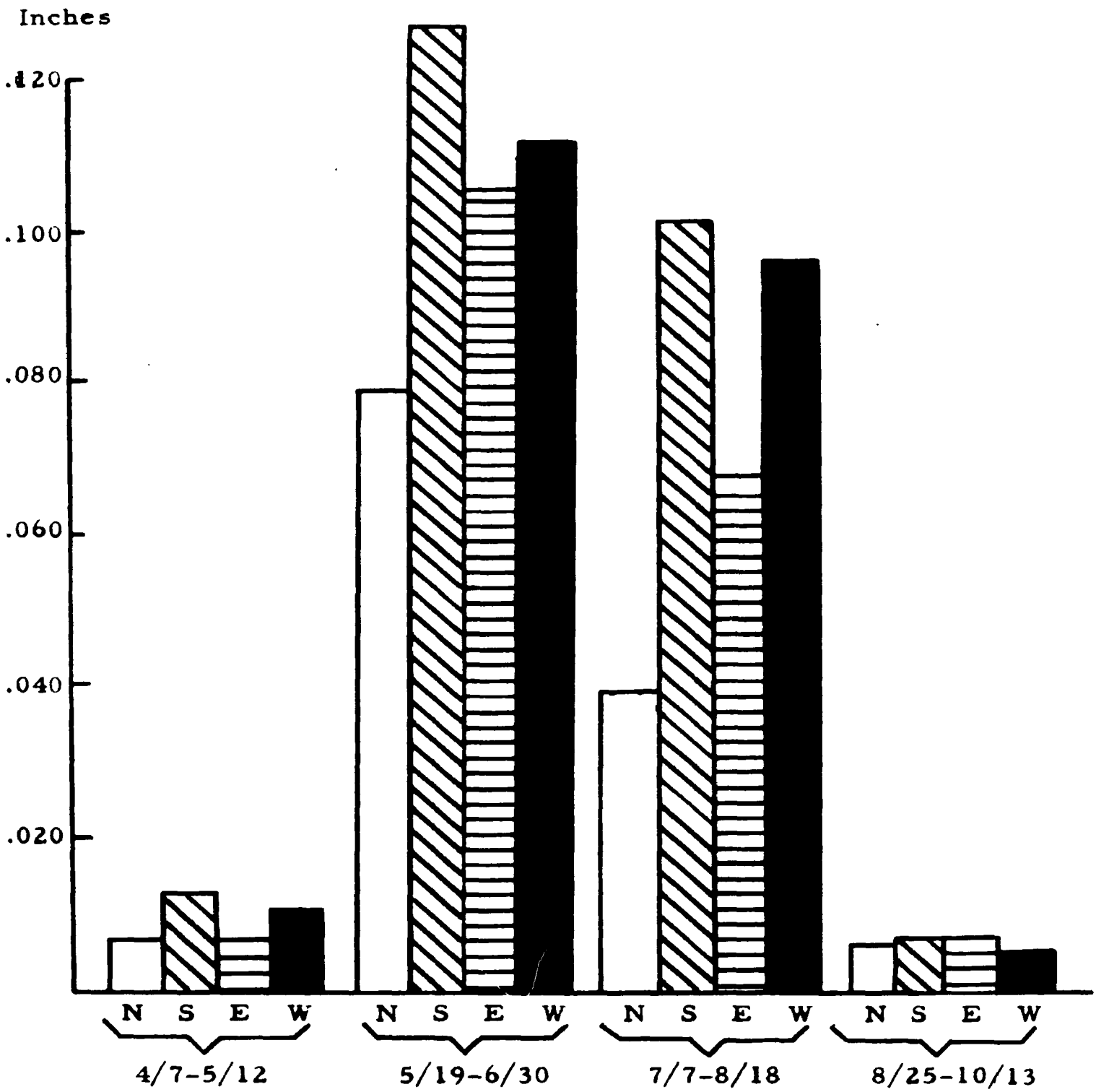


Figure 77. Growth accumulation over specified seasonal periods. Tree 95. 1949.

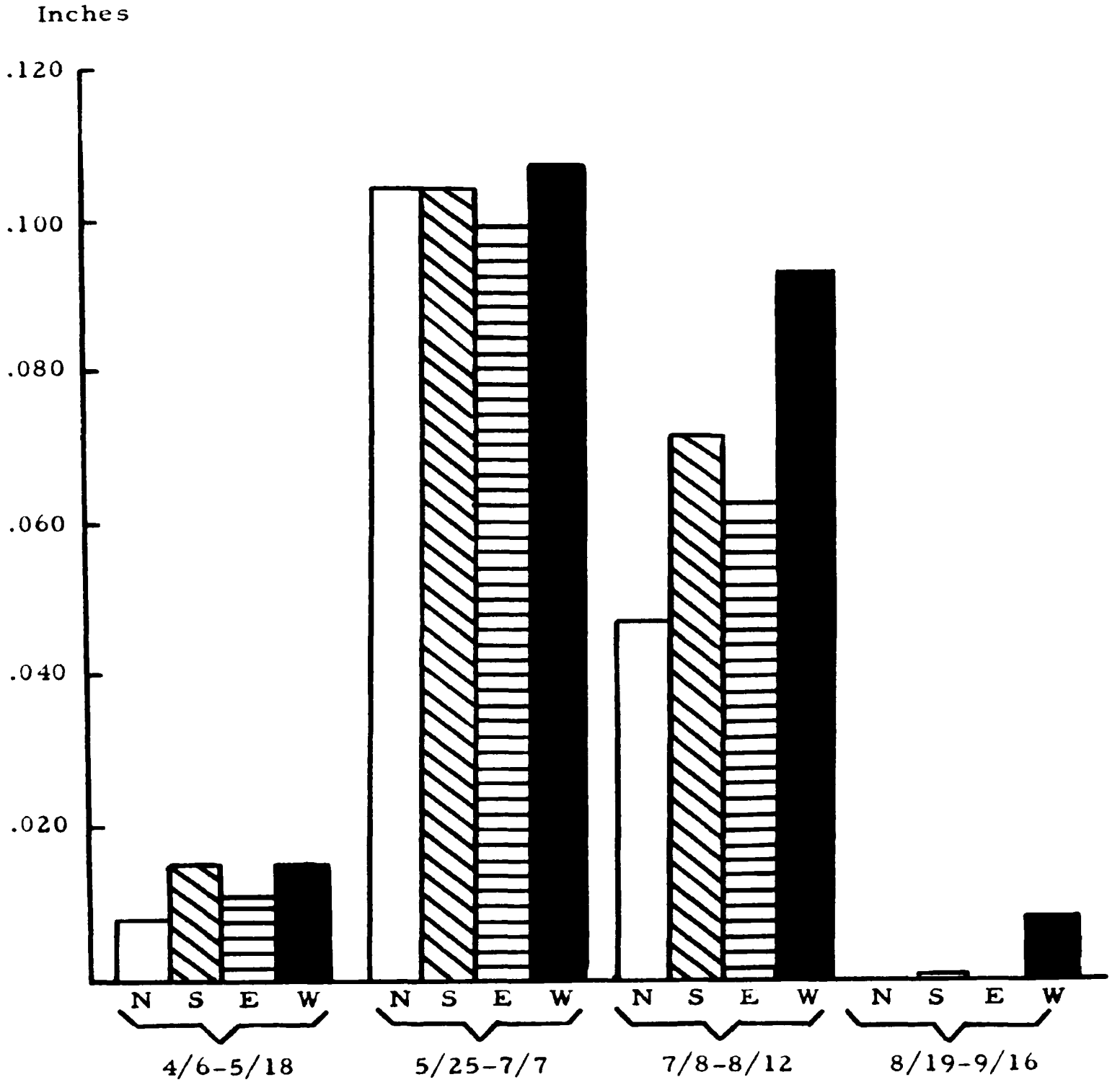


Figure 78. Growth accumulation over specified seasonal periods. Tree 95. 1950.

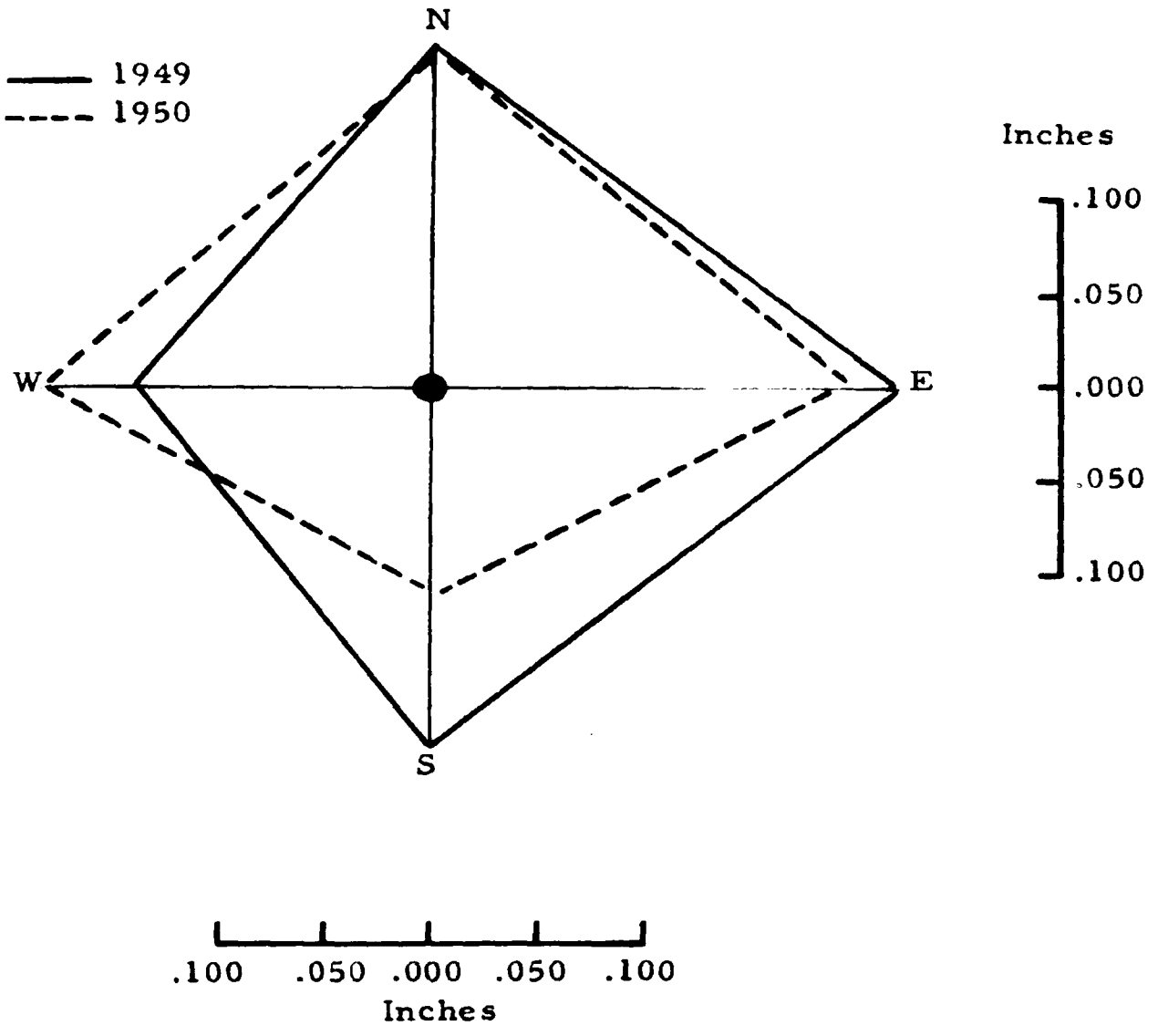


Figure 79. Total seasonal growth as measured along four radii. Tree 96.

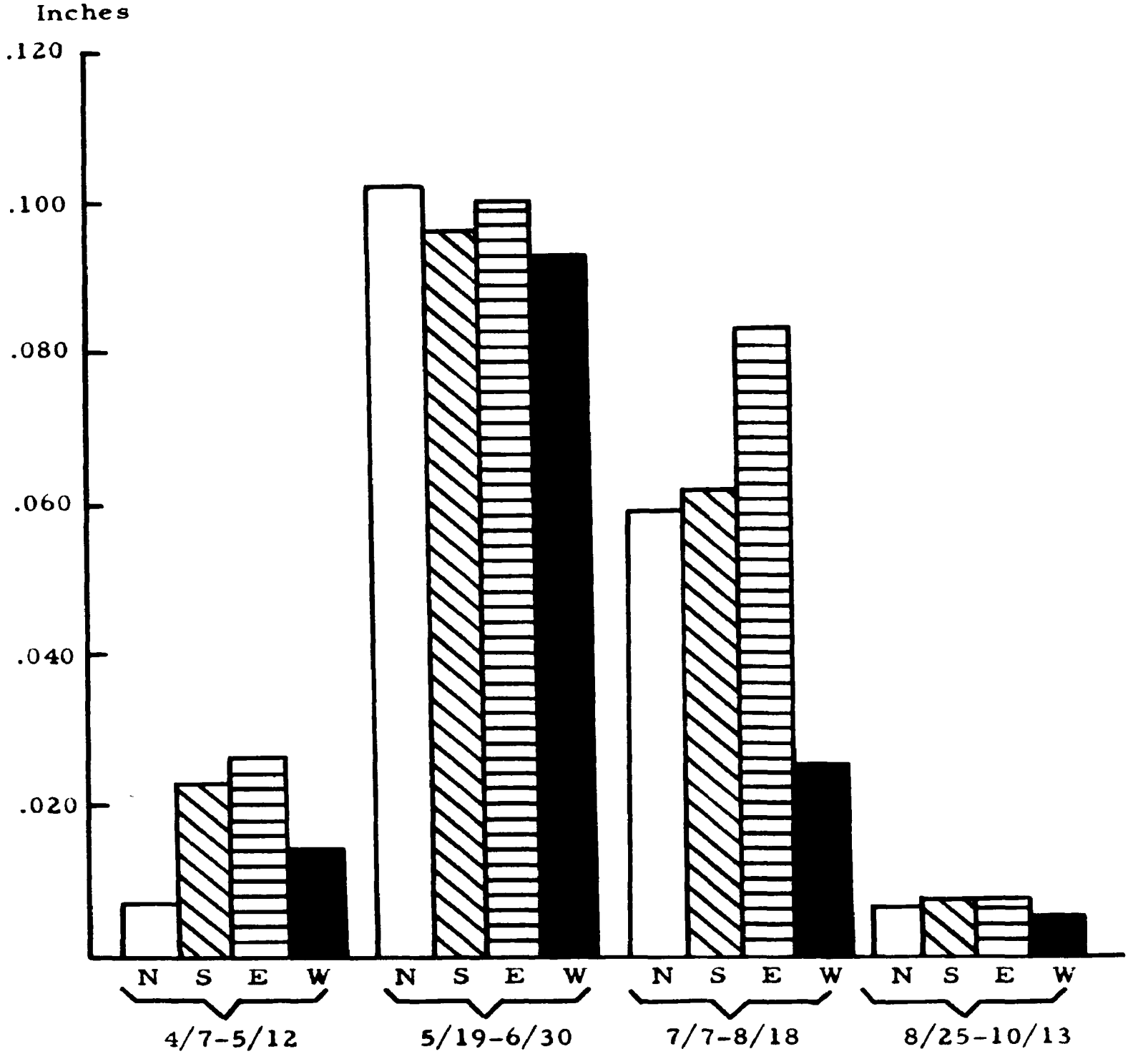


Figure 80. Growth accumulation over specified seasonal periods. Tree 96. 1949.

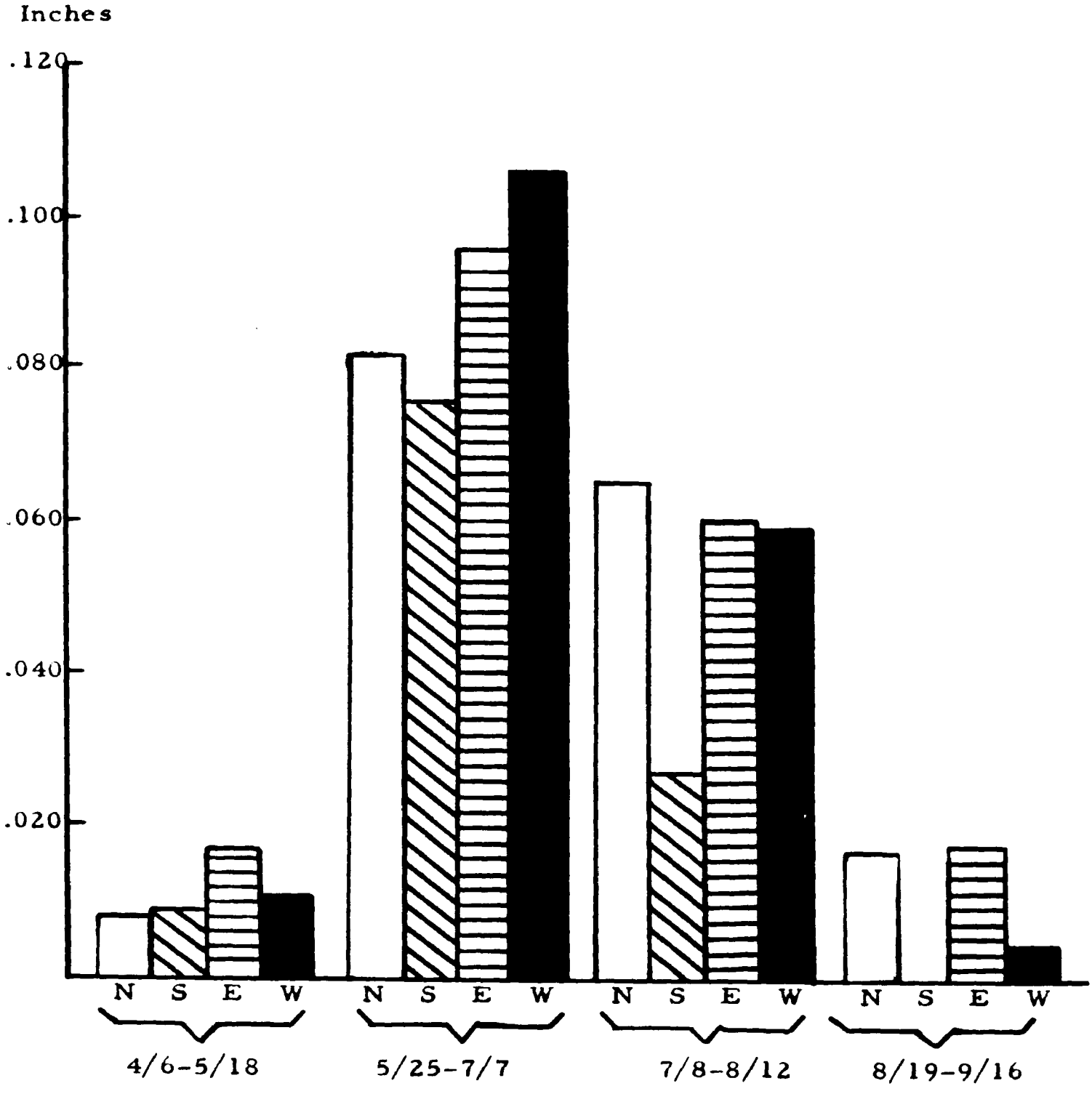


Figure 81. Growth accumulation over specified seasonal periods. Tree 96. 1950.

south radii. In 1950 the increases were practically the same on all four sides of the trunk (Figure 82). Figures 83 and 84 show the seasonal nature of this growth. The first period of growth indicates a greater increase along the south and east radii.

Tree 98

Growing just north of tree 97 (Figure 18), this tree was in the vicinity of the same "blowdown" but was a little farther removed from the area than was tree 97. For both years increases along the east-west axis were conspicuously greater than along the north-south axis (Figure 85). This was true for all portions of the year tabulated (Figures 86 and 87).

Tree 99

This was the only tree measured having a west exposure of leaves and branches (Figure 19). The exposure is not complete but is of such a nature as to receive direct sunlight in the afternoon hours. A relatively large amount of increase was recorded for 1949 and 1950 along all radii (Figure 88). The greatest increase, however, was along the west radius.

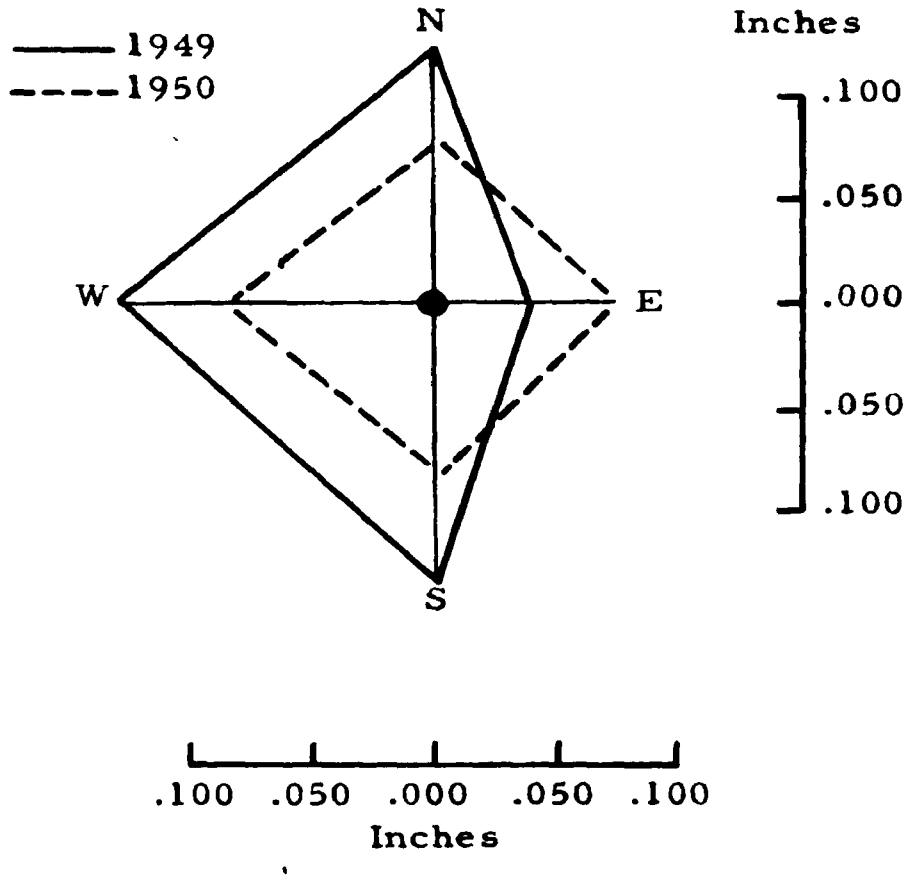


Figure 82. Total seasonal growth as measured along four radii. Tree 97.

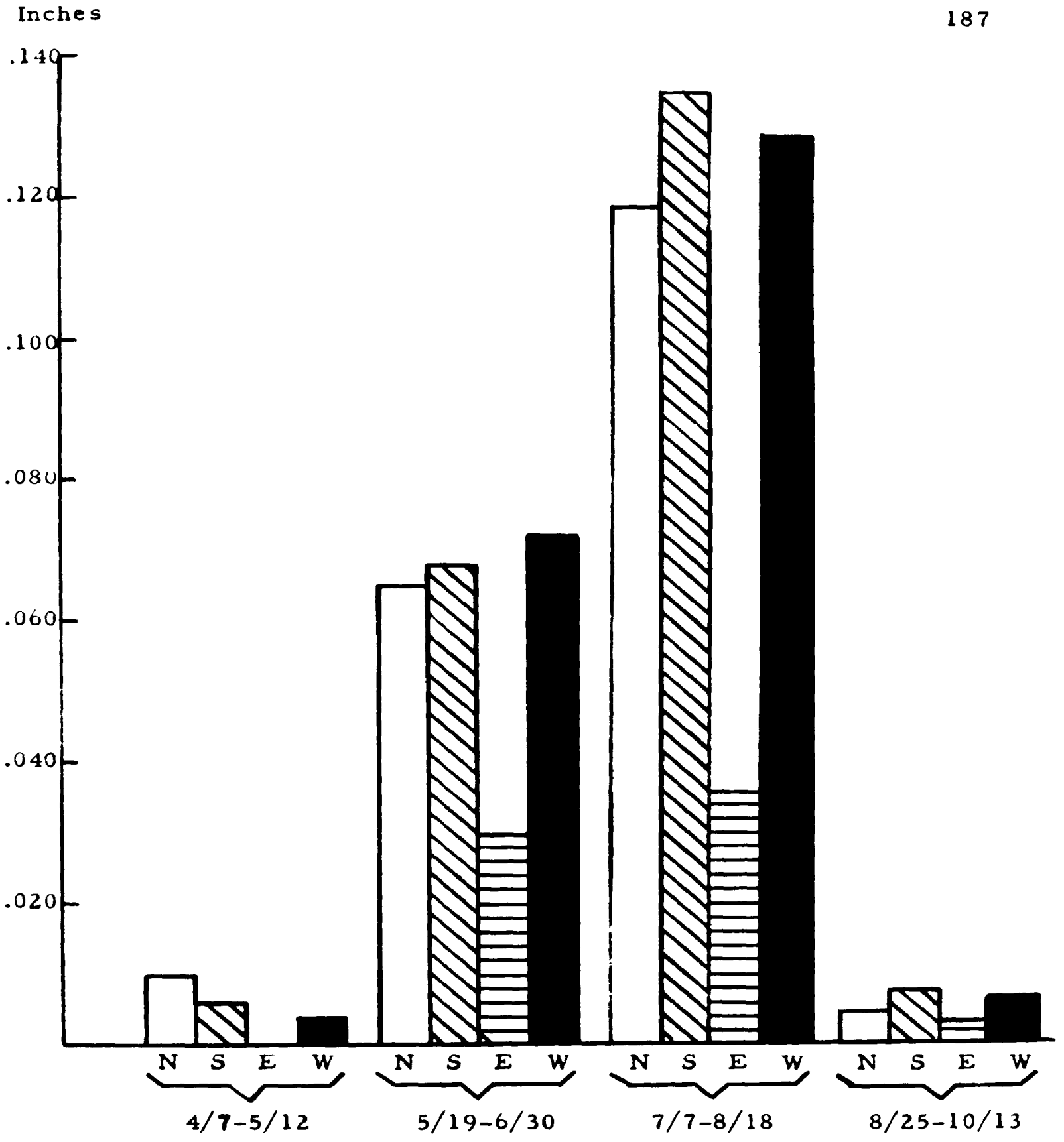


Figure 83. Growth accumulation over specified seasonal periods. Tree 97. 1949.

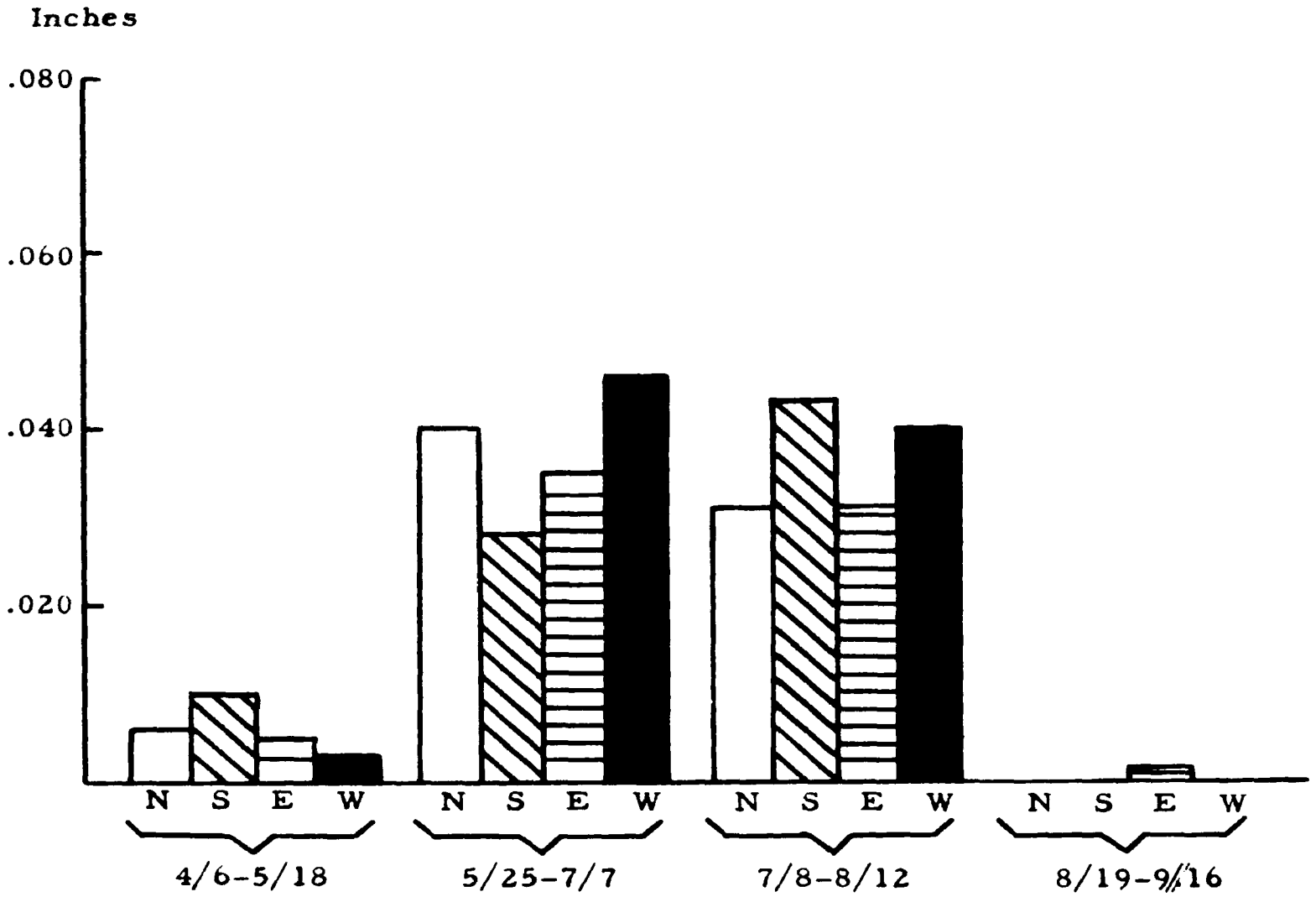


Figure 84. Growth accumulation over specified seasonal periods. Tree 97. 1950.

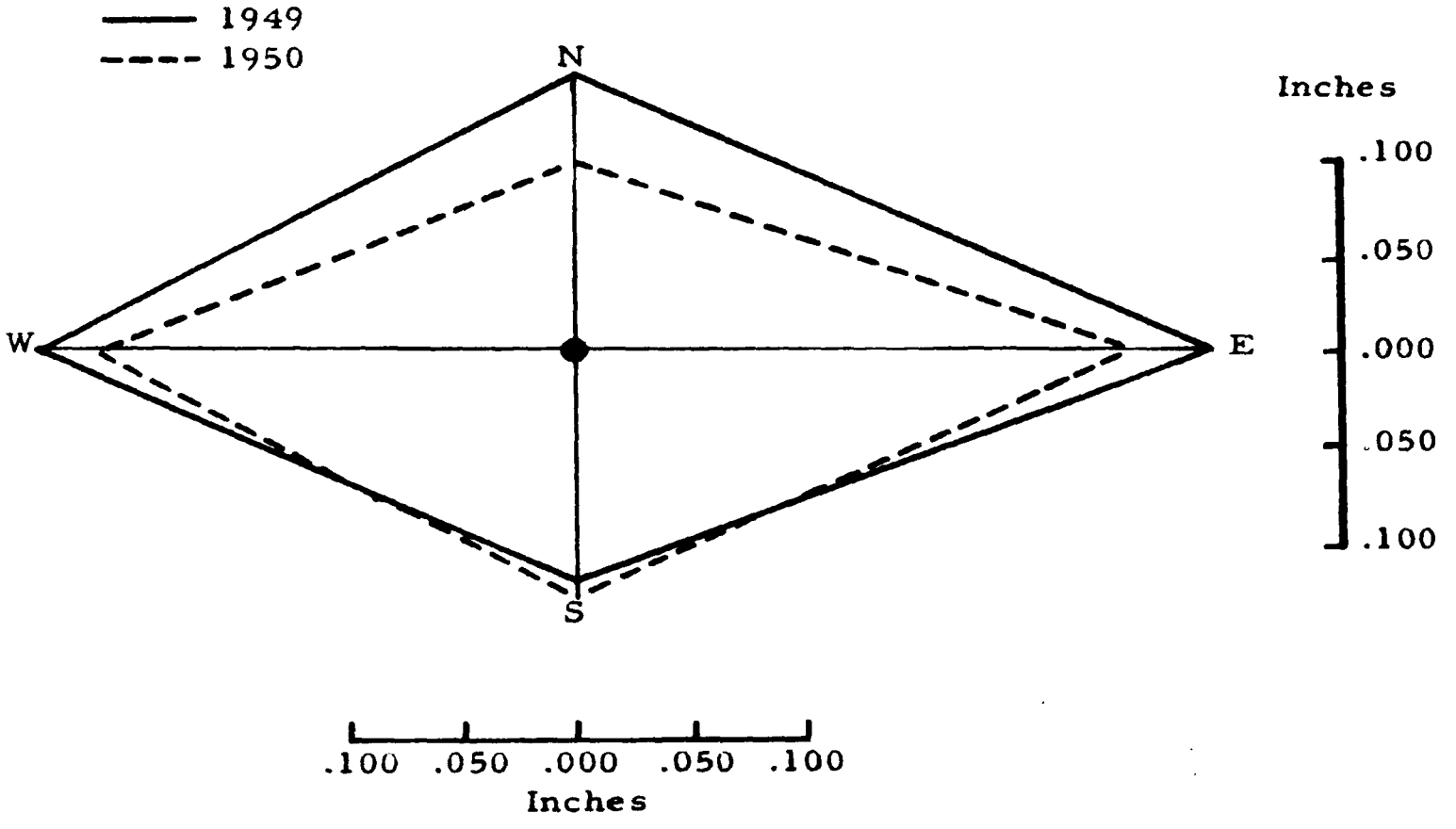


Figure 85. Total seasonal growth as measured along four radii. Tree 98.

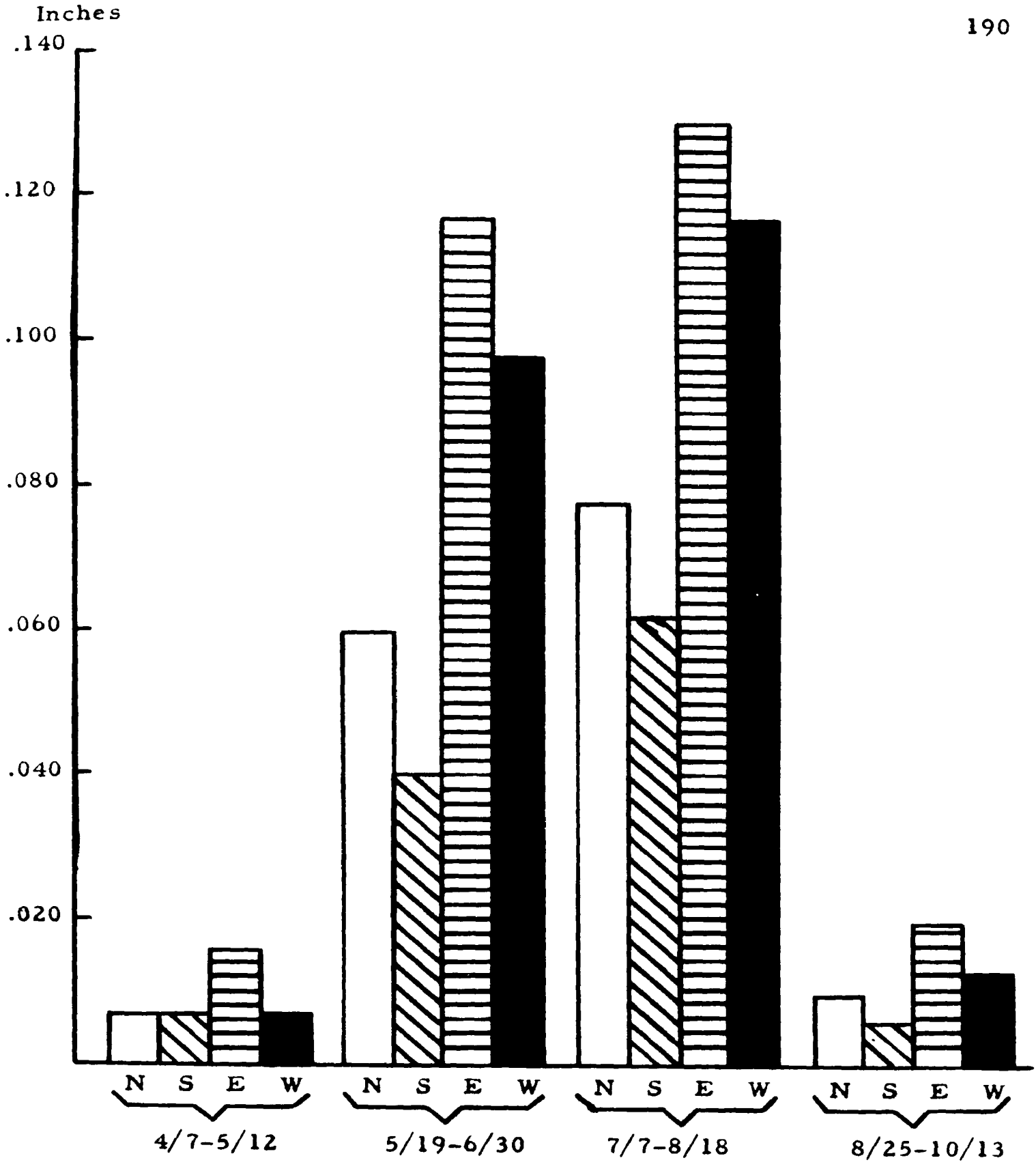


Figure 86. Growth accumulation over specified seasonal periods. Tree 98. 1949.

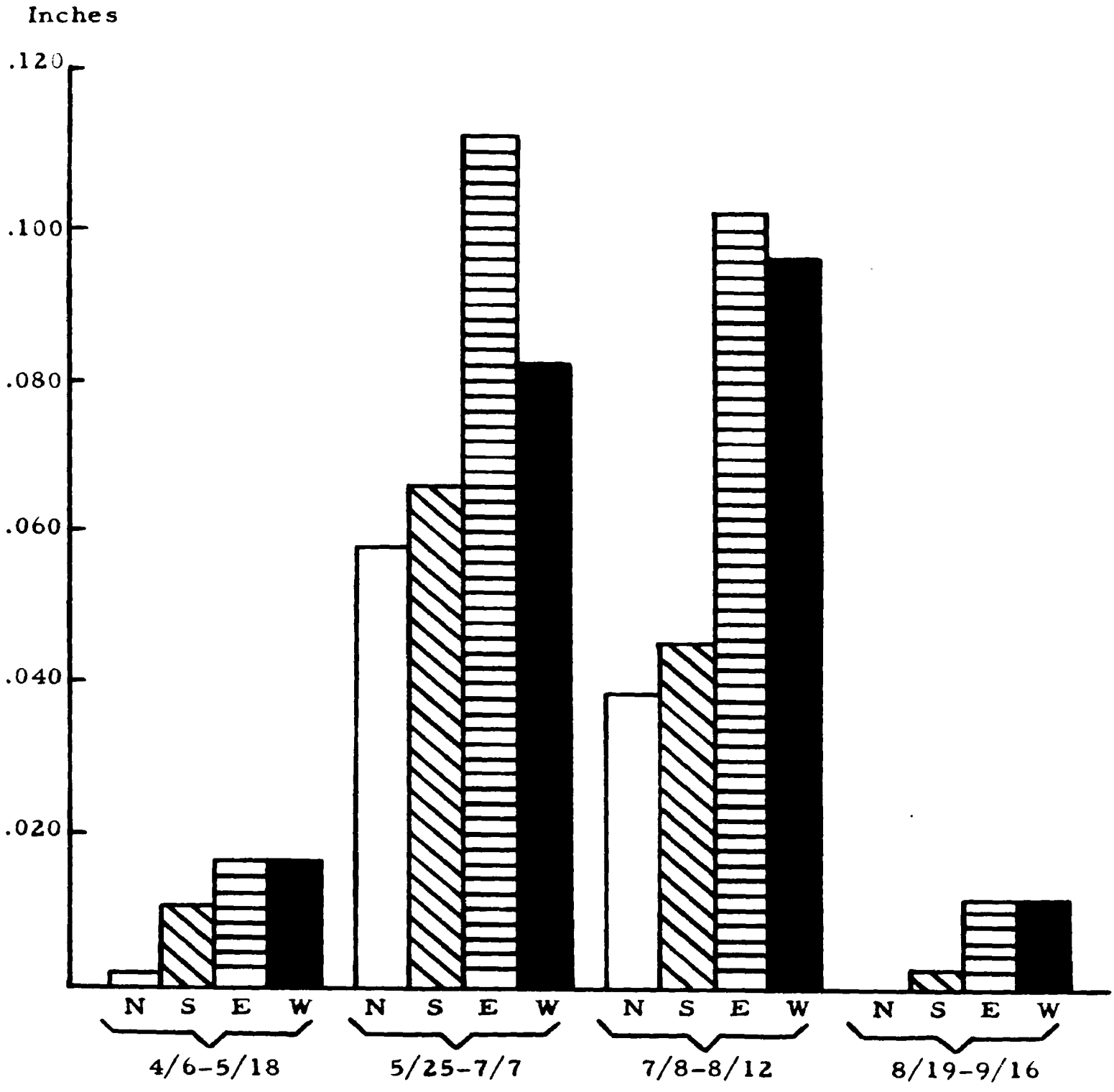
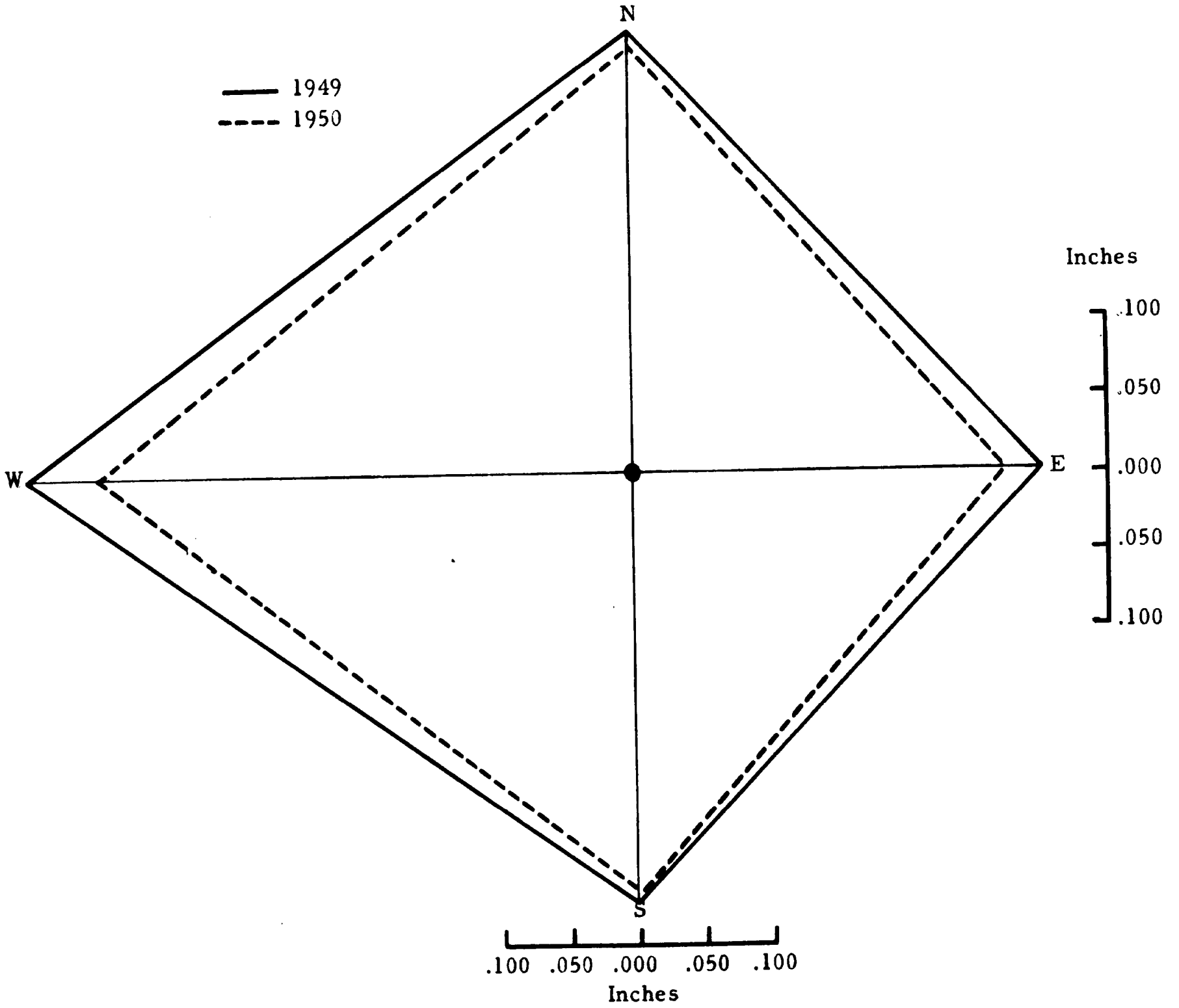


Figure 87. Growth accumulation over specified seasonal periods. Tree 98. 1950.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DBH measurements with calipers (Table II) indicate that eccentric growth has been occurring in an east-west plane for some time. Each portion of the season shows this same tendency (Figures 89 and 90).

The initial weeks of growth for 1949 and 1950 indicate that there was no greater growth on the south and east sides, as was found for those trees with south and east exposures. The greater early season increase occurred in tree 99 along the west radius.

Tree 100

Located within the woodlot and a part of a closed canopy (Figure 20), this large tree showed some tendencies toward greater growth in 1949 along the north and east radii. For 1950, increases were practically the same on all sides (Figure 91). There was no indication of an early season surge of growth on the south and east sides over the other two radii (Figures 92 and 93).

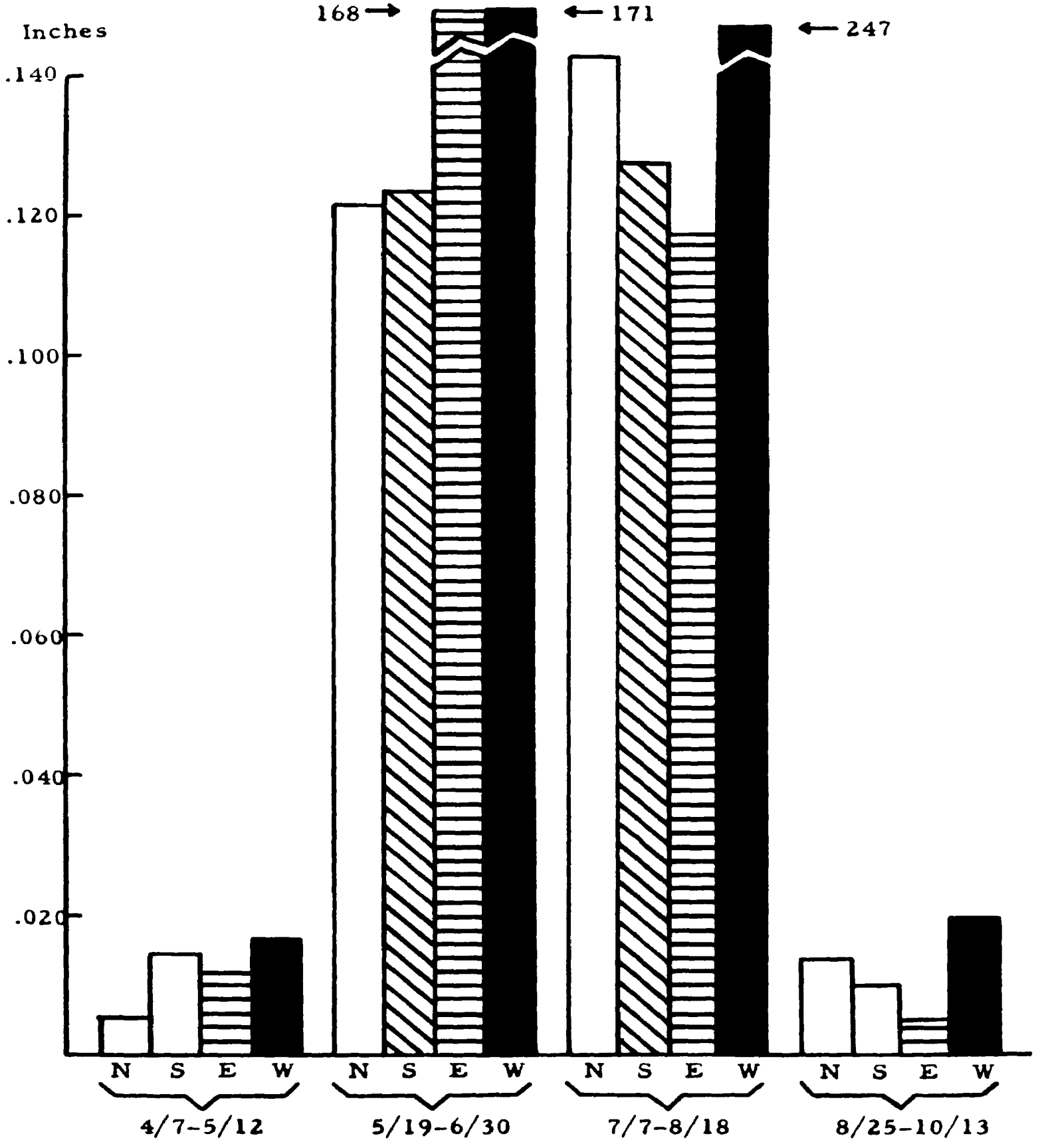

Figure 89. Growth accumulation over specified seasonal periods. Tree 99. 1949.

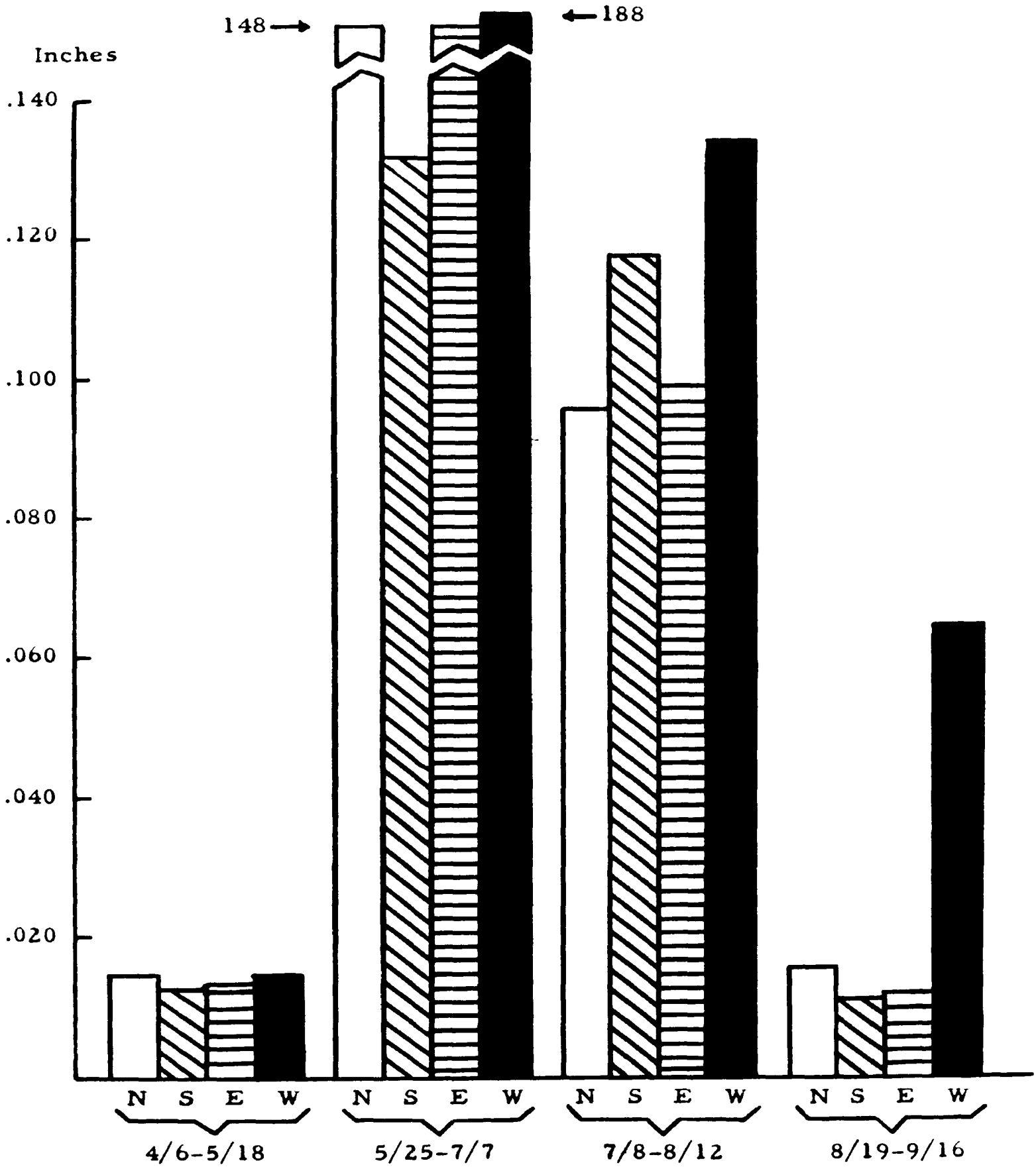

Figure 90. Growth accumulation over specified seasonal periods. Tree 99. 1950.

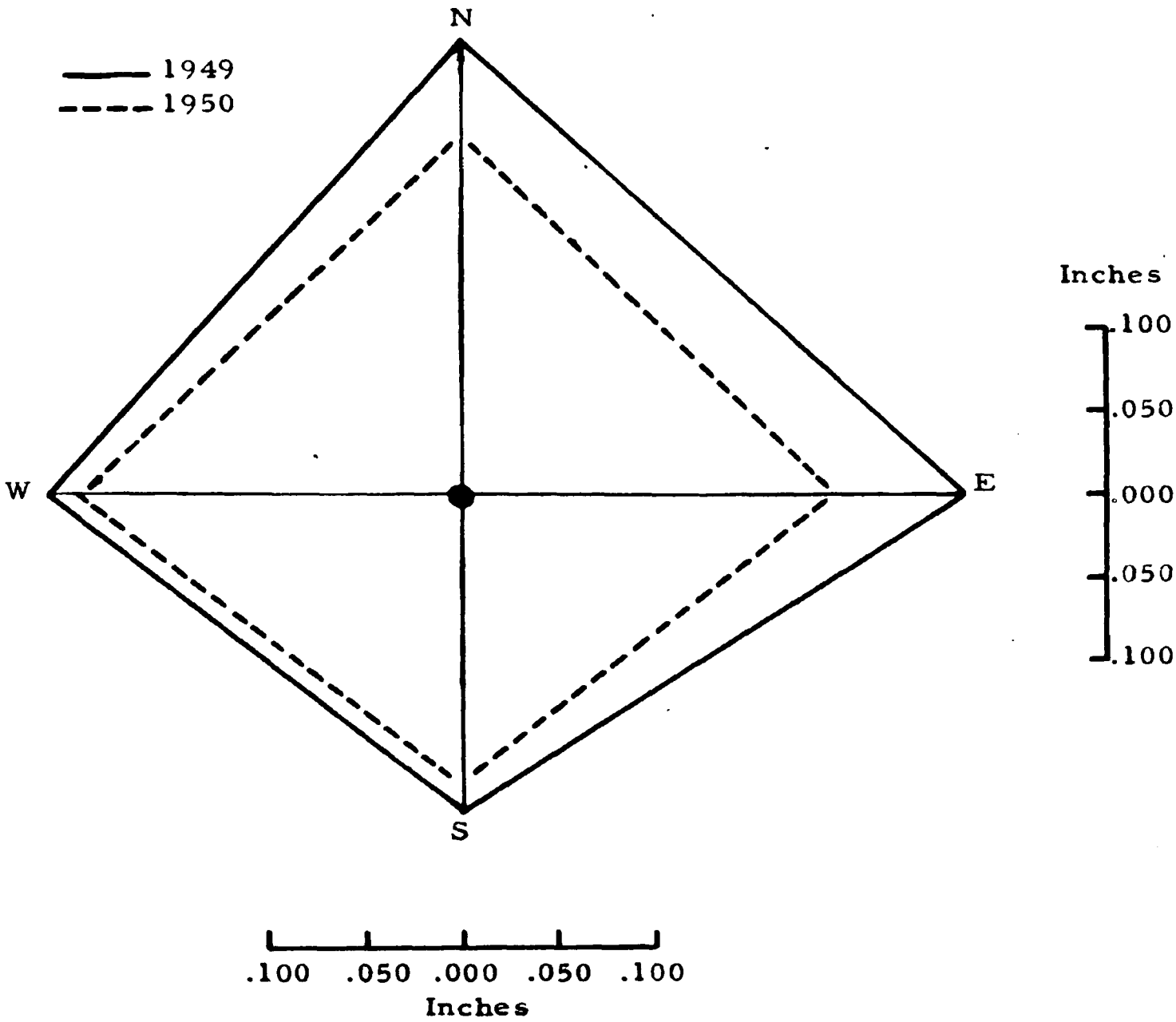

Figure 91. Total seasonal growth as measured along four radii. Tree 100.

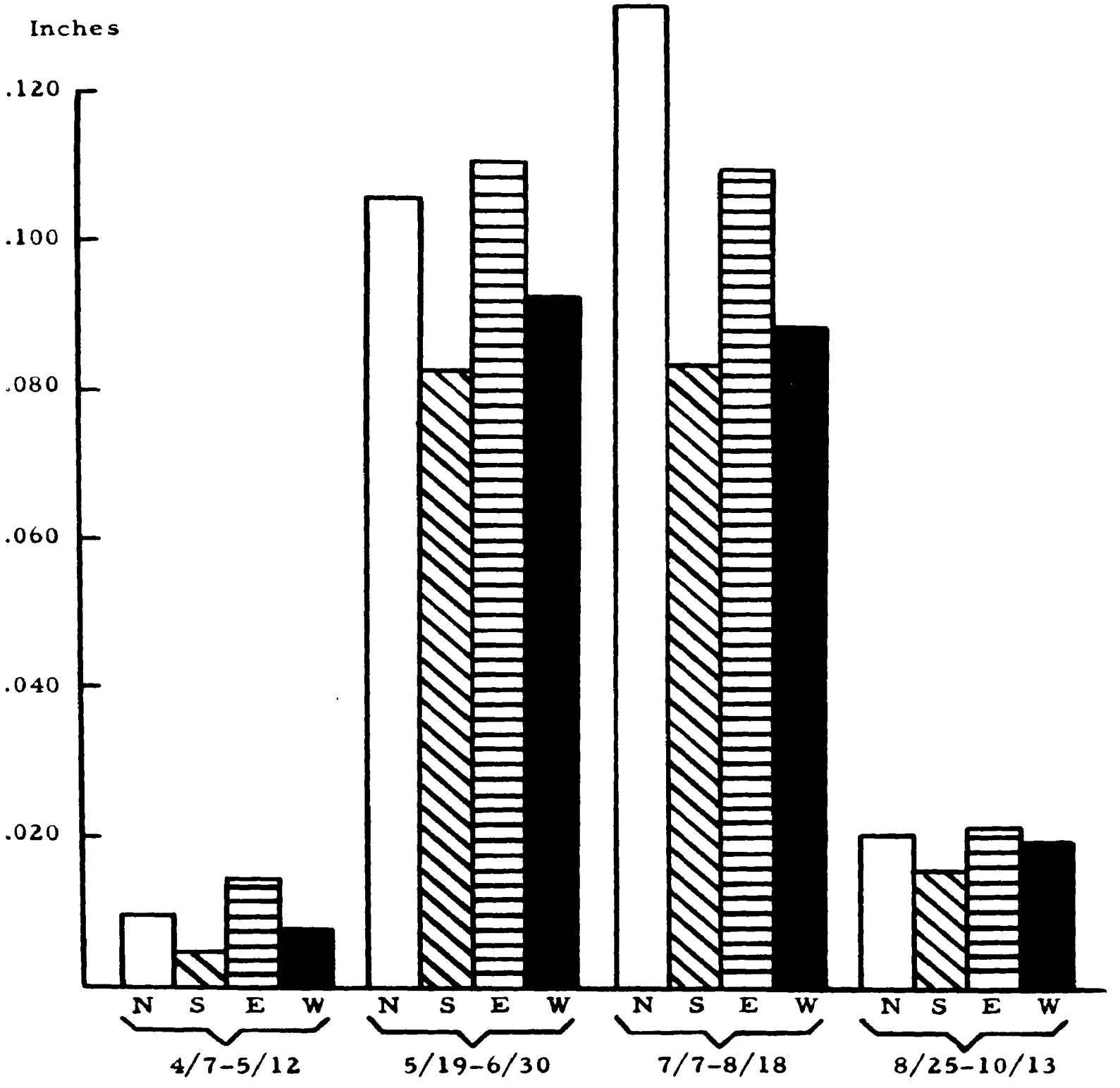

Figure 92. Growth accumulation over specified seasonal periods. Tree 100. 1949.

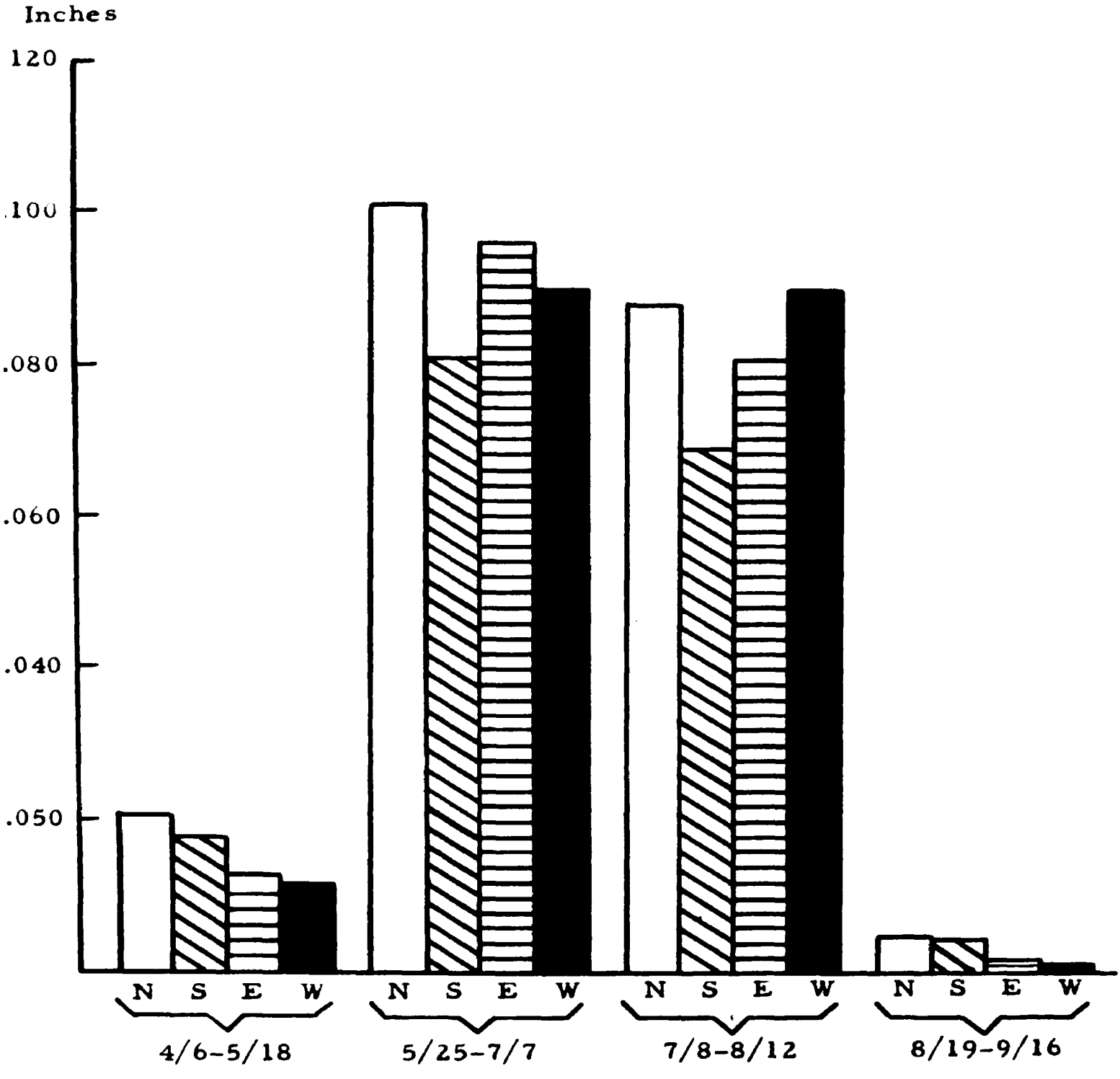

Figure 93. Growth accumulation over specified seasonal periods. Tree 100. 1950.

General Considerations

Trees growing along the extreme south edge of the woodlot (trees 91, 92, 93, 94, and 95), exhibited a much greater amount of branching from the south, southeast and southwest sides of the trunk than from the points on the opposite side of the tree. This can be seen in Figures 11, 12, 13, 14, 15a, 15b, and 16. It is well to remember this, especially in relationship to the quite varied growth patterns shown by these trees.

A similar situation applies to trees 96 and 99. The former (Figure 17a) has a predominance of branches entering the stem from an easterly direction; the latter has no branching extending from the east side of the trunk except at the very crown (Figure 19), yet the east side of tree 99 showed the second greatest increase of the four sides measured.

Figures 64, 67, 70, 73, 76, 79, 82, 85, 88, and 91 all indicate a lesser amount of growth for 1950 than for 1949. In some cases this reduced an eccentric growth pattern to an almost entirely symmetrical pattern (tree 97). In other cases the pattern of eccentric growth was changed, growth being unequal in another direction (tree 96). In tree 94, a relatively

symmetrical growth pattern for 1949 was changed to an asymmetrical pattern for 1950. In trees 93 and 99, the pattern was affected only insofar as the diamond representing growth for 1950 was smaller.

Comparative Observations on Data from the Hydrologic Station and Data Taken in Toumey Woodlot

It was possible in 1950 to secure an entire season's measurements of soil moisture in Toumey Woodlot. Comparing the results obtained in the woodlot with the figures secured from readings taken at the hydrologic station (Figures 41 and 42), it is apparent that serious differences occurred throughout the season. Soil moisture at the hydrologic station (12-inch level) was never above that of the woodlot. It is true that the blocks buried at the hydrologic station were in Conover loam while the blocks buried in Toumey Woodlot were in Hillsdale sandy loam; yet both of these soils, being in the same soil series, do not differ to any great extent from each other. Conover loam is probably a little heavier than Hillsdale sandy loam. Blocks at the hydrologic station were situated in an open field—another difference to be taken into account.

Both locations showed a general trend of moisture decline in August but "plateaus" were apparent in the woodlot which did not appear in the hydrologic station data (Figures 41 and 42). Data from the "edge" stations conformed more satisfactorily with the hydrologic station data for both 1949 and 1950, yet even here the dips in the former were not as severe and recovery was to a higher degree than in the latter case (Figures 59, 60 and 61).

Figures 29 and 30 show the soil temperatures from these two locations. In general, the soil temperature of the woodlot was consistently below that of the hydrologic station except during the early part of the 1950 season when the reverse was true. This would not be too surprising in the light of previous investigations on temperature relationships within a wooded area (Wolfe et al., 1943).

Other Observations on Soil Moisture

Because the soil moisture readings at the three-foot level showed less fluctuation than those at the one-foot level, comparisons of these readings with the radial growth were not

deemed necessary. The curve of soil-moisture availability at the three-foot level is presented in Figures 59b and 61.

Single readings were selected out of the data on soil moisture at the hydrologic station and plotted against the weekly average of daily readings taken from the same location. The dates selected from the data corresponded with the day of moisture readings taken in the woodlot. Results are presented in Figures 94 and 95. The indication is that there is a very slight difference in the curve of available moisture; that single readings at seven-day intervals presented about the same picture of the available water as did continuous daily readings.

Mention has been made by Morrow (1950) that most of the absorbing roots are in the upper part of the "mantle." Using this as a basis, Morrow limited his study of the roots of sugar maple to the upper one inch of soil.

The author realizes the possibility that this might be the most "critical" area for water and mineral absorption and further that the moisture at the depths measured might have had little or no relationship to the water regime of the plant. Yet on the basis of Figures 21a, 21b, 21c, 22, 23a and 23b, and also on the basis of observations made while burying

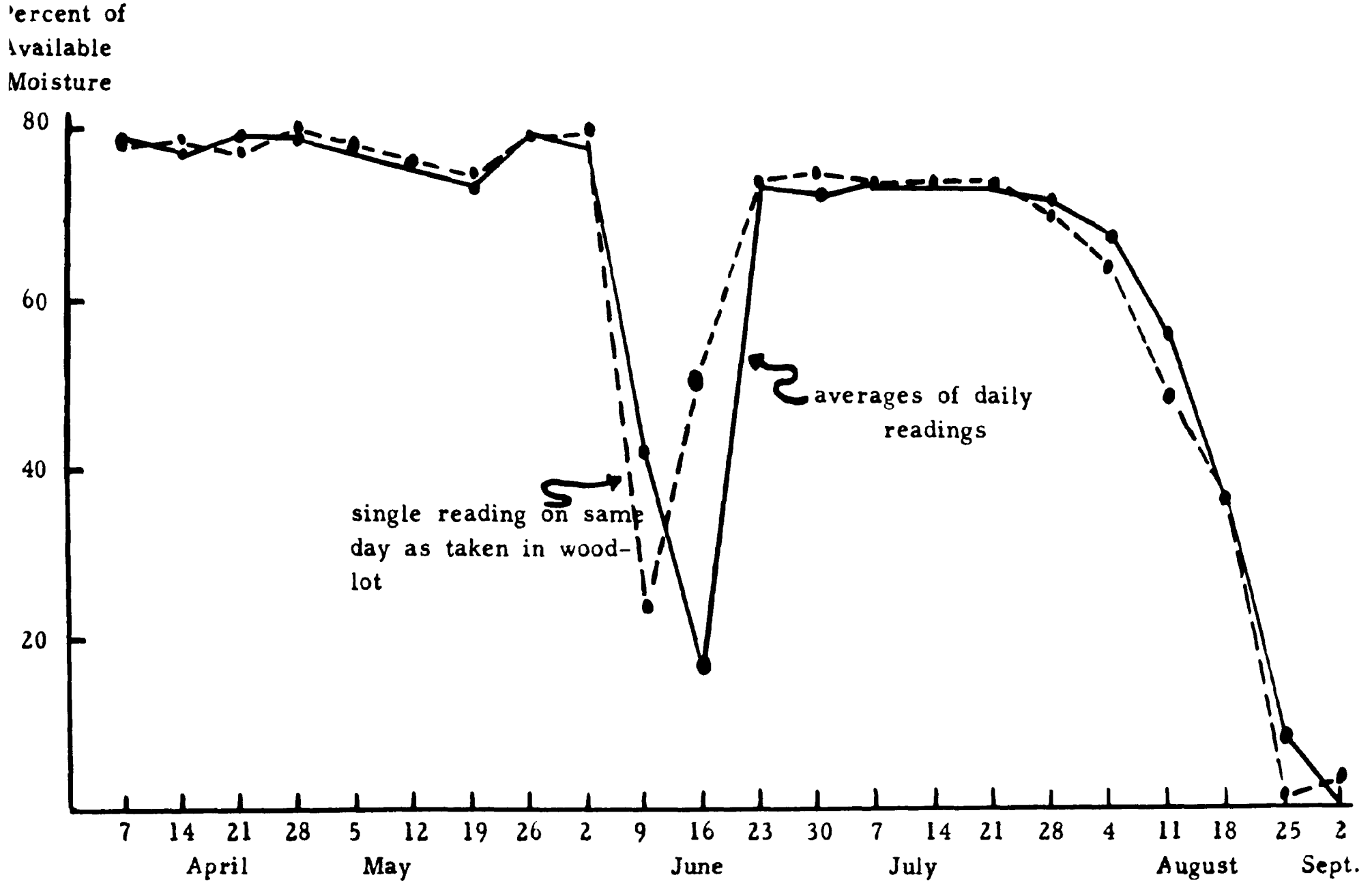

Figure 94. Soil moisture at the hydrologic station. Single weekly readings compared with weekly averages of daily readings. 1949.

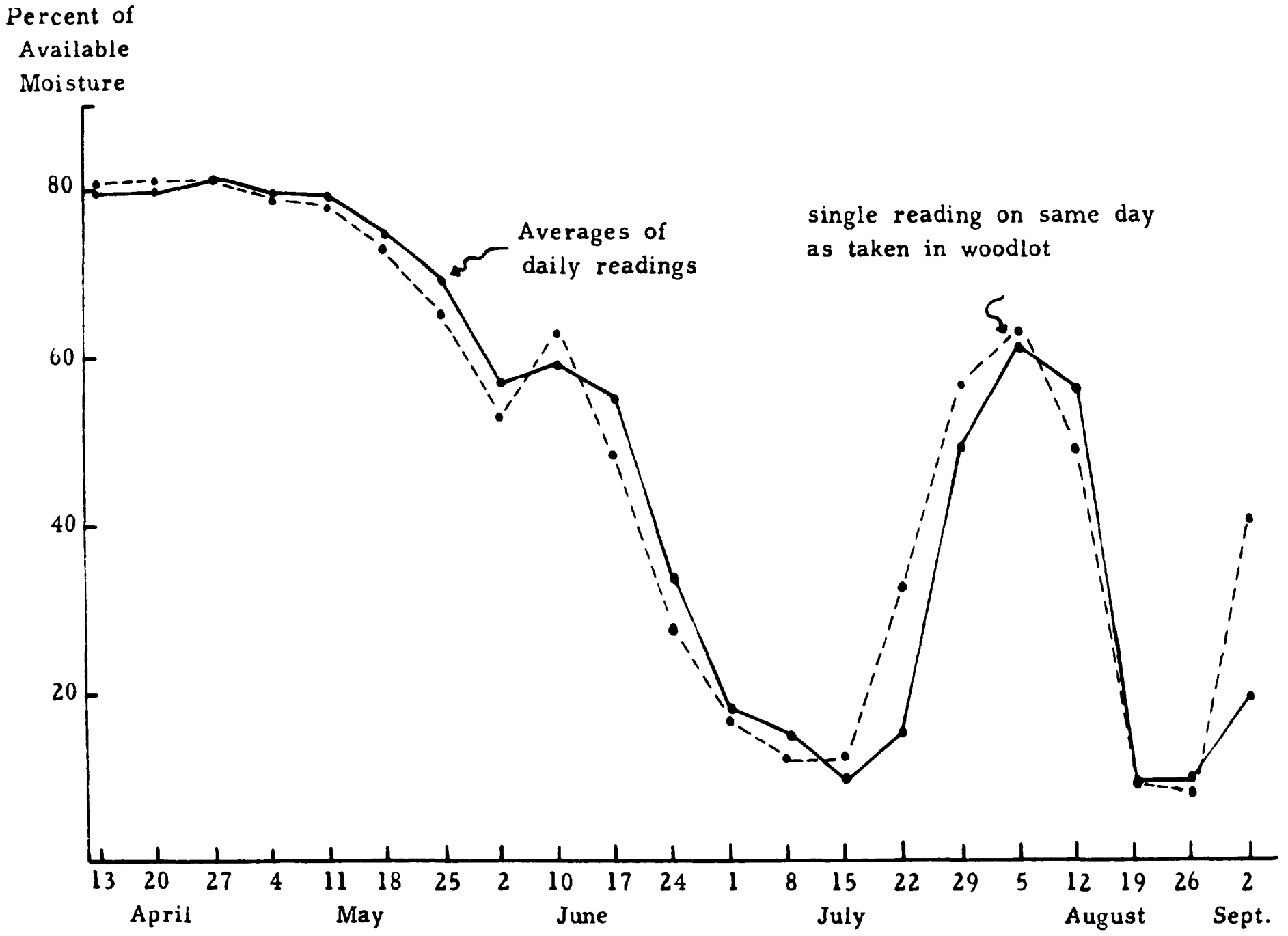

Figure 95. Soil moisture at the hydrologic station. Single weekly readings compared with weekly averages of daily readings. 1950.

the soil blocks, it seems quite possible that in Hillsdale sandy loam a good share of both secondary and small absorbing roots are present throughout the first 10 to 14 inches of soil.

The extention of larger roots below this depth in this particular soil would indicate that some kind of root activity occurs well into the B horizon. A generally high amount of soil water in both the one- and three-foot levels, together with a soil whose texture is fine granular and friable sandy to clay loam sometimes mixed with a little gravel, would allow for such penetration.

Soil moisture observations by Friesner and Ek (1944) in an Acer-Quercus-Fagus community in Indiana indicate a much more rigorous habitat in the 12-inch level than found in Toumey Woodlot. During the entire growing season they found that "growth water" never exceeded 20 percent at the 12-inch level. Further, in the 6-inch level and at the surface increasingly greater amounts of available water were recorded. It would be easier to find cause for concentration of absorbing roots in the very top levels under these circumstances and correlations might be good here.

Even if the same condition held for the absorbing roots of sugar maple in Toumey Woodlot; i.e., that they are concentrated at or near the surface, it would seem that from the results of Friesner and Ek (1944), and Cundiff (1949), that an even higher amount of available moisture would be present in the soil of Toumey Woodlot at the surface.

This would mean that at this top level soil moisture would be very close to 90 to 100 percent available moisture for the entire growing season. This would indicate no more than the results from the 12-inch level indicates.

A final observation should be made on the soil moisture stations established at the south border of the woodlot, stations 20A and 20AA. The former was buried at the 12-inch level at the very edge under the shade of a tree forming the boundary between the woods and the adjoining field. Block 20AA (12-inch depth) was placed outside of the edge in the open field. Tables VIII and X show clearly that the wilting coefficient was reached first at Station 20A. In fact, moisture conditions were much better in the field than at this edge station for nearly every period during which readings were taken.

Back Dating of Environmental Data

Figures 96 and 97 show the growth rate fluctuations exhibited by Size Class II trees in comparison with soil temperature, soil moisture, solar radiation, precipitation and evaporation. In this comparison the weekly periods for the environmental data have been calculated such that they ended 48 hours before the conclusion of the weekly period for growth. Thus, the environmental data have been back dated in an attempt to determine whether or not this might be a more desirable period for comparison of these factors with the growth rate. The results, as presented by Figures 96 and 97, seem not to be as satisfactory for comparison as the results plotted for the same period of time (Figures 30, 32, 36 and 42).

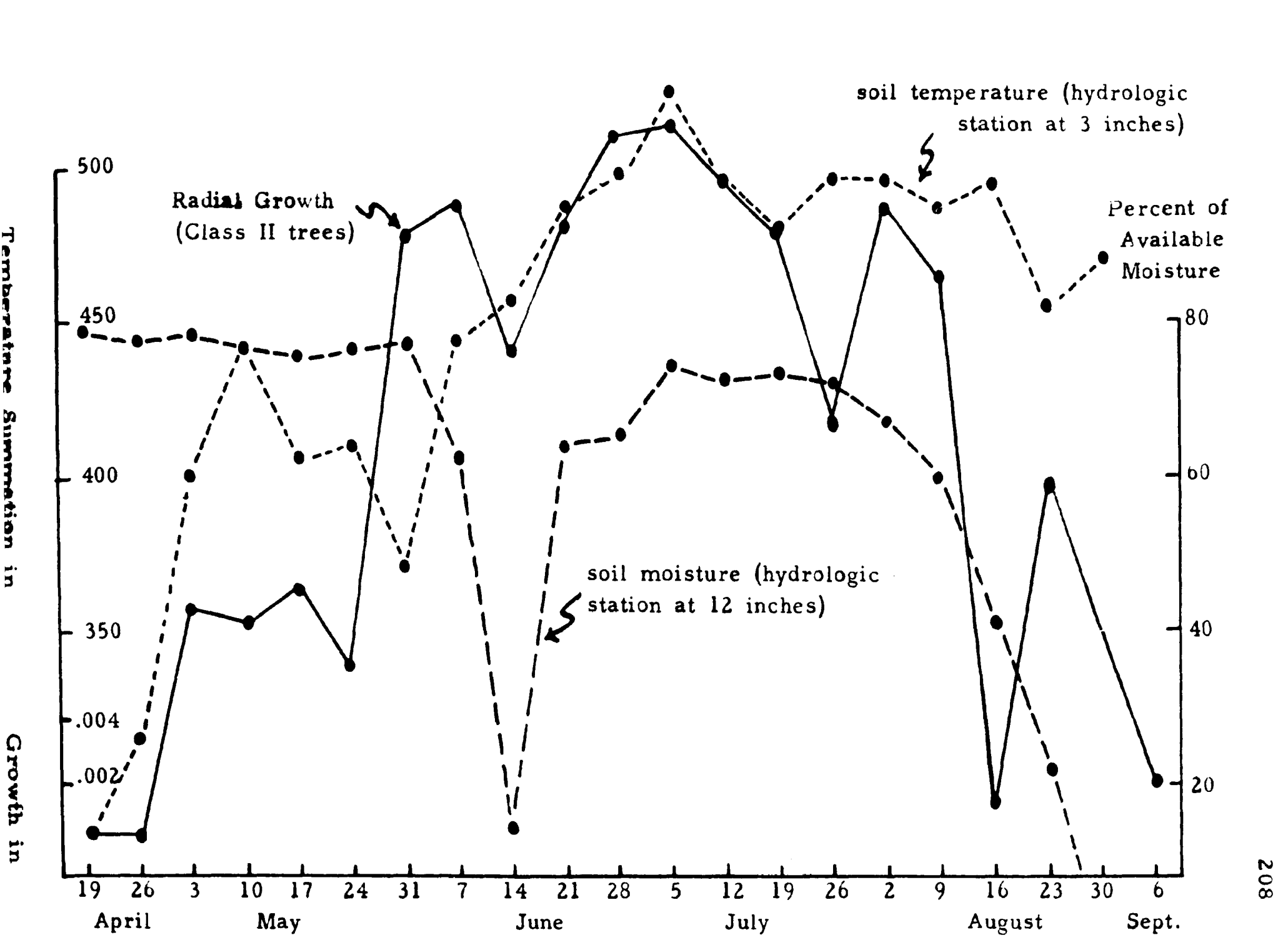

Figure 96. Radial growth - soil moisture, soil temperature comparison. Environmental data back dated by 48 hours. 1949.

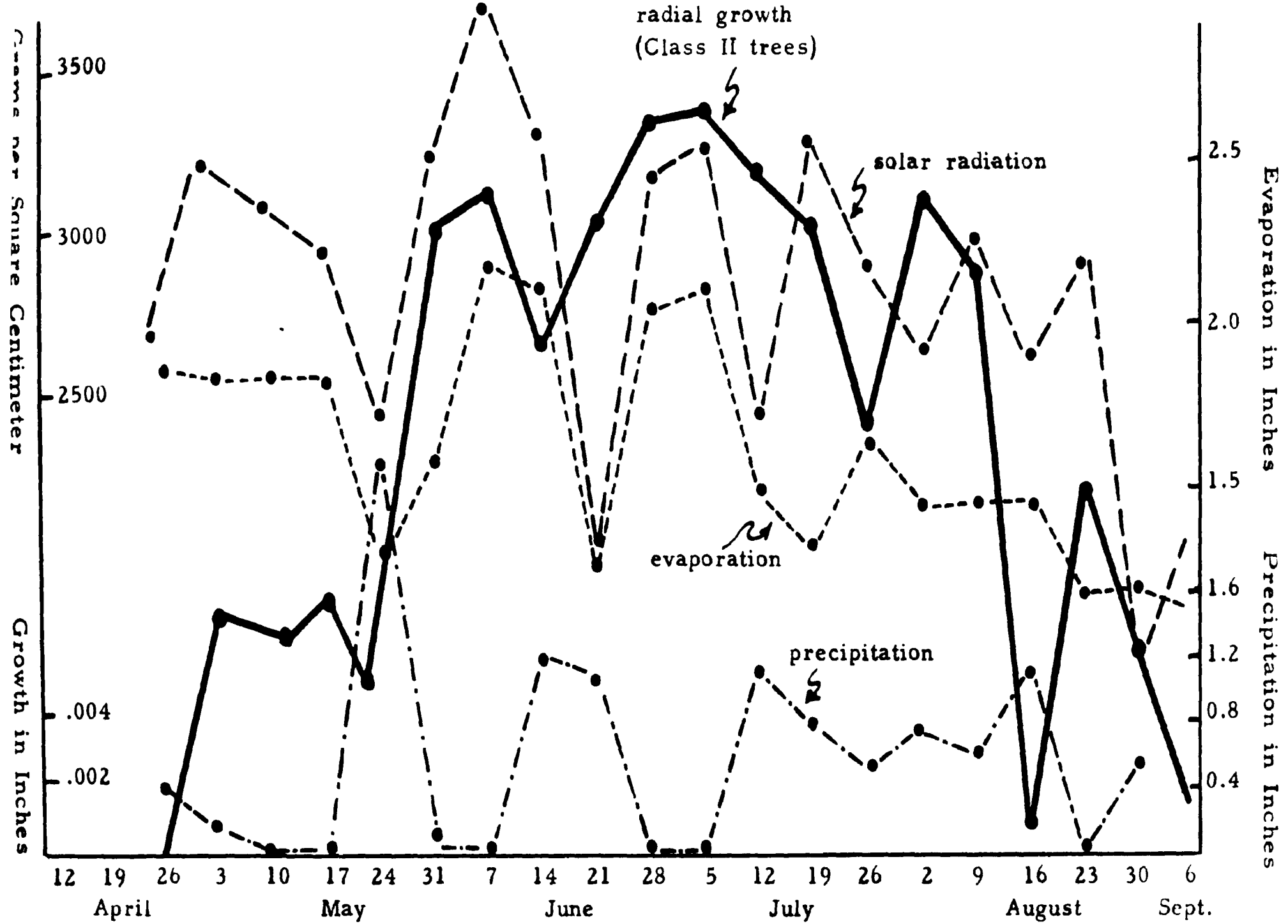

Figure 97 Radial growth - precipitation, evaporation and solar radiation comparison.

DISCUSSION

Introductory Remarks

From the work presented in the past concerning radial increase in trees, it is evident that there is a difference of opinion as to the relative value to be placed on "internal" and "external" factors, as to whether they do or do not influence periodicity of growth. MacDougal (1936) said:

> . . . once awakened, cambium illustrates a fundamental capacity to operate unceasingly without pause or rhythm and at a rate modified only by external conditions and food supply.

In a later paper (1938) he cites evidence of a maple showing continuous leafage and cambial activity:

> The capacity for continuous leafage is more completely illustrated by observations of Coster (1927) on Japanese maple introduced into Java. Three trees in 1925 and 1926 displayed leafy twigs continuously, and all had active cambium in some branches at all times. Spring wood was being formed on some branches, and summer wood on others, in May 1926. The seasonal layers were incomplete in places and not always clearly separable. The layers were closed with the formation of radially compressed fiber-tracheids. The tracheary vessels of the summer or late wood were smaller than those of the spring wood, which were disposed in a ring.

Evidence has already been presented indicating that Priestly (1930) was not convinced that growth activity came to a halt even during the winter.

On the other hand, Friesner (1942) commented:

> External conditions, without doubt, play important roles in determining the time of initiation, time of peak rate and time of cessation of growth and amount of growth, but the growth rhythm occurs independently of definable rhythms in the external environment. They are most likely due to internal physiological conditions, such as available hormones, and other growth substances to other activities.

Rhythmic action of protoplasm has been reported for tissues under uniform-controlled conditions (Friesner, 1921), an action controlled undoubtedly by the physiologic-genetic relationships within the cells involved. Recently, Robbins (1950) concluded that roots of sugar maple probably undergo a cycle of activity internally controlled but influenced by the environment.

Even in the example given by MacDougal (1938), it was indicated that the cambium throughout the tree as a whole did not function continuously. Also, the fact that some twigs were forming springwood while others were forming summerwood could indicate that these different meristematic regions could have been in varying stages of a particular cycle. By this

token, the cycle of cambial activity would vary according to the location in the tree but the cycle itself would be essentially the same.

Based on present information it seems more reasonable to explain the type of growth (i.e., grand period) illustrated in Figures 44 and 45 on the basis of some internal mechanism, altered by the environment only insofar as expressed by Friesner (1942).

It is even possible to entertain thoughts of an "intrinsic control" over growth as it fluctuates throughout the weeks of the growing season, and in any interpretation of growth phenomena under field conditions it seems unwise to exclude this possibility.

On the other hand, it is not at all difficult to recognize that a serious consideration of the environmental factors and their fluctuations could lead to a very satisfactory explanation of growth "irregularities," if they are such, in the growth pattern.

Of these possibilities Skoog and Tsui (1951) said:

> . . . our findings suggest that both organ formation and subsequent development are brought about by quantitative changes in amounts and interactions between nutrients

> and growth factors which are essential for growth of all cells, so that the pattern of development is determined by the relative supplies through synthesis, transport, and accumulation of these materials at particular loci. On this basis, the morphogenetic capacities of a given cell or tissue are limited not only by its genetical potentialities for synthesis but more often by its morphological environment, that is, by its particular position in the structurally complex plant body. This concept demands that normal growth of cells must lead to a unified general pattern of development in all plants of comparable genetic constitution but it permits infinite variation in details.

The questions would then be: What period of time in growth constitutes the "general pattern"? Which fluctuations represent "variations in detail"?

Radial Growth Fluctuations Throughout the Growing Season

Growth Initiation

It appears that the initiation and early course of growth is controlled primarily by the external environment. In both years of measurement radial growth began at a time when the mean weekly air temperatures exceeded 51 degrees Fahrenheit. Soil temperature in 1950 reached 48 degrees on May 11 in the woodlot. For both years the soil temperature averages at the hydrologic station exceeded the 50-degree mark on the week of first enlargement.

It may be that a "threshhold" temperature slightly under 50 degrees Fahrenheit for both air and soil temperatures within the woodlot is a requirement critical for growth initiation. Friesner and Walden (1946) said:

> Temperature appears to be the most important limiting factor in controlling the time of initiation of radial enlargement. This varied from a few days before to as many days after the mean daily air temperature was continuously (or nearly so) above 50 degrees F.

Their study was conducted on two trees of Pinus strobus in Maine, but this condition appears to be essentially true for the sugar maples under study here.

Daubenmire (1949) found that temperature showed no effective control over cambial initiation in 17 species of trees studied in Idaho. Among these was sugar maple. He stated that the heat requirements were "satisfied" earlier than are photoperiodic requirements and that this alone did not stimulate cambial activity. The idea was advanced by him that there is possibly an interaction of these two factors, although in a later paper he stated that his original work (1949) showed "negative evidence of photoperiodic control over inception of cambial activity," an apparently contradictory statement.

Nevertheless, such a similar interrelation seems quite possible in the "light" of these investigations. Figure 34 indicates that the total number of sunlight hours would not be sufficient to explain the initiation of cambial activity in 1949, but associated with temperature this would be possible. The relationship could also be applied to the data for 1950 (Figure 35).

In the strict sense this would not be considered as photo(light)-period, but as "sunlight period." It is possible, that, in addition to the correct degree of temperature, sunlight also has a "threshhold" value as related to cambial initiation, and that they both must be exceeded before the cambium becomes active.

In 1949, the "plateau" (Figures 25, 26 and 27) exhibited as a result of successively low amounts of increase is believed to be correlated with the sharp temperature fluctuations during that same period. This is in disagreement with the findings of Daubenmire (1949):

> Subsequent to the date of beginning of growth, temperatures fell much lower at times, but growth continued unabated; the quiescent periods in late May, 1945, were without relation to temperature.

In 1950, temperatures increased steadily and no such "plateau" was noted. The slight "dip" in rate of growth during the second

week of cambial activity could have little significance and was therefore not considered as a "plateau."

Thus, it is probable that cambial activity, in the sense of cell divisions, and enlargements of new cells, did proceed from a lower rate during the first week to a higher rate the second week. This means an almost uninterrupted increase in growth rate (at breast height) occurred for 1950 up to the time of the first peak rate.

Period of Greatest Metabolic Activity

In terms of "intrinsic" control of the growth pattern (weekly increase intervals), it could be assumed that the relationship suggested by Skoog and Tsui (1951) between nutrients, growth factors and genetic potentialities operated in such a manner as to present periods of greater and lesser "equilibrium." It is possible that the concentration of sugars and amino acids, the rate of formation of which is also at least partially controlled through a gene-enzyme complex, finally reached such a level as to actually block rate of production of a whole chain of chemical substances down to the level of the genes. When

this obstruction was removed, growth would again proceed at accelerated rates until the same event occurred.

It might be thought that whatever substance produced by the genes, assuming there are genes for this function, which is specific for growth or the production of growth substances, was produced at a "sigmoid" rate, the curve of production tapering off due to certain inhibitory action of its own products. A series of the "sigmoid" rates throughout the growing season would still not alter the seasonal nature of the growth rate (i.e., grand period).

Evidence for the genetic control of growth-factor production has been reported by Tatum (1951) and others.

The same mechanism might have been in operation here as was reported by Ishibe for Pinus densiflora in Japan (MacDougal, 1938). There, two maxima and two minima of growth rates were recorded, correlative with the presence and absence of starch reserves. He maintained that a check to cambial activity favored accumulation of starches. It could thus have been that, regardless of the exact rate of manufacture of sugars, periods were reached in which growth proceeded at such a rate

as to deplete starch reserves, thereby causing the observed fluctuations.

Korstian (1921) has reported (Acer negundo):

> It will be noted that the march of diametral growth is interrupted by rest periods of short duration. These rest periods are held to be essential for the maintenance of the proper health and optimum efficiency of the vital activities of the tree.

A consideration of the nature (not the magnitude) of the curves in Figure 46 indicates that the growth exhibited in the specimens studied here conforms to a high degree with growth as reported by Friesner (1942). Two peaks of growth rate occurred at about the same period of time. Further peaks of growth rate were evident for the study here in Michigan—peaks which might have occurred in Indiana had the external conditions been conducive to a longer period of growth.

The curve representing observations by Reimer (1949) (Figure 46) shows a much later beginning of activity, but it, too, reveals two general periods of increased activity. Cambium measured in all three investigations was at breast height.

If this general hypothesis is followed, the environment would be important principally in regulating the time of initiation and possibly the early course of growth, the duration of

growth, and the total amount of growth. After metabolic activities are set into motion, the general character of the growth pattern would then be governed by periods of internal "equilibria." This agrees in most respects with the contention of Friesner (1942). Intrinsic control of growth rate was considered as highly possible by Kienholz (1934).

This point of view needs some further serious investigation under more controlled conditions and over a period of several years, especially so in the light of data and conclusions of other investigators (Kienholz, 1934; Korstian, 1921; Ishibe and MacDougal, 1938; Friesner, 1942).

If the "environmentalistic" point of view is taken, the contention would be that control of the metabolic mechanism operates within a range of "genetic tolerance" and that external factors exert primary dominance throughout the season. It then becomes necessary to find satisfactory explanation for the occasional recessions in rate of radial growth.

The recessions of greatest concern at this point are those occurring during the period in which the bulk of increase was registered. For both years this period was between the first of June and about the middle of August.

Two major recessions were noted (Figures 25, 26, and 27). For both seasons the factor which showed best correlation was the light factor, although this is not to be considered as a simple direct relationship at all times. In 1949 the total number of sunshine hours dropped from 90 to 55 during the week of first recession of growth activity (Figure 34). For 1950, the decrease was from 97 to 63 hours (Figure 35). There was a previous recession in the number of hours of sunshine for 1950, for the week ending June 2. It might be asked: Why did the rate of increase not show some response to this drop if the light factor seems of importance for the first recession?

This can only be explained on the basis that the last day of the period ending June 2, which included light data up to the day of radial recordings, was one during which the sun appeared only 58 minutes. This low reading projected the time curve for sunlight hours 10 to 15 hours lower than it would have gone if the seven-day period for total sunshine had been calculated one day back. The effects of such a low light duration would very probably not have affected growth for that week.

All other periods of low sunlight hours were checked, and in no other case did the last day of the seven-day period

have an unusually low number of sunlight hours. In other words, the remaining weeks showed fewer hours of sunshine because of lower recordings during the early or middle parts of the week.

Solar radiation showed a sharp decrease for this same week (Figures 32 and 33). It is possible that radiation was the factor of real importance; yet for many plants light intensity is said to be at a supra-optimal value much of the time. More will be said of this in the interpretation of the two seasons of growth compared as entities.

The second recession in growth rate appeared the weeks ending July 28, 1949, and July 22, 1950. In terms of the environment as the controlling complex, this recession can be best explained for the two years on different bases.

Figures 32 and 34 show that solar radiation and total hours of sunshine increased appreciably the weeks ending July 21 and July 28, 1949. Figure 28 indicates an increase of mean air temperature to 77 degrees Fahrenheit during the week ending July 28. Soil temperatures increased in the woodlot to 72 degrees Fahrenheit for this period (Figure 30). Evaporation also increased at this time (Figure 36). It thus appears that a steady increase of light and temperature could have brought

about a temporary water deficit in the plant as a result of the transpiration rate exceeding the rate of water absorption from the soil.

The situation for the following week (August 4, 1949) tends to support this possibility, for each of these conditions were reversed and the growth rate increased considerably.

The second recession in 1950 was possibly related to several factors. This was a week (ending July 22) of very high precipitation and low evaporation, in addition to an extreme decrease in both solar radiation and total hours of sunshine. These factors, by their cumulative effects, would present very poor conditions for maximum growth at this time.

To say with certainty just which one was more important would be very difficult and in all probability none is all important, but it does seem likely that light again played a very conspicuous part as it is related both to photosynthetic activity and to the fluctuations of the other environmental factors.

It is undoubtedly true that the ultimate response of the cambium to these factors of the environment would be controlled by the genetic capability of the plant to act in this direction,

as mentioned by Skoog and Tsui (1951). But the environment would "trigger" such a mechanism, whereas if the point of view of "intrinsic" control is followed, the response elicited by the cambium would be more directly "triggered" and guided by the internal balance; the physiological-genetic relationships. These latter would be in operation over a range of environmental conditions not sufficiently extreme to produce such responses. The fluctuations in growth rate at the period of greatest activity of the cambium can be due, then, (1) either to an internal cycle of events or, (2) may be caused more directly by the fluctuations in the external environment. On the basis of the correlations mentioned regarding growth and the environment, evidence is strong in favor of the more immediate control of certain of these environmental factors over the growth rate, but as stated by Snedecor, "The mere existence of correlation is no proof of direct relationship" (Loomis and Shull, 1937).

Growth Cessation

No satisfactory explanation can be found for the near cessation of growth the week ending August 18, 1949 (Figures

25, 26, and 27). Possibly soil moisture decrease for that week was effective in producing this result. This, however, seems unlikely in that, although the available moisture averaged from all stations decreased from 80 to 68 percent, moisture at the stations well within the woods increased slightly to above 95 percent available moisture. All trees, both those growing at the edge and those growing inside the woods, showed this extreme decrease in growth rate.

Air and soil temperatures (Figures 28 and 30) were about 70 degrees or slightly above, and had been even slightly higher the week before. This might have favored lignification of xylem elements (Hansen and Brenke, 1926) and retardation of cell divisions, but if this were true it would be very difficult to explain why growth increased each week from June 23, 1949, to July 7, 1949, when air temperatures increased from 74 to 80 degrees Fahrenheit.

The only other explanation seems to be that this represented another recession caused by certain "intrinsic" factors previously suggested.

Final cessation of growth at breast height varied considerably with the individual specimen and seemed to conform

to no definite external condition. Fraser (1952) reported this same variation in time of growth cessation for trees growing in Canada. Trees growing immediately adjacent to each other ceased enlargement of the stem at different times (Tables IV and V). Daubenmire (1950) mentioned that, ". . . termination of cambial activity is strongly determined by autogenous forces . . ." which could also have been the case here.

From the data presented, one possibility regarding growth cessation seems worth discussion. Even though these trees are very closely related genetically, it is reasonable to assume that they vary in their ability to metabolize under minimum light conditions. Figures 34 and 35 indicate that rapid decrease to below 50 hours of sunshine a week occurred around September 2, 1949, and 1950. Could it have been that sunlight below a certain minimum was inhibitory to some part of the chain of requirements established as requisite for cell production and maturation? Data presented here allow for no such conclusion but they also do not indicate that this could not have been the case. To know the light quality over this period of waning activity and also the behavior of cambium in other parts of the tree might give some more definite leads toward the yet unanswered question of why growth ceases.

A Comparison of Growth Studies

It would indeed be interesting and of no little practical importance to be able to say one of the following—(1) the environment of lower Michigan, (2) the particular population of maples in Tourney Woodlot and possibly the entire area, (3) both factors (1 and 2)—allowed for longer periods of cambial activity for sugar maple and also for generally greater radial increases in this area than reported for other areas. If the results in Figure 46 could be so used it would certainly suggest such a conclusion. However, in some cases of growth studies on sugar maple the details of the habitat are not available. In all cases the number of samples were not the same nor were studies carried on during the same seasons. Also the relative taxonomic position of the specimens studied was not determined, at least along the lines presented by Dansereau and Desmarais (1947).

Therefore, such statements will have to remain without authority or conclusive basis until such a time as the cooperation of several investigators can be secured to carry out simultaneous population-growth studies in various parts of the ecologic range of Acer saccharum-like specimens. Transplant studies

seem completely out of the question unless very young seedlings or saplings were utilized.

Comparison of two seasons' growth by the same specimens can be made with greater safety. It appears that the total amount of growth for the season is under the more direct control of external factors. The following account is a consideration of some of these factors.

That the total amount of rainfall (during the growing season) did not directly influence the amount of growth for 1949 or 1950 is seen from the fact that more precipitation occurred in 1950, the year when less growth was recorded (Table III).

Total solar radiation was greater for 1950. It does not seem that solar radiation had a depressing effect on the amount of wood produced. If this were the case, when the depressing effect was less (Figure 33) (weeks ending June 24 and July 22), growth should have increased, but exactly the opposite was the case. A more likely explanation is that the total hours of sunshine in 1950 were sufficiently less to affect materially the amount of carbon fixation. It is also possible that light quality was affected to such an extent by more cloudy weather in 1950 that had an adverse effect on some metabolic phase.

This would be in agreement with Stalfelt (as cited by Shirley, 1945), who found that on cloudy days photosynthesis was possibly affected by temperature and light.

Air temperature averaged over 2 degrees a day lower for 1950 than for 1949, indicating a generally cooler summer. This alone should favor growth if the results of Hansen and Brenke (1926) are applicable to sugar maple under these conditions. However, the beneficial effects which might have occurred because of lower temperatures might also be offset by too low temperatures at night. The importance of minimum temperatures for many biological phenomena has been emphasized by Daubenmire (1947) and Cain (1944).

The last reasonable possibility apparent to the author for explaining a smaller amount of growth for 1950 is the previously mentioned fruit production, occurring on nearly all of the trees that year. Sufficient quantities of protoplasmic materials may have been diverted to this activity to the general detriment of the somatic activities in the plant.

The writer is inclined to believe that all three (light, temperature and seed production) factors probably played some part in the decreased cambial activity for 1950.

Growth in Various Parts of the Woodlot

Results of groups of trees studied which were located in various parts of the woodlot reveal that, in general, each of the groups compared exhibited a very similar pattern of fluctuations. In almost every case, fluctuations were in the same direction, if not of exactly the same magnitude.

Some differences did occur, however, in the response of the cambium on a relative basis. The most striking of these variations occurred between groups D and F (Figure 47). Between June 23 and July 7, 1949, positive growth fluctuations were recorded for group D at the same time that negative growth fluctuations were recorded for group F. Also in 1950 the same situation was found between July 1 and July 15 (Figure 48). During this period in 1950, soil moisture dropped in the vicinity of group F trees from 79 to about 37 percent available moisture. Near group D trees soil moisture decreased to about 95 percent available moisture (Table X).

It is thus possible that the explanation to this difference lies not in the fact that there was positive fluctuation in the growth of group D trees but that there was <u>not</u> such positive fluctuation in group F trees, the reason for the latter being

the decrease to a relatively low percentage of available moisture around these trees.

Group R trees showed this same type of response in relation to groups P, S, and T for the weeks ending July 7 and July 14, 1949 (Figures 53, 55 and 57). While the latter groups showed the same or slightly greater rates of increase, group R showed a decrease over the previous weeks of growth. Unfortunately it is not possible to compare soil moisture data with this, since readings were not available at that time. It does seem possible, however, that soil moisture at the periphery (area of groups R and F) might have played an important role in causing this response as it apparently did in 1950.

As previously mentioned, there were other cases where lines of fluctuation converged or separated somewhat, indicative of some fluctuation in external conditions at a particular site, but with the information at hand it is not possible to interpret these minor deviations.

The striking similarity of the compared curves emphasizes the cyclic nature of the growth pattern and again it must be stated that this points to a very uniform fluctuation of cambial activity due either to the changing complex of the environment

or the changing "intrinsic" equilibrium; and very possibly to some interassociation of the two. Further evidence that light was very possibly of great importance during the major period of cambial activity is seen in these same figures. The steepness of the decrease in growth rate of the trees in the inside of the woodlot (center and north portions) for the week ending June 16, 1949, is some indication that some factor of light was probably operative in producing this decrease. Both solar radiation and total hours of sunshine decreased sharply this week. The "edge" trees, in some cases, showed a slight decrease in their rate over the previous week but it is never very steep and in some cases there was no decrease at all in their rate over the previous week. This relationship is true for the two major periods of decline in 1950 (Figures 49, 50, 53 and 54).

It is probable then, that on the basis of environmental control, light was deficient to some extent in all parts of the woods, but the deficiencies were felt greatest in the center and north sections of the woodlot, where the compensation point is undoubtedly reached sooner on cloudy afternoons and later on cloudy mornings due to the shading effects of other trees.

In contrast to this behavior, the second period of decline in 1949 was evident in all groups compared. The decrease in individual rate is just about as sharp in each of the two habitats. This would also add support to the explanation given in a previous section for this decrease.

Trees Measured Along Four Radii

Trees measured along four radii which were growing along the south edge of the woodlot showed no over-all similar pattern of development. Tree 92 produced the most eccentric growth pattern. On the basis of this study no definite conclusion can be drawn regarding this response. A more thorough study into the microenvironment surrounding this particular tree might produce more satisfactory results.

At least it can be said that the mere fact that trees are situated on the south edge of the woodlot does not indicate that there will be a definite type of seasonal growth pattern peculiar to this exposure location. This can probably be said also of the other edge trees studied in this woodlot (east and west exposures), but because only one specimen was studied in each of these two exposures, such a conclusion cannot be drawn.

Tree 96 grew least on the west side in 1949, and least on the south side in 1950, very probably indicating again local fluctuations in the microclimate.

Tree 99 seemed not to have such a varying habitat, producing more wood along the west radius in both years. Measurements of the trunk indicate that this might have been a condition of long standing. No other definite conclusions can be made regarding the growth exhibited by this tree.

It is likewise not possible to say with certainty whether or not trees 97 and 98 were materially influenced in their growth by their proximity to the "blowdown" area (Figure 18). If so, the result was apparent in the case of tree 97 only for the 1949 season. Growth at breast height for 1950 was essentially symmetrical.

Trees growing along the south edge of the woodlot produced less increase along the north radius during the first few weeks of growth than along any one of the other three measured radii. In no case was the greater amount of growth found on the north side for these first few weeks of increase. This effect was not apparent in those trees measured along four radii which were located well within the woodlot.

The effects of direct sunlight upon temperatures along the south edge was probably of greater important among the environmental factors as it affected stem metabolism, translocation, and also production of growth substances in the axial meristems.

In reference to all ten trees measured along four radii, it must be said that the reasons for the presence or absence of eccentric growth was of a more complex nature than revealed by this study. The presence of one type of exposure did not give rise to any one type of response as far as the cambium at breast height is concerned. The number of branches arising from each side of the tree seems to give no indication of how the cambium on that side, at about five feet above the ground, will generate tissues. A comparison of the photographs of trees 92 (Figure 12), 94 (Figures 15a and 15b), 96 (Figures 17a and 17b), and 99 (Figure 19), with their respective growth responses, bears this out (Figures 67, 73, 79, and 88).

A closer approximation of the causes for such responses would have to take into consideration the five factors previously mentioned as being of primary importance to eccentric growth;

viz., (1) slope, (2) position of main roots, (3) competition, (4) wind action, (5) character of the grain.

Further Remarks About Environmental Factors

Before the soil-moisture data were available in any quantity, it was thought that the periods of rainfall had some effect upon the surges of radial increase. This possibility was advanced by the author in a preliminary paper given before the Michigan Academy of Science in 1951 (Reimer, 1951a). Now that all the data are available and here presented, he wishes to go on record as believing that: (1) provided the midseason rhythms which were measured were controlled by environmental factors, periods of rainfall were not directly influencial in affecting growth fluctuations of sugar maples growing in Toumey Woodlot; (2) rainfall appeared to be sufficient during the growing season to maintain ample supplies of soil moisture for growth within the undisturbed section of the woodlot; (3) even though rainfall may have affected the amount of growth of trees growing near the south and west edges of this woodlot, over-all correlations were not possible between growth fluctuations occurring during the major period of growth and precipitation or soil

moisture fluctuations for this same period; (4) the presence of cloudy weather (which frequently means precipitation) seemed more important to growth fluctuations as it interfered with the amount of sunlight hours for photosynthesis; or (5) the absence of cloudy weather may have allowed for too much sunlight and too high temperatures which would temporarily have caused higher evaporation and subsequently an increase of transpiration over the "ability" of the plant to absorb moisture from the soil.

It thus appears that soil moisture was at a noncritical level of availability (on both relative and absolute growth terms) during the growing season on the inside portions of the woodlot. It does appear, however, that the lack of sufficient amounts of available moisture (from about mid-July until growth stops in September) near the south and west edges of the woodlot possibly affected the amount of growth of the trees in that area adversely.

Many workers maintain that soil moisture has practically no effect on growth until it has reached approximately the 50 percent level of availability. Furr and Reeve (1945) said that plants undergo a water deficit from about the 50 percent level of availability down to the wilting coefficient. Kramer (1944)

cited work done in Oregon on fruit trees in which fruits were reduced in size at a soil moisture availability of 70 percent.

Kramer, himself, remarked:

> From the standpoint of energy involved in movement of water from soil to plant, there can be little doubt that soil moisture becomes less and less readily available as the moisture content decreases from field capacity to the permanent wilting percentage. . . . In another sense, however, at least in light soils, soil moisture may be practically as readily available to the plant at moisture contents just above the wilting percentage as at field capacity . . . as the soil moisture content of the soil and the moisture content of the plant decrease, the osmotic pressure and the diffusion pressure deficit within the plant increase, while the increase of a few atmospheres in the diffusion pressure deficit of the roots may supply the increased energy gradient necessary to maintain a high level of absorption, it does not appreciably reduce transpiration.

Soil moisture was below the 70 percent availability mark at the 12-inch depth just one time in 1949 (reading of September 16) on the inside of the woodlot and did not fall below 80 percent available moisture at these locations at any time during the growing season of 1950 (Figures 59a and 60). It is also believed that the 12-inch level is, in Toumey Woodlot, a depth at which at least a relatively great number of absorbing roots are located, and therefore, soil-moisture readings at this level represent a reasonable picture of the soil moisture regime for the sugar maples growing in this woodlot.

Soil moisture data gathered from the single block buried in the open field to the south of the woodlot (Tables VIII and X) showed in most cases more available moisture than the block buried under one of the south border trees. Although conclusions cannot be drawn from such a small sample, it is at least suggestive that moisture conditions at the very south edge of the forest might be much more rigorous than in the field. This seems reasonable on the basis that the vegetation at this forest edge presents not a straight more or less flat surface for transpiration and evaporation as is the case with any selected area in the field or in the closed canopy woodlot portion, but presents a curved surface much more extensive per equal ground area than an equal ground area surface exposed in the field or woodlot.

Finally, environmental data calculated for seven-day intervals ending two days before the radial increase readings were taken (Figures 96 and 97) present no better correlations than data plotted for the exact week period ending on the day of recording of radial increases, indicating that back dating of such data was, in this case, of little value.

SUMMARY AND CONCLUSIONS

1. Radial growth of 100 trees of sugar maple (Acer saccharum Marsh) was measured with a dendrometer at weekly intervals during the growing seasons 1949 and 1950. The study was carried out in Toumey Woodlot, located on the campus of Michigan State College in East Lansing, Michigan. Soil moisture and soil temperature were also recorded at weekly intervals over this same period. Other environmental data were secured from a weather station located just outside the woodlot, and also from the weather station at Capitol City Airport at Lansing.

2. The initiation of cambial activity at breast height appeared, from this study, to be related to the increase in air and soil temperatures to the vicinity of the 50-degree-Fahrenheit mark. Data suggest that some component of light (possibly total hours of sunshine) had a threshhold value which had to be exceeded at the same time.

3. Early course of growth fluctuated, in 1949, with sharp variations in air and soil temperatures, suggestive of an interrelation between these two factors.

4. During the period of greatest metabolic activity, two deflections in the growth rate were noted. Both occurred at about the same time in successive years. This would allow for an explanation on the basis of "intrinsic" factors (a cycle of internal unbalance). On the other hand, certain environmental conditions at these times appeared to change sufficiently to have been the primary causes for the lesser amounts of growth. On the basis of this study it could not be stated which of the two was of more immediate importance or whether the two could be separated.

5. The number of sunshine hours appeared of greater possible importance in affecting the decreases in growth rate during the period of greatest metabolic activity than any of the other measured environmental factors, although a simple and direct effect is not to be implied in all cases. The possibilities for indirect effect have been given in each particular case discussed.

6. One cannot discard the possibility that a sharp decrease in solar radiation, disregarding intensity, might have been one of the most important factors affecting radial increase. Three of the four sharp recessions of the growth rate fell at the same time as a sharp deflection in solar radiation was in evidence.

7. Growth ceased in a nonuniform fashion, in contrast to growth initiation. No definite conclusions are made concerning the causes for cessation, although some suggestions are made.

8. Growth fluctuation in various parts of the woodlot, compared among trees of the same size class, showed very similar increase and decrease periods. Where variation was extreme, an explanation for the difference was suggested on the basis of less available moisture near the south and west edges of the woodlot. It was not possible to compare minor fluctuation differences. It was suggested that they too were possibly due to some microclimatic fluctuations, but these were not revealed in this study.

9. The magnitude of growth was less for 1950 than for 1949. This is attributed to one, or a combination, of the following factors: (1) seed production in 1950, no appreciable seed production in 1949; (2) fewer hours of sunshine during the growing season in 1950; (3) lower air and soil temperatures for the 1950 growing season.

10. Growth continued for about 18 weeks in 1949 and about 17 weeks in 1950, probably the longest period of radial growth recorded for this species by a dendrometer in the eastern part of the United States.

11. Trees measured along four radii showed, in nearly all cases, some eccentric growth, but this could not be definitely correlated with any of the factors considered in the study. It does indicate, though, that an "edge" exposure does not necessarily mean better growth conditions on either (1) the side "free" from root competition of the forest, or (2) the side "protected" from the "rigorous" environment presented by the clearing.

12. Exposure of trees 97 and 98 to an opening in the canopy produced no particularly consistent response by the cambium of those trees.

13. Periods of rainfall during the growing season did not correlate with growth fluctuations which occurred during the period of greatest cambial activity.

14. It is possible that periods of rainfall and cloudiness were more important as they decreased the amount of sunlight hours for photosynthesis.

15. The amount of available water in the soil was never at a "critical" level on the inside of the woodlot at the 12-inch and the 36-inch levels and was "critical" at the edges of the woods (south and west) at these depths only during the latter parts of the growing season for all trees.

16. Total growth of trees near the south and west edges of the woodlot was possibly affected by this decrease in soil moisture, but the total growth of trees well within the woodlot seemed to bear no such relationship.

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APPENDIX

A. Data recorded within Toumey Woodlot. (See text for Table I, p. 56; Table II, p. 60; Table III, p. 136.)

B. Data recorded at weather bureau stations.

TABLE IV-A. Weekly radial increases (in inches) for Size Class I (10-15 inches DBH) trees. 1949.

No.	Week Ending						Totals to 5-12
	4-7	4-14	4-21	4-28	5-15	5-12	
1	.001	.000	.000	.000	.015	.009	.025
2	.000	.000	.000	.000	.013	.010	.023
3	.000	.000	.000	.000	.007	.005	.012
4	.000	.000	.000	.000	.010	.006	.016
5	.000	.000	.000	.000	.011	.010	.021
6	.000	.000	.000	.000	.013	.011	.024
7	.001	.000	.000	.000	.010	.006	.017
8	.002	.000	.000	.000	.006	.008	.016
9	.000	.000	.000	.000	.006	.008	.014
10	.000	.000	.000	.000	.000	.005	.005
11	.000	.001	.000	.000	.005	.003	.009
12	.000	.000	.000	.000	.010	.009	.019
13	.000	.000	.000	.000	.005	.005	.010
14	.000	.000	.000	.000	.008	.007	.015
15	.000	.000	.000	.000	.003	.005	.008
16	.000	.000	.000	.000	.006	.007	.013
17	.000	.001	.000	.000	.007	.003	.011
18	.001	.000	.000	.000	.012	.012	.025
19	.000	-.001	.000	.000	.007	.008	.014
20	.000	.000	.000	.000	.007	.007	.014
21	.000	.000	.000	.000	.007	.008	.015
22	.001	.000	.000	.000	.009	.007	.017
23	.000	.000	.000	.000	.013	.009	.022
24	.000	.000	.000	.000	.006	.005	.011
25	.001	.000	.000	.001	.015	.013	.030
26	.000	.000	.000	.000	.008	.008	.016
27	.000	.000	.000	.000	.000	.003	.003
28	.000	.000	.000	.000	.011	.008	.019
29	.000	.000	.000	.000	.002	.005	.007
30	.001	.000	.000	.000	.005	.004	.010
Total	.008	.001	.000	.001	.237	.214	
Arith. Mean	.0003	.000	.000	.000	.0079	.0071	

TABLE IV-A (Continued)

No.	Week Ending							Totals 5-19 to 6-30
	5-19	5-26	6-2	6-9	6-16	6-23	6-30	
1	.017	.008	.003	.020	.016	.018	.025	.107
2	.014	.006	.023	.025	.035	.017	.033	.153
3	.004	.002	.017	.016	.011	.014	.020	.084
4	.005	.005	.015	.017	.017	.022	.031	.112
5	.014	.009	.026	.024	.021	.022	.021	.137
6	.016	.011	.024	.035	.024	.024	.029	.163
7	.011	.009	.024	.028	.012	.022	.026	.132
8	.012	.008	.020	.022	.020	.021	.022	.125
9	.006	.004	.015	.012	.009	.012	.014	.072
10	.005	.000	.016	.010	.006	.008	.009	.054
11	.005	.004	.015	.011	.013	.015	.019	.082
12	.013	.007	.021	.015	.014	.015	.017	.102
13	.009	.003	.023	.021	.018	.018	.010	.102
14	.010	.004	.014	.013	.012	.012	.023	.088
15	.010	.009	.022	.019	.015	.015	.021	.111
16	.009	.005	.023	.018	.014	.015	.025	.109
17	.005	.004	.014	.013	.011	.013	.018	.078
18	.012	.006	.020	.021	.014	.030	.022	.125
19	.012	.003	.022	.022	.015	.017	.023	.114
20	.013	.006	.022	.025	.021	.027	.025	.139
21	.007	.002	.017	.017	.017	.030	.024	.114
22	.016	.009	.019	.023	.018	.031	.022	.138
23	.013	.006	.021	.026	.020	.026	.027	.139
24	.010	.004	.016	.015	.013	.017	.020	.095
25	.016	.008	.023	.029	.020	.022	.028	.146
26	.008	.004	.018	.014	.008	.010	.018	.080
27	-.002	-.003	.005	.002	.000	.000	.002	.004
28	.013	.007	.021	.022	.023	.033	.013	.132
29	.009	.006	.024	.026	.012	.012	.019	.108
30	.007	.005	.020	.022	.011	.011	.021	.097
Total	.315	.161	.563	.583	.460	.549	.627	
Arith. Mean	.0105	.005	.019	.019	.015	.018	.021	

TABLE IV-A (Continued)

No.	Week Ending							Totals 7-7 to 8-18
	7-7	7-14	7-21	7-28	8-4	8-11	8-18	
1	.017	.017	.017	.007	.017	.012	-.007	.080
2	.026	.021	.015	.011	.020	.025	-.001	.117
3	.020	.014	.010	.004	.013	.005	-.009	.057
4	.024	.020	.014	.006	.011	.004	-.011	.068
5	.025	.016	.004	.012	.025	.008	.000	.090
6	.024	.029	.030	.018	.024	.022	.004	.151
7	.031	.026	.024	.020	.023	.021	.004	.149
8	.019	.017	.018	.013	.021	.023	.002	.113
9	.010	.011	.008	.003	.010	.009	.000	.051
10	.006	.012	.014	.014	.023	.026	.007	.102
11	.023	.018	.016	.012	.018	.016	.000	.101
12	.019	.021	.021	.009	.018	.012	.000	.100
13	.019	.033	.015	.013	.028	.027	.003	.138
14	.021	.019	.014	.012	.019	.018	.000	.103
15	.019	.016	.021	.016	.018	.018	.002	.110
16	.024	.021	.027	.015	.022	.019	.000	.128
17	.017	.016	.016	.009	.016	.015	-.001	.088
18	.022	.020	.016	.014	.019	.017	.000	.108
19	.017	.014	.013	.011	.015	.013	.003	.086
20	.012	.022	.029	.013	.019	.016	.000	.111
21	.022	.020	.018	.011	.020	.020	.003	.114
22	.023	.037	.008	.005	.023	.024	.001	.121
23	.022	.019	.009	.015	.025	.019	.000	.109
24	.022	.022	.023	.015	.021	.018	.002	.123
25	.029	.026	.024	.017	.027	.025	.006	.154
26	.020	.018	.018	.015	.024	.024	.005	.124
27	.000	.000	.002	-.002	.004	.000	-.005	-.001
28	.007	.024	.036	.022	.026	.023	.006	.144
29	.016	.018	.022	.016	.028	.020	-.002	.118
30	.013	.019	.006	.006	.020	.017	.002	.083
Total	.569	.586	.508	.352	.597	.516	.014	
Arith. Mean	.0190	.0195	.017	.012	.020	.017	.0005	

TABLE IV-A (Continued)

No.	Week Ending					Totals 8-25 to 10-13	Season Total
	8-25	9-2	9-16	9-30	10-13		
1	.004	.003	.000	.000	-.002	.005	.217
2	.006	.003	.000	.000	.000	.009	.302
3	.001	.004	.000	.000	.000	.005	.158
4	.004	.003	.000	.000	.000	.007	.203
5	.007	.009	.000	.000	.000	.016	.264
6	.012	.016	.000	.000	.000	.028	.366
7	.012	.008	.000	.000	.000	.020	.318
8	.019	.006	.000	.000	.000	.025	.279
9	.001	.004	.000	.000	-.003	.002	.135
10	.016	.011	.000	.000	.000	.027	.188
11	.010	.006	.000	.000	.000	.016	.208
12	.011	.004	.001	.000	.000	.016	.237
13	.015	.014	.004	.003	-.001	.025	.275
14	.013	.007	.001	.000	.000	.021	.227
15	.026	.010	.003	.000	.000	.039	.268
16	.017	.008	.007	.000	.000	.032	.282
17	.014	.006	.002	.000	-.002	.020	.197
18	.013	.003	.000	.003	.000	.019	.277
19	.012	.006	.001	.000	.000	.019	.233
20	.006	.002	.000	.000	.000	.008	.272
21	.014	.007	.001	.000	-.001	.021	.264
22	.009	.003	.007	.000	.000	.019	.295
23	.013	.007	.001	.000	.000	.021	.291
24	.012	.005	.000	.000	.000	.017	.246
25	.018	.011	.000	.000	.001	.030	.360
26	.016	.007	.002	.000	.000	.025	.245
27	.003	.000	.000	.000	.000	.003	.009
28	.017	.010	.007	.000	.000	.034	.329
29	.014	.007	.004	.000	.000	.025	.258
30	.015	.007	.002	.000	.000	.024	.214
Total	.350	.197	.043	.006	-.009		7.417
Arith. Mean	.0117	.0066	.0014	.0002	.0003		

TABLE IV-B. Weekly radial increases (in inches) for Size Class II (15-20 inches DBH) trees. 1949.

No.	Week Ending						Totals to 5-12
	4-7	4-14	4-21	4-28	5-5	5-12	
32	.000	.000	.000	.000	.011	.004	.015
33	.000	.000	.000	.000	.010	.007	.017
34	.001	.000	.000	.000	.003	.004	.008
36	.000	.000	.000	.000	.008	.010	.018
38	.000	.000	.000	.000	.004	.004	.008
39	.000	.001	.000	.000	.004	.007	.012
40	.000	.000	.000	.000	.005	.006	.011
41	.000	.000	.000	.000	.006	.004	.010
43	.000	.001	.000	.000	.008	.003	.012
44	.000	.000	.000	.000	.003	.004	.007
45	.000	.001	.000	.000	.003	.003	.007
46	.001	.000	.000	.000	.009	.006	.016
57	.000	.000	.000	.000	.002	.003	.005
58	.000	.000	.000	.000	.006	.007	.013
59	.000	.000	.000	.000	.010	.012	.022
60	.000	.000	.000	.000	.006	.008	.014
68	.000	.000	.000	.000	.005	.005	.010
71	.003	.000	.000	.000	.005	.004	.012
72	.000	.000	.000	-.001	.011	.011	.021
80	.000	.000	.000	.000	.003	.006	.009
81	.000	.001	.000	.000	.008	.009	.018
82	.001	.000	.000	.000	.013	.008	.022
83	.000	.000	.000	.000	.007	.011	.018
84	.000	.000	.000	.000	.008	.008	.016
85	.000	.000	.000	.000	.009	.009	.018
86	.000	.000	.000	.000	.011	.007	.018
87	.000	.000	.000	.000	.006	.005	.011
88	.000	.000	.000	.000	.015	.008	.023
89	-.001	.000	.000	.001	.011	.007	.018
90	-.001	-.001	.000	.000	.006	.007	.011
Total	.004	.003	.000	.000	.216	.197	
Arith. Mean	.0001	.0001	.000	.000	.007	.007	

TABLE IV-B (Continued)

No.	Week Ending							Totals 5-19 to 6-30
	5-19	5-26	6-2	6-9	6-16	6-23	6-30	
32	.008	.007	.016	.020	.010	.012	.014	.087
33	.010	.002	.018	.023	.016	.030	.028	.127
34	.001	.001	.014	.016	.014	.018	.019	.083
36	.009	.006	.021	.023	.014	.013	.018	.104
38	.007	.007	.022	.022	.016	.028	.028	.130
39	.010	.005	.017	.017	.011	.028	.025	.113
40	.009	.004	.017	.015	.015	.020	.024	.104
41	.003	.000	.012	.015	.011	.015	.009	.065
43	.003	.002	.017	.022	.011	.018	.020	.093
44	.004	-.001	.014	.012	.006	.009	.012	.056
45	.002	.000	.013	.009	.007	.008	.009	.048
46	.005	.008	.020	.021	.024	.025	.030	.133
57	.006	.004	.018	.016	.012	.010	.016	.082
58	.008	.007	.019	.019	.008	.010	.015	.086
59	.007	.009	.021	.020	.014	.016	.023	.110
60	.009	.008	.026	.025	.017	.015	.020	.120
68	.010	.002	.018	.014	.011	.010	.011	.076
71	.005	.003	.020	.022	.018	.019	.024	.111
72	.012	.006	.016	.017	.021	.022	.036	.130
80	.001	.000	.018	.021	.022	.023	.026	.111
81	.013	.010	.020	.019	.020	.024	.026	.132
82	.010	.008	.022	.024	.014	.015	.024	.117
83	.014	.009	.022	.038	.019	.023	.028	.153
84	.014	.009	.023	.024	.020	.026	.028	.144
85	.011	.006	.021	.021	.019	.025	.026	.129
86	.013	.010	.026	.026	.024	.037	.031	.167
87	.007	.007	.019	.017	.015	.020	.026	.111
88	.008	.007	.022	.028	.019	.023	.030	.137
89	.008	.006	.021	.024	.020	.023	.023	.125
90	.010	.002	.021	.015	.017	.020	.025	.110
Total	.237	.154	.574	.605	.465	.585	.674	
Arith. Mean	.0079	.0051	.0191	.0202	.0155	.0195	.0225	

TABLE IV-B (Continued)

No.	Week Ending							Totals 7-7 to 8-18
	7-7	7-14	7-21	7-28	8-4	8-11	8-18	
32	.017	.015	.014	.009	.019	.016	.000	.090
33	.026	.026	.025	.019	.023	.023	.002	.144
34	.015	.020	.020	.016	.018	.019	.004	.112
36	.022	.018	.016	.012	.020	.019	.002	.109
38	.028	.021	.017	.014	.018	.020	.002	.120
39	.024	.024	.023	.015	.020	.017	.001	.124
40	.019	.021	.016	.011	.018	.016	-.001	.102
41	.022	.009	.011	.012	.023	.020	.009	.100
43	.021	.020	.016	.011	.020	.014	.002	.104
44	.011	.011	.011	.007	.010	.007	-.005	.052
45	.008	.014	.013	.008	.016	.013	-.001	.071
46	.022	.021	.017	.012	.024	.024	.000	.120
57	.016	.019	.012	.005	.011	.007	-.008	.062
58	.019	.019	.017	.015	.020	.017	.002	.109
59	.023	.019	.023	.026	.035	.028	.007	.161
60	.019	.025	.025	.013	.021	.010	.000	.113
68	.025	.022	.025	.013	.021	.013	-.003	.116
71	.022	.024	.033	.023	.024	.021	.005	.152
72	.032	.026	.014	.019	.030	.028	.008	.157
80	.033	.030	.021	.019	.033	.027	.005	.168
81	.024	.022	.015	.010	.019	.014	.000	.104
82	.028	.025	.022	.015	.016	.022	.000	.128
83	.025	.026	.025	.017	.023	.026	.003	.145
84	.029	.020	.024	.006	.035	.029	.000	.143
85	.022	.015	.016	.007	.017	.009	-.006	.080
86	.029	.024	.023	.012	.012	.017	-.002	.115
87	.025	.019	.020	.009	.016	.013	-.003	.099
88	.033	.029	.027	.016	.021	.031	.005	.162
89	.021	.018	.018	.010	.015	.009	-.003	.088
90	.027	.021	.016	.009	.011	.007	-.001	.090
Total	.687	.623	.575	.390	.609	.536	.024	
Arith. Mean	.023	.021	.019	.013	.020	.018	.0008	

TABLE IV-B (Continued)

No.	Week Ending					Totals 8-25 to 10-13	Season Totals
	8-25	9-2	9-16	9-30	10-13		
32	.014	.009	.000	.000	.000	.023	.215
33	.011	.008	.000	.000	.000	.019	.307
34	.011	.010	.000	.000	.004	.025	.228
36	.023	.005	.000	.000	.000	.028	.259
38	.013	.006	.001	.000	.000	.020	.278
39	.010	.007	.002	.000	.000	.019	.268
40	.012	.006	.000	.000	.000	.018	.235
41	.024	.014	.005	.003	.000	.046	.227
43	.008	.000	.002	.000	.000	.010	.219
44	.005	.000	.000	.000	.000	.005	.120
45	.008	.002	.000	.000	.000	.010	.136
46	.009	.006	.000	.000	.000	.015	.284
57	.005	.003	.000	.000	-.001	.007	.156
58	.015	.003	.000	.000	.000	.018	.226
59	.023	.013	.000	.010	.000	.046	.339
60	.018	.015	.003	.005	.000	.041	.288
68	.012	.005	.000	.000	.000	.017	.219
71	.014	.007	.002	.000	.000	.023	.298
72	.020	.012	.010	.000	.000	.042	.350
80	.018	.010	.003	.000	.000	.031	.319
81	.008	.006	-.001	.000	.000	.013	.267
82	.012	.003	.007	.008	.000	.030	.297
83	.009	.007	.000	.000	-.002	.014	.330
84	.009	.011	.002	.000	.000	.022	.325
85	.002	.004	.000	.000	.000	.006	.233
86	.005	.005	.000	.000	-.002	.008	.308
87	.004	.003	.000	.000	.000	.007	.228
88	.006	.009	.003	.000	.000	.018	.340
89	.007	.001	.000	.000	.000	.008	.239
90	.006	.000	.000	.003	-.003	.006	.217
Total	.341	.190	.039	.029	-.004		7.755
Arith. Mean	.011	.006	.001	.001	.000		

TABLE IV-C. Weekly radial increases (in inches) for Size Class III (over 20 inches DBH) trees. 1949.

No.	Week Ending						Totals to 5-12
	4-7	4-14	4-21	4-28	5-5	5-12	
31	.000	.000	.000	.000	.003	.005	.008
35	.000	.000	.000	.000	.006	.005	.011
37	.000	.000	.000	.000	.007	.006	.013
42	.000	.000	.000	.000	.013	.005	.018
47	.000	.000	.000	.000	.005	.007	.012
48	.000	.000	.000	.000	.009	.006	.015
49	.000	.000	.000	.000	.004	.002	.006
50	.000	.000	.000	.000	.008	.009	.017
51	.000	-.001	.000	.000	.000	.002	.001
52	.000	.000	.000	.000	.006	.005	.011
53	.001	.000	.000	.000	.007	.006	.014
54	.001	.000	.000	.000	.003	.004	.008
55	.000	.001	.000	.000	.003	.002	.006
56	.000	-.001	.000	.000	.011	.012	.022
61	.000	.000	.000	.000	.008	.007	.015
62	.000	.000	.000	.000	.012	.006	.018
63	.000	.000	.000	.000	.002	.007	.009
64	.000	.000	.000	.000	.004	.006	.010
65	.000	.000	.000	.000	.007	.007	.014
66	.000	.000	.000	.000	.008	.010	.018
67	-.001	.000	.000	.000	.010	.008	.017
69	.000	.000	.000	.000	.000	.001	.001
70	.000	.000	.000	.000	.003	.006	.009
73	.000	.000	.000	.000	.009	.009	.018
74	-.002	.001	.001	.000	.005	.008	.013
75	.000	.001	.000	.000	.011	.005	.017
76	.000	.000	.000	-.001	.001	.003	.003
77	.000	-.001	.000	-.001	.004	.009	.011
78	-.001	-.002	.000	.000	.004	.009	.010
79	.000	.000	.000	.000	.006	.006	.012
Total	-.002	-.002	.001	-.002	.179	.183	
Arith. Mean	.000	.000	.000	.000	.006	.006	

TABLE IV-C (Continued)

No.	Week Ending							Totals 5-19 to 6-30
	5-19	5-26	6-2	6-9	6-16	6-23	6-30	
31	.008	.003	.015	.013	.013	.012	.015	.079
35	.006	.005	.017	.021	.024	.020	.028	.121
37	.006	.005	.015	.012	.013	.011	.015	.077
42	.009	.007	.018	.022	.024	.028	.036	.144
47	.005	.007	.018	.020	.011	.012	.020	.093
48	.015	.006	.018	.015	.025	.022	.033	.134
49	.004	-.002	.013	.010	.008	.011	.010	.054
50	.009	.005	.019	.019	.018	.020	.021	.111
51	-.002	.001	.017	.018	.007	.013	.012	.066
52	.011	.003	.022	.023	.023	.029	.037	.148
53	.013	.004	.018	.021	.019	.021	.026	.122
54	.007	.002	.008	.027	.012	.013	.040	.109
55	.007	.004	.009	.012	.008	.008	.006	.054
56	.023	.011	.026	.024	.025	.026	.029	.164
61	.008	.006	.024	.025	.020	.024	.031	.138
62	.011	.009	.019	.021	.019	.020	.021	.120
63	.005	.006	.018	.019	.014	.015	.021	.098
64	.010	.007	.022	.021	.012	.015	.015	.102
65	.005	.006	.016	.019	.014	.014	.021	.095
66	.014	.008	.018	.017	.013	.014	.026	.110
67	.009	.007	.018	.018	.013	.018	.023	.106
69	.000	-.002	.008	.010	.008	.010	.008	.042
70	.001	.005	.015	.018	.017	.018	.026	.100
73	.008	.008	.017	.018	.014	.015	.024	.104
74	.008	.003	.020	.018	.022	.027	.035	.133
75	.011	.002	.016	.014	.018	.019	.021	.101
76	.005	.001	.015	.016	.009	.011	.010	.067
77	.015	.005	.022	.024	.025	.030	.029	.150
78	.018	.010	.025	.023	.024	.028	.028	.156
79	.008	.000	.017	.016	.018	.018	.015	.092
Total	.257	.142	.523	.554	.490	.542	.682	
Arith. Mean	.0086	.0047	.0174	.0185	.0163	.018	.0227	

TABLE IV-C (Continued)

No.	Week Ending							Totals 7-7 to 8-18
	7-7	7-14	7-21	7-28	8-4	8-11	8-18	
31	.009	.009	.003	-.003	.005	.002	.000	.025
35	.025	.021	.020	.011	.019	.016	.001	.112
37	.014	.015	.009	.004	.015	.010	-.004	.063
42	.034	.030	.024	.024	.035	.036	.005	.188
47	.027	.021	.017	.006	.016	.011	-.002	.096
48	.029	.023	.018	.012	.023	.021	.006	.132
49	.005	.008	.007	.002	.005	.002	-.009	.020
50	.016	.014	.015	.007	.018	.015	.000	.085
51	.010	.011	.009	.005	.014	.010	-.005	.054
52	.032	.026	.020	.015	.021	.020	.002	.136
53	.025	.020	.022	.014	.016	.013	.001	.111
54	.015	.027	.015	.015	.020	.021	.002	.115
55	.002	.001	.023	.007	.015	.002	-.006	.044
56	.029	.028	.021	.014	.026	.021	.002	.141
61	.027	.023	.015	.010	.024	.015	.000	.114
62	.020	.015	.014	.008	.012	.009	-.005	.073
63	.019	.016	.013	.005	.011	.006	-.007	.063
64	.017	.019	.015	.011	.016	.009	-.003	.084
65	.021	.015	.013	.007	.012	.013	.000	.081
66	.029	.024	.018	.014	.016	.017	.000	.118
67	.021	.019	.014	.010	.015	.012	-.001	.090
69	.003	.006	.003	-.003	.005	.001	-.010	.005
70	.023	.018	.018	.010	.013	.011	-.003	.090
73	.025	.019	.017	.009	.019	.012	.006	.107
74	.029	.026	.023	.017	.015	.022	.003	.135
75	.022	.016	.014	.012	.017	.015	.001	.097
76	.010	.010	.013	.007	.016	.013	.002	.071
77	.024	.023	.020	.011	.021	.020	.005	.124
78	.016	.025	.015	.011	.013	.007	-.004	.083
79	.016	.013	.010	.006	.009	.002	-.005	.051
Total	.594	.541	.458	.278	.482	.384	-.028	
Arith. Mean	.0198	.018	.0152	.0093	.016	.0128	.0009	

TABLE IV-C (Continued)

No.	Week Ending					Totals 8-25 to 10-13	Season Totals
	8-25	9-2	9-16	9-30	10-13		
31	-.007	.002	.000	.000	.000	-.005	.107
35	.011	.006	.001	.000	.000	.018	.262
37	.007	.003	.000	.000	.000	.010	.163
42	.026	.016	.013	.000	.000	.055	.405
47	.012	.006	.001	.001	.000	.020	.221
48	.010	.005	.002	.003	-.003	.017	.298
49	.007	.002	.000	.000	.000	.009	.089
50	.009	.002	.000	.003	-.003	.011	.224
51	.005	.002	.001	.000	.000	.008	.129
52	.013	.009	.004	.003	-.003	.026	.321
53	.014	.005	.001	.001	.000	.021	.268
54	.011	.006	.000	.001	-.001	.017	.249
55	.003	.000	.000	.002	-.003	.002	.106
56	.011	.004	.000	.003	-.003	.015	.342
61	.008	.002	.000	.000	.000	.010	.277
62	.007	.000	.000	.000	.000	.007	.218
63	.004	.002	.000	.000	-.002	.004	.174
64	.006	.004	.000	.000	-.001	.009	.205
65	.009	.005	.000	.000	.000	.014	.204
66	.010	.006	.000	.000	.000	.016	.262
67	.006	.000	.000	.000	.000	.006	.219
69	.005	.000	.000	.000	.000	.005	.053
70	.007	.002	.000	.000	-.002	.007	.206
73	.000	.003	.000	.000	.000	.003	.232
74	.012	.005	.002	.000	.000	.019	.300
75	.008	.004	.001	.003	.000	.016	.231
76	.008	.004	.000	.003	-.002	.013	.154
77	.011	.006	.000	.003	-.002	.018	.303
78	.004	.001	.000	.003	-.003	.005	.254
79	.001	.001	-.001	.003	-.003	.001	.156
Total	.238	.113	.025	.032	-.031		6.632
Arith. Mean	.008	.004	.0009	.001	.001		

TABLE V. Weekly radial increases (in inches) of trees measured along four radii. 1949.

No.	Week Ending						Totals to 5-12
	4-7	4-14	4-21	4-28	5-5	5-12	
91N	.000	-.001	.000	.000	.009	.008	.016
91S	.000	.000	.000	.000	.009	.008	.017
91E	.001	-.001	.001	.000	.010	.007	.017
91W	.003	.000	.000	.000	.010	.010	.023
92N	.000	.000	.000	.000	.006	.006	.012
92S	.000	.000	.000	.000	.009	.005	.014
92E	.000	.000	.000	.000	.000	.001	.001
92W	.000	.000	-.001	.000	.003	.003	.005
93N	.001	.000	.000	.000	.004	.004	.009
93S	.000	.000	.000	.000	.006	.005	.011
93E	.000	.000	.000	.000	.006	.007	.013
93W	.000	.000	.000	.000	.003	.007	.010
94N	.001	.000	.000	.000	.002	.004	.007
94S	.000	.000	.000	.000	.009	.004	.013
94E	-.001	.000	.000	.000	.007	.006	.012
94W	.001	.000	.000	.000	.008	.004	.013
95N	.000	.000	.000	.000	.003	.004	.007
95S	.000	.000	.000	.000	.008	.005	.013
95E	.000	.000	.000	.001	.003	.003	.007
95W	.000	.000	.000	.000	.007	.004	.011

TABLE V (Continued)

No.	Week Ending						Totals to 5-12
	4-7	4-14	4-21	4-28	5-5	5-12	
96N	.000	.000	.000	.000	.002	.005	.007
96S	.001	.000	.000	.000	.011	.011	.023
96E	.001	.000	.000	.000	.016	.009	.026
96W	.000	.000	.000	.000	.006	.008	.014
97N	.003	.000	.000	.000	.003	.004	.010
97S	.000	.000	.000	.000	.005	.001	.006
97E	-.002	.000	.000	.000	.000	.002	.000
97W	.000	.000	.000	.000	.000	.004	.004
98N	.000	.000	.000	.000	.003	.004	.007
98S	.000	.000	.000	.000	.003	.004	.007
98E	.000	.000	.000	.000	.008	.008	.016
98W	.000	.000	.000	.000	.002	.005	.007
99N	.000	-.002	.000	.000	.004	.004	.006
99S	.000	.000	.000	.003	.007	.005	.015
99E	.000	.000	.000	.000	.006	.006	.012
99W	.000	.000	.000	.000	.009	.008	.017
100N	.000	.000	.000	.000	.005	.005	.010
100S	.000	.000	.000	.001	.000	.004	.005
100E	.000	.000	.000	.002	.006	.007	.015
100W	.000	-.001	.001	.000	.002	.006	.008

TABLE V (Continued)

No.	Week Ending							Totals 5-19 to 6-30
	5-19	5-26	6-2	6-9	6-16	6-23	6-30	
91N	.007	.007	.017	.015	.011	.024	.023	.104
91S	.009	.007	.014	.011	.004	.022	.014	.081
91E	.009	.005	.014	.018	.020	.022	.024	.112
91W	.013	.008	.017	.014	.019	.018	.022	.111
92N	.005	.004	.014	.011	.021	.023	.034	.112
92S	.005	.005	.016	.014	.015	.022	.025	.102
92E	.000	.000	.007	.006	.007	.011	.008	.039
92W	-.004	.003	.011	.008	.008	.008	.008	.042
93N	.001	.007	.015	.012	.012	.019	.024	.090
93S	.011	.006	.022	.016	.013	.037	.031	.136
93E	.004	.006	.019	.017	.019	.025	.034	.124
93W	.008	.008	.024	.020	.018	.026	.034	.138
94N	.008	.006	.016	.014	.018	.021	.029	.112
94S	.005	.004	.016	.015	.022	.026	.033	.121
94E	.010	.007	.018	.017	.021	.025	.030	.128
94W	.009	.007	.017	.019	.022	.027	.030	.131
95N	.003	.004	.013	.011	.015	.012	.020	.078
95S	.008	.006	.016	.017	.021	.024	.033	.125
95E	.004	.005	.016	.012	.019	.021	.027	.104
95W	.009	.005	.018	.018	.013	.022	.025	.110

TABLE V (Continued)

No.	Week Ending							Totals 5-19 to 6-30
	5-19	5-26	6-2	6-9	6-16	6-23	6-30	
96N	.012	.008	.017	.015	.013	.018	.018	.101
96S	.014	.006	.015	.013	.012	.016	.019	.095
96E	.009	.006	.020	.018	.012	.020	.014	.099
96W	.009	.008	.017	.013	.013	.017	.016	.092
97N	.002	.001	.013	.012	.011	.012	.014	.065
97S	.000	.000	.011	.012	.013	.016	.016	.068
97E	-.002	.007	.000	.006	.008	.006	.006	.031
97W	.000	.000	.013	.014	.011	.017	.017	.072
98N	.005	.000	.011	.008	.011	.014	.011	.060
98S	.000	-.001	.010	.009	.006	.008	.008	.040
98E	.013	.008	.020	.023	.014	.018	.021	.117
98W	.006	.002	.017	.018	.017	.019	.019	.098
99N	.011	.007	.024	.024	.015	.022	.019	.122
99S	.013	.008	.019	.024	.015	.019	.026	.124
99E	.017	.007	.022	.026	.023	.035	.038	.168
99W	.018	.005	.022	.032	.025	.029	.040	.171
100N	.005	.006	.018	.020	.012	.015	.030	.106
100S	.001	.004	.018	.015	.012	.012	.021	.083
100E	.004	.006	.020	.018	.015	.023	.025	.111
100W	.005	.004	.018	.017	.004	.022	.023	.093

TABLE V (Continued)

No.	Week Ending							Totals 7-7 to 8-18
	7-7	7-14	7-21	7-28	8-4	8-11	8-18	
91N	.022	.018	.012	.011	.016	.011	-.002	.088
91S	.014	.010	.004	.005	.010	.005	-.006	.042
91E	.025	.020	.018	.007	.011	.012	-.008	.087
91W	.020	.007	.008	.018	.013	.010	-.006	.070
92N	.015	.016	.012	.009	.013	.009	-.004	.070
92S	.021	.015	.009	.008	.013	.005	.000	.071
92E	.002	.003	.003	-.001	.002	.001	-.001	.009
92W	.005	.006	.005	.000	.004	.001	-.007	.014
93N	.020	.020	.012	.009	.016	.014	-.006	.085
93S	.029	.024	.015	.010	.016	.013	-.003	.104
93E	.033	.030	.024	.007	.020	.013	-.002	.125
93W	.033	.030	.021	.015	.019	.016	.000	.134
94N	.024	.025	.014	.008	.014	.012	.001	.098
94S	.025	.010	.015	.010	.018	.011	-.002	.087
94E	.021	.014	.015	.015	.012	.014	.000	.091
94W	.024	.024	.018	.009	.019	.013	-.001	.106
95N	.017	.014	.007	.005	.004	.003	-.011	.039
95S	.030	.025	.015	.011	.010	.012	-.003	.100
95E	.021	.017	.011	.007	.012	.006	-.007	.067
95W	.031	.023	.019	.009	.012	.007	-.006	.095

TABLE V (Continued)

No.	Week Ending							Totals 7-7 to 8-18
	7-7	7-14	7-21	7-28	8-4	8-11	8-18	
96N	.016	.014	.011	.006	.010	.007	-.005	.059
96S	.017	.015	.010	.004	.011	.007	-.003	.061
96E	.015	.022	.021	.007	.012	.010	-.005	.082
96W	.013	.013	.009	.005	.008	.005	-.008	.025
97N	.010	.009	.009	.004	.008	.007	-.008	.039
97S	.013	.013	.011	.004	.011	.006	-.005	.053
97E	.003	.003	.003	-.003	.003	.001	-.009	.001
97W	.012	.010	.010	.006	.008	.004	-.004	.046
98N	.011	.016	.015	.012	.013	.006	-.005	.068
98S	.010	.012	.013	.009	.014	.010	-.006	.062
98E	.021	.025	.024	.016	.025	.018	.001	.130
98W	.020	.022	.021	.013	.024	.017	.000	.117
99N	.026	.028	.028	.017	.023	.021	.001	.144
99S	.031	.028	.024	.012	.016	.017	.000	.128
99E	.027	.020	.024	.010	.017	.020	.000	.118
99W	.046	.043	.039	.030	.040	.033	.016	.247
100N	.031	.025	.023	.017	.020	.015	.001	.132
100S	.019	.016	.015	.010	.014	.010	.000	.084
100E	.020	.020	.016	.014	.020	.020	.000	.110
100W	.020	.017	.015	.006	.015	.015	.001	.089

TABLE V (Continued)

No.	Week Ending					Totals 8-25 to 10-13	Season Totals
	8-25	9-2	9-16	9-30	10-13		
91N	.009	.002	.000	.000	.000	.011	.219
91S	.004	.002	.000	.000	.000	.006	.146
91E	.005	.002	.000	.000	.000	.007	.223
91W	.002	.003	.000	.002	.000	.007	.211
92N	.007	.001	.000	.000	.000	.008	.202
92S	.005	.001	.002	.000	.000	.008	.195
92E	.002	.002	.000	.000	.000	.004	.053
92W	.004	.003	.000	.000	-.001	.006	.067
93N	.000	.003	.001	.000	.000	.004	.188
93S	.009	.003	.000	.000	.000	.012	.263
93E	.009	.004	.000	.000	.000	.013	.275
93W	.009	.004	.001	.000	.000	.014	.296
94N	.007	.004	.002	.000	.000	.013	.230
94S	.008	.005	-.001	.000	.000	.012	.233
94E	.011	.004	.001	.000	.000	.016	.247
94W	.001	.004	.000	.000	.000	.005	.255
95N	.003	.002	.000	.001	.000	.006	.130
95S	-.002	.003	.000	.000	.000	.001	.239
95E	.004	.001	.001	.000	.000	.006	.184
95W	.004	.001	.000	.000	.001	.006	.222

TABLE V (Continued)

No.	Week Ending					Totals 8-25 to 10-13	Season Totals
	8-25	9-2	9-16	9-30	10-13		
96N	.004	.002	.000	.000	.000	.006	.173
96S	.005	.002	.000	.000	.000	.007	.186
96E	.005	.002	.000	.000	.000	.007	.214
96W	.003	.002	.000	.000	.000	.005	.136
97N	.005	.002	.000	-.002	.000	.005	.119
97S	.007	.001	.000	.000	.000	.008	.135
97E	.006	-.001	.000	.000	.000	.005	.037
97W	.006	.001	.000	.000	.000	.007	.129
98N	.005	.005	.000	.000	.000	.010	.145
98S	.006	.000	.000	.000	.000	.006	.115
98E	.015	.005	.000	.000	.000	.020	.283
98W	.011	.002	.000	.000	.000	.013	.235
99N	.010	.004	.000	.000	.000	.014	.286
99S	.007	.003	.000	.000	.000	.010	.277
99E	.002	.003	.000	.000	.000	.005	.303
99W	.013	.010	-.003	.000	.000	.020	.455
100N	.011	.009	.001	.000	.000	.021	.269
100S	.007	.005	.004	.000	.000	.016	.188
100E	.014	.008	.000	.000	.000	.022	.258
100W	.013	.006	.001	.000	.000	.020	.210

TABLE VI-A. Weekly radial increases (in inches) for Size Class I (10-15 inches DBH) trees. 1950.

No.	Week Ending							Totals to 5-18
	4-6	4-13	4-20	4-27	5-4	5-11	5-18	
1	.000	-.001	-.002	-.002	.000	.011	.012	.018
2	-.001	-.002	.001	-.002	.002	.014	.015	.027
3	.002	-.002	-.001	-.002	-.002	.013	.008	.020
4	.002	-.003	-.001	-.002	.000	.008	.007	.011
5	.002	-.006	.000	.000	-.001	.010	.007	.012
6	-.002	-.002	-.001	.000	.000	.015	.016	.026
7	.002	-.002	.000	-.001	.000	.012	.018	.029
8	.003	-.002	-.001	.000	.000	.004	.005	.009
9	.000	-.003	-.002	-.001	.000	.008	.005	.007
10	.004	-.002	-.002	-.002	-.002	.018	.014	.028
11	.004	-.003	-.003	-.002	-.002	.012	.006	.012
12	.004	-.004	-.002	.001	-.003	.005	.004	.005
13	-.002	.000	-.002	-.001	-.001	.005	.007	.006
14	.002	-.003	.000	-.002	-.003	.010	.013	.017
15	.002	-.003	-.001	-.001	-.002	.008	.005	.008
16	.001	-.002	-.001	-.002	-.004	.013	.008	.013
17	-.004	.000	.000	.000	-.002	.007	.008	.009
18	.000	-.001	-.001	-.002	-.002	.011	.006	.011
19	-.002	.000	-.001	.000	-.001	.013	.011	.020
20	.002	-.003	.000	-.001	-.002	.015	.014	.025
21	-.001	-.001	.000	-.002	-.003	.012	.007	.012
22	-.004	-.002	-.001	-.001	.000	.013	.008	.013
23	.001	-.002	.000	-.002	-.002	.011	.015	.021
24	-.001	-.002	.001	.000	-.002	.006	.008	.010
25	.004	-.003	-.001	-.001	-.002	.012	.016	.023
26	-.001	-.001	.000	-.001	-.004	.015	.013	.021
27	.007	-.003	.000	-.004	.000	——	——	.000
28	.001	-.002	.000	-.001	-.001	.015	.013	.025
29	.002	-.004	-.002	-.001	-.002	.010	.005	.008
30	.004	.000	-.001	-.001	-.002	.006	.006	.012
Total	.031	-.064	-.024	-.036	-.042	.312	.280	
Arith. Mean	.001	-.002	-.001	-.001	-.001	.010	.009	

TABLE VI-A (Continued)

No.	Week Ending						Totals 5-25 to 7-1
	5-25	6-2	6-10	6-17	6-24	7-1	
1	.017	.023	.022	.014	.010	.016	.102
2	.017	.019	.019	.023	.019	.026	.122
3	.011	.011	.011	.008	.006	.011	.058
4	.010	.015	.019	.011	.011	.013	.079
5	.012	.013	.022	.018	.013	.017	.095
6	.017	.023	.024	.022	.016	.026	.128
7	.021	.022	.022	.021	.017	.023	.126
8	.015	.022	.024	.014	.013	.015	.103
9	.011	.014	.012	.010	.006	.005	.058
10	.022	.020	.029	.021	.019	.022	.133
11	.008	.016	.018	.014	.012	.013	.081
12	.008	.016	.020	.017	.013	.008	.082
13	.015	.014	.018	.011	.013	.014	.085
14	.010	.016	.018	.016	.012	.018	.090
15	.018	.028	.027	.020	.010	.016	.119
16	.009	.013	.016	.010	.013	.017	.078
17	.010	.014	.014	.010	.011	.009	.068
18	.017	.023	.026	.016	.017	.018	.117
19	.020	.023	.022	.012	.016	.019	.112
20	.015	.023	.023	.023	.018	.019	.121
21	.010	.018	.022	.017	.017	.017	.101
22	.015	.021	.018	.021	.009	.029	.113
23	.013	.018	.023	.020	.015	.021	.110
24	.010	.019	.026	.019	.020	.021	.115
25	.016	.024	.022	.020	.012	.020	.114
26	.020	.019	.013	.009	.010	.009	.080
27	.013	.014	.008	.006	.009	.008	.058
28	.017	.022	.025	.020	.016	.021	.121
29	.009	.017	.026	.020	.017	.008	.097
30	.009	.012	.015	.012	.011	.010	.069
Total	.415	.552	.604	.475	.401	.489	
Arith. Mean	.014	.016	.0175	.016	.013	.016	

TABLE VI-A (Continued)

No.	Week Ending						Totals 7-8 to 8-12
	7-8	7-15	7-22	7-29	8-5	8-12	
1	.016	.017	.008	.015	.014	.010	.080
2	.020	.020	.011	.021	.022	.013	.107
3	.011	.012	.004	.009	.004	.004	.044
4	.013	.013	.011	.009	.012	.009	.067
5	.015	.018	.012	.013	.020	.011	.089
6	.017	.018	.012	.012	.022	.011	.092
7	.023	.028	.015	.017	.018	.014	.115
8	.019	.018	.017	.021	.020	.013	.108
9	.010	.007	.006	.009	.008	.010	.050
10	.023	.022	.010	.017	.017	.016	.105
11	.010	.015	.009	.014	.018	.018	.084
12	.013	.014	.007	.010	.008	.005	.057
13	.021	.021	.015	.012	.013	.011	.093
14	.017	.016	.011	.017	.021	.014	.096
15	.019	.012	.010	.015	.016	.014	.086
16	.020	.016	.007	.013	.013	.010	.079
17	.016	.015	.006	.012	.010	.011	.070
18	.034	.007	.015	.019	.019	.014	.108
19	.021	.019	.013	.014	.012	.009	.088
20	.020	.014	.008	.020	.014	.013	.089
21	.021	.010	.013	.015	.015	.013	.087
22	.017	.019	.016	.016	.021	.012	.101
23	.028	.021	.009	.014	.014	.014	.100
24	.024	.024	.018	.019	.020	.014	.119
25	.017	.018	.020	.018	.020	.021	.114
26	.018	.019	.018	.020	.019	.016	.110
27	.016	.015	.008	.016	.015	.015	.085
28	.018	.012	.008	.008	.003	.010	.059
29	.010	.010	.008	.011	.009	.007	.055
30	.015	.018	.007	.018	.010	.013	.081
Total	.542	.488	.332	.444	.447	.365	
Arith. Mean	.018	.016	.011	.015	.015	.012	

TABLE VI-A (Continued)

No.	Week Ending				Totals 8-19 to 9-16	Season Totals
	8-19	8-26	9-2	9-16		
1	-.001	.000	.002	.000	.001	.201
2	.006	.000	.007	-.002	.011	.267
3	.000	.000	.002	.000	.002	.124
4	.000	.002	.000	.000	.002	.159
5	.011	.000	.003	-.001	.013	.209
6	.007	.000	.000	.000	.007	.253
7	.011	.005	.000	.001	.017	.287
8	.015	.003	.000	.002	.020	.240
9	.004	.000	.000	.000	.004	.119
10	.011	.005	.008	.001	.025	.291
11	.014	.002	.010	.003	.029	.206
12	.000	-.002	.000	.000	-.002	.142
13	.007	-.001	.000	-.002	.004	.188
14	.016	.005	.000	-.001	.020	.223
15	.017	.000	.000	.000	.017	.230
16	.016	.002	.005	.000	.023	.193
17	.007	.000	.003	.000	.010	.157
18	.015	.000	.000	-.001	.014	.250
19	.005	.007	.000	.000	.012	.232
20	.001	.000	.000	.000	.001	.236
21	.010	.003	.000	.000	.013	.213
22	.017	.003	.010	.002	.032	.259
23	.013	.001	.000	.000	.014	.245
24	.015	.003	.000	.000	.018	.262
25	.018	.007	.000	.000	.025	.276
26	.017	.004	.000	.000	.021	.232
27	.015	.002	.005	.000	.022	.165
28	.019	.000	.000	-.001	.019	.224
29	.000	.000	.000	.000	.000	.160
30	.008	-.001	.000	.000	.007	.169
Total	.294	.050	.055	.001		6.412
Arith. Mean	.010	.002	.002	.000		

TABLE VI-B. Weekly radial increases (in inches) for Size Class II (15-20 inches DBH) trees. 1950.

No.	Week Ending							Totals to 5-18
	4-6	4-13	4-20	4-27	5-4	5-11	5-18	
32	.001	-.002	-.002	-.001	.000	.012	.015	.023
33	.002	-.002	.000	-.003	-.001	.018	.012	.026
34	.003	-.003	-.001	-.002	.002	.011	.012	.022
36	-.002	-.002	-.001	-.002	-.001	.009	.004	.005
38	.003	-.003	.000	-.002	-.002	.009	.005	.010
39	.002	-.004	.000	-.001	-.001	.008	.007	.011
40	.002	-.003	-.002	.000	-.001	.009	.009	.014
41	.003	-.002	-.002	-.001	.000	.016	.017	.031
43	-.001	-.002	-.001	-.001	-.002	.014	.011	.018
44	-.001	-.001	-.001	-.002	.000	.001	.005	.001
45	-.002	-.002	.000	-.001	-.001	.006	.004	.004
46	-.001	.000	-.002	.000	-.001	.010	.008	.014
57	.001	-.002	-.003	-.002	.000	.009	.009	.012
58	-.001	-.002	-.002	-.002	.000	.010	.007	.010
59	.003	-.002	-.001	-.002	-.001	.014	.012	.023
60	.004	-.005	.000	-.002	-.002	.013	.009	.017
68	.000	-.003	-.003	-.003	.000	.013	.009	.013
71	.001	-.002	-.001	-.001	-.001	.010	.009	.015
72	.000	-.002	-.001	-.003	.000	.016	.015	.025
80	.000	-.001	-.004	-.001	-.002	.012	.008	.012
81	.000	-.003	-.001	-.001	-.002	.011	.007	.011
82	.004	.000	-.002	-.001	-.002	.021	.012	.032
83	.001	-.003	-.001	-.002	-.003	.017	.014	.023
84	.002	-.006	.000	-.002	.000	.004	.010	.008
85	.001	-.002	-.001	-.002	-.001	.012	.014	.021
86	-.002	-.001	-.001	-.002	-.002	.015	.015	.022
87	.002	-.003	-.001	-.003	.000	.012	.008	.015
88	-.002	.000	.002	-.003	.003	.010	.022	.032
89	-.003	-.001	.000	-.002	-.001	.014	.007	.014
90	-.006	-.002	.000	.000	.000	.014	.008	.014
Total	.014	-.066	-.032	-.049	-.022	.350	.304	
Arith. Mean	.000	-.002	-.001	-.002	-.001	.012	.010	

TABLE VI-B (Continued)

No.	Week Ending						Totals 5-25 to 7-1
	5-25	6-2	6-10	6-17	6-24	7-1	
32	.020	.024	.021	.015	.014	.011	.105
33	.022	.028	.029	.017	.015	.014	.125
34	.018	.016	.018	.016	.015	.007	.090
36	.012	.020	.026	.013	.011	.010	.092
38	.010	.019	.032	.024	.017	.023	.125
39	.013	.020	.022	.018	.014	.017	.104
40	.017	.019	.019	.013	.015	.015	.098
41	.024	.028	.026	.008	.015	.022	.123
43	.018	.013	.011	.010	.011	.011	.074
44	.002	.004	.008	.008	.010	.008	.040
45	.003	.013	.016	.011	.012	.011	.066
46	.012	.015	.020	.018	.015	.018	.098
57	.012	.013	.021	.014	.012	.013	.085
58	.017	.021	.024	.019	.014	.018	.113
59	.019	.020	.019	.011	.012	.014	.095
60	.012	.016	.022	.022	.019	.026	.117
68	.012	.017	.021	.012	.013	.017	.092
71	.013	.016	.017	.014	.014	.019	.093
72	.017	.018	.022	.019	.014	.018	.108
80	.008	.026	.024	.022	.015	.024	.119
81	.014	.020	.020	.019	.013	.018	.104
82	.023	.028	.029	.018	.015	.017	.130
83	.023	.022	.023	.019	.015	.026	.128
84	.010	.031	.021	.007	.011	.016	.096
85	.016	.021	.020	.015	.011	.014	.097
86	.026	.027	.025	.024	.016	.020	.138
87	.012	.014	.019	.014	.011	.015	.085
88	.037	.034	.029	.033	.020	.030	.183
89	.012	.017	.020	.019	.015	.018	.101
90	.013	.010	.017	.014	.014	.019	.087
Total	.467	.590	.641	.486	.418	.509	
Arith. Mean	.016	.017	.019	.016	.014	.017	

TABLE VI-B (Continued)

No.	Week Ending						Totals 7-8 to 8-12
	7-8	7-15	7-22	7-29	8-5	8-12	
32	.013	.006	——	.004	.001	.007	.031p
33	.013	.012	.015	.010	.013	.014	.077
34	.018	.019	.014	.022	.011	.015	.099
36	.016	.009	.013	.011	.013	.013	.075
38	.027	.020	.021	.020	.019	.017	.124
39	.019	.021	.019	.019	.021	.013	.112
40	.018	.018	.015	.016	.014	.019	.100
41	.023	.025	.018	.029	.032	.028	.155
43	.012	.010	.005	.004	.002	.002	.035
44	.010	.010	.002	.005	.000	.000	.027
45	.014	.011	.006	.011	.011	.011	.064
46	.021	.020	.013	.019	.018	.012	.103
57	.016	.014	.005	.012	.008	.008	.063
58	.013	.018	.009	.018	.020	.015	.093
59	.020	.019	.016	.021	.010	.017	.103
60	.026	.024	.017	.024	.023	.013	.127
68	.018	.022	.008	.018	.011	.014	.091
71	.023	.017	.008	.016	.021	.018	.103
72	.021	.018	.026	.014	.023	.009	.110
80	.024	.020	.017	.024	.018	.017	.120
81	.018	.017	.015	.018	.023	.012	.103
82	.028	.022	.019	.024	.030	.021	.144
83	.029	.027	.020	.018	.023	.017	.134
84	.016	.015	.018	.020	.025	.015	.109
85	.012	.014	.004	.011	.010	.008	.059
86	.024	.024	.017	.016	.022	.014	.117
87	.017	.017	.011	.014	.013	.010	.082
88	.015	.013	.014	.025	.025	.020	.112
89	.018	.021	.013	.012	.017	.011	.092
90	.020	.014	.009	.023	.022	.016	.104
Total	.562	.517	.387p	.498	.499	.406	
Arith. Mean	.019	.017	.013	.017	.017	.0135	

TABLE VI-B (Continued)

No.	Week Ending				Totals 8-19 to 9-16	Season Totals
	8-19	8-26	9-2	9-16		
32	.015	.000	.008	.000	.023	.182
33	.010	.002	.008	.000	.020	.248
34	.018	.004	.000	.000	.022	.233
36	.004	.000	.002	.000	.006	.178
38	.012	.004	.000	.000	.016	.275
39	.014	.001	.004	-.001	.018	.245
40	.010	.009	.000	.000	.019	.231
41	.025	.000	.000	.000	.025	.334
43	.000	.000	-.007	.003	-.004	.123
44	.000	-.001	.000	.000	-.001	.067
45	.010	.000	.000	-.002	.008	.142
46	.000	-.001	.000	.000	-.001	.214
57	.001	.000	.000	.000	.001	.161
58	.016	.002	.000	.000	.018	.234
59	.013	.008	.000	.000	.021	.242
60	.022	.001	.000	.001	.024	.285
68	.011	.002	.000	.000	.013	.209
71	.017	.003	.000	.001	.021	.232
72	.009	.005	.002	.000	.016	.259
80	.015	.000	.000	.000	.015	.266
81	.015	.001	.000	-.002	.014	.232
82	.018	.008	.001	.000	.027	.333
83	.018	.006	.002	.000	.026	.311
84	.019	-.001	.000	.000	.018	.231
85	.000	-.002	.000	.000	-.002	.175
86	.013	.000	.000	.000	.013	.290
87	-.001	.000	.000	.000	-.001	.181
88	.018	.001	.006	-.003	.022	.349
89	.007	.000	.001	.000	.008	.215
90	.014	.006	.000	.000	.020	.225
Total	.343	.058	.027	-.003		6.902
Arith. Mean	.011	.002	.001	.000		

TABLE VI-C. Weekly radial increases (in inches) for Size Class III (over 20 inches DBH) trees. 1950.

No.	Week Ending							Totals to 5-18
	4-6	4-13	4-20	4-27	5-4	5-11	5-18	
31	.001	-.001	-.002	.000	-.002	.007	.005	.008
35	.002	-.002	-.003	.000	-.005	.013	.010	.015
37	-.001	-.002	.000	-.002	.000	.013	.004	.012
42	.004	-.003	.000	.000	-.001	.008	.018	.026
47	.000	-.001	.000	-.002	.000	.032	.009	.039
48	-.003	-.001	.000	-.001	.001	.011	.010	.017
49	-.005	.000	-.001	.000	-.001	.005	.002	.000
50	.002	-.002	.000	-.002	-.001	.011	.007	.015
51	.000	-.001	-.002	-.002	.001	.006	.004	.006
52	.001	-.004	.000	-.001	.000	.010	.005	.011
53	-.003	.000	-.003	-.002	-.001	.003	.008	.002
54	.002	-.002	.001	-.003	-.003	.007	.005	.007
55	-.002	-.002	-.002	-.002	.001	.005	.004	.002
56	-.004	-.001	-.001	-.001	.000	.012	.012	.017
61	-.001	-.001	-.001	-.002	.000	.006	.011	.012
62	.001	-.004	.001	-.002	-.003	.013	.005	.011
63	-.004	-.002	.000	-.002	.000	.009	.007	.008
64	.000	-.003	-.003	-.002	.000	.012	.006	.010
65	-.002	-.002	-.001	-.002	.000	.011	.004	.008
66	-.002	-.002	-.001	-.002	.000	.009	.008	.010
67	-.002	-.001	.000	-.002	-.002	.012	.012	.017
69	.001	-.002	-.002	-.002	-.001	.006	.001	.001
70	-.004	.000	.000	-.001	.000	.007	.005	.007
73	.000	-.001	-.001	-.002	-.001	.012	.009	.016
74	.010	-.002	-.002	.000	-.002	.002	.007	.011
75	-.007	.000	-.001	-.002	.002	.003	.009	.004
76	-.003	-.002	.000	-.001	.000	.011	.006	.011
77	-.003	-.001	-.001	.000	.000	.008	.009	.012
78	-.004	-.001	-.002	-.001	.000	.012	.006	.010
79	-.005	-.001	.000	.000	.000	.011	.008	.013
Total	-.301	-.047	-.027	-.041	-.018	.285	.216	
Arith. Mean	-.001	-.002	-.001	-.001	-.001	.010	.007	

TABLE VI-C (Continued)

No.	Week Ending						Totals 5-25 to 7-1
	5-25	6-2	6-10	6-17	6-24	7-1	
31	.007	.011	.014	.012	.010	.013	.067
35	.016	.024	.024	.019	.013	.018	.114
37	.006	.010	.012	.007	.004	.008	.047
42	.034	.036	.032	.023	.016	.024	.165
47	.018	.017	.017	.011	.004	.015	.082
48	.017	.021	.020	.017	.014	.017	.106
49	.005	.009	.008	.010	.010	.015	.057
50	.011	.010	.015	.017	.015	.018	.086
51	.011	.008	.008	.006	.006	.004	.045
52	.012	.022	.030	.026	.019	.018	.127
53	.011	.017	.022	.022	.017	.014	.103
54	.006	.014	.010	.010	.016	.019	.075
55	.007	.005	.005	.011	.001	.003	.032
56	.021	.023	.021	.020	.016	.018	.119
61	.016	.020	.025	.026	.022	.025	.134
62	.009	.010	.019	.017	.011	.016	.082
63	.009	.015	.015	.008	.009	.007	.063
64	.014	.015	.016	.012	.009	.011	.077
65	.006	.008	.012	.009	.010	.010	.055
66	.020	.021	.021	.014	.011	.011	.098
67	.013	.018	.020	.015	.012	.015	.093
69	.002	.006	.008	.008	.008	.009	.041
70	.003	.006	.014	.012	.011	.017	.063
73	.009	.015	.020	.020	.017	.023	.104
74	.012	.016	.020	.017	.017	.020	.102
75	.009	.014	.002	.004	.015	.011	.055
76	.008	.015	.020	.014	.012	.009	.078
77	.015	.018	.017	.021	.021	.023	.115
78	.014	.020	.017	.015	.014	.013	.093
79	.015	.018	.015	.013	.010	.012	.083
Total	.356	.462	.499	.419	.370	.436	
Arith. Mean	.012	.0135	.015	.014	.012	.0145	

TABLE VI-C (Continued)

No.	Week Ending						Totals 7-8 to 8-12
	7-8	7-15	7-22	7-29	8-5	8-12	
31	.013	.013	.004	.006	.003	.004	.043
35	.017	.023	.010	.015	.010	.007	.082
37	.017	.013	.009	.010	.013	.012	.074
42	.033	.026	.029	.010	.045	.022	.165
47	.020	.015	.000	.015	.010	.008	.068
48	.022	.019	.015	.014	.015	.010	.095
49	.017	.020	.011	.012	.011	.006	.077
50	.019	.014	.009	.015	.010	.010	.077
51	.012	.012	.009	.012	.009	.014	.068
52	.023	.020	.012	.017	.019	.009	.100
53	.004	.005	.009	.021	.019	.017	.075
54	.020	.011	.006	.018	.019	.014	.088
55	.000	.004	-.003	.000	.002	.001	.004
56	.014	.018	.016	.015	.023	.020	.106
61	.024	.022	.019	.021	.019	.016	.121
62	.016	.012	.010	.009	.006	.007	.060
63	.008	.008	.001	.005	.003	.003	.028
64	.014	.012	.010	.008	.007	.006	.057
65	.014	.013	.010	.011	.012	.010	.070
66	.014	.019	.012	.012	.012	.007	.076
67	.015	.018	.012	.016	.020	.016	.097
69	.009	.005	-.001	.005	.001	.002	.021
70	.020	.021	.016	.018	.021	.015	.111
73	.022	.017	.008	.016	.012	.012	.087
74	.023	.021	.020	.018	.023	.018	.123
75	.015	.015	.013	.016	.024	.011	.094
76	.009	.013	.007	.008	.006	.007	.048
77	.019	.025	.009	.019	.023	.022	.117
78	.017	.016	.012	.013	.015	.008	.081
79	.014	.012	.007	.010	.008	.003	.054
Total	.484	.462	.301	.385	.420	.317	
Arith. Mean	.012	.015	.010	.013	.014	.011	

TABLE VI-C (Continued)

No.	Week Ending				Totals 8-19 to 9-16	Season Totals
	8-19	8-26	9-2	9-16		
31	.000	.000	.000	.000	.000	.118
35	.005	.002	.009	.001	.017	.228
37	.009	-.001	.002	.000	.010	.143
42	.028	.000	.000	.001	.029	.385
47	.002	.000	.000	.000	.002	.191
48	.010	-.002	.000	.000	.008	.226
49	.000	.000	.000	.000	.000	.134
50	.005	.000	.000	.000	.005	.183
51	.001	.000	.000	.000	.001	.120
52	.008	.004	.000	-.001	.011	.249
53	.015	.011	.001	.002	.029	.209
54	.010	.000	.001	.000	.011	.181
55	.001	.000	.000	.000	.001	.039
56	.015	.014	.006	.001	.036	.278
61	.012	.001	.002	.000	.015	.282
62	.003	.000	.003	.002	.008	.161
63	.000	.000	.000	.000	.000	.099
64	.001	.000	.001	.000	.002	.146
65	.000	-.002	.001	.000	-.001	.132
66	.002	.000	.003	.000	.005	.189
67	.015	-.001	.002	.001	.017	.224
69	.000	-.001	.000	.000	-.001	.062
70	.013	.003	.007	-.002	.021	.202
73	.006	.000	.000	.000	.006	.213
74	.010	.002	.000	.000	.012	.248
75	.012	.008	.000	.002	.022	.175
76	.004	.000	-.008	.004	.000	.137
77	.020	.013	.000	.002	.035	.279
78	.001	.000	.002	.000	.003	.187
79	.001	.000	.000	.000	.001	.151
Total	.199	.051	.032	.013		5.571
Arith. Mean	.007	.002	.001	.000		

TABLE VII. Weekly radial increases (in inches) of trees measured along four radii. 1950.

No.	Week Ending							Totals to 5-18
	4-6	4-13	4-20	4-27	5-4	5-11	5-18	
91N	-.003	-.001	.000	-.002	-.002	.015	.005	.012
91S	-.005	-.001	.000	.000	-.002	.010	.004	.006
91E	.002	-.002	.000	-.002	-.001	.013	.010	.020
91W	.000	-.003	.000	.000	-.004	.008	.006	.007
92N	-.004	-.001	.001	-.002	-.002	.007	.003	.001
92S	-.002	.000	-.001	-.001	.000	.010	.004	.010
92E	.000	-.001	-.002	-.003	-.002	.004	.001	-.003
92W	-.001	-.001	.000	-.002	-.002	——*	.005	-.001
93N	-.001	-.003	-.001	-.001	-.003	.013	.004	.008
93S	.000	-.002	.000	-.003	-.003	.014	.005	.011
93E	.002	-.002	-.002	-.002	-.002	.009	.011	.014
93W	.000	-.001	-.001	-.001	-.002	.004	.009	.008
94N	-.001	-.001	-.001	-.002	-.003	.014	.002	.008
94S	.002	-.002	.007	-.002	-.004	.007	.009	.017
94E	-.001	-.001	-.001	-.002	-.001	.014	.007	.015
94W	.001	-.002	-.001	-.002	-.002	.013	.004	.011
95N	.000	-.001	-.002	.000	-.001	.008	.004	.008
95S	.000	-.001	-.001	-.003	.000	.011	.007	.015
95E	.000	-.002	-.001	-.002	-.001	.012	.005	.011
95W	.002	-.002	.000	-.002	-.003	.012	.008	.015

* mechanical failure

TABLE VII (Continued)

No.	Week Ending							Totals to 5-18
	4-6	4-13	4-20	4-27	5-4	5-11	5-18	
96N	.000	-.001	.000	-.002	-.002	.010	.003	.008
96S	-.004	.000	.000	-.001	.000	.009	.005	.009
96E	.001	.005	.000	-.002	-.003	.007	.009	.017
96W	-.001	-.003	.000	-.002	-.001	.012	.006	.011
97N	.001	-.002	-.001	-.002	.000	.008	.002	.006
97S	.001	-.001	.000	-.002	-.003	.010	.005	.010
97E	.000	-.003	.000	-.002	-.003	.007	.006	.005
97W	-.003	-.001	.000	-.002	-.002	.009	.002	.003
98N	-.001	-.002	.000	-.002	-.002	.005	.004	.002
98S	-.001	-.002	-.002	.000	-.003	.013	.006	.011
98E	.001	-.002	-.002	-.001	-.003	.012	.012	.017
98W	-.001	-.001	-.002	-.001	-.003	.012	.013	.017
99N	.003	-.001	-.002	-.002	-.003	.011	.009	.015
99S	-.001	.000	-.002	.000	-.002	.011	.005	.011
99E	.002	-.001	-.002	-.001	-.002	.010	.007	.013
99W	.000	-.003	-.001	-.002	-.002	.005	.018	.015
100N	.000	-.001	-.001	-.002	-.001	.014	.012	.021
100S	.002	-.002	-.002	-.002	-.002	.015	.009	.018
100E	.002	-.002	.001	-.003	.002	.006	.007	.013
100W	.000	-.002	-.001	-.002	-.002	.011	.008	.012

TABLE VII (Continued)

No.	Week Ending						Totals 5-25 to 7-1
	5-25	6-2	6-10	6-17	6-24	7-1	
91N	.006	.016	.022	.017	.013	.020	.094
91S	.009	.010	.013	.011	.005	.007	.055
91E	.016	.019	.018	.014	.011	.015	.093
91W	.013	.014	.019	.014	.009	.019	.088
92N	.009	.006	.013	.012	.008	.012	.060
92S	.003	.008	.011	.008	.007	.016	.053
92E	.006	.005	.006	.007	.006	.005	.035
92W	.002	.006	.004	.008	.004	.008	.032
93N	.010	.011	.018	.015	.008	.013	.075
93S	.013	.017	.025	.015	.012	.023	.105
93E	.018	.024	.022	.019	.008	.031	.122
93W	.016	.015	.020	.020	.010	.038	.129
94N	.003	.012	.016	.011	.010	.010	.062
94S	.009	.017	.019	.014	.012	.018	.089
94E	.014	.020	.015	.015	.014	.011	.089
94W	.010	.015	.018	.017	.015	.023	.098
95N	.021	.022	.021	.017	.010	.012	.103
95S	.016	.024	.021	.017	.012	.013	.103
95E	.012	.022	.021	.018	.009	.016	.098
95W	.013	.021	.020	.016	.015	.021	.106

TABLE VII (Continued)

No.	Week Ending						Totals 5-25 to 7-1
	5-25	6-2	6-10	6-17	6-24	7-1	
96N	.012	.018	.018	.013	.010	.010	.081
96S	.010	.015	.018	.015	.008	.009	.075
96E	.018	.023	.019	.014	.010	.011	.095
96W	.016	.022	.023	.020	.010	.014	.105
97N	.003	.005	.010	.007	.007	.008	.040
97S	.002	.006	.004	.005	.007	.004	.028
97E	.000	.005	.008	.006	.008	.008	.035
97W	.001	.007	.010	.008	.011	.009	.046
98N	.012	.010	.011	.009	.010	.007	.059
98S	.008	.010	.014	.014	.010	.011	.067
98E	.024	.024	.023	.019	.013	.010	.113
98W	.015	.019	.013	.012	.013	.011	.083
99N	.020	.027	.032	.031	.016	.022	.148
99S	.015	.025	.030	.022	.016	.020	.128
99E	.016	.032	.031	.027	.019	.023	.148
99W	.025	.037	.042	.044	.024	.016	.188
100N	.014	.020	.023	.015	.013	.016	.101
100S	.011	.015	.019	.014	.010	.012	.081
100E	.017	.019	.022	.015	.012	.011	.096
100W	.017	.019	.018	.014	.011	.011	.090

TABLE VII (Continued)

No.	Week Ending						Totals 7-8 to 8-12
	7-8	7-15	7-22	7-29	8-5	8-12	
91N	.015	.016	.014	.015	.014	.014	.088
91S	.013	.002	.004	.005	.005	.005	.034
91E	.015	.013	.012	.012	.015	.010	.077
91W	.012	.010	.018	.011	.012	.012	.075
92N	.012	.011	.009	.010	.006	.007	.055
92S	.010	.010	.014	.006	.009	.005	.054
92E	.009	.006	.003	.006	.003	.002	.029
92W	.011	.011	.005	.007	.005	.003	.042
93N	.015	.014	.009	.009	.012	.012	.071
93S	.024	.019	.015	.018	.018	.016	.110
93E	.015	.020	.015	.011	.016	.015	.092
93W	.017	.025	.014	.021	.010	.005	.092
94N	.013	.010	.005	.008	.005	.005	.046
94S	.019	.014	.010	.017	.011	.010	.081
94E	.017	.016	.007	.009	.008	.004	.061
94W	.019	.016	.009	.013	.005	.005	.067
95N	.011	.011	.005	.009	.005	.006	.047
95S	.017	.012	.011	.010	.013	.008	.071
95E	.014	.012	.009	.010	.008	.009	.062
95W	.020	.020	.021	.016	.014	.001	.092

TABLE VII (Continued)

No.	Week Ending						Totals 7-8 to 8-12
	7-8	7-15	7-22	7-29	8-5	8-12	
96N	.014	.011	.008	.009	.014	.010	.065
96S	.008	.006	——*	.005	.005	.003	.027
96E	.010	.009	.007	.010	.014	.010	.060
96W	.012	.009	.009	.009	.012	.008	.059
97N	.010	.008	.003	.005	.002	.003	.031
97S	.011	.007	.006	.008	.004	.007	.043
97E	.011	.009	.000	.006	.003	.002	.031
97W	.013	.007	.004	.007	.004	.005	.040
98N	.008	.014	.002	.008	.005	.002	.039
98S	.014	.011	.004	.008	.005	.004	.046
98E	.018	.020	.012	.021	.017	.015	.103
98W	.019	.017	.013	.016	.020	.012	.097
99N	.024	.023	.017	.012	.002	.018	.096
99S	.030	.020	.017	.019	.023	.009	.118
99E	.015	.021	.016	.019	.019	.010	.100
99W	.019	.026	.014	.025	.023	.027	.134
100N	.017	.024	.015	.017	.009	.006	.088
100S	.013	.017	.008	.010	.011	.010	.069
100E	.016	.017	.011	.012	.016	.009	.081
100W	.017	.019	.014	.015	.017	.008	.090

* mechanical failure

TABLE VII (Continued)

No.	Week Ending				Totals 8-19 to 9-16	Season Totals
	8-19	8-26	9-2	9-16		
91N	.014	.001	.003	.000	.018	.212
91S	.001	.000	.000	.000	.001	.096
91E	.000	.000	.006	-.001	.005	.195
91W	.001	.000	.000	.000	.001	.171
92N	——*	——*	.000	.000	.000	.116
92S	.002	.000	-.006	.003	-.001	.116
92E	.000	.000	.000	.000	.000	.061
92W	.000	-.002	-.001	.000	-.003	.070
93N	.008	-.002	.002	.000	.008	.162
93S	.010	-.001	.010	.002	.021	.247
93E	.016	-.001	.008	-.002	.021	.249
93W	.016	-.006	.004	.001	.015	.244
94N	.005	.000	.001	.000	.006	.122
94S	.002	.000	.008	.001	.011	.198
94E	.004	-.001	.000	.000	.003	.168
94W	.001	.000	.000	.000	.001	.177
95N	.000	.000	.000	.000	.000	.158
95S	.001	.000	.000	.000	.001	.190
95E	.000	-.001	.000	.000	-.001	.170
95W	.002	.000	.006	.001	.009	.222

* mechanical failure

TABLE VII (Continued)

No.	Week Ending				Totals 8-19 to 9-16	Season Totals
	8-19	8-26	9-2	9-16		
96N	.008	.004	.004	.001	.017	.171
96S	.000	-.003	.000	.000	-.003	.108
96E	.012	.001	.005	.000	.018	.190
96W	.006	-.004	.003	.000	.005	.180
97N	.000	-.002	.000	.000	-.002	.077
97S	.000	-.001	.000	.001	.000	.081
97E	.000	.000	.001	.000	.001	.072
97W	.000	-.007	.003	.002	-.002	.087
98N	.000	-.007	.000	.003	-.004	.096
98S	.001	.002	.000	.000	.003	.127
98E	.012	.000	.000	.000	.012	.245
98W	.013	-.001	.000	.000	.012	.209
99N	.011	.005	.000	.000	.016	.275
99S	.012	.000	.000	.000	.012	.269
99E	.010	.003	.000	.000	.013	.274
99W	.033	.012	.015	.005	.065	.402
100N	.005	.000	.000	.000	.005	.215
100S	.004	.000	.000	.000	.004	.172
100E	.000	.000	.000	.000	.002	.192
100W	.000	.001	.000	.000	.001	.193

TABLE VIII. Percentage available moisture at stations in Toumey Woodlot. 1949.

Date	Station I (av. 2)		Station II (av. 2)		Station III (av. 2)	
	A	B	A	B	A	B
7-14	93%	93%	88%	90%	78%	83%
7-21	91	93	79	85	59	78
7-28	91	93	47	70	31	69
8-4	82	85	18	38	12	37
8-11	73	67	18	38	19	16
8-18	65	66	14	10	7	10
8-25	32	52	1	2	0	0
9-2	23	45	0	0	0	0
9-16	10	27	0	0	0	0
9-30	9	11	0	0	0	0

Date	Station IV (av. 2)		Station V (av. 2)		Station VI (av. 2)	
	A	B	A	B	A	B
7-14	97%	100%	94%	93%	100%	99%
7-21	91	97	89	94	100	99
7-28	80	99	95	92	100	99
8-4	62	93	36	84	100	99
8-11	51	77	34	66	100	100
8-18	60	86	31	50	100	100
8-25	42	60	7	27	97	99
9-2	42	43	3	16	95	97
9-16	39	20	0	0	95	97
9-30	40	13	1	1	91	93

TABLE VIII (Continued)

Date	Station VII (av. 2)		VIII (av. 2)		IX (av. 2)		X (av. 2)	
	A	B	A	B	A	B	A	B
7-14	100%	86%	93%	93%	95%	87%	95%	92%
7-21	100	86	96	93	95	87	92	91
7-28	100	86	96	96	93	86	92	87
8-4	100	86	91	94	91	85	87	84
8-11	100	91	93	94	95	87	89	83
8-18	100	91	96	96	95	85	91	73
8-25	99	86	82	89	85	80	60	51
9-2	97	86	76	83	85	79	51	34
9-16	95	84	66	64	76	72	57	14
9-30	93	84	60	50	77	67	47	8

Date	Station XI (av. 1)		XII (av. 2)		XIII (av. 1)		XX	
	A	B	A	B	A	B	A	AA
7-14	95%	100%	87%	91%	100%	100%	41%	95%
7-21	89	100	77	90	100	100	35	91
7-28	77	100	35	88	100	100	19	85
8-4	87	100	9	73	100	100	7	17
8-11	87	100	8	48	100	100	5	29
8-18	87	100	2	26	100	100	3	69
8-25	55	95	0	6	99	100	0	19
9-2	41	91	0	4	95	100	0	15
9-16	33	75	0	1	91	100	0	15
9-30	29	57	0	0	91	91	0	21

TABLE IX. Arithmetic means. 1949.

Date	Stations					
	"Edge" (av. 6)		"Inside" (av. 7)		All (13)	
	A	B	A	B	A	B
7-14	89%	92%	97%	93%	93%	93%
7-21	81	89	96	94	89	92
7-28	63	85	94	93	80	90
8-4	36	68	93	93	67	81
8-11	34	52	95	94	67	74
8-18	30	41	96	92	65	69
8-25	13	23	82	86	51	57
9-2	11	18	79	81	47	52
9-16	8	8	73	72	43	43
9-30	8	4	70	64	41	37

TABLE X. Percentage available moisture at stations in Toumey Woodlot. 1950.

Date	Station					
	I (av. 2)		II (av. 2)		III (av. 2)	
	A	B	A	B	A	B
4-6	68%	71%	71%	81%	85%	100%
4-13	68	72	71	78	78	90
4-20	71	72	74	80	81	100
4-27	71	69	74	85	86	100
5-4	74	75	78	82	84	92
5-11	74	75	78	82	82	90
5-18	74	75	78	81	82	89
5-25	76	76	81	81	83	87
6-1	80	87	87	97	100	92
6-10	81	80	86	87	86	86
6-17	80	82	85	86	82	86
6-24	82	81	81	82	81	86
7-1	81	82	79	81	72	84
7-8	79	82	62	75	42	78
7-15	72	81	37	58	23	75
7-22	81	81	80	78	71	70
7-29	82	82	78	72	58	65
8-5	85	86	80	64	59	49
8-12	82	86	59	46	24	32
8-19	70	83	18	19	2	13
8-26	53	77	0	16	0	8
9-2	87	81	81	13	78	5
9-16	82	83	26	13	47	5

TABLE X (Continued)

Date	Station					
	IV (av. 2)		V (av. 2)		VI (av. 2)	
	A	B	A	B	A	B
4-6	73%	68%	73%	85%	74%	73%
4-13	71	71	73	70	74	73
4-20	74	74	74	83	78	70
4-27	68	85	82	87	78	77
5-4	75	76	80	72	82	77
5-11	79	77	80	72	85	80
5-18	79	74	80	73	85	80
5-25	83	80	81	71	86	82
6-1	89	100	86	97	89	86
6-10	87	82	83	78	91	86
6-17	87	82	85	77	87	88
6-24	86	89	83	77	95	91
7-1	82	82	74	75	87	86
7-8	78	82	57	75	87	88
7-15	60	80	29	74	91	95
7-22	86	85	78	72	91	95
7-29	91	73	82	70	91	93
8-5	86	84	80	66	91	93
8-12	81	80	76	60	87	91
8-19	52	73	34	57	85	88
8-26	38	56	90	50	93	95
9-2	86	65	83	81	93	95
9-16	72	60	78	78	87	91

TABLE X (Continued)

Date	Station							
	VII (av. 2)		VIII (av. 2)		IX (av. 2)		X (av. 2)	
	A	B	A	B	A	B	A	B
4-6	77%	71%	73%	73%	74%	74%	81%	90%
4-13	76	71	73	72	74	74	75	90
4-20	77	73	73	76	76	74	79	90
4-27	78	73	74	76	73	75	83	93
5-4	83	73	81	77	75	75	85	95
5-11	82	74	80	77	83	77	82	82
5-18	83	74	82	77	83	77	85	82
5-25	86	76	83	80	84	75	85	85
6-1	90	80	85	90	87	88	95	97
6-10	83	80	86	82	91	82	91	90
6-17	88	80	85	84	89	82	87	88
6-24	91	80	87	83	93	81	95	95
7-1	88	82	86	84	89	81	89	84
7-8	88	82	86	84	89	80	87	85
7-15	91	83	89	90	88	83	81	82
7-22	91	85	89	88	93	82	91	93
7-29	93	85	89	90	93	82	91	86
8-5	89	85	89	86	93	82	95	92
8-12	89	85	86	88	89	81	89	88
8-19	83	81	83	88	83	77	79	82
8-26	97	85	91	93	100	89	76	80
9-2	93	85	87	93	95	86	91	100
9-16	89	85	89	95	89	86	87	97

TABLE X (Continued)

Date	Station							
	XI (av. 1)		XII (av. 2)		XIII (av. 1)		XX	
	A	B	A	B	A	B	A	AA
4-6	80%	95%	89%	91%	82%	80%	80%	85%
4-13	78	91	89	91	82	80	78	74
4-20	80	85	93	95	85	80	75	91
4-27	82	95	95	95	87	91	82	87
5-4	85	74	97	91	91	82	85	95
5-11	82	78	100	100	91	82	78	91
5-18	85	73	84	100	91	82	78	91
5-25	85	73	97	100	95	82	78	91
6-1	91	95	100	100	100	100	87	100
6-10	91	80	91	100	100	87	80	100
6-17	87	80	86	95	100	91	78	95
6-24	91	80	90	100	100	85	75	95
7-1	87	78	85	84	100	85	64	87
7-8	91	80	78	82	100	87	37	69
7-15	85	75	55	81	95	85	12	29
7-22	87	100	77	79	100	95	62	87
7-29	91	82	74	77	100	91	30	85
8-5	95	85	73	77	100	95	29	87
8-12	87	82	46	77	100	87	8	78
8-19	82	78	12	71	95	87	0	33
8-26	78	75	5	59	91	85	0	27
9-2	91	100	75	41	100	100	74	85
9-16	87	100	70	41	100	100	67	80

TABLE XI. Arithmetic means. 1950.

Date	Stations					
	"Edge" (av. 6)		"Inside" (av. 7)		All (13)	
	A	B	A	B	A	B
4-6	76%	83%	77%	79%	77%	81%
4-13	75	79	76	79	75	79
4-20	78	84	78	78	78	81
4-27	79	87	79	83	79	85
5-4	81	81	83	79	82	80
5-11	82	83	84	79	83	80
5-18	79	82	85	78	82	80
5-25	83	82	86	79	85	81
6-1	90	95	91	91	91	93
6-10	86	85	90	84	88	85
6-17	84	85	89	85	87	85
6-24	84	86	93	85	89	85
7-1	79	81	89	83	84	82
7-8	66	79	90	84	79	81
7-15	46	75	89	83	69	80
7-22	79	77	92	91	86	85
7-29	77	73	93	87	86	81
8-5	77	71	93	88	86	80
8-12	61	63	90	86	76	76
8-19	31	53	84	83	60	69
8-26	31	44	89	86	62	67
9-2	82	48	93	94	88	73
9-16	62	47	90	93	77	72

TABLE XII. Soil temperature recorded at stations in Toumey Woodlot (at 3-inch level, in degrees Fahrenheit). 1949.

Date	Station							
	I	II	III	IV	V	VI	VII	VIII
7-14	66	67	68	68	64	66	65	64
7-21	70	71	70	70	67	68	66	66
7-28	70	75	72	74	74	72	70	69
8-4	64	67	68	68	65	65	64	66
8-11	68	69	69	70	65	67	65	65
8-18	68	70	70	70	67	68	67	67
8-25	67	72	72	71	68	69	70	68
9-2	56	58	56	60	55	57	56	56
9-16	56	58	60	60	58	57	58	58
9-30	45	49	49	50	49	50	50	50

Date	Station						
	IX	X	XI	XII	XIII	XXA	XXAA
7-14	64	67	66	68	67	68	76
7-21	65	65	66	70	67	72	72
7-28	70	72	71	73	71	74	76
8-4	66	64	64	68	65	69	72
8-11	66	67	65	70	67	70	76
8-18	67	68	67	70	68	71	74
8-25	66	68	73	73	70	74	79
9-2	57	56	56	56	57	55	64
9-16	58	58	60	59	58	60	62
9-30	50	50	49	51	50	50	54

TABLE XIII. Arithmetic mean soil temperature recorded at stations in Toumey Woodlot (at 3-inch level, in degrees Fahrenheit). 1949.

Date	Stations					
	"Edge" (av. 6)		"Inside" (av. 7)		All (av. 13)	
7-14	401	67	459	66	460	66
7-21	418	70	463	66	881	68
7-28	438	73	495	71	933	72
8-4	400	67	454	65	854	66
8-11	411	68	462	66	873	67
8-18	415	69	472	67	887	68
8-25	423	70	484	69	907	70
9-2	341	57	395	56	736	57
9-16	351	58	407	58	758	58
9-30	293	49	349	50	642	49

TABLE XIV. Soil temperature recorded at stations in Toumey Woodlot (at 3-inch level, in degrees Fahrenheit). 1950.

Date	Station							
	I	II	III	IV	V	VI	VII	VIII
4-6	31	37	39	38	34	35	35	34
4-13	33	36	38	34	35	34	36	35
4-20	42	46	42	41	41	40	40	40
4-27	40	44	45	42	40	43	41	41
5-4	54	63	63	58	56	58	55	57
5-11	56	56	58	56	53	55	54	55
5-18	54	58	57	58	53	51	53	53
5-25	56	57	58	58	55	55	55	54
6-2	55	56	57	57	55	54	55	54
6-10	60	63	63	62	59	59	60	59
6-17	53	54	53	56	53	53	54	54
6-24	64	65	68	66	65	63	64	63
7-1	62	64	65	64	62	61	62	62
7-8	62	66	66	62	65	61	61	61
7-15	62	63	63	61	62	61	60	62
7-22	62	65	66	64	63	63	64	62
7-29	66	69	66	67	65	65	66	65
8-5	62	64	65	64	62	62	62	62
8-12	60	61	61	62	60	60	60	60
8-19	61	62	62	63	63	62	61	62
8-26	61	62	62	62	64	62	61	62
9-2	60	61	60	61	62	60	60	61
9-16	58	59	59	60	61	59	59	59

TABLE XIV (Continued)

Date	Station						
	IX	X	XI	XII	XIII	XXA	XXAA
4-6	34	36	36	36	37	39	49
4-13	34	36	33	35	35	36	42
4-20	40	41	41	44	41	44	46
4-27	42	42	42	44	41	45	44
5-4	58	56	56	59	62	66	64
5-11	54	55	54	56	53	58	57
5-18	53	52	53	62	52	57	64
5-25	55	54	55	58	55	58	61
6-2	54	55	56	57	55	56	62
6-10	59	59	60	64	60	61	72
6-17	53	52	52	54	54	53	58
6-24	63	63	64	70	64	66	74
7-1	61	61	62	66	62	65	68
7-8	62	62	62	66	60	64	78
7-15	61	61	62	66	60	62	74
7-22	62	63	63	68	62	64	72
7-29	64	65	65	69	64	68	70
8-5	62	62	62	65	62	62	72
8-12	60	60	60	61	60	60	66
8-19	62	61	61	64	61	62	70
8-26	62	62	61	63	61	61	69
9-2	61	60	61	62	60	61	64
9-16	59	59	58	61	60	59	63

TABLE XV. Arithmetic mean soil temperature recorded at stations in Toumey Woodlot (at 3-inch level, in degrees Fahrenheit). 1950.

Date	Stations					
	"Edge" (av. 6)		"Inside" (av. 7)		All (av. 13)	
4-6	215	36	247	35	462	36
4-13	211	35	243	35	454	35
4-20	256	43	283	40	539	41
4-27	255	42	292	42	547	42
5-4	353	59	402	57	755	58
5-11	335	56	325	46	715	55
5-18	342	57	367	52	709	55
5-25	342	57	383	55	725	56
6-2	337	56	383	55	720	55
6-10	371	62	416	59	787	61
6-17	323	54	372	53	695	53
6-24	398	66	444	63	842	65
7-1	383	64	431	62	814	63
7-8	387	64	429	61	816	63
7-15	377	63	427	61	804	62
7-22	388	65	439	63	827	64
7-29	402	67	454	65	856	66
8-5	382	64	434	62	816	63
8-12	365	61	420	60	785	60
8-19	375	62	430	61	805	62
8-26	374	62	441	63	815	63
9-2	366	61	423	60	789	61
9-16	358	60	413	59	771	59

TABLE XVI. Difference in weekly growth rate of group C trees. 1949.

Tree	Week (beginning with week ending 5-12)					
	1	2	3	4	5	6
76	.002	.004	-.004	.014	.001	-.007
77	.005	.011	-.010	.017	.002	.001
78	.004	.014	-.008	.015	-.002	.001
Total	.011	.029	-.022	.046	.001	-.005
Arith. Mean	.004	.010	-.007	.015	.000	-.002

Tree	Week (beginning with week ending 5-12)					
	7	8	9	10	11	12
76	.002	-.001	.000	.000	.003	-.006
77	.005	-.001	-.005	-.001	-.003	-.009
78	.004	.000	-.012	.009	-.010	-.004
Total	.011	-.002	-.017	.008	-.010	-.019
Arith. Mean	.004	-.001	-.006	.003	-.003	-.006

Tree	Week (beginning with week ending 5-12)					
	13	14	15	16	17	18
76	.009	-.003	-.011	.006	-.004	-.004
77	.010	-.001	-.015	.006	-.005	-.005
78	.002	-.006	-.011	.008	-.003	-.003
Total	.021	-.010	-.037	.020	-.012	-.012
Arith. Mean	.007	-.003	-.012	.007	-.004	-.004

TABLE XVII. Differences in weekly growth rate of group C trees. 1950.

Tree	Week (beginning with week ending 5-18)					
	1	2	3	4	5	6
76	-.005	.002	.007	.005	-.006	-.002
77	.001	.006	.003	-.001	.004	.000
78	-.006	.008	.006	-.003	-.002	-.001
Total	-.010	.016	.016	.001	-.004	-.003
Arith. Mean	-.003	.005	.005	.000	-.001	-.001

Tree	Week (beginning with week ending 5-18)				
	7	8	9	10	11
76	-.003	.000	.004	-.006	.001
77	.002	-.004	.006	-.016	.010
78	-.001	.004	-.001	-.004	.001
Total	-.002	.000	.009	-.026	.012
Arith. Mean	-.001	.000	.003	-.009	.004

Tree	Week (beginning with week ending 5-18)				
	12	13	14	15	16
76	-.002	.001	-.003	-.004	-.008
77	.004	-.001	-.002	-.007	-.013
78	.002	-.007	-.007	-.001	.002
Total	.004	-.007	-.012	-.012	-.019
Arith. Mean	.001	-.002	-.004	-.004	-.006

TABLE XVIII. Differences in weekly growth rate of group D trees. 1949.

Tree	Week (beginning with week ending 5-12)					
	1	2	3	4	5	6
35	-.001	.001	-.001	.012	.004	.003
65	.000	-.002	.001	.010	.003	-.005
66	.002	.004	-.006	.010	-.001	-.004
Total	.001	.003	-.006	.032	.006	-.006
Arith. Mean	.000	.001	-.002	.011	.002	-.002

Tree	Week (beginning with week ending 5-12)					
	7	8	9	10	11	12
35	-.004	.008	.010	-.004	-.001	-.009
65	.000	.007	.000	-.006	-.002	-.006
66	.001	.012	.003	-.005	-.006	-.004
Total	-.003	.027	.013	-.015	-.009	-.019
Arith. Mean	-.001	.009	.004	-.005	-.003	-.006

Tree	Week (beginning with week ending 5-12)					
	13	14	15	16	17	18
35	.008	-.003	-.015	.010	-.005	-.005
65	.005	.001	-.013	.009	-.004	-.005
66	.002	.001	-.017	.010	-.004	-.006
Total	.015	-.001	-.045	.029	-.013	-.016
Arith. Mean	.005	.000	-.015	.010	-.004	-.005

TABLE XIX. Differences in weekly growth rate of group D trees. 1950.

Tree	Week (beginning with week ending 5-18)					
	1	2	3	4	5	6
35	-.003	.006	.008	.000	-.005	-.006
65	-.007	.002	.002	.004	-.003	.001
66	-.001	.012	.001	.000	-.007	-.003
Total	-.011	.020	.011	.004	-.015	-.008
Arith. Mean	-.004	.007	.004	.001	-.005	-.003

Tree	Week (beginning with week ending 5-18)				
	7	8	9	10	11
35	.004	-.001	.006	-.013	.005
65	.000	.004	-.001	-.003	.001
66	.000	.003	.005	-.007	.000
Total	.005	.006	.010	-.023	.006
Arith. Mean	.002	.002	.003	-.008	.002

Tree	Week (beginning with week ending 5-18)				
	12	13	14	15	16
35	-.005	-.003	-.002	-.003	.007
65	.001	-.002	-.010	-.002	.003
66	.000	-.005	-.005	-.002	.003
Total	-.004	-.010	-.017	-.007	.013
Arith. Mean	-.001	-.003	-.006	-.002	.004

TABLE XX. Differences in weekly growth rate of group F trees. 1949.

Tree	Week (beginning with week ending 5-12)					
	1	2	3	4	5	6
56	.001	.011	-.012	.015	-.002	.001
61	-.001	.001	-.002	.018	.001	-.005
79	.000	.002	-.008	.017	-.001	.002
Total	.000	.014	-.022	.050	-.002	-.002
Arith. Mean	.000	.005	-.007	.017	-.001	-.001

Tree	Week (beginning with week ending 5-12)					
	7	8	9	10	11	12
56	.003	.003	.000	-.001	-.007	-.007
61	.004	.007	-.004	-.004	-.008	-.005
79	.000	-.003	.001	-.003	-.003	-.004
Total	.005	.007	-.003	-.008	-.018	-.016
Arith. Mean	.002	.002	-.001	-.003	-.006	-.005

Tree	Week (beginning with week ending 5-12)					
	13	14	15	16	17	18
56	.012	-.005	-.019	.009	-.007	-.004
61	.014	-.009	-.015	.008	-.006	-.002
79	.003	-.007	-.007	.006	.000	-.002
Total	.029	-.021	-.041	.023	-.013	-.008
Arith. Mean	.010	-.007	-.014	.008	-.004	-.003

TABLE XXI. Differences in weekly growth rate of group F trees. 1950.

Tree	Week (beginning with week ending 5-18)					
	1	2	3	4	5	6
56	.000	.009	.002	-.002	-.001	-.004
61	.005	.005	.004	.005	.001	-.004
79	-.003	.007	.003	-.003	-.002	-.003
Total	.002	.021	.009	.000	-.002	-.011
Arith. Mean	.001	.007	.003	.000	-.001	-.004

Tree	Week (beginning with week ending 5-18)				
	7	8	9	10	11
56	.002	-.004	.004	-.002	-.001
61	.003	-.001	-.002	-.003	.002
79	.002	.002	-.002	-.005	.003
Total	.007	-.003	.000	-.010	.004
Arith. Mean	.002	-.001	.000	-.003	.001

Tree	Week (beginning with week ending 5-18)				
	12	13	14	15	16
56	.008	-.003	-.005	-.001	-.008
61	-.002	-.003	-.004	-.011	.001
79	-.002	-.005	-.002	-.001	.000
Total	.004	-.011	-.011	-.013	-.007
Arith. Mean	.001	-.004	-.004	-.004	-.002

TABLE XXII. Differences in weekly growth rate of group K trees. 1949.

Tree	Week (beginning with week ending 5-12)					
	1	2	3	4	5	6
85	.000	.002	-.005	.015	.000	-.002
87	-.001	.002	.000	.012	-.002	-.002
89	-.004	.001	-.002	.015	.003	-.004
90	.001	.003	-.008	.019	-.006	.002
Total	-.004	.008	-.015	.046	-.008	-.006
Arith. Mean	-.001	.002	-.004	.011	-.002	-.001

Tree	Week (beginning with week ending 5-12)					
	7	8	9	10	11	12
85	.006	.001	-.004	-.007	.001	-.009
87	.005	.006	-.001	-.006	.001	-.011
89	.003	.000	-.002	-.003	.000	-.008
90	.003	.005	.002	-.006	-.005	-.007
Total	.017	.012	-.005	-.022	-.003	-.035
Arith. Mean	.004	.003	-.001	-.005	-.001	-.009

TABLE XXII (Continued)

Tree	Week (beginning with week ending 5-12)				
	13	14	15	16	17
85	.010	-.008	-.015	.008	.002
87	.007	-.003	-.016	.007	-.001
89	.005	-.006	-.012	.010	-.006
90	.002	-.004	-.008	.007	-.006
Total	.024	-.021	-.051	.032	-.011
Arith. Mean	.006	-.005	-.013	.008	-.003

TABLE XXIII. Differences in weekly growth rate of group K trees. 1950.

Tree	Week (beginning with week ending 5-18)					
	1	2	3	4	5	6
85	.002	.002	.005	-.001	-.005	-.004
87	-.004	.004	.002	.005	-.005	-.003
89	-.007	.005	.005	.003	-.001	-.004
90	-.006	.005	-.003	.007	-.003	.000
Total	-.015	.016	.009	.014	-.014	-.011
Arith. Mean	-.004	.004	.002	.003	-.003	-.003

Tree	Week (beginning with week ending 5-18)				
	7	8	9	10	11
85	.003	-.002	.002	-.010	.007
87	.004	.002	.000	-.006	.003
89	.003	.000	.003	-.008	-.001
90	.005	.001	-.006	-.005	.014
Total	.015	.001	-.001	-.029	.023
Arith. mean	.004	.000	.000	-.007	.006

TABLE XXIII (Continued)

Tree	Week (beginning with week ending 5-18)				
	12	13	14	15	16
85	-.001	-.002	-.008	-.002	.002
87	-.001	-.003	-.011	.001	.000
89	.005	-.006	-.004	-.007	.001
90	-.001	-.006	.002	-.008	-.006
Total	.002	-.017	-.021	-.016	-.003
Arith. Mean	.000	-.004	-.005	-.004	-.001

TABLE XXIV. Differences in weekly growth rate of group L trees. 1949.

Tree	Week (beginning with week ending 5-12)					
	1	2	3	4	5	6
33	-.003	.003	-.008	.016	.005	-.007
34	.001	-.003	.000	.013	.002	-.002
82	-.005	.002	-.002	.014	.002	-.010
83	.004	.003	-.005	.013	.016	-.019
84	.000	.006	-.005	.014	.001	-.004
86	-.004	.006	-.003	.016	.000	-.002
Total	-.007	.017	-.023	.086	.026	-.044
Arith. Mean	-.001	.003	-.004	.014	.004	-.007

Tree	Week (beginning with week ending 5-12)					
	7	8	9	10	11	12
33	.014	-.002	-.002	.000	-.001	-.006
34	.004	.001	-.004	.005	.000	-.004
82	.001	.009	.004	-.003	-.003	-.007
83	.004	.005	-.003	.001	-.001	-.008
84	.006	.002	.001	-.009	.004	-.018
86	.013	-.006	-.002	-.005	-.001	-.011
Total	.042	.009	-.006	-.011	-.002	-.054
Arith. Mean	.007	.001	-.001	-.002	.000	-.009

TABLE XXIV (Continued)

Tree	Week (beginning with week ending 5-12)				
	13	14	15	16	17
33	.004	.000	-.021	.009	-.003
34	.002	.001	-.015	.007	-.001
82	.001	.006	-.022	.012	-.009
83	.006	.003	-.023	.006	-.002
84	.029	-.006	-.029	.009	.002
86	.000	.005	-.019	.007	.000
Total	.042	.009	-.129	.050	-.013
Arith. Mean	.007	.001	-.021	.008	-.002

TABLE XXV. Differences in weekly growth rate of group L trees. 1950.

Tree	Week (beginning with week ending 5-18)					
	1	2	3	4	5	6
33	-.006	.010	.006	.001	-.012	-.002
34	.001	.006	-.002	.002	-.002	-.001
82	-.009	.011	.005	.001	-.011	-.003
83	-.003	.009	-.001	.001	-.004	-.004
84	.006	.000	.021	-.010	-.014	.004
86	.000	.011	.001	-.002	-.001	-.008
Total	-.011	.047	.030	-.007	-.044	-.014
Arith. Mean	-.002	.008	.005	-.001	-.007	-.002

Tree	Week (beginning with week ending 5-18)				
	7	8	9	10	11
33	-.001	-.001	-.001	.003	-.005
34	-.008	.011	.001	-.005	.008
82	.002	.011	-.006	-.003	.005
83	.011	.003	-.002	-.007	-.002
84	.005	.000	-.001	.003	.002
86	.004	.004	.000	-.007	-.001
Total	.013	.028	-.009	-.016	.007
Arith. Mean	.002	.005	-.001	-.003	.001

TABLE XXV (Continued)

Tree	Week (beginning with week ending 5-18)				
	12	13	14	15	16
33	.003	.001	-.004	-.008	.006
34	-.011	.004	.003	-.014	-.004
82	.006	-.009	-.003	-.010	-.007
83	.005	-.006	.001	-.012	-.004
84	.005	-.010	.004	-.020	.001
86	.006	-.008	-.001	-.013	.000
Total	.014	-.028	.000	-.077	-.008
Arith. Mean	.002	-.005	.000	-.013	-.001

TABLE XXVI. Differences in weekly growth rate of group P trees. 1949.

Tree	Week (beginning with week ending 5-12)					
	1	2	3	4	5	6
12	-.001	.004	.008	.004	-.003	-.004
13	.002	.007	-.001	.004	-.007	.002
14	.003	-.003	.006	.002	-.002	-.004
15	-.003	.013	.010	-.001	-.007	-.010
Total	.001	.021	.023	.009	-.019	-.016
Arith. Mean	.000	.007	.007	.002	-.005	-.004

Tree	Week (beginning with week ending 5-12)					
	7	8	9	10	11	12
12	-.005	.005	.001	-.007	.003	-.002
13	.001	.007	.000	-.006	-.003	.001
14	.006	-.001	-.001	-.005	.006	.004
15	.006	.003	-.007	-.002	.005	.001
Total	.008	.014	-.007	-.020	.011	.004
Arith. Mean	.002	.003	-.002	-.005	.003	.001

TABLE XXVI (Continued)

Tree	Week (beginning with week ending 5-12)				
	13	14	15	16	17
12	-.003	-.005	-.002	.002	.000
13	-.002	-.004	-.008	.001	-.002
14	-.007	.002	-.011	-.005	-.001
15	-.002	.003	-.017	.000	.000
Total	-.014	-.004	-.038	-.002	-.003
Arith. Mean	-.003	-.001	-.009	.000	-.001

TABLE XXVII. Differences in weekly growth rate of group P trees. 1950.

Tree	Week (beginning with week ending 5-18)					
	1	2	3	4	5	6
12	-.001	.004	-.006	.014	-.006	-.001
13	.000	.004	-.006	.020	-.002	-.003
14	-.001	.003	-.006	.010	-.001	-.001
15	.002	.005	-.001	.013	-.003	-.004
Total	.000	.016	-.019	.057	-.012	-.009
Arith. Mean	.000	.004	-.005	.014	-.003	-.002

Tree	Week (beginning with week ending 5-18)					
	7	8	9	10	11	12
12	.001	.002	.002	.002	.000	-.012
13	.000	-.008	.009	.014	-.018	-.002
14	.000	.011	-.002	-.002	-.005	-.002
15	.000	.006	-.002	-.003	.005	-.005
Total	.001	.011	.007	.011	-.018	-.021
Arith. Mean	.000	.003	.002	.003	-.004	-.005

TABLE XXVII (Continued)

Tree	Week (beginning with week ending 5-18)				
	13	14	15	16	17
12	.009	-.006	-.012	.011	-.007
13	.015	-.001	-.024	.012	-.001
14	.007	-.001	-.018	.013	-.006
15	.002	.000	-.016	.024	-.016
Total	.033	-.008	-.070	.060	-.030
Arith. Mean	.008	-.002	-.017	.015	-.007

TABLE XXVIII. Differences in weekly growth rate of group R trees. 1949.

Tree	Week (beginning with week ending 5-12)					
	1	2	3	4	5	6
1	-.006	.008	-.009	-.005	.017	-.004
2	-.003	.004	-.008	.017	.002	.010
3	-.002	-.001	-.002	.015	-.001	-.005
4	-.004	-.001	.000	.010	.002	.000
Total	-.015	.010	-.019	.037	.020	.001
Arith. Mean	-.004	.002	-.005	.009	.005	.000

Tree	Week (beginning with week ending 5-12)					
	7	8	9	10	11	12
1	.002	.007	-.008	.000	.000	-.010
2	-.018	.016	-.007	-.005	-.006	-.004
3	.003	.006	.000	-.006	-.004	-.006
4	.005	.009	-.007	-.004	-.006	-.008
Total	-.008	.038	-.022	-.015	-.016	-.028
Arith. Mean	-.002	.009	-.005	-.004	-.004	-.007

TABLE XXVIII (Continued)

Tree	Week (beginning with week ending 5-12)				
	13	14	15	16	17
1	.010	-.005	-.019	.011	-.001
2	.009	.005	-.026	.007	-.003
3	.009	-.008	-.014	.010	.003
4	.005	-.007	-.015	.015	-.001
Total	.033	-.015	-.074	.043	-.002
Arith. Mean	.008	-.004	-.018	.011	.000

TABLE XXIX. Differences in weekly growth rate of group R trees. 1950.

Tree	Week (beginning with week ending 5-18)					
	1	2	3	4	5	6
1	.001	.005	.006	-.001	-.008	-.004
2	.001	.002	.002	.000	.004	-.004
3	-.005	.003	.000	.000	-.003	-.002
4	-.001	.003	.005	.004	-.008	.000
Total	-.004	.013	.013	.003	-.015	-.010
Arith. Mean	-.001	.003	.003	.001	-.004	-.002

Tree	Week (beginning with week ending 5-18)				
	7	8	9	10	11
1	.006	.000	.001	-.009	.007
2	.007	-.006	.000	-.009	.010
3	.005	.000	.001	.008	.005
4	.002	.000	.000	-.002	-.002
Total	.020	-.006	.002	-.012	.020
Arith. Mean	.005	-.001	.000	-.003	.005

TABLE XXIX (Continued)

Tree	Week (beginning with week ending 5-18)				
	12	13	14	15	16
1	-.001	-.004	-.011	.001	.002
2	.001	-.009	-.007	-.006	.007
3	-.005	.000	-.004	.000	.002
4	.003	-.003	-.009	.002	-.002
Total	-.002	-.016	-.031	-.003	.009
Arith. Mean	.000	-.004	-.008	-.001	.002

TABLE XXX. Differences in weekly growth rate of group S trees. 1949.

Tree	Week (beginning with week ending 5-12)					
	1	2	3	4	5	6
5	-.001	.004	-.005	.017	-.002	-.003
6	-.002	.005	-.005	.013	.011	-.011
7	-.004	.005	-.002	.015	.004	-.016
9	.002	-.002	-.002	.011	-.003	-.003
Total	-.005	.012	-.014	.056	.010	-.033
Arith. Mean	-.001	.003	-.003	.014	.002	-.008

Tree	Week (beginning with week ending 5-12)					
	7	8	9	10	11	12
5	.001	-.001	.004	-.009	-.012	.008
6	.000	.005	-.005	.005	.001	-.012
7	.010	.004	.005	-.005	-.002	-.004
9	.003	.002	-.004	.001	-.003	-.005
Total	.014	.010	.000	-.008	-.016	-.013
Arith. Mean	.003	.002	.000	-.002	-.004	-.003

TABLE XXX (Continued)

Tree	Week (beginning with week ending 5-12)				
	13	14	15	16	17
5	.013	-.017	-.008	.007	.002
6	.006	-.002	-.018	.008	.004
7	.003	-.002	-.017	.008	-.004
9	.007	-.001	-.009	.001	.003
Total	.029	-.022	-.052	.024	.005
Arith. Mean	.007	-.005	-.013	.006	.001

TABLE XXXI. Differences in weekly growth rate of group S trees. 1950.

Tree	Week (beginning with week ending 5-18)					
	1	2	3	4	5	6
5	-.003	.005	.001	.009	-.004	-.005
6	.001	.001	.006	.001	-.002	-.006
7	.006	.003	.001	.000	-.001	-.004
9	-.003	.006	.003	-.002	-.002	-.004
Total	.001	.015	.011	.008	-.009	-.019
Arith. Mean	.000	.004	.003	.002	-.002	-.005

Tree	Week (beginning with week ending 5-18)				
	7	8	9	10	11
5	.004	-.002	.003	-.006	.001
6	.010	-.009	.001	-.006	.000
7	.006	.000	.005	-.013	.002
9	-.001	.005	-.003	-.001	.003
Total	.019	-.006	.006	-.026	.006
Arith. Mean	.005	-.001	.001	-.006	.001

TABLE XXXI (Continued)

Tree	Week (beginning with week ending 5-18)				
	12	13	14	15	16
5	.007	-.009	.000	-.011	.003
6	.010	-.011	-.004	-.007	.000
7	.001	-.004	-.003	-.006	-.005
9	-.001	.002	-.006	-.004	.000
Total	.017	-.022	-.013	-.028	-.002
Arith. Mean	.004	-.005	-.003	-.007	.000

TABLE XXXII. Differences in weekly growth rate of group T trees. 1949.

Tree	Week (beginning with week ending 5-12)					
	1	2	3	4	5	6
16	.001	.002	-.004	.018	-.005	-.004
17	-.004	.002	-.001	.010	-.001	-.002
29	.003	.004	-.003	.018	.002	-.014
30	-.001	.003	-.002	.015	.002	-.011
Total	-.001	.011	-.010	.061	-.002	-.031
Arith. Mean	.000	.003	-.002	.015	.000	-.008

Tree	Week (beginning with week ending 5-12)					
	7	8	9	10	11	12
16	.001	.010	-.001	-.003	.006	-.012
17	.002	.005	-.001	-.001	.000	-.007
29	.000	.007	-.003	.002	.004	-.006
30	.000	.010	-.008	.006	-.013	.000
Total	.003	.032	-.013	.004	-.003	-.025
Arith. Mean	.001	.008	-.003	.001	-.001	-.006

TABLE XXXII (Continued)

Tree	Week (beginning with week ending 5-12)				
	13	14	15	16	17
16	.007	-.003	-.019	.017	-.009
17	.007	-.001	-.016	.015	-.008
29	.012	-.008	-.022	.016	-.007
30	.014	-.003	-.015	.013	-.008
Total	.040	-.015	-.072	.061	-.032
Arith. Mean	.010	-.004	-.018	.015	-.008

TABLE XXXIII. Differences in weekly growth rate of group T trees. 1950.

Tree	Week (beginning with week ending 5-18)					
	1	2	3	4	5	6
16	-.005	.001	.004	.003	-.006	.003
17	.001	.002	.004	.000	-.004	.001
29	-.005	.004	.008	.009	-.006	-.003
30	.000	.003	.003	.003	-.003	-.001
Total	-.009	.010	.019	.015	-.019	.000
Arith. Mean	-.002	.002	.005	.004	-.005	.000

Tree	Week (beginning with week ending 5-18)				
	7	8	9	10	11
16	.004	.003	-.004	-.009	.006
17	-.002	.007	-.001	-.009	.006
29	-.009	.002	.000	-.002	.003
30	-.001	.005	.003	-.011	.011
Total	-.008	.017	-.002	-.031	.026
Arith. Mean	-.002	.004	.000	-.008	.006

TABLE XXXIII (Continued)

Tree	Week (beginning with week ending 5-18)				
	12	13	14	15	16
16	.000	-.003	.006	-.014	.003
17	-.002	.001	-.004	-.007	.003
29	-.002	-.002	-.007	.000	.000
30	-.008	.003	-.005	-.009	.001
Total	-.012	-.001	-.010	-.030	.007
Arith. Mean	-.003	.000	-.002	-.007	.002

APPENDIX B

TABLE XXXIV. Total weekly rainfall as measured at the hydrologic station near Toumey Woodlot. 1949.

Week Ending	Total in Inches
4-7	.01
4-14	.45
4-21	.89
5-5	.15
5-12	.00
5-19	2.34
5-26	.18
6-2	.00
6-9	.03
6-16	2.31
6-23	.00
6-30	.00
7-7	.15
7-14	1.77
7-21	.05
7-28	.59
8-4	.59
8-11	1.22
8-18	.53
8-25	.00
9-1	.82
9-8	.68
9-15	.61
9-22	.98
9-29	.08
10-6	1.18
10-13	1.04

TABLE XXXV. Total weekly rainfall as measured at the hydrologic station near Toumey Woodlot. 1950.

Week Ending	Total in Inches
4-6	1.62
4-13	.53
4-20	.19
4-27	2.43
5-4	.01
5-11	.15
5-18	.02
5-25	1.19
6-2	2.23
6-10	.45
6-17	.81
6-24	.95
7-1	.39
7-8	Trace
7-15	.68
7-22	3.07
7-29	.62
8-5	.96
8-12	.32
8-19	.00
8-26	1.19
9-2	2.98
9-16	3.08

TABLE XXXVI. Evaporation in inches as measured at the hydrologic station near Tourney Woodlot. 1949.

Week Ending	Total	Arithmetic Mean
4-7	.92	.13
4-14	1.62	.23
4-21	1.08	.15
4-28	1.90	.27
5-5	2.12	.30
5-12	1.92	.27
5-19	1.87	.27
5-26	1.33	.19
6-2	2.07	.30
6-9	2.14	.31
6-16	1.65	.24
6-23	1.59	.23
6-30	2.14	.31
7-7	2.13	.30
7-14	1.44	.21
7-21	1.65	.24
8-4	1.43	.20
8-11	1.79	.26
8-18	1.29	.18
8-25	1.41	.20
9-1	1.12	.16
9-8	1.32	.19
9-15	1.09	.16
9-22	1.13	.16
9-29	1.08	.15
10-6	1.07	.15
10-13	1.01	.14

TABLE XXXVII. Evaporation in inches as measured at the hydrologic station near Toumey Woodlot. 1950.

Week Ending	Total	Arithmetic Mean
4-6	.47	.08
4-13	.75	.11
4-20	1.01	.14
4-27	.90	.13
5-4	1.06	.15
5-11	1.43	.20
5-18	1.64	.23
5-25	1.49	.21
6-2	1.99	.25
6-10	2.16	.27
6-17	1.45	.21
6-24	1.92	.27
7-1	1.67	.24
7-8	1.78	.26
7-15	1.77	.25
7-22	.07	.01
7-29	.82	.12
8-5	1.19	.17
8-12	1.97	.28
8-19	1.55	.22
8-26	1.51	.22
9-2	.09	.01
9-16	1.96	.14

TABLE XXXVIII. The ratio of precipitation to evaporation (P/E value) for 1949. Figures taken from data of the hydrologic station.

Week Ending	P/E Value in Percent
4-14	.28
4-21	.82
4-28	.21
5-5	.07
5-12	.00
5-19	1.25
5-26	.14
6-2	.00
6-9	.60
6-16	.73
6-23	.00
6-30	.00
7-7	.07
7-14	1.05
7-21	.03
7-28	.31
8-4	.41
8-11	.70
8-18	.41
8-25	.00
9-1	.73
9-15	.64

TABLE XXXIX. The ratio of precipitation to evaporation (P/E value) for 1950. Figures taken from data of the hydrologic station.

Week Ending	P/E Value in Percent
4-13	.71
4-20	.19
4-27	.27
5-4	.01
5-11	.10
5-18	.01
5-25	.80
6-2	1.12
6-10	.31
6-17	.55
6-24	.49
7-1	.23
7-8	.00
7-15	.38
7-22	44.00
7-29	.76
8-5	.81
8-12	.16
8-19	.00
8-26	.79
9-2	32.50

TABLE XL. Soil moisture as recorded at the hydrologic station near Toumey Woodlot. 1949.

Week Ending	Resistance (in ohms)	Weekly Average of Daily Totals (in ohms)*	Percent Available Moisture	Single Reading (in percent) Taken at Date Indicated
4-7	4,885	814	79	78
4-14	5,160	860	77	78
4-21	4,955	826	79	77
4-28	4,125	825	79	80
5-5	3,335	834	78	78
5-12	5,250	875	76	76
5-19	5,545	924	75	74
5-26	4,885	814	79	79
6-2	5,200	867	77	79
6-9	17,310	2,885	41	23
6-16	75,920	12,653	16	52
6-23	6,020	1,003	72	73
6-30	6,450	1,075	71	74
7-7	5,780	963	73	73
7-14	6,020	1,003	72	73
7-21	4,830	966	73	73
7-28	6,315	1,052	71	69
8-4	7,325	1,254	67	63
8-11	10,630	1,772	55	48
8-18	19,700	3,283	36	36
8-25	145,675	24,279	9	1
9-2	556,750	92,792	0	3

* some daily readings not available

TABLE XLI. Soil moisture as recorded at the hydrologic station near Toumey Woodlot. 1950.

Week Ending	Resistance (in ohms)	Weekly Average of Daily Totals (in ohms)*	Percent Available Moisture	Single Reading (in percent) Taken at Date Indicated
4-6	4,525	754	81	82
4-13	4,625	771	80	81
4-20	4,650	775	80	81
4-27	4,490	748	81	81
5-4	4,810	802	79	79
5-11	4,920	820	79	78
5-18	5,520	920	75	73
5-25	6,820	1,137	69	65
6-2	8,165	1,633	57	53
6-10	10,920	1,560	59	63
6-17	10,805	1,801	55	48
6-24	24,000	4,000	34	28
7-1	60,050	10,008	18	17
7-8	89,375	14,896	15	12
7-15	135,375	22,562	9	12
7-22	85,325	14,221	15	33
7-29	12,480	2,080	49	57
8-5	8,860	1,477	61	63
8-12	10,290	1,715	56	49
8-19	128,350	21,392	9	9
8-26	151,000	25,167	9	8
9-2	62,550	10,425	18	41

* some daily readings not available.

TABLE XLII. Soil temperature as recorded at the hydrologic station near Tourney Woodlot. 1949.

Week Ending	Total (in degrees Fahrenheit)	Weekly Average of Daily Totals (in degrees Fahrenheit)
4-7	271	39
4-14	296	42
4-21	272	39
4-28	330	47
5-5	445	64
5-12	403	58
5-19	436	62
5-26	379	54
6-2	397	57
6-9	441	63
6-16	465	66
6-23	484	69
6-30	435	62
7-7	529	76
7-14	494	71
7-21	487	70
7-28	530	76
8-4	490	70
8-11	501	72
8-18	488	70
8-25	450	64
9-2	510	73
9-16	814	58*

* two-week average

TABLE XLIII. Soil temperature as recorded at the hydrologic station near Toumey Woodlot. 1950.

Week Ending	Total (in degrees Fahrenheit)	Weekly Average of Daily Totals (in degrees Fahrenheit)
4-6	239	34
4-13	233	33
4-20	273	39
4-27	271	39
5-4	291	42
5-11	335	48
5-18	365	52
5-25	386	55
6-2	471	59
6-10	488	61
6-17	435	62
6-24	433	62
7-1	450	64
7-8	455	65
7-15	475	68
7-22	461	66
7-29	461	66
8-5	461	66
8-12	442	63
8-19	445	64
8-26	444	66
9-2	208*	69

* three readings

TABLE XLIV. Air temperature (in degrees Fahrenheit) as recorded at Capitol City Airport, Lansing, Michigan. 1949.

Week Ending	Summation Temperature	Weekly Average of Daily Totals (in degrees Fahrenheit)
4-7	286	41
4-14	338	48
4-21	291	41
4-28	357	51
5-5	464	66
5-12	387	55
5-19	455	64
5-26	370	53
6-2	427	61
6-9	446	64
6-16	501	72
6-23	516	74
6-30	546	79
7-7	559	80
7-14	491	70
7-21	505	72
7-28	538	77
8-4	475	68
8-11	538	77
8-18	502	72
8-25	476	68
9-2	462	66
9-16	830	60
9-30	772	55

TABLE XLV. Air temperature (in degrees Fahrenheit) as recorded at Capitol City Airport, Lansing, Michigan. 1950.

Week Ending	Summation Temperature	Weekly Average of Daily Totals (in degrees Fahrenheit)
3-30	257	37
4-6	259	37
4-13	236	34
4-20	317	45
4-27	302	43
5-4	335	48
5-11	378	54
5-18	405	58
5-25	448	64
6-2	492	62
6-10	532	66
6-17	461	66
6-24	467	67
7-1	457	65
7-8	467	67
7-15	489	70
7-22	475	68
7-29	494	71
8-5	477	68
8-12	473	68
8-19	477	68
8-26	458	65
9-2	477	68

TABLE XLVI. Total solar radiation as recorded at the hydrologic station adjacent to Toumey Woodlot. 1949.

Week Ending	Total Radiation in Gram-calories Per Square Centimeter (Langley units)
4-7	2,418.0
4-14	3,387.6
4-21	2,542.0
4-28	2,912.4
5-5	3,206.6
5-12	3,112.2
5-19	2,444.5
5-26	2,668.9
6-2	2,502.5
6-9	3,808.1
6-16	2,236.2
6-23	2,908.3
6-30	2,921.9
7-7	2,808.5
7-14	2,702.9
7-21	3,119.2
7-28	3,207.9
8-4	2,655.9
8-11	2,779.1
8-18	2,523.4
8-25	2,964.1
9-1	1,655.1
9-8	1.949.7
9-15	1,810.5
9-22	1,607.1
9-29	2,003.6
10-6	1,555.8

TABLE XLVII. Total solar radiation as recorded at the hydrologic station adjacent to Toumey Woodlot. 1950.

Week Ending	Total Radiation in Gram-calories Per Square Centimeter (Langley units)
4-6	1,472.8
4-13	1,682.3
4-20	2,427.1
4-27	1,953.5
5-4	2,554.3
5-11	3,026.8
5-18	3,434.2
5-25	3,538.5
6-2	3,084.9*
6-10	3,850.7*
6-17	3,251.5
6-24	2,966.1
7-1	3,672.4
7-8	3,733.9
7-15	4,004.4
7-22	2,823.4
7-29	3,526.9
8-5	2,999.8
8-12	3,456.6
8-19	3,137.3
8-26	2,996.9
9-2	1,745.7
9-16	1,978.9*

* daily average x 7

TABLE XLVIII. Total amount of sunshine as measured at Capitol City Airport, Lansing, Michigan. 1949.

Week Ending	Hours and Minutes
4-7	48:02
4-14	78:48
4-21	55:56
4-28	70:29
5-5	80:34
5-12	70:45
5-19	60:37
5-26	63:50
6-2	87:03
6-9	90:24
6-16	55:11
6-23	84:19
6-30	77:47
7-7	72:41
7-14	70:53
7-21	83:02
7-28	88:52
8-4	61:05
8-11	78:12
8-18	72:52
8-25	90:33
9-2	49:00
9-16	45:58*

* daily average x 7

TABLE XLIX. Total amount of sunshine as measured at Capitol City Airport, Lansing, Michigan. 1950.

Week Ending	Hours and Minutes
5-4	51:44
5-11	65:50
5-18	80:14
5-25	81:16
6-2	72:27*
6-10	97:05*
6-17	77:18
6-24	63:18
7-1	79:28
7-8	84:55
7-15	92:47
7-22	58:57
7-29	88:28
8-5	67:20
8-12	86:12
8-19	70:12
8-26	66:38
9-2	37:15
9-16	44:22*
9-30	48:68*

* daily average x 7

TABLE L. Amount of cloudiness as recorded at Capitol City Airport, Lansing, Michigan. Degrees of cloudiness recorded on a scale of zero to ten. 1949.

Week Ending	Total	Weekly Average of Daily Totals
4-7	34	5.0
4-14	22	3.0
4-21	35	5.0
4-28	38	5.0
5-5	28	4.0
5-12	33	4.5
5-19	53	7.5
5-26	46	6.5
6-2	31	4.0
6-9	25	3.5
6-16	47	6.5
6-23	36	5.0
6-30	42	6.0
7-7	41	6.0
7-14	45	6.0
7-21	31	4.0
7-28	27	4.0
8-4	43	6.0
8-11	26	3.5
8-18	24	3.0
8-25	11	1.5
9-2	39*	6.5

* average of six

TABLE LI. Amount of cloudiness as recorded at Capitol City Airport, Lansing, Michigan. Degrees of cloudiness recorded on a scale of zero to ten. 1950.

Week Ending	Total	Weekly Average of Daily Totals
4-6	57	8.0
4-13	65	9.0
4-20	49	7.0
4-27	61	8.5
5-4	52	7.0
5-11	47	6.5
5-18	37	5.0
5-25	28	4.0
6-2	54	6.5
6-10	35	4.5
6-17	43	6.0
6-24	47	6.5
7-1	31	4.0
7-8	34	5.0
7-15	22	3.0
7-22	45	6.5
7-29	30	4.0
8-5	40	5.5
8-12	24	3.0
8-19	32	4.5
8-26	33	4.5
9-2	61	8.5

TABLE LII. Available soil moisture as recorded at the hydrologic station near Tourney Woodlot. Data is back dated from the time of radial growth increment readings by 48 hours. 1949.

Week Ending	Resistance (in ohms)	Weekly Average of Daily Totals (in ohms)*	Percent Available Moisture
4-12	5,140	857	77
5-19	4,925	821	79
4-26	5,020	837	78
5-3	2,470	823	79
5-10	5,150	858	77
5-17	5,420	903	76
5-24	5,161	860	77
5-31	5,015	836	78
6-7	7,815	1,302	63
6-14	83,500	13,917	15
6-21	7,780	1,297	65
6-28	7,445	1,241	66
7-5	4,725	945	75
7-12	6,075	1,012	73
7-19	4,835	967	74
7-26	6,045	1,007	73
8-2	6,970	1,162	68
8-9	8.900	1,483	61
8-16	16,430	2,738	42
8-23	44,000	7,333	23
8-30	464,750	77,458	0

* some daily readings not available

TABLE LIII. Total precipitation as recorded at the hydrologic station near Tourney Woodlot. Data is back dated from the time of radial growth increment readings by 48 hours. 1949

Week Ending	Inches
4-12	.01
4-19	1.34
4-26	.40
5-3	.15
5-10	.00
5-17	.03
5-24	2.48
5-31	.01
6-7	.03
6-14	1.20
6-21	1.11
6-28	.000
7-5	.000
7-12	1.14
7-19	.79
7-26	.53
8-2	.69
8-9	.60
8-16	1.15
8-23	.000
8-30	.55

TABLE LIV. Evaporation (open pan) as recorded at the hydrologic station near Toumey Woodlot. Data is back dated from the time of radial growth increment readings by 48 hours. 1949.

Week Ending	Inches
4-12	1.36
4-19	1.04
4-26	2.01
5-3	1.97
5-10	1.98
5-17	1.98
5-24	1.39
5-31	1.72
6-7	2.32
6-14	2.22
6-21	1.38
6-28	2.18
7-5	2.24
	(1.61)
7-12	1.38
7-19	1.44
7-26	1.78
8-2	1.58
8-9	1.59
8-16	1.60
8-23	1.31
8-30	1.33
	(1.26)
9-14	2.52

TABLE LV. Soil temperature as recorded at the hydrologic station near Toumey Woodlot. Data is back dated from the time of radial growth increment readings by 48 hours. 1949.

Week Ending	Weekly Summation in Degrees Fahrenheit
4-12	282
4-19	284
4-26	315
5-3	401
5-10	441
5-17	408
5-24	412
5-31	372
6-7	445
6-14	457
6-21	488
6-28	497
7-5	525
7-12	497
7-19	482
7-26	498
8-2	497
8-9	489
8-16	496
8-23	457
8-30	472

TABLE LVI. Total solar radiation as recorded at the hydrologic station near Toumey Woodlot. Data is back dated from the time of radial growth increment readings by 48 hours. 1949.

Week Ending	Total Radiation in Grams Per Square Centimeter (Langley units)
4-12	3,013.8
4-19	2,375.1
4-26	2,823.3
5-3	3,452.9
5-10	3,056.3
5-17	2,944.8
5-24	2,405.7
5-31	3,212.3
6-7	3,685.8
6-14	3,264.0
6-21	1,968.2
6-28	3,150.4
7-5	3,248.1
7-12	2,416.6
7-19	3,267.0
7-26	2,865.2
8-2	2,600.3
8-9	2,976.7
8-16	2,567.3
8-23	2,884.6
8-30	1,670.1