THE EFFECT OF CERTAIN CLIMATIC FACTORS ON THE HEIGHT GROWTH OF RED PINE IN CHIPPEWA COUNTY, MICHIGAN

Thesis for the Degree of M. S.

MICHIGAN STATE COLLEGE

Allen Frederick Horn, Jr.

1951

This is to certify that the

thesis entitled

"The Effect of Certain Climatic Factors on the Height Growth of Red Pine in Chippewa County, Michigan"

presented by

Allen Horn

has been accepted towards fulfillment of the requirements for

M.S. degree in Forestry

T. D. Stevens
Major professor

Date May 18, 1951

O-169

THE EFFECT OF CERTAIN CLIMATIC FACTORS ON THE HEIGHT GROWTH OF RED PINE IN CHIPPEWA COUNTY, MICHIGAN

By

ALLEN FREDERICK HORN, JR.

A THESIS

Submitted to the School of Graduate Studies of Michigan
State College of Agriculture and Applied Science
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Forestry

1951

THESIS

ACKNOWLEDGMENTS

The author gratefully acknowledges the aid he received from Maurice W. Day in planning this study and for making the experimental files of the Dunbar Forest Experiment Station available to him, and to Dr. William D. Baten for his suggestions and instruction in doing the statistical analyses presented here. Thanks too, to Earl J. Hodgkins who directed and edited the writing of this dissertation.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
Review of Literature	3
Statement of the Problem	5
PROCEDURE	8
Field and Office Work	8
Description and History of Plots Measured . .	14
DATA AND DISCUSSION	27
Analysis of Average Yearly Height Growth Tables	27
The Effect of Previous Year's Precipitation on Height Growth	29
The Effect of Rainfall During the Growing Season on Height Growth	30
The Effect of Temperature During the Growing Season on Height Growth	33
The Effect of Cloud Cover During the Growing Season on Height Growth	36
SUMMARY AND CONCLUSIONS	39
LITERATURE CITED	42

INTRODUCTION

This study deals with the effect of climate on the height growth of plantation-grown red pine, *Pinus resinosa* Ait. The field work was done in Chippewa County, Michigan, on the property of the Dunbar Forest Experiment Station, and on the Raco Ranger District of the Marquette National Forest.

From the viewpoint of those interested in the production of wood, the bole or stem is the most important part of the tree. As a result of growth, this stem assumes, upon maturity, a modified conical shape. This growth does not progress at a uniform rate either in height or diameter. It varies with age, progressing slowly at youth and maturity, but rapidly during the period of immaturity. There are variations of growth within these broad periods, too. Such variations may be caused by attacks of insects, disease, fire, variations in competition, or the yearly variations in weather.

Much is known about the causes of differences in rate of diameter growth. Cultural work; e.g., thinning is done in the forest to improve diameter increment, because it is known that trees closely spaced put on diameter growth slowly. In recent years the invention of the dial-gauge dendrometer has allowed the forester to make radial measurements of tree stems over very short periods. When these radial measurements are correlated with certain factors of daily weather; i.e., temperature and precipitation, there is a marked relation between radial growth and changes in temperature and precipitation (3).

The science of the study of tree rings is based on the supposition that the width of the annual ring is a function of the precipitation for that year. This theory has become widely accepted and much of our archaeological information is based on it.

Little is known however about the causes of variation in yearly height growth. That there is such a diversity is easily seen. In the majority of the coniferous tree species the distance between the adjacent branch whorls represents the height growth for one year. The red pine is one of the conifers that exhibits this property. The author has seen plantations of red pine where the distance between branch whorls of trees growing in full sunlight has varied from nine tenths of a foot to three and three tenths feet.

The variation in height growth follows the same broad pattern as diameter growth. It is slow during the seedling stage and maturity, and rapid during the period of immaturity. Fire, attacks of insects and diseases, competition and variations in climate also have an adverse effect on height growth.

The problem of variability of height growth in relation to climatic factors is almost unexplored. The author found very few references to this problem when he was looking for literature concerning previous investigations.

Review of Literature

Cook, (2) made a five year study of the height growth of coniferous species at Stephentown, New York. Red pine was one of the species included in the study. His study differed from the author's in that he had phenological data. Measurements were made weekly from a marked point on the previous year's growth. With this information he was able to determine the dates of beginning and cessation of height growth of the several species measured.

The red pine was found to make consistently the earliest start and to have the second shortest growing season. For the five year period 1933-1937, the starting date averaged May 4, and the average date of cessation of height growth was June 27. The average length of the height growing season was 54 days.

Cook did not use statistical methods to correlate growth to climate but he observed that, "Red pine in 1936 (with 5.71 inches of rain) made almost as good growth as in 1937 (with 9.01 inches of rain) and substantially better than in 1935 (with 5.14 inches of rain)." His conclusions were that: "Exceptional deficiency in rainfall appeared to retard growth. Unseasonably low temperatures after growth started may have been the cause of temporary slackening. Normal weather fluctuations however appear to have had but little influence in changing the course or amount of growth."[1]

Hiley and Cunliffe, (6) made a study in England similar to Cook's work in New York. Their study included coniferous species but they did not use red pine.

Phenological data was collected for the years 1920 and 1921. The height growth was measured twice a week from a point just below the terminal bud. These height increments were then correlated to selected meteorological conditions during the growing season by means of the correlation coefficient. The only significant correlation they reported was growth to maximum and average shade temperature during the growing season.

In another experiment, Hiley and Cunliffe, obtained the annual height increments of Corsican pine from 1907-1921. They concluded that: "The effect of the hot dry season of 1921 was both to shorten the growing season and

---

1 D. B. Cook, "Five Seasons' Growth of Conifers," Ecology, 22: 285-296, 1941.

to reduce the daily increments."[2] They also found a significant correlation between these height increments and rainfall from April to June, and a slightly lower correlation coefficient between increment and rainfall from the preceding October to June.

Friesner, (5) made a study of the relationship between the elongation of primary, secondary, and tertiary axes of red and white pine on the campus of Butler University. In conjunction with this experiment he plotted the daily elongation of the axes against maximum and minimum daily temperatures. There was a marked relationship between the peaks and troughs of these curves which led Friesner to believe that the temperature changes affected the growth process.

Statement of the Problem

The original plan was to ascertain whether or not there was a definite relationship between yearly height growth and one or more elements of weather. This relationship was not too definite as will be shown later, because plots that were thought to be similar did not show a systematic growth pattern from year to year.

---

2 W. E. Hiley and N. Cunliffe, "An Investigation into the Relation between Height Growth of Trees and Meteorlogical Conditions," Oxford Forestry Memoirs, 1: 1-19, 1922.

The field work was done in the summer of 1950. Yearly height increments of twenty trees were taken for the years 1942 to 1949 on six of the eight plots. On the remaining two plots twenty trees were measured for the five year period, 1945 to 1949, because these trees were younger and height growth was too variable before 1945.

Several soil borings were made in each plot to aid in identifying the soil type and to make certain there was no major variability in soil type within the plot. Identification was also made of the major species of ground cover as an aid in determining the productivity of the site.

Copies were made of the Dunbar Forest Experiment Station's weather records for 1942-1949 and the weather records of the Raco Ranger District of the Marquette National Forest for 1945-1949.

The growth data was compiled and an analysis of variance was made of it to test the significance of the variations in growth. Using this growth data the author compared average yearly height growth to selected elements of climate by means of statistical and graphical analyses. Those elements of climate that were used in this study are:

1. Previous year's precipitation
2. Rainfall during the growing season

3. Average temperature during the growing season

4. Average cloud cover during the growing season

PROCEDURE

Field and Office Work

A special tool described by Liming (7) and pictured in Figure 1, was constructed for measuring the internodes which represent yearly height increments.

Figure 1

Liming Height Measuring Pole in Use

It consisted of jointed sections of bamboo pole with a pointer attached to the end of the uppermost section. The sections are carried in a golf bag with a four foot reference pole fastened to it. The measuring pole is graduated in tenths of feet. The calibrations begin at four feet with the pointer and the numbers increasing as you go down the pole. To measure the height of a tree, enough of the four foot measuring sections are put together for the pointer to reach the tip of the tree. The four foot reference pole is held upright on the ground in front of the person and the measuring pole is held alongside of it. The height of the tree can then be read directly at the top of the reference pole.

When using the pole in the field care must be taken to keep the sections close to the stem as the pole is being extended or the pointer will swing out too far from the stem to make accurate measurements possible. The pole is easier to use when the trees have been pruned up high enough for the person to stand close to the trunk. To find the distance between adjacent branch whorls the author measured the height of each whorl above the ground and then subtracted the difference between them.

To make sure that each tree measured had approximately the same amount of competition throughout its life, only trees surrounded by other trees on three or all sides were chosen. This was done in all plots but one, where isolated trees were measured to see if widely spaced trees put on more yearly height growth than closely spaced plantation grown trees.

The author started out making soil borings alongside of each tree measured to see if there were local variations in the soil profile within plots such as presence or absence of hardpan layer, depth of hardpan layer, differences in soil type, that would cause variations in height growth. This plan was abandoned after the first plot was taken because there was only slight variation both in the soil profile and in height growth. Subsequently several random soil borings were taken in each plot in order to identify the soil type and to see that there was no major variation of soil type within the plot. Particular attention was paid to the depth of the A horizon and the distance to and thickness of the hardpan layer when present.

A species list of the ground cover was made for each plot to aid in determining the quality of the site. Certain species of plants have rigid site requirements, and their presence or absence on a site may be used as an index of site quality for the production of tree crops.

Detailed histories of the plantations in which the plots were located were procured from the files of the Dunbar Forest Experiment Station and the Norway Ranger Station. This was done to make certain that plots that were grouped together had a similar beginning and a similar treatment, and that no extraneous factors that might possibly affect height growth would be present.

The period 1942-1949, was chosen for this study because the weather records of the Dunbar Forest Experiment Station date back to 1942. The author tried to use this same period for the plots taken on the Marquette National Forest, but it was found that there was too much variability within years for height growth measurements previous to 1945 on two of the plots measured. This variability in height growth occurred when the trees were young, and was probably due to differences in competition between the red pine and the ground cover and not to variations in climate. Because of this the period 1945-1949 was chosen for plots taken on the Marquette National Forest.

The weather records for the Dunbar Forest Experiment Station were obtained from the Station's files. No records were obtainable for the year 1946 so the total annual precipitation from the United States Weather Bureau office at Sault Ste. Marie, Michigan, was used for that year. The Dunbar Station is located eighteen miles south of Sault Ste. Marie and the annual precipitation figures for the two stations are similar.

The weather records from the Norway Ranger Station were obtained from the unpublished files of the United States Weather Bureau office in East Lansing, Michigan. There are frequent omissions in these records and in 1948 the Norway Ranger Station did not begin recording weather data until the first of June. For studying the effects of an element of climate on height growth on a yearly basis, the Dunbar Station weather records were used for all plots. When correlating the effect of cloud cover on height growth the cloud cover records of the Norway Ranger Station were used for all plots because the Dunbar Station does not keep records of daily cloud cover.

Summary tables (Tables 1 and 2) of average height growth by plots and years were compiled for the eight plots measured. The variations in growth between years was so slight that an analysis of variance of these tables was made to determine whether or not the differences in height growth among years and among plots were significant. It was found that these differences were significant, and also that the yearly variations among plots were not consistent. Because of this the plots were regrouped on the basis of similarity of soil type. These groups of plots were then correlated to the selected elements of climate by means of the correlation coefficient. An empirically fitted curve was used to show the relationship between yearly height increment and the selected meteorological factor when the correlation coefficient of that particular meteorological factor and height growth was significant.

TABLE 1

Average Yearly Height Growth in Feet of Plots 1-5

Plots	8 Year Ave.	1949	1948	1947	Years 1946	1945	1944	1943	1942
1	2.0	1.6	1.8	2.1	2.1	2.2	2.1	1.9	2.1
2	2.0	1.8	1.9	2.0	2.0	2.0	2.2	2.0	2.0
3	1.9	2.1	1.8	1.9	1.7	2.0	2.1	1.6	1.9
4	1.9	1.8	2.1	1.9	2.0	1.8	2.0	1.7	1.8
5	1.8	1.9	1.8	1.8	1.7	1.8	2.0	1.6	1.7
Yearly Average		1.8	1.9	1.9	1.9	2.0	2.1	1.8	1.9

TABLE 2

Average Yearly Height Growth in Feet of Plots 6-8

Plots	5 Year Ave.	1949	1948	Years 1947	1946	1945
6	1.9	2.1	2.0	1.9	1.9	1.9
7	2.0	2.0	1.8	1.9	2.1	2.1
8	1.1	1.4	0.8	1.1	1.1	1.2
Yearly Average		1.8	1.5	1.6	1.7	1.7

Description and History of Plots Measured

The eight plots measured were arranged in three groups based on soil order, soil texture, and similarities in plot histories. Plots 1-5 taken on the Dunbar Station were all grouped together. The plantations are 22-23 years old. The soil order is mainly intrazonal with some poorly drained zonal, and the soil textures are all sandy loams. All of the land had been used for agriculture previous to the planting of red pine. Plots 6 and 7 measured on the Marquette National Forest were considered as a group. Their ages are 17 and 15 years respectively. Both soil types are of the zonal order and their textures are sandy loam and loamy sand. These were open field areas before they were planted. Plot 8 was considered separately. It is 21 years old and growing on a very droughty zonal soil type. This area had been burned over many times previous to planting. The survival is poor.

Plots 1, 2, and 3 were all taken in Compartment 5 of the Dunbar Forest. This area was cleared for agricultural use sometime between 1903 and 1910. It was cropped until 1927 when the fertility became so low and the quack grass so thick that no paying crop of hay or grain could be raised. The planting was made in May, 1927, using 2-0 stock, 4-6 inches high from the Michigan

State College nursery at East Lansing, Michigan. The area was furrow plowed with a team, and the planting was done with a shovel, slit method, in the furrows. The original spacing was 6x8 feet. The whole plantation is situated on a low and level site. Plots 1 and 3 were located on the Brimley very fine sandy loam type. The soil profile description is (4):

1. Plow layer brownish-gray very fine sandy loam.
2. Dark amber-brown very fine sandy loam may be faintly cemented, 6-8 inches thick.
3. Yellow-brown very fine sand spotted with rust brown 9-12 inches thick.
4. Yellowish-brown very fine sand mottled with gray, containing lenses of silt, 12-24 inches thick.
5. Tough heavy chocolate-colored laminated lacustrine silts and clays free from gravel, extending to a depth of three feet and more.

The drainage conditions were rather poor when the planting was done.

Plot 2 was located on the Bohemian fine sandy loam type. The profile description is (4):

1. Plow layer brown-gray fine sandy loam.
2. Dark brown fine sandy loam usually not cemented, 6-8 inches thick.
3. Light brown loamy fine sand 10-12 inches thick.
4. Pale rose-gray fine sand somewhat compacted but not cemented, extends to a depth of three feet or more.

This site was slightly higher than plot 1, and the drainage conditions were better at the time of planting.

The trees in plot 2 were several feet taller than those trees in plots 1 and 3 but the average yearly height growth for the eight-year period was the same, (within 0.1 feet), for all three plots.

Figure 2

A Close-Up View of Plot 2 Showing Length of Internodes.

The Prunning Saw is About 24 Inches Long.

Therefore it seems reasonable to assume that the trees in plot 2 made their rapid growth fairly early in life before

the eight year measurements were made, while the other trees were hampered by poor drainage.

Plot 3 consisted of isolated border trees. They were taller than the trees in plot 1 but not quite as tall as those trees in plot 2. Because of their isolated position it was thought that they would grow more rapidly due to increased sunlight and soil moisture available to them. This was not found to be the case. The average yearly height growth for the eight-year period was 1.9 feet. This was 0.1 feet less than the average yearly height growth of plots 1 and 2. No explanation could be found for this discrepancy.

Plots 4 and 5 were taken in Compartment 3 of the Dunbar Forest Experiment Station. This plantation was started in the spring of 1928. The stock was 2-0 red pine, 4-6 inches high, and was procured from the Michigan State College nursery at East Lansing, Michigan. The planting was done with a planting iron after the area was plowed. Original spacing was 6x8 feet. According to information from the files of the Dunbar Station the original cover type was tamarack and spruce. This area was cleared in 1925 as a demonstration by the Upper Peninsula Land Clearing Company for the Dunbar School of Agriculture. It was used as crop land until 1927. The surface drainage in this compartment is very slow, and the site is level and low.

Figure 3

An Interior View of Plot 4. Note varying Distances Between Branch Scars.

Figure 4

A close-Up View of A Tree in Plot 4 Showing Variations in Height Growth. The Pole is 4 Feet Long.

Plot 4 was taken on the Bruce fine sandy loam soil type. The profile description is (4):

1. Plow layer dull gray loamy fine sand.
2. Gray very fine sand with brownish-yellow staining, 12-18 inches thick.
3. Pale salmon colored compact very fine sand and silt layers; extends to a depth of three feet or more.

Plot 5 was located on the Brimley very fine sandy soil type which has already been described.

The total height of plot 4 was several feet more than the total height of plot 5, and the average yearly height growth for the eight year period was 1.9 feet for plot 4 and 1.8 feet for plot 5. This difference in total height and average yearly height growth was probably due to the layer of clay, at a depth of 11 inches, that underlies plot 5.

Plot 6 was measured in plantation, P-48 on the Raco Ranger District. It was planted in the fall of 1933 with 2-0 red pine from the Federal Forest Nursery at Rhinelander, Wisconsin. The original spacing was 6x8 feet, and the planting was done in furrows with a planting iron. Red and white pine was the original cover type on this area. It was burned over sometime previous to 1920. Most of this area was cleared and farmed prior to the time it was planted. Bohemian very fine sandy loam, previously described, is the soil type in this area.

Figure 5

Looking Into Plots 4 and 5. Plot 5 Underlain by a Claypan is on the Left Side of the Photo.

Plot 7 was located on the Marquette National Forest in plantation P-79, planted in the fall of 1935.

Figure 6

A General View of Plot 7. Planted in 1935

These Trees Have an Average Height of About 20 Feet.

The stock was 2-0 red pine from the Wyman Federal Nursery located at Manistique, Michigan. These were planted in furrows with a planting iron and the original spacing was 6x8 feet. The original cover type in this area was mixed hardwoods and white pine. A fire occurred on this area in 1930. The soil type is Strong's loamy sand. The profile description is (9):

1. Plow layer gray or lavender fine or medium sand.
2. Dark brown slightly cemented loamy sand 6-12 inches thick.
3. Loose yellow sand with a depth range of 20-30 inches.
4. Sand with lenses and layers of red clay and silt and pockets of gravel and some boulders.

Figure 7

A View Showing Variations in Height Growth of a Tree in Plot 7. The 12 foot Pole Covers an 8 Year Period.

Figure 8

A Close-Up of Figure 7. The Distance Between the Author's Hands is 3 Feet.

The average yearly height growth for a five year period was 2.0 feet for both plots 6 and 7.

Plot 8 was located in the Marquette National Forest on the Rubicon sand soil type. Because of the very droughty condition of this soil and the resulting poor height growth this plot was not put into one of the other two groups but will be considered separately. This plot was taken in plantation P-38C. It was planted in the spring of 1929 with 2-0 red pine from the Federal Nursery in Minnesota. The planting was done with planting irons in furrows, and the original spacing was 8x8 feet. Pine was the original cover type in this area and it had been burned over many times prior to 1925. Survival was very poor in this plantation. The trees measured were in small groups or isolated. The average yearly height growth for the five year period was 1.1 feet. The description of the Rubicon sand profile is (4):

1. Plow layer pinkish-gray loose fine sand.
2. Reddish-brown loamy fine sand; 3-10 inches thick.
3. Yellowish-red fine sand weakly cemented in places; 6-14 inches thick.
4. Reddish-yellow line sand becoming coarser with depth. Many feet thick.

While in the field the author made note of the ground cover associated with each plot to be used as an aid in determining the site quality. Since than he has checked the literature available (1), and found that plant indicator species are best used when dealing with natural grown, mature forests. Also, rather than being an indication of site quality, these indicator plants are most useful as an expression of available soil moisture. A list of the major ground cover species associated with

Figure 9

A General View of Plot 8 Showing the Poor Survival of the Red Pine. The Jack Pine are Naturally Reproduced.

each group of plots is presented here as an indication of what is commonly found associated with coniferous plantations in this area. These represent stages in secondary succession on these areas.

Plots 1-5, poorly drained

Acer saccharum Marsh.
Acer rubrum L.
Betula papyrifera Marsh.
Quercus borealis var. maxima Marsh.
Rubus spp.
Lactuca canadensis L.

Plots 6 and 7, well drained

Phleum pratense L.
Erigeron annuus L.
Anaphalis margaritacea L.
Cornus canadensis L.
Polytrichum juniperinum Willd.
Pteris aquilina L.

Plot 8, excessively drained

Soladago spp.
Vaccinium pennsylvanicum Lam.
Salix humilis Marsh.
Pteris aquilina L.
Cladonia rangiferina L.

DATA AND DISCUSSION

Analysis of Average Yearly Height Growth Tables

Because the variation of average yearly height growth between years and within plots was so small, an analysis of variance based on Tables 1 and 2 was made to see if these differences were significant (see Tables 3 and 4). It was found that there was a significant variation of height growth for years within all plots measured. Climate was the only variable occurring over this period so it was assumed that climate caused the variation in yearly height growth. Plots also varied. Soil type and site were the only variables in this case which would cause height growth to vary. The interaction between years and plots was significant too. This means that the year to year height growth pattern was not consistent among the various plots. The significance of the interaction was probably due to combining plots of different soil types in the analysis of variance. The variation in soil types caused the trees to be from different populations.

This method of analysis of variance limits the conclusions that may be drawn from this study to the particular plots measured. To have made this study more general in nature the analysis of variance would have had to

TABLE 3

Analysis of Variance, Plots 1-5[1]

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Years	7	4.30	0.61**
Plots	4	4.54	1.13**
Interaction	28	12.35	0.44**
Sampling error	755	62.91	0.08
Total	794	84.10	

1Table 3 was based on the 795 original measurements made in plots 1-5. Table 1 contains the averages of these measurements.

** denotes significance beyond 1% level

TABLE 4

Analysis of Variance, Plots 6-8[1]

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Years	4	3.39	0.85**
Plots	2	51.53	25.77**
Interaction	8	3.08	0.39**
Sampling error	285	17.01	0.06
Total	299	75.01	

1Table 4 was based on the 300 original measurements made in plots 6-8. Table 2 contains the averages of these measurements.

be done by the usual method, (8) i.e., using the mean square for interaction, when significant, to test the other sources of variation. The use of this method in this case gives a mean square for the interaction that is so large that the variations in years and plots can not be detected.

The Effect of Previous Year's Precipitation on Height Growth

The correlations between the various elements of climate and height growth were made by the use of the correlation coefficient. The formula for the correlation coefficient is: $r = \frac{N\Sigma XY-(\Sigma X)(\Sigma Y)}{\sqrt{[N\Sigma X^2-(\Sigma X)^2][N\Sigma Y^2-(\Sigma Y)^2]}}$ where r = correlation coefficient, N = number of observations, X = height growth, and Y = an element of climate. The correlation coefficient is a measure of the dependency of one observation on another. Disregarding the sign, the value of r cannot exceed 1.0. This value implies complete linear dependency of one observation on the other; i.e., a unit increase or decrease in one observation will cause a corresponding change in the other observation. An r value of 0 means the observations are completely independent. The number of observations determines whether or not the r value will be significant for values between 0 and 1.0.

Plots 1-5, taken on the Dunbar Station were the only group that showed a significant correlation of height growth to previous years' precipitation. The r value for this correlation coefficient was 0.47 with 33 degrees of freedom, which is significant beyond the 1% level. This means that the yearly height growth of these plots during the years 1943-1949 was dependent upon the amount of precipitation that occurred during the previous year. These plots were located on soil types which were poorly drained and most of them were underlain by a hardpan layer. The moisture holding capacity of these soils are very high. Presumably these poorly drained soils are able to store enough water from the previous year's precipitation or store enough food during the previous year so that the rainfall during the growing season has little effect on the height growth.

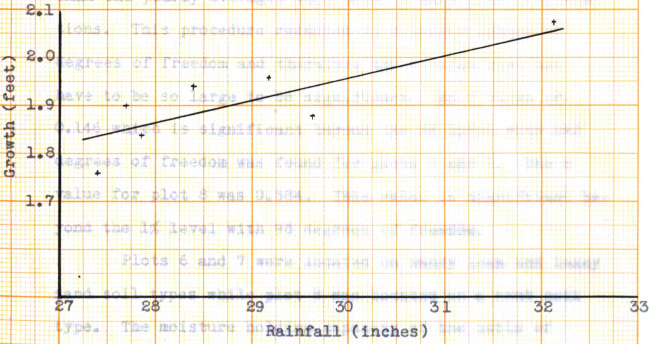
A graphical representation of the effect of previous year's precipitation on height growth is shown by the empirically fitted curve in Figure 10. This curve is balanced for altitude and tilt.

The Effect of Rainfall During the Growing Season on Height Growth

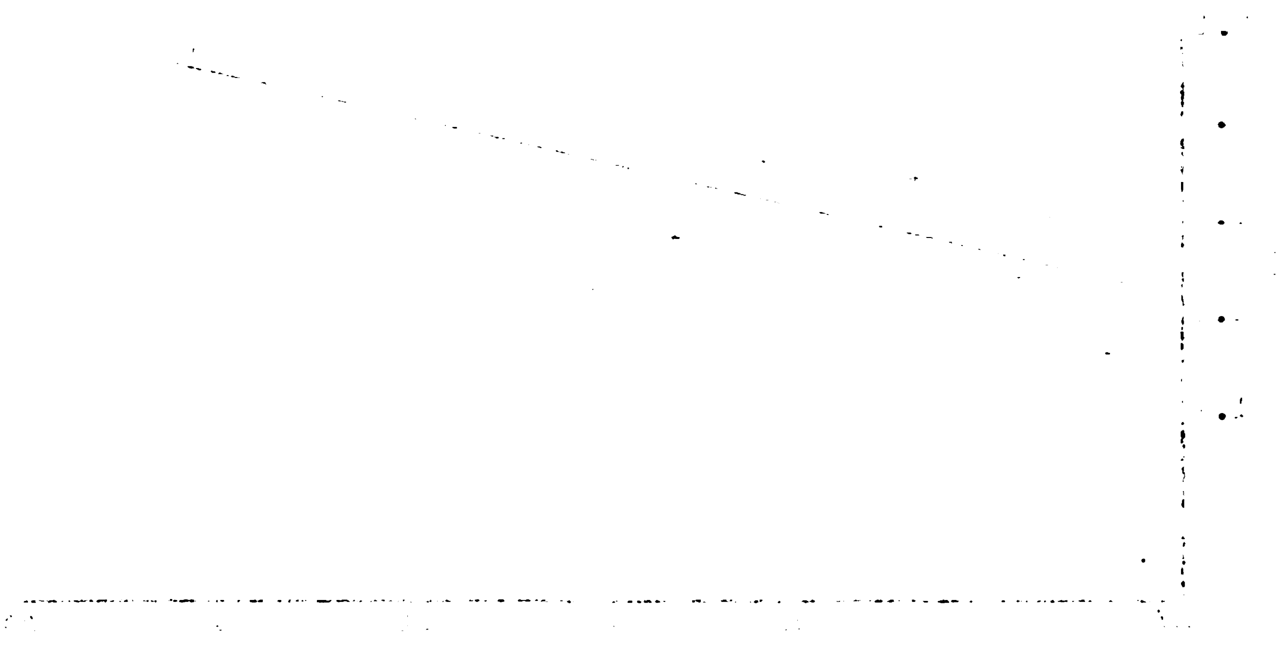
The months of May, June, and July were taken to represent the height growth season of red pine in this area. There is no exact data to bear out this assumption but Mr. Maurice W. Day, Director of the Dunbar Forest

Figure 10

The Effect of Previous Year's Rainfall on the Height Growth of Red Pine for Plots 1-5



Footnote: Each point on the above curve represents the average of one hundred yearly height growth measurements.



Experiment Station, who is well acquainted with this area felt that this period would include the height growth season.

The height growth of both groups of plots taken on the Marquette National Forest, 6 and 7 on well drained soil types and 8 on an excessively drained soil type was found to be dependent on rainfall occurring during this period. The individual height growth measurements rather than the yearly averages were used to make these correlations. This procedure resulted in a larger number of degrees of freedom and therefore the r value does not have to be so large to be significant. An r value of 0.146 which is significant beyond the 5% level with 198 degrees of freedom was found for plots 6 and 7. The r value for plot 8 was 0.584. This value is significant beyond the 1% level with 98 degrees of freedom.

Plots 6 and 7 were located on sandy loam and loamy sand soil types while plot 8 was located on a sand soil type. The moisture holding capacity of the soils of plots 6 and 7 is considerably better than the droughty Rubicon sand of plot 8. It is interesting to note that as the moisture holding capacity of the soils decreases the apparent dependency of height growth to rainfall during the growing season increases.

The two graphs showing the relationship of height growth to rainfall during the growing season for plots 6 and 7, and 8 are shown in Figures 11 and 12. These graphs are corrected for altitude but not for tilt because there were not enough observations to do this accurately. All of these relationships are shown by straight line graphs because of this. Also the natural pattern seems to be linear.

The Effect of Temperature During the Growing Season on Height Growth

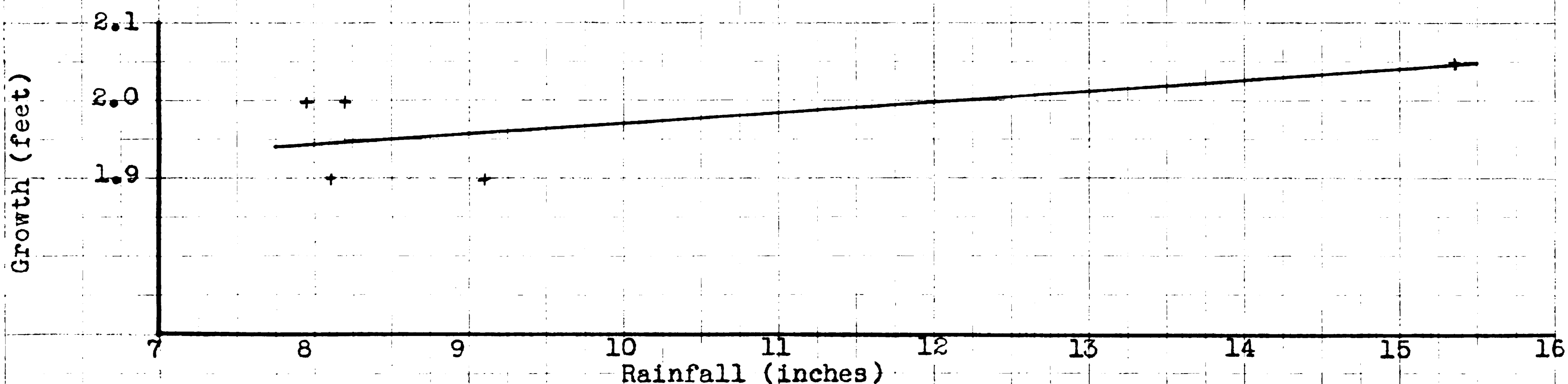
Plot 8 on the Rubicon sand soil type was the only one to show a significant correlation of height growth to temperature during the growing season. With 98 degrees of freedom this r value of 0.31 was significant beyond the 1% level. Plots 6 and 7 with the intermediate moisture relationships just missed being significant at the 5% level. Their r value was 0.138. To be significant with 198 degrees of freedom the value would have had to been 0.139.

As moisture becomes more limiting there is an increasing tendency for temperature during the growing season to influence height growth through its effect on moisture relationships. This relationship of height growth to temperature during the growing season for plot

Figure 11

The Effect of Rainfall During the Growing Season on the Height

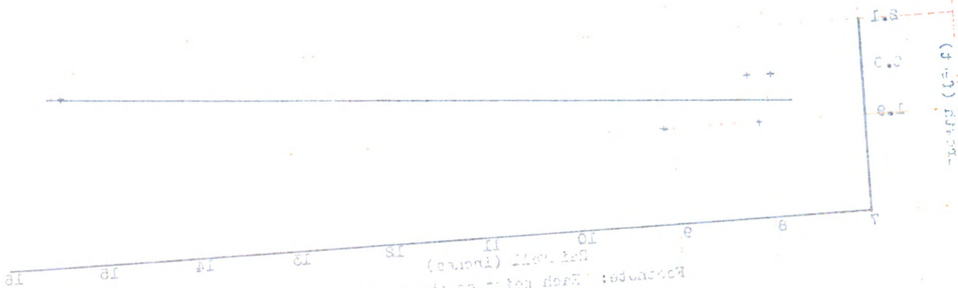
Growth of Red Pine for Plots 6 and 7



Footnote: Each point on the above curve represents the average of forty yearly height growth measurements.

Figure 11

The Effect of Rainfall During the Growing Season on the Height Growth of Red Pine for Plots 6 and 7

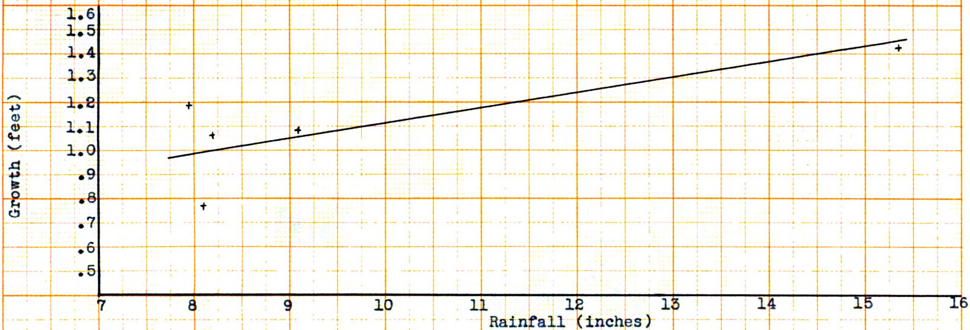


Footnote: Each point on the above curve represents the average of forty randomly selected growth measurements.

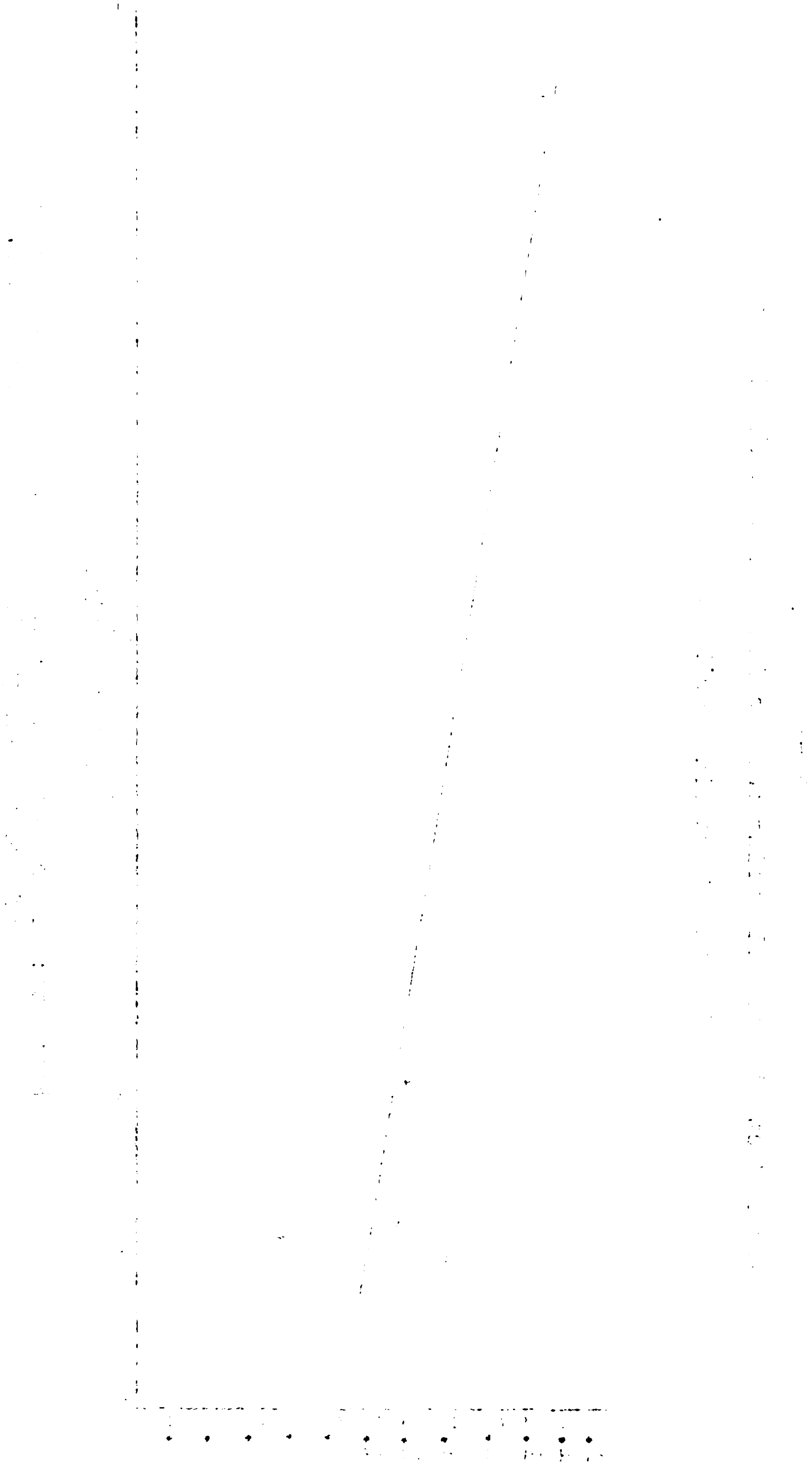
Figure 12

The Effect of Rainfall During the Growing Season on the Height

Growth of Red Pine for Plot 8



Footnote: Each point on the above curve represents the average of twenty yearly height growth measurements.



8 is shown by the straight line graph in Figure 13. This curve is corrected for altitude but not for tilt.

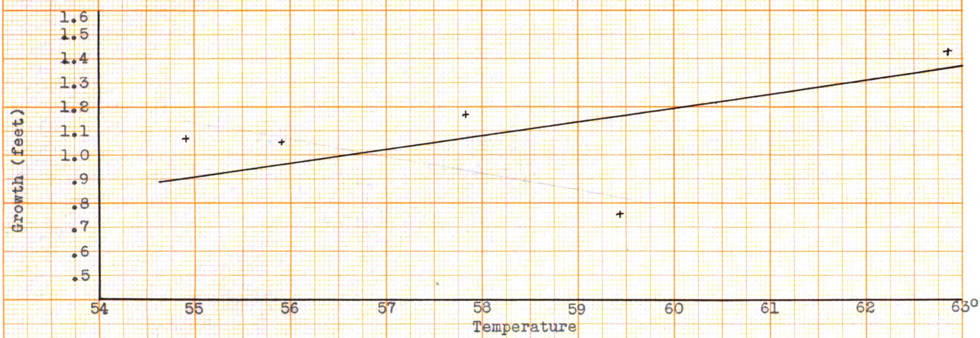
The Effect of Cloud Cover During the Growing Season on Height Growth

Cloud cover was chosen as one of the elements of climate to be studied because in an indirect way it would show whether or not the amount of sunshine influenced height growth. The average cloud cover for the months May, June and July was calculated from the daily observations for the years 1945-1949, and these figures were used in determining the correlation coefficient.

Plot 8 was the only one to show a significant correlation of annual height growth to cloud cover during the growing season. The r value was 0.524 which is significant beyond the 1% level with 98 degrees of freedom. This shows that height growth increased as cloud cover increased. This relationship is probably caused by the increased amount of precipitation and lessened evaporation associated with increased cloud cover rather than the fact that more intense sunlight would inhibit height growth. A graphic representation of the effect of cloud cover on height growth for plot 8 is shown in Figure 14.

Figure 13

The Effect of Average Temperature During the Growing Season on the Height Growth of Red Pine for Plot 8

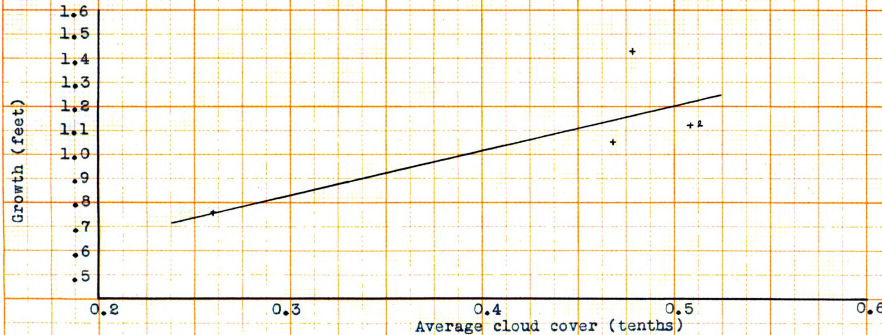


Footnote: Each point on the above curve represents the average of twenty yearly height growth measurements.

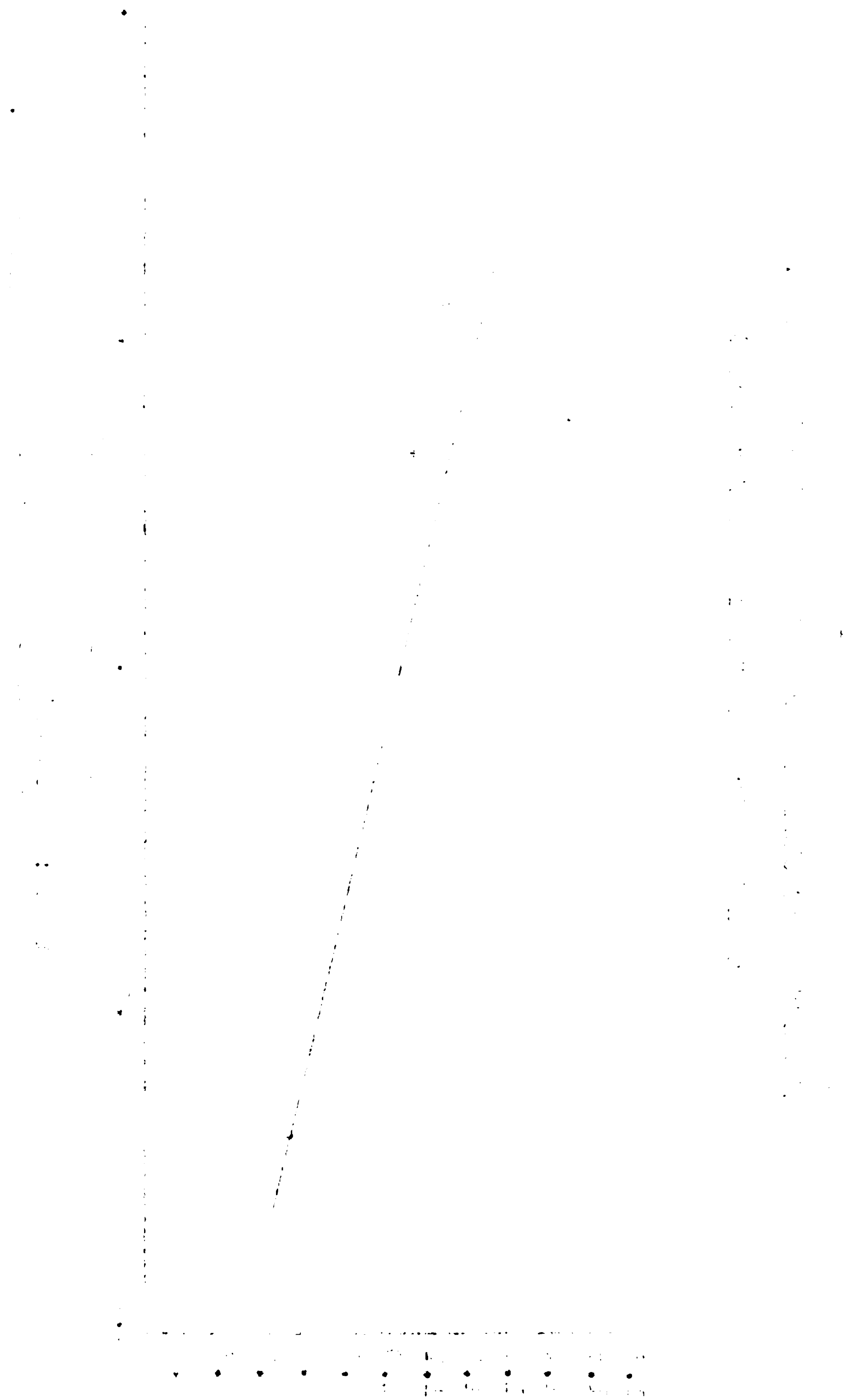
Figure 14

The Effect of Cloud Cover During the Growing Season

on the Height Growth of Red Pine for Plot 8



Footnote: Each point on the above curve represents the average of twenty yearly height growth measurements.



SUMMARY AND CONCLUSIONS

This study deals with the effect of climate on the height growth of plantation grown red pine, Pinus resinosa Ait. The field work was done in Chippewa County, Michigan on the property of the Dunbar Forest Experiment Station, and on the Raco Ranger District of the Marquette National Forest.

The yearly height growth of twenty trees was measured for an eight or in some cases a five-year period on each of eight plots. Several soil borings were made in each plot to aid in determining the soil type and to make certain there was no major variability of soil type within the plots.

Copies were made of the Dunbar Forest Experiment Station's weather records for 1942-1949 and the weather records of the Raco Ranger District for 1945-1949.

The growth data was compiled and an analysis of variance was made of the average yearly height growth for all plots. This analysis showed that there was a significant variation between plots, years, and plots x years interaction. This data was then placed into three groups based on differences in soil type, method of establishment, and age of the plantations. Using this growth data the author correlated for each group the average yearly height growth to selected elements of climate by means of statistical and graphical analyses. Those elements of climate used in this study are:

1. Previous years' precipitation
2. Rainfall during the growing season
3. Average temperature during the growing season
4. Average cloud cover during the growing season

Some interesting conclusions may be drawn for the period 1942-1949 and 1945-1949 for those plots measured.

One group of plots was located on poorly drained soil types and the height growth of these plots proved to have a significant correlation with previous years' precipitation. The height growth of another group of plots located on well drained soils had a significant correlation to rainfall during the growing season. An even higher correlation of height growth to rainfall during the growing season was obtained for the third group of plots located on very droughty soil type. As soil drainage improves or moisture holding capacity decreases there is a definite tendency for height growth to depend on rainfall during the growing season.

As available soil moisture becomes less due to improved soil drainage the influence of temperature during the growing season on height growth increases.

The height growth of the one plot in the droughty soil type group had a significant correlation with three elements of climate: Rainfall during the growing season, temperature during the growing season, and cloud cover during the growing season. Here it appears that as the site becomes more adverse climate plays a more important part in regulating the height growth of the red pine.

The conclusions drawn from this study would also be applicable to other red pine plantations if the conditions were similar to those reported by the author.

To anyone wishing to repeat an experiment similar to this one the author suggests that he limit the scope of the study to one soil type, or that he take several plots on the same soil type so that the analysis of variance could be handled by the plot replication method. Either method would decrease the number of variables present and thereby have a tendency to reduce the mean square for interaction.

Phenological data for red pine in this area would also have been helpful. If the author had data on length of the height growth season and the average dates for beginning and cessation of height growth for red pine in this area, correlations of height growth to more restricted elements of climate would have been possible. This would probably have led to more concrete results than those presented here.

LITERATURE CITED

1. Cajander, A. K., "Theory of Forest Types," Acta Forestalia Fennica, 29:95-108, 1926.

2. Cook, D. B., "Five Seasons' Growth of Conifers," Ecology, 22:285-296, 1941.

3. Dils, R. E., and M. W. Day, The Effect of Precipitation and Temperature Upon The Radial Growth of Red Pine. Unpublished, 1951, 4 pp.

4. Division of Soil Survey, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, Soil Series Descriptions, U. S. Department of Agriculture.
   Bohemian Series
   Brimley Series
   Bruce Series
   Rubicon Series

5. Friesner, Ray C., "Correlation of Elongation in Primary, Secondary and Tertiary Axes of Pinus strobus and P. resinosa," Butler University Botanical Studies, 6:1-9, May, 1943.

6. Hiley, W. E., and N. Cunliffe, "An Investigation into the Relations Between Height Growth of Trees and Meteorological Conditions," Oxford Forestry Memoirs, 1:1-19, 1922.

7. Liming, Franklin, "A Sectional Pole for Measuring Tree Heights," Journal of Forestry, 44:512-514, July, 1946.

8. Snedecor, George W., Statistical Methods. Fourth edition; Ames, Iowa: Iowa State College Press, 1946, 485 pp.

9. Veatch, J. O., and others, Soil Survey of Chippewa County, Michigan. Washington: United States Department of Agriculture, Bureau of Chemistry and Soils, 1927, 44 pp.