GROWTH STUDIES OF SCOTCH PINE IN STINCHFIELD WOODS

by

SHERMAN D. WHIPPLE

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Ann Arbor, Michigan
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Professor L. J. Young
School of For. and Con.
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Dear Sir:

This problem was worked out and presented in partial fulfillment of the requirements for a Master's Degree in Forestry.

Because of the nature of this problem, a more thorough study has been made of the physical factors involved than of the chemical factors. This was done because the probability of usuable results being obtained from an intensive study of the chemical factors would have been negligible.

I here wish to express my appreciation to Professor M. W. Senstius, of the Department of Geology, who so kindly permitted me to use the facilities of the Soil Labatory, and for his assistance in the assistance in the technicalities of soil analysis, and for his helpful pointers on procedure.

Professor L. J. Young was also most helpful in offering suggestions as to procedure and on methods used.

Very respectfully,

Sherman D. Whipple

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GROWTH STUDIES OF SCOTCH PINE IN STINCHFIELD WOODS

I

INTRODUCTION

Three separate plots of Scotch pine (*Pinus sylvestris*), whose seed has come from southern Bavaria, Europe, were planted in the Stinchfield Woods property belonging to the University of Michigan, School of Forestry and Conservation. Plot 23 was planted in 1933, while Plots 27 and 28 were planted in 1936. Each plot was planted with a spacing of 6' by 6', and all subsequent treatment has been of a similar nature with the exception that Plot 23 was pruned two years before data for this study were secured. All but parts of Plot 28 have closed canopies.

Before these plots were planted to pine, the whole area had been in corn for several years. The results of improper treatment of the soil at that time had caused considerable amounts of soil losses through erosion on the steeper slopes and, as there is considerable variation in the degree of slope from one plot to another, the amount of erosion between plots varies considerably. Plot 23 has very little slope and has a slightly higher elevation than either of the other two plots. Plot 27 has a gentle slope of from 4 percent to 8 percent while Plot 28 has a steeper slope of from 20 percent to 60 percent.

From these areas I have attempted to correlate the varying rates of growth of the average dominant and co-dominant trees of each plot with the average dominant and co-dominant trees of the other plots and to relate the cause of these variations to some of the factors that may influence plant growth.

II

PROCEDURE

A. Securing of Growth Data

Because of the age of the stands, diameter measurements would have been too small for representative data; height measurements, therefore, were used. These data were secured by reading directly from a graduated pole placed beside the individual tree. Measurements were read to the nearest two tenths of a foot and only of the trees in the dominant and co-dominant class of each stand. A one hundred percent survey was made of Plots 23 and 28 and part of Plot 27.

TABLE I

GROWTH RATE TABLE OF SCOTCH PINE

Plot number	23	27	28
Age of stand	13	10	10
Number of trees			
Dominant	43	66	110
Co-dominant	78	50	54
Average height in feet			
Dominant	27.3	17.6	12.4
Co-dominant	25.5	16.3	11.2
Average annual height growth in feet			
Dominant	2.10	1.76	1.24
Co-dominant	1.96	1.63	1.12

All height measurements were taken in November of 1946. The growth data were made up in table form as in TABLE I, p. 3. An average present height in feet was figured for each class of each plot. From this figure, the average annual height growth in feet is calculated.

B. Securing of Soil Samples

Soil samples have been secured from holes, the location of which are indicated in Fig. 1, p. 5., dug in representative portions of each plot. Six holes were dug three feet deep on each plot, from each of which one sample was taken at the first foot level (surface soil), and one sample was taken at the second foot level (subsoil). Along with this an ocular study was made of the soil below the two foot level, the distribution of tree roots, and the depth to which the organic discoloration extended.

In numbering the samples those taken from the surface soil have been given odd numbers in the order in which the holes were dug. Similarly the samples from the subsoil were given even numbers. Samples numbered from 1 to 12 are from Plot 27, samples numbered from 13 to 24 are from Plot 28, and samples numbered from 25 to 36 are from Plot 23.

C. Mechanical Analysis.

Preparation: Each sample to be analysed was first air-dried for 24 hours and then weighed and passed through a series of sieves with round holes,

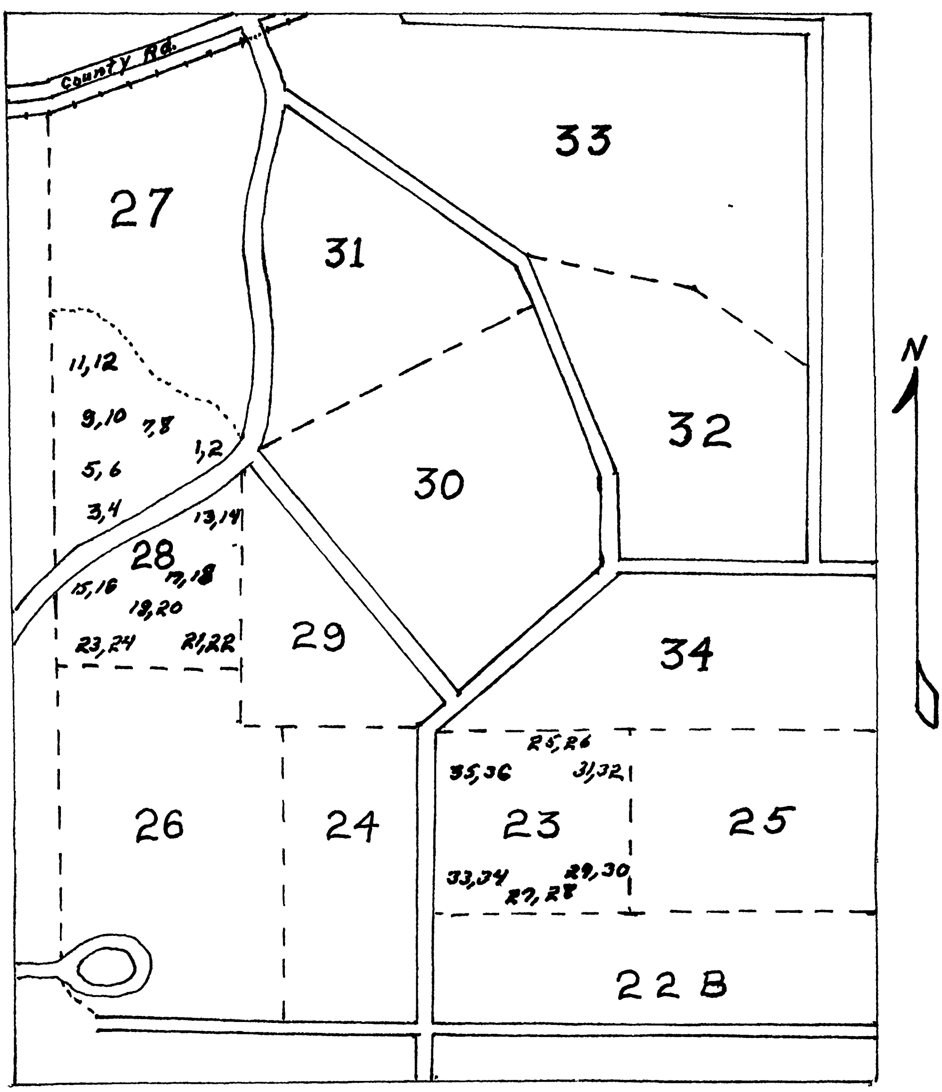


Fig. 1

A portion of Stinchfield Woods showing the location of the soil samples.

the diameters of which were 5 mm, 3 mm, and 2 mm. Each part was then weighed again and calculated as to percentages. All material over 2 mm in diameter is classed as gravel. A bar graph was made of the sum of the gravel in each sample and represented on Fig. 2, p. 7.

The material that passed through the 2 mm sieve is called fine earth material (F. E.). It is this portion of the sample that is used for all subsequent analysis both mechanical and chemical.

Method: The hydrometer (Bouyoucos) method was used here with some variation as to procedure (1, 2).

Fifty grams of each sample of fine earth were taken and dispersed by mixing it in a solution of distilled water and sodium silicate for 10 minutes. After having been dispersed, the mixture was poured into a graduated cylinder. The cylinder was then filled to a specified depth, 1150 cc., and shaken thoroughly, and the time noted when it was set down. After 40 seconds a reading was made from a graduated hydrometer placed in the cylinder. This was done three times and an average taken. Corrections were made for differences in temperature and results calculated as to percentages of sand from 2 mm to 0.05 mm.

Fig. 2

The percentage of the total soil sample in gravel.

Readings were taken at the end of the first hour and again at the end of the second hour for determining the percentages of conventional clay of the older classification, or clay less than 0.005 mm in diameter, and clay of the new classification, or clay less than 0.002 mm in diameter. Corrections were made for variations in temperature according to Bouyoucos (1). The difference between the clay of the new and the clay of the old classification is the percentage of fine silt, or percentage of material from 0.005 mm to 0.002 mm. Coarse silt (0.05 mm to 0.005 mm) is computed by subtracting the sum of the sand, fine silt, and clay less than 0.002 mm from 100.

The total sand (2 mm to 0.05 mm) was recovered by careful decantation according to the Illinois method, wherein the soil from the beaker used in the hydrometer test was transferred to a half pint bottle and the clay and silt, or all particles less than 0.05 mm, are removed by mixing the soil with tap water and allowing the coarser material to settle at the rate of 7 cm in 35 seconds, or 5 seconds per cm, and siphonning off with the water the unsettled material. This was repeated until water above the 7cm mark at 35 seconds was clear, indicating that all material less than 0.05 mm had been removed. The greater part of the remaining water was decanted and the sediment left in the bottle was oven dried. This dried material, or sand from 2 mm to 0.05 mm, was passed through a series of round holed sieves of known diameters. The sand remaining in each sieve was weighed and calculated into percentages. The classification of the corresponding sizes are as follows:

Very coarse sand	2.000 mm to 1.000 mm
Coarse sand	1.000 mm to 0.500 mm
Medium sand	0.500 mm to 0.250 mm
Fine sand	0.250 mm to 0.100 mm
Very fine sand	0.100 mm to 0.050 mm

The sum of the sand percentages by decantation furnish a check on the results as determined by the Bouyoucos method, which came within satisfactory limits.

Development of Curves: The percentages calculated from the above procedure are plotted on a chart and summation curves are fitted to them as shown on Figs. 3 to 8, p. 10 to 15. The data on the left side of this figure indicate the sum percentages of fine earths larger than a known size, while the other side indicates the sum percentages of fine earths less than a known size. The sizes are calculated according to the semi-logarithmic scale because the differences between the sizes vary. Each curve is in a different color representing a different sample in that horizon. Only the six samples of the same depth of each plot are on one

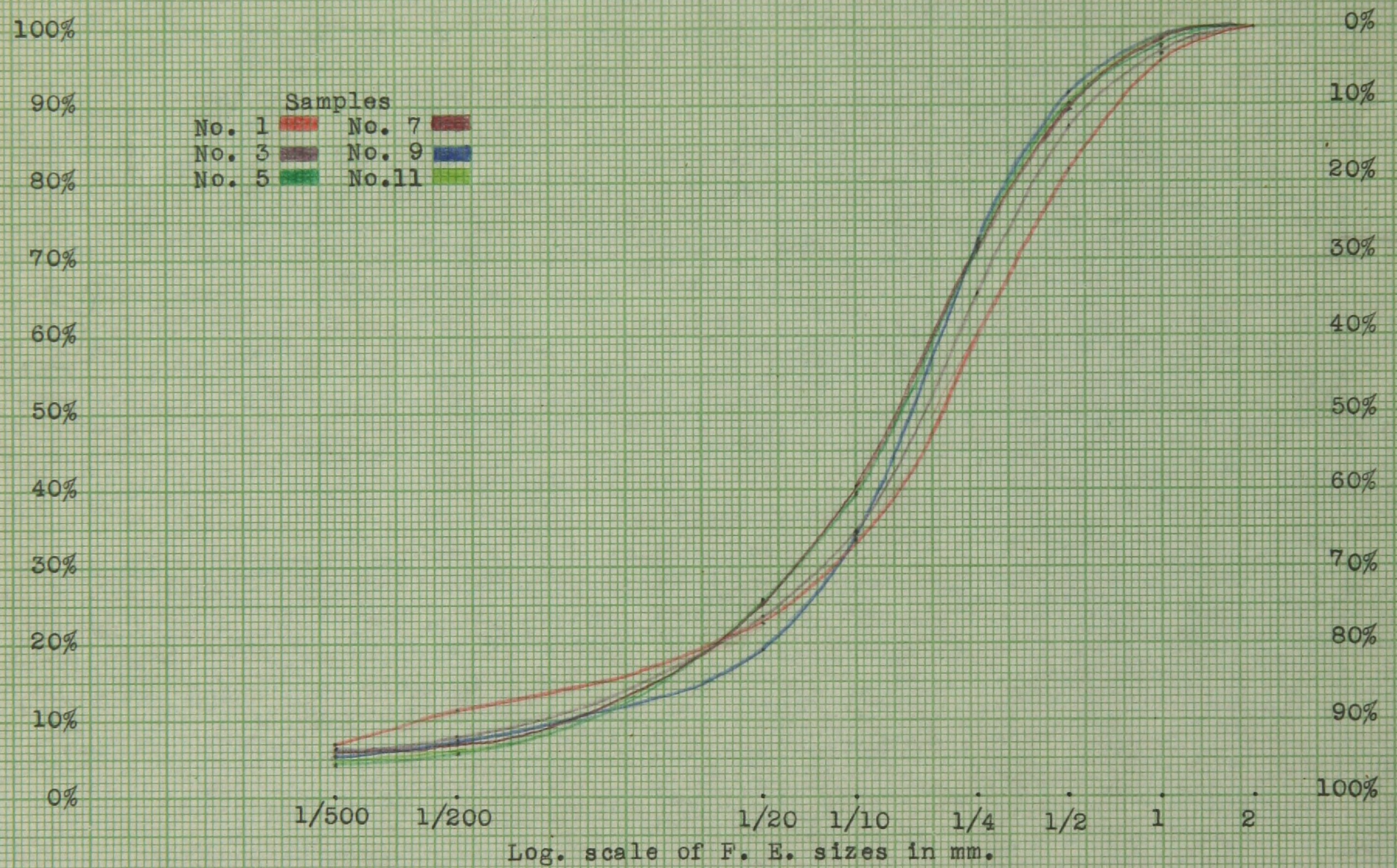


Fig. 3

A percentage distribution of the F. E. particles in the surface soil of Plot 27.

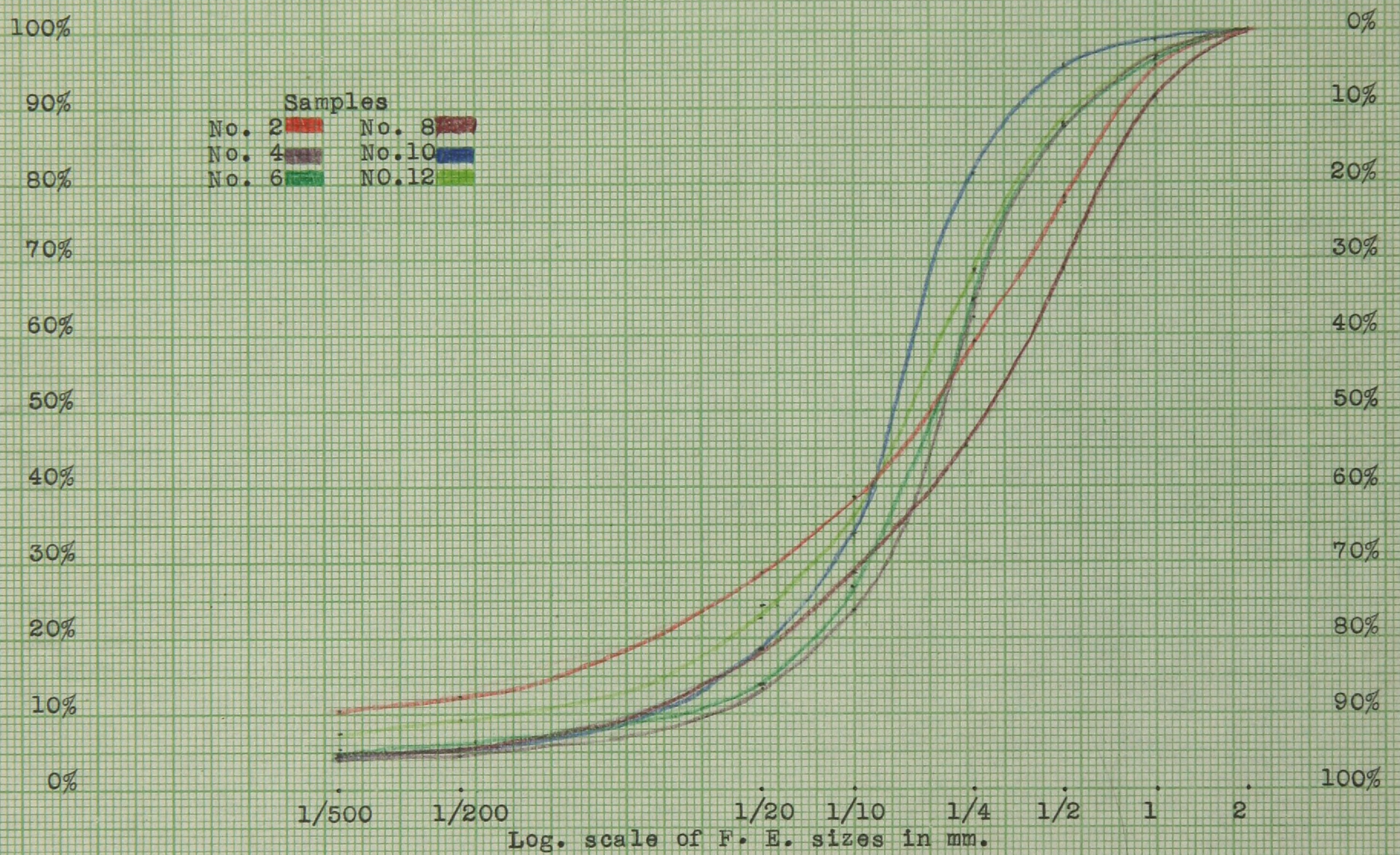


Fig. 4

A percentage distribution of the F. E. particles in the subsoil of Plot 27.

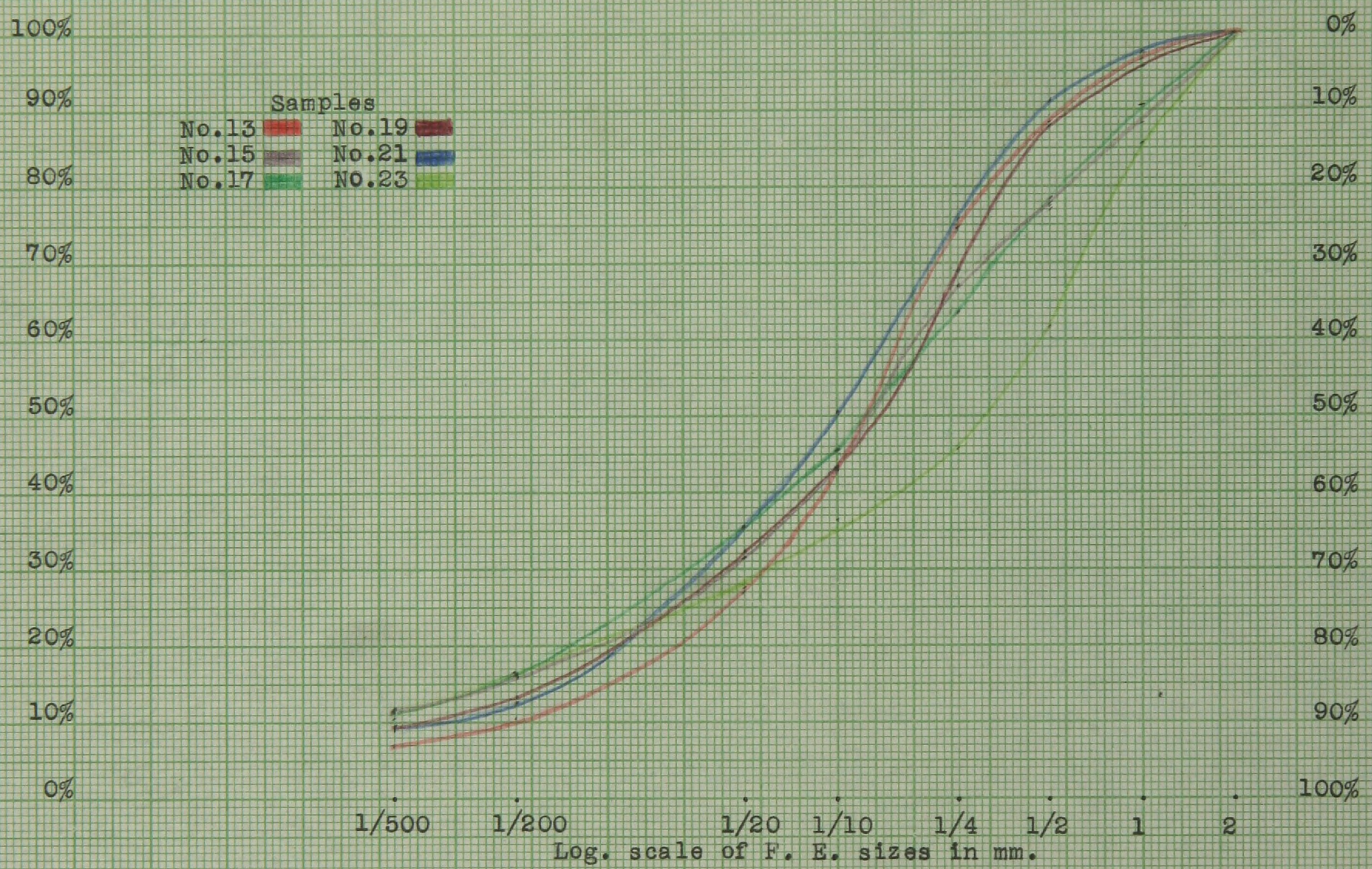


Fig. 5

A percentage distribution of the F. E. particles in the surface soil of Plot28

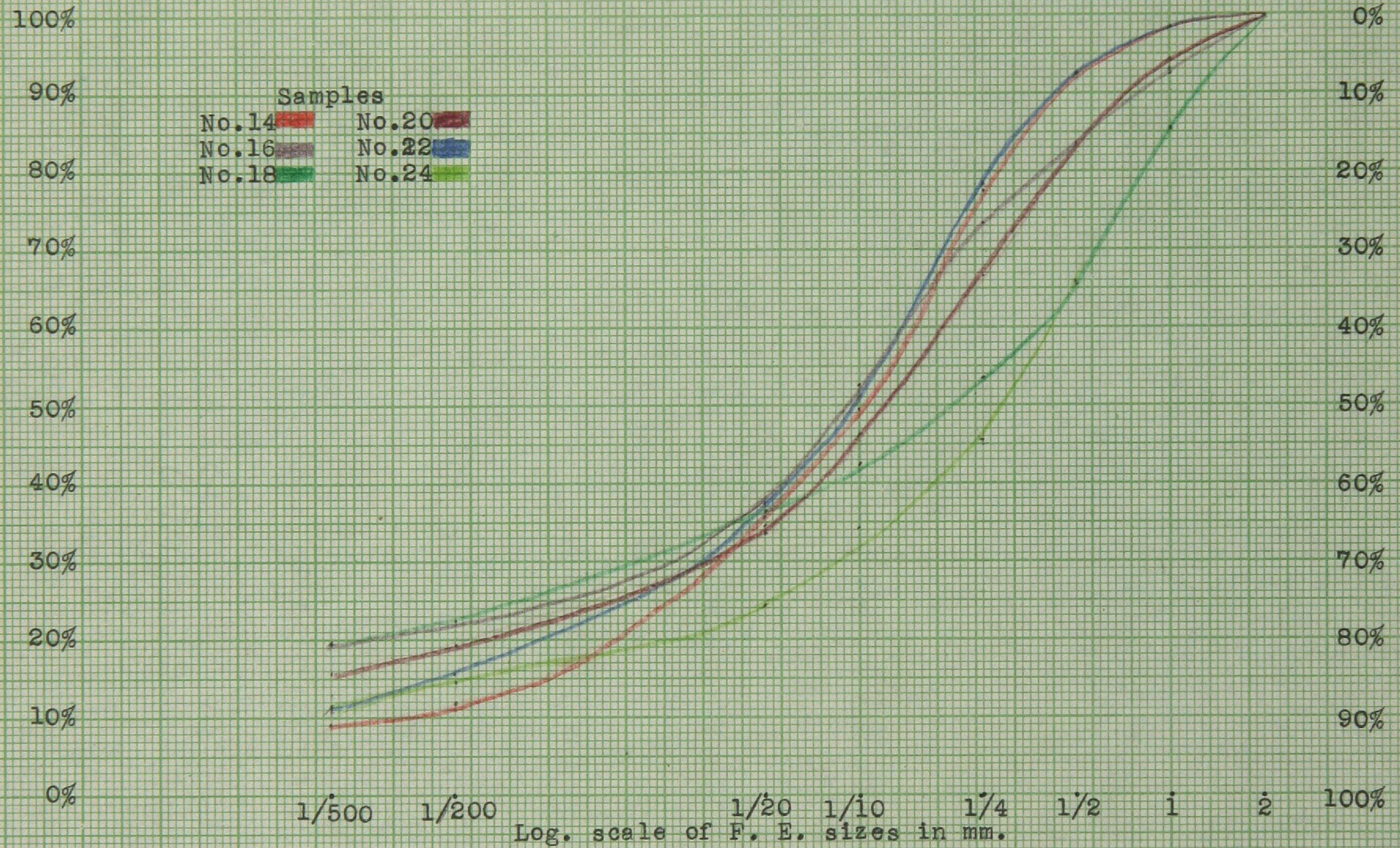


Fig. 6

A percentage distribution of the F. E. particles in the subsoil of Plot 28.

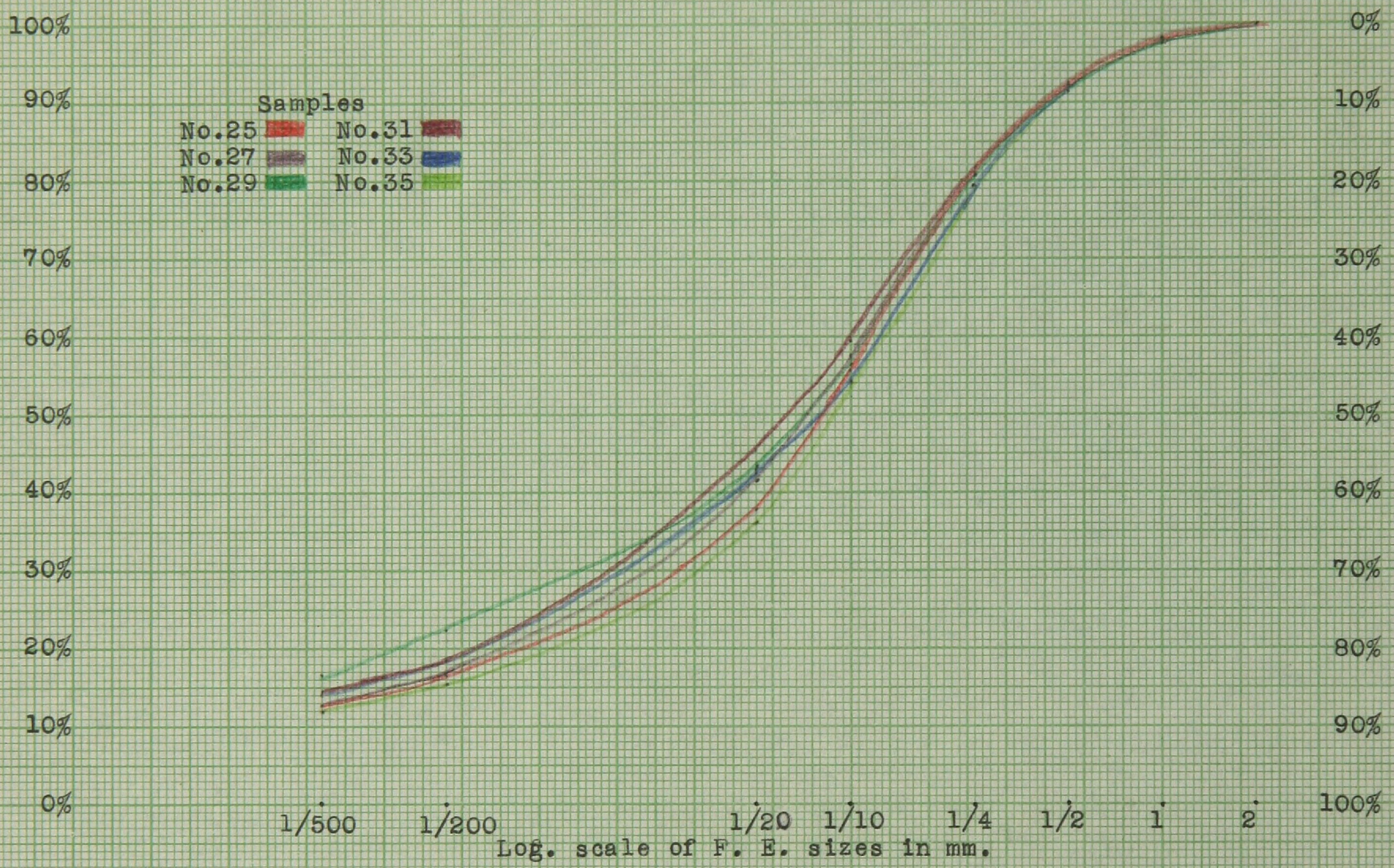


Fig. 7

A percentage distribution of the F. E. particles in the surface soil of Plot 23.

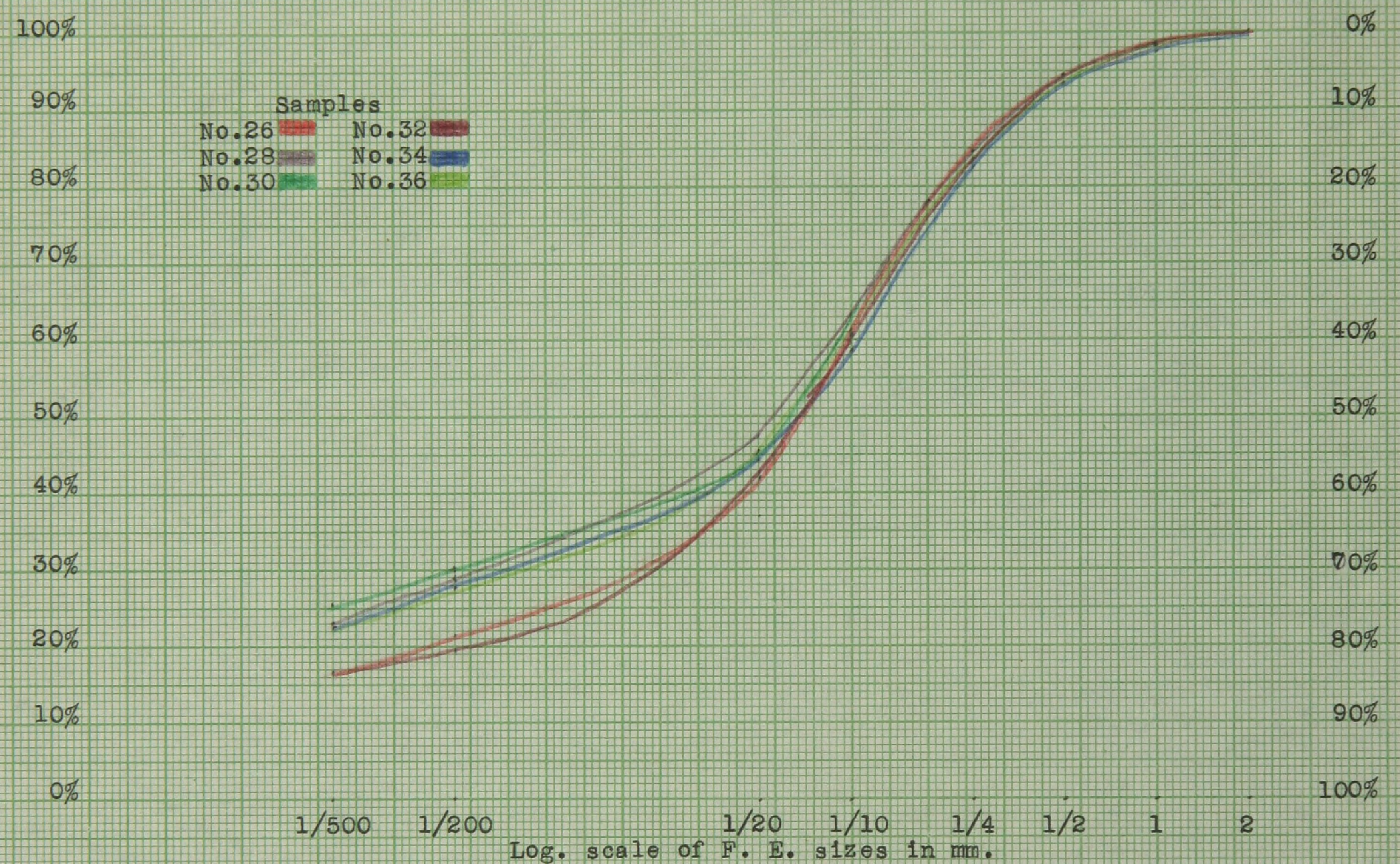


Fig. 8

A percentage distribution of the F. E. particles in the subsoil of Plot 23.

figure or all the subsoil is recorded on one figure and all the surface soil is recorded on another figure. The figure shows the variation between conventional sizes of soil.

After plotting a curve for each sample, an average of all the samples in each plot was calculated and is presented as on Fig. 9, p. 17. It is this figure that proves the effect of the soil texture if any.

Classification: For classification of the soil as to texture two methods have been used. Both methods use a triangular diagram, but the divisions into various categories in each are different and the sizes of the particles considered to be silt and clay are different.

In the new classification, Fig. 10, p. 18, which is a preliminary attempt now being formulated by the U. S. Bureau of Soils. The sand, silt, and clay used are of the following sizes:

Sand........................	2.000 mm to 0.050 mm
Silt........................	0.050 mm to 0.002 mm
Clay........................	less than 0.002 mm

In the older classification presented by Davis and Bennett Fig. 11, p. 19 (4), the sizes of sand, silt, and clay are as follows:

Sand........................	2.000 mm to 0.050 mm
Silt........................	0.050 mm to 0.005 mm
Clay........................	less than 0.005 mm

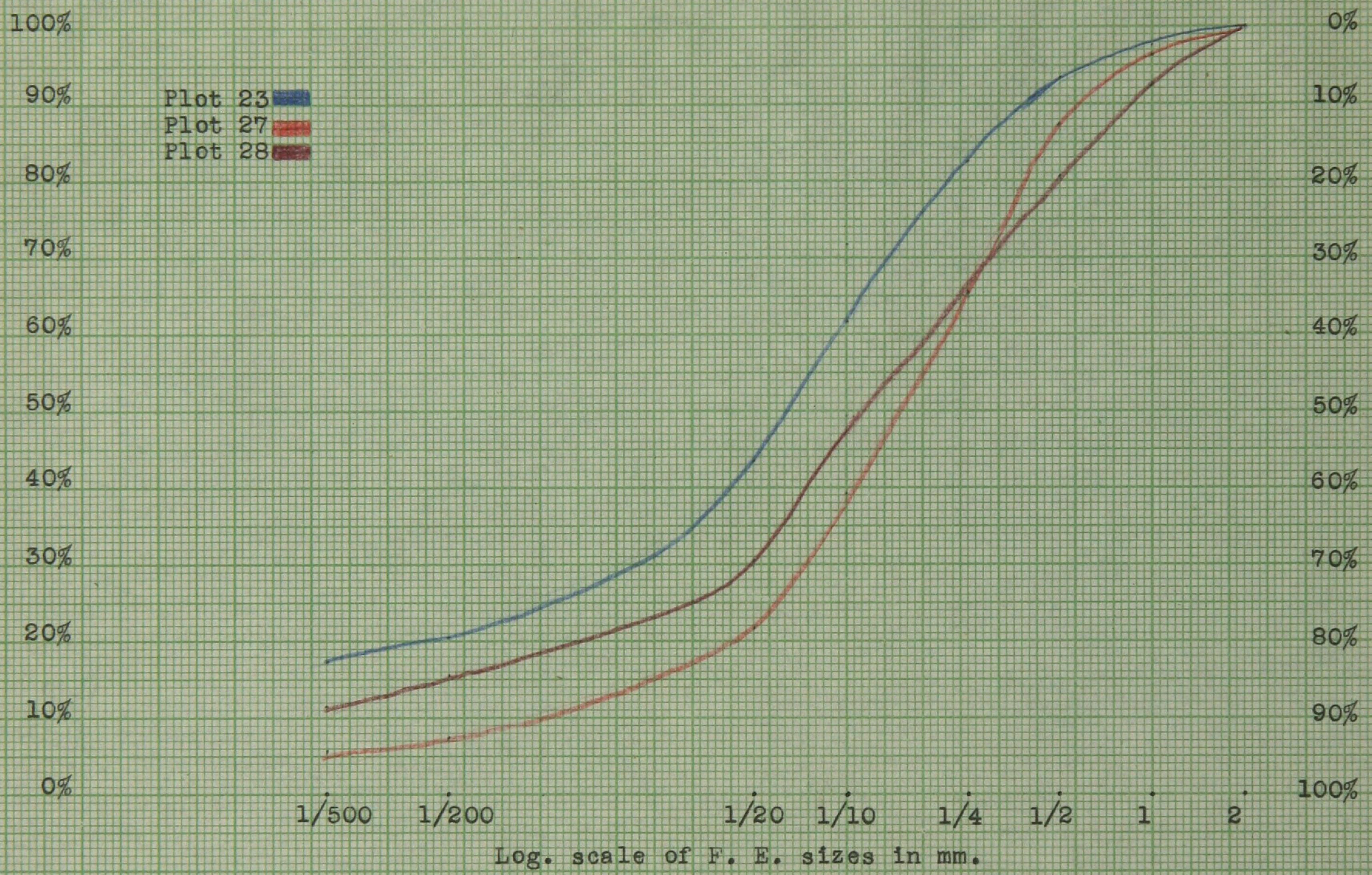


Fig. 9

A percentage distribution of the F.E. particles of all the samples in each plot.

Fig. 10

New method for a soil classification diagram

Sand - 2 mm to 0.05 mm.
Silt - 0.05 mm to 0.002 mm
Clay - less than 0.002 mm

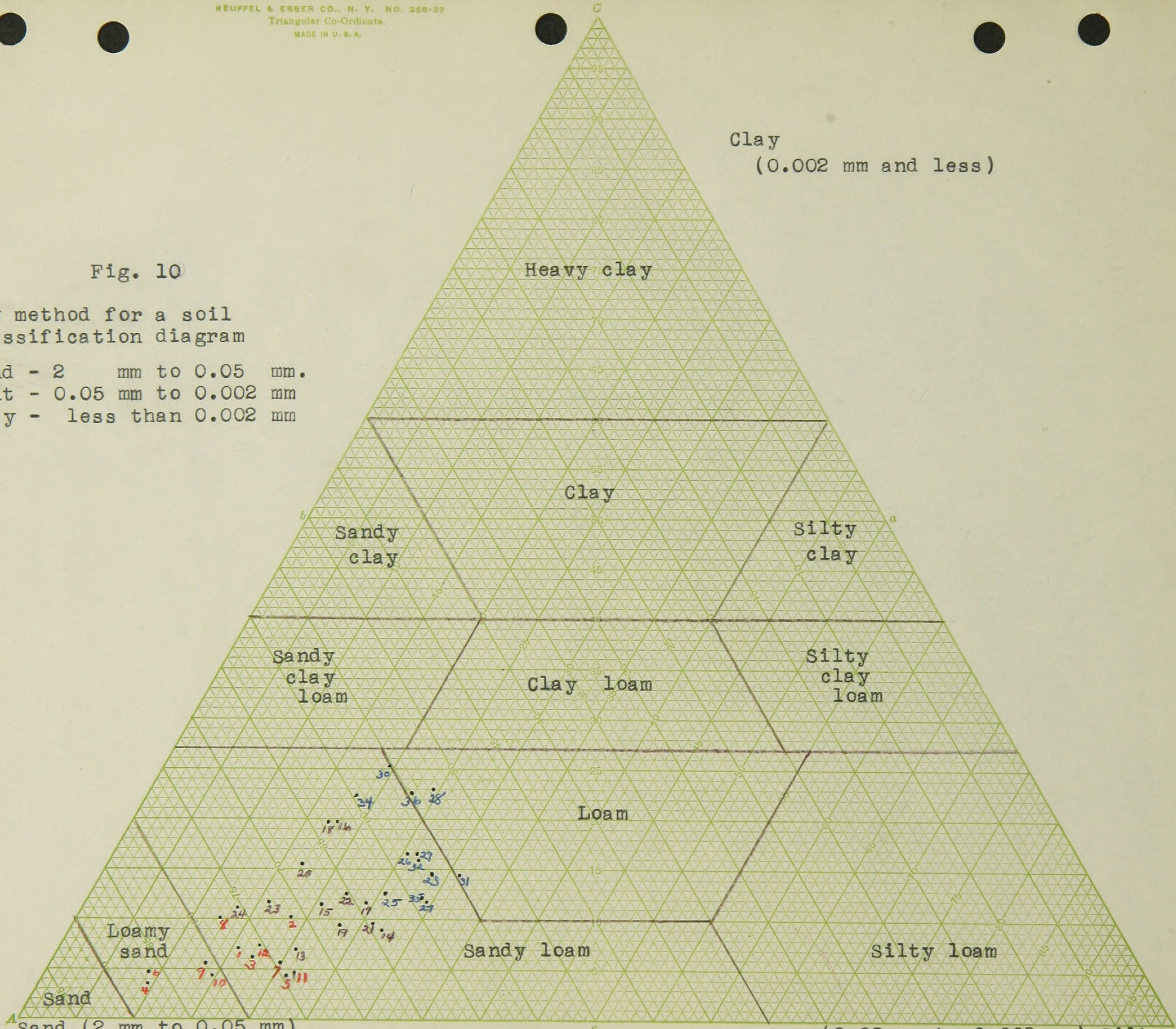
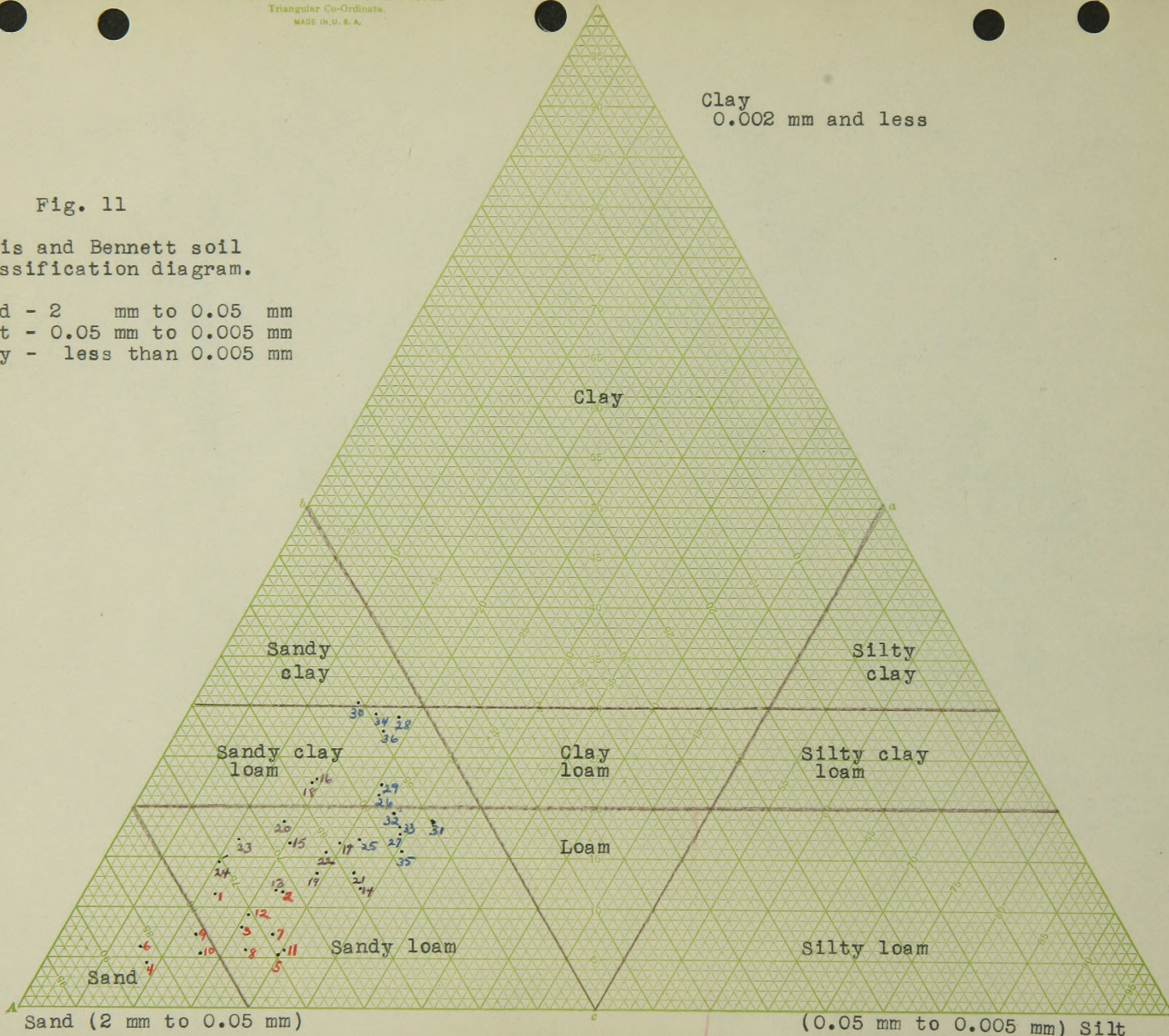


Fig. 11

Davis and Bennett soil classification diagram.

Sand - 2 mm to 0.05 mm
Silt - 0.05 mm to 0.005 mm
Clay - less than 0.005 mm



The amounts of the various sizes in percentages as computed by the hydrometer method are plotted on these diagrams to determine a relative classification for soils according to texture.

Chemical Analysis: Soil fertility was determined by the colorimetric system of C. H. Spurway (3), which uses a soil extract in reaction with specific reagents, the results of which are compared with color charts and the corresponding amounts of the chemical in question are read directly from these color charts. The figures in TABLE II, p. 21 give the parts per million in the soil extract or pounds of chemical per million pounds of soil (Ppm.). This can be converted to pounds per acre to a 6 inch depth by multiplying the original figure by eight.

A test for acidity was made by placing half a spoonful of soil on a folded Soiltex paper and washed through with a Soiltex solution (3). The results of this test are read directly from a color chart.

TABLE II

AMOUNT OF NUTRIENTS IN PARTS PER MILLION PARTS OF SOIL AS TAKEN FROM EACH SAMPLE

Sample Number	Nitrate	Ammonia	Phosphate	Potasium	Calsium	pH
1	11	2	1.00	1	100	4.9
2	20	1	1.00	1	125	5.7
3	15	3	1.00	2	150	4.5
4	11	2	0.75	0	125	4.5
5	25	10	0.50	1	100	5.5
6	10	1	0.50	0	90	4.4
7	25	3	0.75	1	125	7.2
8	10	2	0.50	1	150	7.3
9	17	1	1.00	1	90	4.9
10	16	2	0.50	0	80	4.5
11	12	5	1.00	1	130	4.6
12	10	1	1.00	6	50	4.5
13	25	9	0.75	4	90	4.5
14	6	1	0.50	0	40	4.5
15	10	5	0.75	5	150	7.3
16	6	1	0.25	1	140	7.6
17	25	3	0.50	5	130	5.8
18	2	2	0.50	1	150	8.1
19	25	3	0.50	1	120	5.6
20	10	5	0.50	0	140	4.4
21	25	8	0.75	1	140	5.4
22	6	1	0.00	0	100	4.6
23	25	8	0.75	5	130	6.9
24	5	1	0.50	0	170	7.3
25	15	10	0.50	6	120	5.6
26	8	3	0.50	0	90	4.8
27	25	9	0.50	11	130	5.3
28	6	1	0.50	1	80	4.6
29	25	3	0.75	8	120	4.6
30	0	1	1.50	0	140	4.9
31	15	5	0.50	2	140	4.9
32	4	1	0.50	0	100	4.7
33	18	8	0.75	4	140	5.4
34	10	2	0.50	0	130	5.1
35	25	5	0.75	0	130	4.6
36	2	3	0.50	5	140	5.4

III

RESULTS

A. Mechanical Analysis

A complete mechanical analysis was made and the effects of gravel, fine earths, and classification of soil texture are treated individually in comparison with the growth rate data. A general analysis is made in the final conclusion.

Gravel: In Fig. 2, p. 7 there can be seen a large variation between the amounts of gravel in each plot. This variation can be correlated to the location where the sample was taken as to its character as in Plot 27, which is the area that had been badly eroded, the samples with low percentages are from the lower or higher portion of the stand.

The figures in the following table indicate that the percentage of the samples in gravel are greater where the growth rate is the slowest, while the gravel percentages are the least in the stand that has the most rapid growth.

TABLE III

COMPARISON OF GRAVEL TO GROWTH RATES

Plot Number	23	28	27
Percentage of gravel	7.7%	21.3%	29.3%
Average annual growth rates	2.03'	1.69'	1.18'

<u>Fine Earths</u>: From the study of Figures 3 to 8 several general features show up. With the exception of a few out of place curves, the variation between any of the curves is small indicating, thereby, that the soil texture is somewhat similar in all samples. The variation between individual samples is greater where the slope is the steepest and can be assumed to be due to erratic character of erosion on slopes.

The variation between the samples of the surface soil is less than the variation between the samples of subsoil. The more uniformity of the surface soil is assumed to be due to the effect of similar physical factors that have acted on surface soil and not on the subsoil. No inferences can be reached in comparing the subsoil and the surface soil separately because the character of each varies only slightly and because of the age of these stands. This agrees with Hicock, et. al. (6), who found that in young stands the subsoil had no controlling effect on growth rates, and also with Coile(7) who found that "No single soil character of any one horizon was well correlated with site index".

For a more general comparison, figures representing the average percentages of the differently sized particles in each stand are used (See Fig. 9, p.17). According to Cooper (5), "Plots with the smallest degree of erosion had the best growth." This was shown by this experiment in Plot 23 where the trees with the most rapid growth are on the same plot with the higher percentage of F. E. and the smaller degree of slope. On the other hand Plot 28, which has the least rapid growth rate, has the next highest percentage of particles less than $\frac{1}{4}$ mm in diameter. This shows no correlation between Plots 27 and 28. The growth rate irregularity is due to other conditions not being equal. According to Wilde (8), when other conditions are equal, the higher the percentage of smaller particles, the better is the growth rate.

The percentage of particles more than $\frac{1}{4}$ mm in diameter vary indirectly as to the rate of growth, as do the gravel percentages. As the amount of gravel or larger soil particles left is greater in proportion than the amount of finer particles in eroded soils, the amount of larger soil particles here indicates the amount of erosion that has taken place on these plots. Although the F. E. particles larger than $\frac{1}{4}$ mm have a definite correlation to the growth rates, they are not the only factors that enter into this relationship.

Classification: Most of the samples classified by either method belong to the textural class called Sandy loam. The main difference between these two methods is that in the Davis and Bennett method several of the samples from Plot 23 and two of the samples from Plot 27 are classed as Sandy clay loam soils while in the latter method these are classed as Sandy loam or Loam soils. Both methods show Plot 27 to contain more clay than the others. There is also a tendency in both for the surface soil to be higher in sand and silt and less in clay than the subsoil.

These data indicate that, although the results obtained from F. E. tests may have an effect on the growth rates, they are not the limiting factors and do not carry much weight here. This is inferred from Wilde (8) that "the rate of growth is often closely correlated with the soil texture---through the influence of soil texture on soil moisture, soil aeration, and soil nutrients."

B. Other Physical Factors

The only other physical factors that could not be eliminated before analysis are: topography, amount of erosion, and moisture holding capacity of the soil. The results of the treatment of the soil before planting to pine has combined the effect of the degree of slope with erosion and has resulted in an adverse factor in the rates of growth (See TABLE IV, p. 26. In other words, the steeper the slope the more erosion and the less the rate of growth.

TABLE IV

AMOUNT OF EROSION AND DEGREE OF SLOPE COMPARED TO THE GROWTH RATES

Plot Number	23	27	28
Average annual growth rates	2.03'	1.69'	1.18'
Percent of slope	0-1%	4-8%	20-60%
Probable erosion	light	light to medium	heavy

The moisture holding capacity is closely related to the previous two factors as indicated by Weaver and Clement (9), Chap. VIII, that eroded soils have a low absorption capacity for moisture which results in decreased moisture content and soil fertility. As moisture content and soil fertility are determining factors in growth of all plants, it can easily be seen that the moisture holding capacity is one of the limiting factors of the difference in growth rates found.

C. Chemical

The results of the chemical analysis on each sample taken are recorded in TABLE III, p. 22. This analysis was made only of those plant nutrients that are considered the most important to plant growth. These figures represent the quantity of dissolved or easily soluble substances, or those elements most likely to be available to plant growth at the time of sampling.

An average figure for the amount of chemical in each plot is shown in the following table to make comparisons easier.

TABLE V

AVERAGE AMOUNTS OF DIFFERENT CHEMICALS PER PLOT

Plot	No_3	NH_4	P.	K	Ca	PH
23	151	51	8	36	120	5.0
27	181	33	9	15	110	5.2
28	168	47	6	23	125	6.0

In TABLE III, p. 22, the nitrate content is seen to be greater in the surface soil, where the organic matter is more abundant and aeration is better than in the subsoil which is to be expected and also according to Schreiner and Brown (10), but there is no important difference between plots. The nitrate content of all three plots is rather high considering that the land was so depleted before the pine was planted.

The ammonia content is also higher in the surface soil and has no significant difference between plots. The relationship of the ammonia to nitrate in the same plot shows generally that where the amount of ammonia is the smallest, the nitrate content is the largest which indicates that the nitrate forming bacteria are more prevalent here than in the others. This, however, does not correlate with the growth rates.

The phosphate and potassium content is very low for this type of soil according to the specifications set up by Pierce et. al. (11) and Cooper et. al. (12). No significant difference can be determined from either of these chemicals. This analysis does, however, show the familiar contention that soils with more clay contains more potash.

The calcium content, which is higher than that in the average soil, does not have any influence on the growth rates here. Because of the positive carbonate reaction, it can be contended generally that toxic amounts of either aluminum, iron, or magnesium are not present. This follows the contention of Weir (13) p. 278, that toxicity can be directly correlated to acidity.

The pH of the soil in general is slightly acid to neutral, although a few of the samples that were high in calcium had a more alkaline reaction. The acidity of the soil is the only chemical factor that resulted in changes in proportion to the rate of the growth (See TABLE V, p. 27). According to the tests the growth rate increased as the acidity increased. If one or more of the physical factors of plant growth are limiting, it is illogical to expect a correlation between plant growth and the results of the chemical testing of soils (3).

SUMMARY AND CONCLUSIONS

The results of the laboratory investigation show that there is no direct relationship between the rate of growth and the chemical composition of the soils. This is indicated by the fact that there is very little if any variation in the amounts of plant nutrients in the different plots. There seems, however, to be a more or less clear relationship between the pH and the rate of growth i.e. the greater acidity, within the observed limits, the better the appearance of the stand. More specifically, the pH range of 4.6 to 5.6, which in Spurway's classification is described as very strongly acid to medium acid appears to be the best range for growth. This agrees well with the findings of other investigators to the effect that pine trees do better in an acid soil than in a neutral to slightly alkaline soil.

The relationship between the texture and growth rates is not so clear. The soils of Plot 23 that have the most clay show a better growth than the soils of Plot 27 and 28 that contain less clay. However, of the last two plots the one with more clay shows less growth than the one with less clay, indicating that there is some other limiting factor present. The soils that contain the most gravel, mainly in Plot 28, have produced a stand with poorer growth than the soils of Plots 23 and 27 containing lesser amounts of gravel (See TABLE III, p. 22). Thus the greater amounts of gravel in the soil on Plot 28 seem to have offset the effect of the larger clay content.

The greater amount of gravel in the surface soil of Plot 28 is probably due to the greater amount of erosion. This greater amount of erosion in turn is owing to the steeper slopes in said plot (See TABLE IV, p. 26).

The results of this study show that determinations of texture and nutrient content alone do not always suffice as indicators of growth possibilities, because slope, amount of erosion, and possibly other factors of the site have to be taken into consideration.

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