Masters Theses 1911 - February 2014

1938

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FARNSWORTH - 1938

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By

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Thesis Submitted as Partial Requirements
for the Degree of Master of Science

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Massachusetts State College
Amherst, Massachusetts

May 1938

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to Dr. Walter S. Eisenmenger, head of the department, for his assistance in the selection and the outlining of the problem, and for his very helpful suggestions and encouragement throughout the course of the investigations.

Especial acknowledgment is made to Mr. Charles Thayer for assisting in the collecting of the soils and for information concerning the geology of the area.

The writer is indebted to other members of the staff for suggestions which have been very helpful as a means of completing this work.

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INTRODUCTION

Man has long attempted to establish a system whereby soils may be differentiated. This interest in soil classification and in soil type dates back centuries before the Christian era; but it was, of course, not designated as such at that time, nor was it considered from a scientific point of view.

Lee (23) states, "The early Greek and Roman philosophers, as represented by the writings of Cato, Pliny, and Columella, showed a very intimate knowledge and interest in soils. According to early Chinese records, studies of soil classification were in use as early as 2,357 to 2,261 B. C. in the Yao dynasty." These early classifications, however, seemed to go no further in their differentiation than to list a soil as productive or unproductive. The real significance back of this productiveness could not be understood.

Until about the 17 th and 18 th centuries the role of soil was thought to be one mostly of support for the growing plants. Such a trend of thought was responsible for the establishment of the idea that a soil is only a soil no matter what or where it may be. Soil was looked upon as a static body, and was considered agriculturally rather than scientifically. The present day attitude toward the soil has changed greatly from that of the past. The study of soils now falls within a definite category in the field of science, and investigators look upon soil as being a body which varies in character, depending upon the numerous factors which affect it, and the factors by which it has been effected.

Marbut (21) recently spoke of a soil not as a static body but rather one of constant change. Shaw (23) defines a soil "--- as a natural body having a definite morphology, developed by the forces of weathering from organic and inorganic materials."

The unproductiveness of a soil is now attributed to the unavailability of certain nutrient elements and to certain physical conditions of the soil. Nitrogen, phosphorus, and potassium have been regarded as the limiting elements for plant growth. The nitrifying efficiency of a soil is considered to be an index of soil productivity; that is, a soil showing high nitrifying power is regarded as one likely to possess a relatively suitable physical structure and sufficient nutrients for plant growth.

The physical condition of a soil plays a very important role in determining the rate of plant growth and the microbiological activity in the soil. Soils of the same chemical composition may give widely varied plant-growth responses if either the physical structure or environmental conditions (rainfall and temperature) is varied any considerable degree.

According to the present system of soil classification soils are classified as to "soil type". This method has been arbitrarily adopted by soil scientists. It fits very well into the present system of soil studies and seems to be the most satisfactory yet tried.

When a definite area (state or county) has been surveyed and the soils named and classified, the series name of a soil indicates the elevation and locality where this soil type may be found. The series name also has reference to the material from which a soil has been weathered and conditions under which it was laid down. The soil class indicates the texture of the soil and offers certain indices as to its physical character.

OBJECT OF INVESTIGATIONS

The object of this investigation is to determine some differences in soils of Massachusetts as indicated by their nitrifying efficiency.

In Hampden and Hampshire Counties of Massachusetts sixty-seven soil types have been named and described (22). It can easily be seen that it would be quite impossible to make a very detailed study of all these soil types or to perform, within a short period of time, more than a few experiments on the several types selected. Eleven soil types representative of Massachusetts soils in general were chosen for the investigation. These soil types are listed and described later in this report.

In the state of Massachusetts commercial fertilizers are of major importance in agriculture. In many instances inorganic fertilizers are being used without serious thought as to the effect upon the future supply of organic matter in the soil. It can be seen that should certain of these soils respond equally as well to applications of organic material as they do to inorganic substances then greater benefit can be derived from the use of organic material. Certain soils may contain a relatively high amount of organic matter and better response may thus be received from the use of inorganic materials.

Nitrification, of some of the soils of Massachusetts, will be studied as influenced by soil type and source of nitrogen. Eleven soil types are to be considered and each type shall have as a source of nitrogen, native nitrogen in the soil, ammonium phosphate, ammonium sulphate, dried blood, and cotton seed meal. Nitrate accumulation will be determined under laboratory conditions of controlled moisture and temperature.

In conjunction with the soil cultures for nitrification study, another set of cultures, under like conditions, will be planted into barley. Plant growth in these soils will be studied in relation to nitrification and source of nitrogen.

REVIEW OF LITERATURE

An exhaustive review of literature regarding nitrification is soil would make up a cumbersome volume. However, information on nitrification as affected by soil type is limited. Therefore, the literature cited will be confined to the work of a few men whose findings pertain to the following topics: nitrification and soil fertility relationships, factors which influence nitrification, the relationship of nitrification to plant growth, and some effects of soil type upon nitrification.

Nitrification and Soil Fertility Relationships

Due to the important position nitrates hold in plant nutrition and to the close relationship which exists between soil nitrates and crop production, the nitrifying power of the soil is recognized as one of the very important factors affecting its fertility.

The soil culture method of determining nitrification is considered by Burgess (10) as "--- by far the most accurate biological soil test yet perfected for predicting probable fertility. In fact, it is probably the best single test of any description yet developed for ascertaining the comparative crop-producing powers of arable soils. Active nitrification may not be the cause of high fertility, yet those conditions which tend to promote rapid nitrification are very evidently identical with those which tend to give us enhanced crop yields."

Waksman (39) states that while nitrification is a valuable and essential asset in fertility, it probably does not, under normal conditions, become a limiting factor in crop production. He warns (38) against laying too much stress on the relation of any microbiological process to soil fertility. He emphasises the fact, however, that nitrification studies may yield valuable information for the estimation of soil fertility. Waksman does state (39) that the work of certain investigators shows a definite correlation between the nitrifying power of a soil and its crop productivity.

In support of Waksman's statement the work of Brown (7) and (8) shows that in every instance higher ammonification and nitrification were accompanied by higher crop yields. Fred (14) and Murphy (30) have noted a similar correlation. Russell (33), in writing of nitrification, shows the importance of nitrates in the soil, but states "--- that to measure the speed at which nitrates are formed in soil does not measure the rate of nitrification as is sometimes assumed, but the rate at which ammonia is produced." Should nitrogen be added to the soil in the organic form then ammonification is important. However, should inorganic ammonium salts be used then nitrification is ultimately the process necessary to render the nitrogen available for plant assimilation.

Lipman (25), after studying the availability of nitrogenous fertilizers in various California soils, states, "For plant growth purposes, therefore, we are reasonably safe in assuming that the problem of nitrogen nutrition is chiefly one of supplying to the root zone enough nitrates at different periods in the life of the plant to increase normal growth."

Nitrates are considered to be the form in which nitrogen is absorbed by plants. The work of Arnon (2), Beaumont (3), and others (37) (11) shows that under certain controlled conditions ammonium nitrogen can be utilized by plants and result in growth comparable to that obtained with nitrate nitrogen.

At present, however, for all practical purposes, the process of nitrification is deemed necessary for nitrogen nutrition of plants unless nitrate salts are used as the source of nitrogen.

Factors Which Influence Nitrification

Among the conditions which tend to promote the formation of nitrates in the soil Waksman (39) has listed: a proper moisture supply, a pH value greater than 4.6, and the absence of large quantities of soluble organic matter.

Moisture: Moisture requirements for maximum nitrification seem to vary with the type of soil studied. This would probably account for the variability in optimum moisture conditions reported in literature.

Lipman (24) places the optimum moisture at 15 per cent. Harris (19) shows that maximum nitrification occurred in soils when the moisture content was at 25 per cent. He found that nitrification was slightly retarded when 30 per cent was reached. Paterson and Scott (31) place the optimum moisture content at 14 per cent. After making a study of twenty-two soils Greaves (17) reports that when soils contained 60 per cent of their moisture-holding capacity nitrification was at a maximum. Gainey (15) obtained the highest nitrification when the soil studied was 70 per cent saturated. For nitrification determinations Waksman (39) recommends a moisture content of 50 to 60 per cent of the moisture-holding capacity of the soil. Fraps (13) reports that when the moisture content was above optimum for a soil the nitrification was retarded more than when the moisture content was below optimum.

Results from the investigations here cited seem to show that the optimum moisture for nitrification is about 18 to 25 per cent, or between 50 and 60 per cent of the moisture holding capacity of the soil. Moisture content undoubtedly does not become a limiting factor for nitrification unless the moisture content is less than 33 per cent, or exceeds 66 per cent, of the moisture holding capacity of the soil.

Reaction: Nitrification is reported to proceed best at a reaction near the neutral point or slightly alkaline. Waksman (39) reports the optimum reaction as pH 7.1, the limiting acid reaction being from pH 3.9 to 4.5, and the limiting alkaline reaction from pH 8.9 to 9.0.

Organic Matter: Nitrification has been found to decrease temporarily in the presence of a large supply of organic matter in the soil; or in other words, when there is a wide carbon:nitrogen ratio in the soil, nitrates do not accumulate until this ratio has become greatly narrowed.

Moore and Beaumont (27) in a study of nitrification in a mulch of waste hay and straw suggested that nitrification occurred mainly in the lower layer of the mulch rather than in the soil, and then only after the C:N ratio of the mulch had been considerably narrowed by decay. Three years were necessary to reduce the ratio to a point where nitrates began to accumulate. The upper limit of this ratio appears to be 15:1 . According to Sievers (34) the ratio of C:N must approach 12:1 before crops receive any nitrogen benefit from applications of manure. Martin (26) reports that when straw was incorporated with soil the result was a decline in nitrate accumulation. The intensity and duration of this decline was in proportion to the quantity of straw used.

It would seem, then, that if there were no nitrate accumulation in a soil, one would expect a rather wide carbon:nitrogen ratio. If, on the other hand, nitrates were accumulating in the soil and the soil showed a high total nitrogen content, a high nitrate accumulation would be expected provided other factors were favorable to nitrification. Gainey (16) reports that as the nitrogen content of a soil increases the nitrifying efficiency becomes greater. In the study of 125 fertile and non-fertile soils he found some exceptions however. He says that if care were taken in the selection of soil samples a convincing relationship should exist between total nitrogen content and nitrifying efficiency. Earlier work by Sievers and Holtz (35) verifies Gainey's statement.

Effects of Soil Type Upon Nitrification

Brown (9) shows that the effect of soil type on nitrification is important in soil processes. As a result of certain of his investigations he states that "The significance of the soil type in all soil fertility studies is emphasized by the results secured on a large number of field experiments located in all sections of Iowa, on carefully selected areas where soil is typical of an individual and extensively developed type. The response to fertilizing materials is very different on the various soil types."

Withers (40) compared the nitrifying powers of several soil types. He used the Cecil sandy loam as a standard, its nitrate accumulation being placed at 100. The results of the nitrifying capacity of the other soil types calculated on this basis are as follows:

Light Soils		Medium Soils	
Norfolk fi. sa. loam	50	Porters loam	84
Durham sandy loam	71	Porters black loam	106
Herndon sandy loam	36		
Cecil sandy loam	87		
Porters gravelly loam	71		
Porters sandy loam	59		
Cecil sandy loam	100		
Durham sandy loam	11		
Heavy Soils		**Very Light Soils**	
Porters red clay	74	Tarboro Sand	16
		Norfolk sand	18

These results seem to show that nitrification in soils varies greatly with the soil type as well as with soil class. Loam possessed the highest nitrifying power, followed by the sandy loams and clays, but nitrification dropped to a rather low point in the light open sands.

Reed (32), after determining the nitrifying efficiency of 44 virgin and cultivated soils, gives the following relations:

Nitrification in Virgin Soils-

Fine sand	(average)- 5.46	mgs. of nitrate-nitrogen in 100 grams of soil
Sandy loam	3.18	
Loam	9.04	
Clay loam	20.50	
Clay	5.61	

Cultivated Soils-

Cecil sand	1.50	
Sandy loam	7.28	
Cecil loam	22.50	
Clay loam	40.39	
Cecil clay	25.11	

He states, "From this work is it evident that the open sandy soils are strikingly low, the loams and the clay loams are as impressingly high, and in the heavier clays again a falling off is evident."

Beaumont (4) made some investigations on nitrification in Massachusetts soils under field conditions. From investigations on Gloucester, Merrimac, and Hartford* sandy loams, and the Suffield silt loam, it was shown, "--- that the lighter types of soils studied have a high nitrifying power under conditions of intensive culture and in the presence of large amounts of nitrifiable material. As much as 509 parts per million of nitrates were found under conditions of heavy fertiliz-

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*- The Hartford series has since been designated as the Agawam series.

ation and intensive culture of the Hartford sandy loam, while on the same type of soil but under less intensive conditions of soil management very moderate concentrations of less than 50 parts per million were found. In the Merrimac sandy loam a maximum concentration of 673 parts per million was found in plots growing tobacco and receiving heavy applications of commercial fertilizer alone; and on plots receiving the same amount of commercial fertilizer and in addition animal manure, a maximum of 797 parts per million was reached. In the heavy Suffield silt loam, a maximum of 84 parts per million was reached on the soils supplied with manure, while on Hartford sandy loam under similar conditions the maximum was 101. The Gloucester sandy loam gave a maxima of 96 and 36 parts per million on mulched and unmulched land respectively."

From the above data it appears that the light, well drained Massachusetts soils, typified by the three mentioned in the quotation above, have a high nitrifying efficiency. Soil type is important in nitrification, but Beaumont states, "--- that under the range of conditions studied, the kind of soil management and manurial systems are more important."

Relationship of Nitrification to Plant Growth

As already stated, the studies of Brown (7) (8), Fred (14), and Murphy (30) seem to indicate that there is a pronounced relationship between the nitrifying efficiency of a soil and the plant growth.

Russell (33), in discussing the relationships between nutritive supply and plant growth in soil, suggests that Liebig assumed the nutritive effect to be proportional to the amount of nutrients present. Hellriegel, however, presents results much to the contrary. He grew barley plants in pots of sand and all necessary factors were applied excepting nitrogen. The first increment of nitrogen brought about a certain definite increase in yield; the second and third increments of nitrogen, contrary to Liebig's assumption, brought about a more pronounced increase in yield; but when the fourth and fifth increments were applied the effects were less pronounced. This would suggest an effect similar to the law of diminishing returns.

Mitscherlich (33) was among the first to attempt the application of a mathematical equation to such results. He stated that "--- the increase of crop produced by unit increments of the lacking factor is proportional to the decrement from the maximum." In other words, a maximum crop yield should be obtained if conditions were ideal for plant growth, "--- but in so far as any essential factor is deficient there is a corresponding shortage in the yield. The yield rises if some lacking factor is added, and goes up all the further the lower it had previously fallen."

Gregory (18), from his work with mineral nutrition of plants, found that the relation of yield to nitrogen and potassium absorbed, where nitrogen is minimal, is linear. If the elements are applied in constant ratio the relation is the same. If, however, potassium is at a minimum Mitscherlich's relation appears. In both cases, when yield is plotted against the amount of nutrient absorbed in excess, the curve of yield gives an increasing slope.

These citations indicate that if nitrates are available for plant absorption the growth should tend toward a maximum provided other factors do not become limiting.

CLIMATIC FEATURES OF HAMPSHIRE COUNTY

The various soil types being considered in this investigation are found in and about Amherst, in Hampshire County, Massachusetts at elevations ranging from 50 to 500 feet above sea level. The climate (22) of Hampshire County is humid and is marked by long cold winters and comparatively short but warm summers. There is evidence that the valley in summer acts as an oven in retaining heat, consequently crops mature in a shorter time than on the upland. It is reasonable to assume that a great variation exists between the temperatures of the valley and those of the upland, especially on the plateau west of the valley where the elevations are much higher than in the rest of the region. The precipitation is well distributed so that sufficient moisture is available for the growing of crops.

At the Amherst meteorological station, 222 feet above sea level, precipitation has been found to range from 30.68 inches (in 1908) to 58.04 inches (in 1888) with a mean of 44.17 inches. Temperature recordings have shown a variation ranging from a -22° F. in winter to 101° F. in summer. Snowfall may be expected anytime between late October and early April.

The average date of the last killing frost as reported at the station is May 4, and the earliest is

October 2. Frost has been recorded, however, as late as may 26 and as early as September 4.

Climatic conditions are well suited to dairying, livestock raising, poultry raising, to orcharding, and to the growing of general farm crops. The active growing season of five months is usually ample for most crops grown in the valley.

GEOLOGICAL AND PHYSIOGRAPHICAL FEATURES OF THE AREA*

The State of Massachusetts lies about midway across the Appalachian Mountain system in its great sweep from Newfoundland to Alabama. Emerson (12) states, "This area lies just south of the region where the great folds of this mountain system were compressed against the Adirondacks, by forces thrusting from the east, in a zone where the ancient unfolded rocks of New York from the foreland. As the rocks now at the surface could have attained their present condition only under weight of a great mass of superincumbent material, and as the surface everywhere shows steeply dipping and truncated layers, it is evident that erosion by wind and frost and streams has worn down these great folds as they rose into prominent mountain chains, leaving a low plateau showing mountainous structure but without the mountains. The agents of erosion cut the mass down toward sea level, the goal to which all erosion tends, and almost reached it for the region was worn down to a peneplain.

"At the completion of this epoch of erosion the surface of the State was a nearly continuous plain, sloping southward and eastward. This plain was then raised as a whole, without folding, but by broad warping and tilting,

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* -- See (1), (12), and (22)

so that in the northwestern part of the State it stood about 2,000 feet above sea level. As a result of this uplift the streams, which ran southward and eastward across the plain, cut deep trenches in the upland. In the soft sandstones of the Connecticut Valley and the soluble limestones of the Housatonic Valley these trenches were widened into broad, flatbottomed valleys, the beginning of new, transient peneplains, whose elevation was determined not by sea level but by obstructions farther downstream.

"Thus erosion has marked out broad topographic divisions of the State, which are also the broad geologic divisions. These are enumerated as follows:

First: The Cambrian and Ordovician limestone valley of the Housatonic, in which steep schist ridges rise from Greylock to Canaan Mountain, and which is a sort of prong of the Great Appalachian Valley.

Second: The broad Archean-Silurian upland of eastern Berkshire County. This higher western axial part of the upland is underlaid by Archean rocks, on which rests belts of schists and limestones that are infolded in granites and that have curved northwesterly trends. The erosion of the limestones in pre-Cambrian time formed deep curved valleys, into which the Cambrain and Ordovician seas penetrated and deposited their own limestones, the subsequent erosion of which has disclosed the older marbles. The rocks of the uplands have in part been thrust over the limestones of the Housatonic Valley along fault planes and form a lobed or scalloped escarpment facing it. These and other faults have exercised considerable control over the direction and depth of erosion. The eastern half of the upland slopes gradually eastward and is made up of northward-trending schist ranges, which include many beds of limestone and are much cut by granite. The divide lies along the higher, western crest of the upland, and the greater part of it is drained southward to the Connecticut, only the curved limestone valleys being drained westward to the Housatonic.

Third: The Devonian-Triassic valley of the Connecticut, in which there are sharp trap ranges topographically much like Monument Mountain in the Housatonic Valley. Great faults along the scraps of both sides of the valley have lowered and thus preserved the sandstones in which the valley has been cut to form a younger incipient peneplain.

Fourth: The central upland, or Worcester County plateau, made up of alternate broad bands of Carboniferous granite and narrower bands of folded schists, repeating in part the structure and lithology of the western upland.

Fifth: The bordering slope that descends gradually eastward and southeastward from the irregular but fairly definite escarpment bounding the central upland. The descent is by no means uniform, and the general surface, if restored by filling the valleys to the height of the hilltops, would be not at all smooth and would not have a regular and gentle slope from the central upland to the coast.

The rocks of this fifth division, which is about equal in area to the first four combined, also present a greater diversity in kind and structure than those of any other division. Periods of sedimentation in parts of the area were interrupted by periods of deformation and followed by periods of intrusion. As a result the division is a great complex of stratified rocks, different parts of which are assigned to the pre-Cambrian, Cambrian, Devonian, and Carboniferous periods, respectively, and of igneous rocks of several ages- pre-Cambrian, Devonian, and early and late Carboniferous. The whole complex has been several times faulted and folded and has been deeply eroded, so that in parts of the area rocks of presumed Archean age are exposed.

Sixth: The Coastal Plain, which includes the Cape Cod peninsula and the Islands south of the mainland. This division is almost wholly covered by Quaternary glacial drift, but Cretaceous and Tertiary strata are exposed at a few places, and probably underlie practically the whole area."

Hampshire County is located in the more western part of the state and includes portions of three of the geological and physiographical divisions as enumerated by Emerson.

The western part of Hampshire County is included in the eastern portion of the second geological division comprising the eastern foothills of the Berkshire Range; the central one-third of the County is included in the third geological division; and the eastern part of the County is included in the western portion of the fourth geological or physiographical division.

From the physiographical divisions it can be seen that Hampshire County is an extremely dissected somewhat uneven plateau. About midway between the eastern and the western boundaries of the state the Connecticut River Valley extends north and south. The Valley is approximately five miles wide where it enters the northern side of the area. It extends to a width of about fifteen miles, within a short distance, and maintains this width throughout the area southward.

Bordering the valley on the east and west are the mountain ranges of the second and fourth geological divisions. The floor of the valley lies about 400 to 700 feet below the plateau, that is, the plateau of the higher peneplain. Near the southern border of the county, on the east side of the river, the Holyoke Range extends east and west. On the west bank of the river at Mount Tom the range continues southward and westward.

During the glacial period the entire area was glaciated and there is evidence that numerous glacial lakes were present throughout the area. It is very evident that the Connecticut Valley became blocked on the south and as a result a large portion of the area became a lake of ice. The region adjacent to the ice beds and lake level was reworked by streams and water forming what has been designated as terraces and kames. The next higher level was subjected to more extreme glaciation and includes the glacial terraces, and the hill regions.

DESCRIPTION OF SOILS (22)

The soils of the county have been grouped and seperated on the bases of the area and elevation at which they occur, their color, and the mode of their formation. The soil series name within a group is based on the material from which the soil was derived, internal structure, drainage factors, substratum, color, and other evident physical variations.

The soil types used in the experimental work are described as typical members of the soil group under which they have been surveyed. The Soil Groups, and the soils used are enumerated as follows:

Connecticut River Valley Soils

The soils of this group include only those soils of the terrace and bottom land of the present river. These are of alluvial origin.

<u>Hadley Silt Loam:</u> The Hadley series comprises the chief agricultural soil of the area. The surface ranges from fairly level to gently sloping. The color is dark greenish-yellow or olive, becomes paler with depth, and the meally, mellow condition of the surface soil extends from five to ten feet below the surface. The soil is well drained but it has a large moisture storing capacity.

The structure allows for easy root penetration. The soil is low in organic matter.

<u>Agawam fine sandy loam:</u> This soil type ranks next to Hadley very fine sandy loam in agricultural importance. It occurs as high terraces along the river but well below the general terrace plain of the valley. The profile is poorly defined. The surface soil (0 to 8 inches) is a dark brown, mellow, fine sandy loam. The subsoil (8 to 24 inches) is yellowish brown. At two feet the color is greenish yellow and at three feet the soil becomes a gray loamy sand. The surface relief is fairly level, but because of the elevation drainage is well established. The substratum is not sufficiently porous to cause excessive drainage; the soil has a good moisture holding capacity.

Old Glacial Terrace Soils

The soils of this group (Glacial Terrace Soils) are located outside the terrace and flood plain of the Connecticut Valley. The soils of this group, the Chicopee, and the Merrimac series, were derived from Triassic sandstone. These soils have been subject to leaching to a greater extent than have the soils developed on the glacial till, and they are derived from material from which, in the course of deposition, much of the finer material has been removed. The Merrimac sandy loam was chosen for the present study.

Merrimac sandy loam: The surface six-inches are a brownish sandy loam. The subsoil (6 to 18 inches) is yellowish-brown, and at the lower depth of this zone becomes a loose grayish-yellow or gray sandy loam. The substratum consists of beds of sand and gravel. Drainage is thorough, and if the substratum is near the surface it is often impossible to grow crops on this soil. Gravel does not occur in the surface soil.

Soils of the Kames

The soils developed on the kames, which are associated with the terraces, have a profile similar to that of the sandier and gravelly terraces, but differ from them in that the relief is hummocky whereas the terrace soils are uniformly smooth. Soils of this group were weathered from kame deposits and are of the Manchester, Hinkley, and Windsor series. The Hinkley gravelly sandy loam was chosen for the study.

Hinkley gravelly sandy loam: The Hinkley gravelly sandy loam is one of the poorer soils of the state. Drainage is excessive. Most of the land is in forest. Grass stand is poor except in very wet seasons. The surface soil (0 to 4 inches) is sandy loam. It contains a large amount of organic matter most of which is decomposing forest vegetation. The subsoil (4 to 20 inches) is somewhat coarse sand containing large amounts of gravel and rocks. The color is reddish-yellow. The substratum is composed entirely of heavy stones and gravel.

Other Terrace Soils

Other soils of some agricultural importance which have been developed on the terraces, and which occur almost entirely within the bounds of the Connecticut Valley, are of the Enfield, Suffield, Melrose, and Scarboro series. The Suffield fine sandy loam was chosen for the study.

Suffield fine sandy loam: Suffield fine sandy loam is characterized by sandy material overlying a clay bed. The surface soil is brown, and the subsoil is yellowish brown and rests at a depth of about two feet on a green-tinged fairly heavy clay substratum. The sandy material is closely associated with the Merrimac and Chicoppe series, all of them having been derived from red Triassic sandstone. The clay substratum holds the moisture, and crops rarely suffer in dry seasons.

Hill Soils of the Rift Valley

The soils of the rift valley were developed on the hill regions within the bounds of the Connecticut Valley. Soils of this group of the Cheshire, Holyoke, and Weathersfield series. These soils, with the exception of Holyoke stony fine sandy loam, have been weathered from till derived from red sandstone and shale. The surface soils are brown, subsoils are reddish-brown, and the substrata red or pink. Some soils of the Cheshire and the Weathersfield series were chosen for study.

<u>Cheshire fine sandy loam:</u> Cheshire fine sandy loam is the most important soil of this group. It has a brown mellow surface soil, a reddish-brown fairly firm subsoil, and a firm but not too compact red till substratum lying below a depth of two feet. This soil occurs on low smooth hills near the center of the east and west sides of the valley.

<u>Cheshire sandy loam:</u> Cheshire sandy loam is less extensive than the Cheshire fine sandy loam. It has a pink subsoil instead of red, and the material is less firm. The relief is slightly more rolling and drainage is more thorough. Profile characteristics are much the same as those of Cheshire fine sandy loam.

<u>Weathersfield loam:</u> Weathersfield loam closely resembles the Cheshire soils. It occupies the low smoothly rounded hills in the south-central part of the valley. The surface soil is dark brown and the subsoil is fairly heavy red sandy clay, passing at a depth of

about 20 inches into tightly compact or rather tightly cemented red till. Drainage is well established.

Soils of the Eastern Hills

The soils of the eastern hill region constitute the Gloucester, Essex, Brookfield, and Whitman series. The Gloucester series represents shallow till soils that have brown or dark brown surface soils. This is underlein by mellow but firm yellowish brown subsoil which becomes paler with depth. The substratum is a grayish, light, gritty till. These soils contain varying quantities of granitic bowlders on the surface and throughout the soil mass. Gloucester fine sandy loam was chosen for this study.

Gloucester fine sandy loam: Gloucester fine sandy loam is typical of the Gloucester series. The relief ranges from gently rolling to hilly. The substratum shows little or no compaction. Drainage in most places is good.

Soils of the Western Highlands

The soils of the western highlands include the members of the Worthington, Woodbridge, Shelburne, Becket, Berkshire, Blandford, Peru, and Hollis series. The

Worthington loam was used in this study as a representative soil of this group.

Worthington loam: Worthington loam is the most extensive soil of this group. It is developed on the flattened ridge tops of the northwestern part of the area. The surface soil is a very dark brown loam. The subsoil is shallow and is brown in color. It grades into dark greenish-yellow or olive colored till of medium texture and slight compaction. This compaction, however, does not prevent the penetration of roots. This soil has been slightly influenced by limestone.

Miscellaneous Soils

Other soils of the state, not included in the major soil groups, have been classified as miscellaneous soils. Muck soil of this group was chosen for the study.

Muck: Muck soil belongs to the group of miscellaneous soils and is of organic nature. Muck occurs in the smaller stream bottoms and in shallow filled-in lakes. The soil is poorly drained. It consists of deposits of more or less decayed plant remains mixed with variable quantities of mineral matter. Deposits vary from 3 to 10 feet in depth. Brush and aquatic shrubs grow well in the area.

METHODS OF EXPERIMENTATION

When soils are cultivated over a long period of years, a change will occur in certain of the chemical and biological characteristics. Because of this fact it was decided to use virgin soils, or at least soils which had not been subjected to cultivation or treatment for a number of years and were tending to revert to a virgin condition.

Samples from the top soil and the subsoil of the soil types were collected in the early fall. The depth at which samples of each soil was collected is as follows:

Soil Type	Depth of Top soil	Depth of Subsoil
Agawam fine s. l.	0 to 8 inches	8 to 16 inches
Cheshire sandy loam	0 to 5 inches	5 to 15 inches
Cheshire fi. sa. l.	0 to 5 inches	5 to 15 inches
Gloucester f. s. l.	0 to 5 inches	5 to 12 inches
Hadley silt loam	0 to 5 inches	5 to 15 inches
Hinkley gr. sa. l.	0 to 4 inches	4 to 16 inches
Merrimac sandy loam	0 to 6 inches	6 to 18 inches
Muck	0 to 10 inches	
Suffield fi. sa. l.	0 to 10 inches	10 to 18 inches
Weathersfield loam	0 to 6 inches	6 to 15 inches
Worthington loam	0 to 7 inches	7 to 15 inches

The soils were taken into the laboratory and air dried.

The air-dried soils were screened through a 12-mesh sieve to remove any leaves, roots, and stones, and to mix each soil thoroughly. The soil was then used for the experimental work. The nitrification and plant growth experiments were carried out under laboratory conditions, the moisture and temperature being kept as nearly constant as possible throughout the experiment.

Before the investigations were begun certain preliminary experiments were made upon the soils to supply information necessary in the preparation of the soils for the experimental work, and in the interpretation of the data secured from the investigations.

All calculations were to be made on the basis of oven dry soil; hence it was necessary to determine the moisture content of each soil. This was done by placing a weighed amount of soil into a crucible, heating in an oven at 105° C. for 24 hours. The amount of moisture lost was determined and the percentage moisture in each soil was calculated. Inasmuch as the moisture content of each soil was to be maintained at optimum it was necessary to determine the moisture holding capacity of each soil. These determinations were made by the Hilgard method (20).

The soil types as named were collected from areas as designated by Latimer (22), but in order to have a more complete report concerning the physical constituents and condition of each soil, a rapid mechanical analysis was made on each. The method used in these determinations wa the Hydrometer Method of mechanical analysis by Bouyoucos (5) and (6).

In the review of literature it was shown that the nitrifying capacity of soil is affected by its total nitrogen content. The influence of the organic matter content of the soil upon the nitrification process was shown by Martin (26) and Moore and Beaumont (27). To ascertain what effect these factors might have upon the outcome of this experiment total nitrogen determinations were made on all soils. Loss on ignition was also determined. Total nitrogen determinations were made by the Kjeldahl method (34).

It was shown in the review of literature that the relative amounts of nutrients in the soil are important factors influencing plant growth. If one nutrient should be present in quantity sufficient to cause an increased growth and if there is not enough of other nutrients in the soil to satisfy the plant needs, then the growth may be limited or there will be a deficiency of these elements in the plant. Nitrogen was the only plant nutrient being considered in this experiment and so was the only one which was to be added to increase the quantity above that present in the original soil. In order to obtain data which would show to what extent other plant nutrients might become limiting factors during the course of the experiment, a analysis by Morgan's method (28) was made of each soil to determine the relative amounts of phosphorus, calcium, and potassium present.

Ammonia nitrogen was also determined by Morgan's method. It was thought that if ammonia nitrogen was high there might be a relation between that and the rapidity in which nitrification started. In all instances ammonia nitrogen was found to be less than five pounds per acre. Since ammonification was not being studied no further consideration was given this factor.

The pH was determined on all soils at the beginning of the experiment, after nitrification experiments had reached a three-week's incubation period, and again at the end of the nitrification tests. These determinations were made electrometrically, using the quinhydrone electrode and a Leeds and Northop potentiometer. The soils of this region are acid in character. Waksman (39) recommends the addition of calcium carbonate to acid soils to bring about an optimum reaction for nitrification. In this investigation, however, no lime was added to these soils and no attempt was made to regulate the pH. This, it was thought, would thus show the relation of nitrification to pH in Massachusetts soils and show whether soils with a high pH nitrified more efficiently than do the soils of a more acid nature .

For the nitrification studies in the experiment the beaker method was used and all soil cultures were prepared in duplicate. The top soil and the subsoil of each soil type were treated as separate soil samples. Three hundred grams of each soil were prepared in duplicate in series of five samples each, and each series of soil samples was given the same treatments. The soil samples within a series being treated as follows:

Beaker Number 1 - Soil with nothing added.

2 - Soil with ammonium phosphate added.

(12.16 % N. - .01545 gms. $NH_4H_2PO_4$ added.)

3- Soil with ammonium sulphate added.

(21.18 % N. -- .00887 gms. $(NH_4)_2SO_4$ added.)

4- Soil with dried blood added.

(11.86 % N. - .01584 gms. dried blood added.)

5- Soil with cotton seed meal added.

(5.47 % N. - .03436 gms. cotton seed meal.)

These sources of nitrogen were applied in amounts sufficient to supply 125 pounds of nitrogen to two million pounds of soil, that is, .00188 grams of nitrogen to each beaker containing 300 grams of soil.

The moisture content of each soil was brought to between 60 and 65 per cent of its moisture holding capacity, and during the incubation period moisture was kept as nearly constant as possible. All soils were incubated at 28° to 32° C.

Nitrates in each soil were determined at the beginning of the experiment and at weekly intervals throughout an incubation period of six-weeks. Twenty-gram portions of soil (oven dry basis) were removed from each beaker and nitrates were determined by the phenol disulphonic acid method (34).

The set-up used in the study of plant growth in these soils was as follows: six-hundred-gram portions of each soil were arranged in crystallizing dishes in series of five and given the same nitrogen treatments, in the same ratio, as were the soils in the nitrification studies. These dishes were 7.5 cm. x 12.5 cm.

Thirty-six barley plants were grown in each dish, and in certain instances where it was impossible, because of the bulk of the soil, as in muck, to use 600 grams of soil sufficient nitrogen was applied to give the same ratio as was used in the nitrification tests.

The moisture content of each soil was brought to 65 per cent of the moisture holding capacity and kept as nearly at this value as possible throughout the period of plant growth.

The plants were grown in the green house for a period of six weeks. The aerial portion of each plant in each soil was measured and the average height of the plants in each soil under each treatment was determined.

The plants were dried and weighed. The average weight of the plants in each dish was calculated.

PRESENTATION OF EXPERIMENTAL RESULTS

The results and data obtained from the experimental investigations are presented in tabular and graphic form in the following pages.

Table 1 contains data pertaining to the moisture content, moisture-holding capacity, total nitrogen content, and the loss on ignition of each soil.

Table 2 contains the data of the results of the mechanical analysis of each soil and shows the percentage sand, silt, and clay.

Table 3 shows the relative amounts of the plant nutrients in each soil.

Table 4 contains a record of soil pH and any changes that occurred during the experiment.

Tables I to XI show the rate of nitrification and the nitrate accumulation in the soils.

Figures I to XI are graphic representations of the nitrification tables.

Tables and figures I-A to XI-A represent the average height (in centimeters) and the average weight (in grams) of the plants grown in each soil under each treatment.

Table 1

SOIL TYPE		PER CENT MOISTURE	MOISTURE-HOLDING CAPACITY	TOTAL N PPM.	PER CENT LOSS ON IGNITION
Agawam	A*	1.91	63.45	939	5.75
	B+	1.43	58.58	551	4.38
Cheshire (s.l.)	A	1.71	67.32	2,056	8.32
	B	1.32	49.46	536	3.33
Cheshire (f.s.l.)	A	2.30	70.35	1,312	6.35
	B	1.44	59.93	419	3.11
Gloucester	A	1.96	58.98	1,096	5.78
	B	1.44	54.40	784	4.77
Hadley	A	.63	49.97	308	2.01
	B	.99	56.26	489	2.65
Hinkley	A	1.28	42.47	934	5.74
	B	.48	27.74	74	.48
Merrimac	A	.85	28.87	507	1.84
	B	.46	27.74	77	.71
Muck		9.82	252.11	2,799	53.87
Suffield	A	2.26	65.19	1,624	6.49
	B	1.47	48.54	459	3.05
Weathersfield	A	3.40	65.33	1,649	6.93
	B	1.70	54.39	486	3.52
Worthington	A	1.87	67.94	1,228	6.21
	B	1.29	49.07	522	3.83

A* -- Top soil B+ -- Subsoil

Table 2

MECHANICAL ANALYSIS OF SOILS

Sand (1.0-0.05mm), Silt (.05-.002mm), and Clay (.002-.000mm) Fractions

Soil Type		Per cent Sand	Per cent Silt	Per cent Clay
Agawam	A	49.4	45.2	6.4
	B	27.6	62.0	10.4
Cheshire (s.l.)	A	47.6	46.0	6.4
	B	49.6	40.0	10.4
Cheshire (f.s.l.)	A	40.4	53.2	6.4
	B	37.6	52.0	10.4
Gloucester	A	53.6	39.0	7.4
	B	53.0	36.6	10.4
Hadley	A	49.6	42.1	8.3
	B	50.6	43.0	6.4
Hinkley	A	73.6	20.0	6.4
	B	91.6	4.2	4.2
Merrimac	A	77.6	16.0	6.4
	B	86.6	9.0	4.4
Muck				
Suffield	A	52.6	39.0	8.4
	B	57.6	32.0	10.4
Wethersfield	A	45.6	46.0	8.4
	B	46.4	42.2	12.4
Worthington	A	55.6	38.0	6.4
	B	56.6	35.0	8.4

Table 3

RELATIVE AMOUNT OF NUTRIENT ELEMENTS IN SOILS

Soil Type		P	K	Ca	NH_3 N.
		Nutrient Elements			
Agawam	A	Md	L	L	VL
	B	Md	L	VL	VL
Cheshire (s.l.)	A	Md H	L	L	VL
	B	Md	L	VL	VL
Cheshire (f.s.l.)	A	Md	L	VL	VL
	B	Md	L	VL	VL
Gloucester	A	L	L	VL	VL
	B	L	L	VL	VL
Hadley	A	Md H	Md	Md H	VL
	B	Md	L	Md	VL
Hinkley	A	L	L	VL	VL
	B	L	L	VL	VL
Muck		Md	L	Md	VL
Suffield	A	Md	L	VL	VL
	B	Md	L	L	VL
Weathersfield	A	Md	L	VL	VL
	B	H	L	L	VL
Worthington	A	Md	L	VL	VL
	B	Md	L	VL	VL

Interpretive Key*	P	K	Ca	NH_3 N.
	Pounds per Acre			
VL --------			400	Less than 5
L --------	25	150	750	
Md --------	50	200	1,000	
Md H ------	100		2,000	
H --------	200			

Table 4

Reaction of Top Soil and Subsoil During Course of Experiment.
Soils having been treated as shown.

TREATMENT	TOP SOIL pH-INITIAL	TOP SOIL THIRD WEEK	TOP SOIL FINAL	SUBSOIL pH-INITIAL	SUBSOIL THIRD WEEK	SUBSOIL FINAL
AGAWAM						
Soil	5.8	5.9	5.5	5.4	5.5	5.4
$NH_4H_2PO_4$	5.8	5.8	5.4	5.4	4.7	4.7
$(NH_4)_2SO_4$	5.8	5.6	5.3	5.4	4.8	4.5
Dried Blood	5.8	5.6	5.4	5.4	5.0	4.7
C. S. Meal	5.8	5.5	5.4	5.4	5.0	4.9
CHESHIRE (s.l.)						
Soil	5.9	5.6	5.3	5.9	5.9	5.5
$NH_4H_2PO_4$	5.9	5.4	5.3	5.9	5.9	5.3
$(NH_4)_2SO_4$	5.9	5.5	5.1	5.9	5.9	5.2
Dried Blood	5.9	5.5	5.3	5.9	5.9	5.3
C. S. Meal	5.9	5.5	5.3	5.9	5.8	5.5
CHESHIRE (f.s.l.)						
Soil	5.8	5.1	5.3	5.8	5.7	5.8
$NH_4H_3PO_4$	5.8	5.4	5.4	5.8	5.9	5.3
$(NH_4)_2SO_4$	5.8	5.6	5.4	5.8	5.7	5.4
Dried Blood	5.8	5.4	5.4	5.8	5.9	5.8
C. S. Meal	5.8	5.5	5.4	5.8	5.9	5.6
GLOUCESTER						
Soil	5.4	5.4	5.4	5.1	5.0	4.8
$NH_4H_2PO_4$	5.4	5.4	5.0	5.1	4.6	4.5
$(NH_4)_2SO_4$	5.4	5.1	4.8	5.1	4.8	4.3
Dried Blood	5.4	5.0	5.0	5.1	4.7	4.5
C. S. Meal	5.4	5.1	5.0	5.1	4.8	4.7
HADLEY						
Soil	6.8	6.9	6.6	6.5	6.5	6.4
$NH_4H_2PO_4$	6.8	6.2	6.4	6.5	5.9	6.1
$(NH_4)_2SO_4$	6.8	6.2	6.1	6.5	5.8	6.0
Dried Blood	6.8	6.4	6.6	6.5	6.0	6.1
C. S. Meal	6.8	6.4	6.6	6.5	6.2	6.2
MERRIMAC						
Soil	5.4	5.8	5.1	5.9	6.3	5.6
$NH_4H_2PO_4$	5.4	5.4	4.7	5.9	6.7	5.1
$(NH_4)_2SO_4$	5.4	5.4	4.6	5.9	6.3	5.0
Dried Blood	5.4	5.4	4.7	5.9	6.6	5.2
C. S. Meal	5.4	5.6	4.7	5.9	6.6	5.6

Table 4
(continued)

TREATMENT	TOP SOIL pH-INITIAL	TOP SOIL THIRD WEEK	TOP SOIL FINAL	!	SUBSOIL pH-INITIAL	SUBSOIL THIRD WEEK	SUBSOIL FINAL
HINKLEY				!			
Soil	5.2	5.5	5.9	!	5.4	5.6	6.2
$NH_4H_2PO_4$	5.2	6.0	5.7	!	5.4	6.4	6.5
$(NH_4)_2SO_4$	5.2	5.5	5.5	!	5.4	6.0	6.2
Dried Blood	5.2	5.7	5.9	!	5.4	6.1	6.4
C. S. Meal	5.2	5.7	5.6	!	5.4	6.1	6.4
MUCK							
Soil	5.4	5.5	5.5	!			
$NH_4H_2PO_4$	5.4	5.5	5.4	!			
$(NH_4)_2SO_4$	5.4	5.3	5.3	!			
Dried Blood	5.4	5.4	5.5	!			
C. S. Meal	5.4	5.4	5.4	!			
SUFFIELD							
Soil	5.9	6.2	5.6	!	5.7	5.7	5.7
$NH_4H_2PO_4$	5.9	5.6	5.4	!	5.7	5.5	5.0
$(NH_4)_2SO_4$	5.9	5.4	5.2	!	5.7	5.5	5.1
Dried Blood	5.9	5.7	5.6	!	5.7	5.6	5.5
C. S. Meal	5.9	5.7	5.4	!	5.7	5.6	5.4
WEATHERSFIELD							
Soil	5.6	5.7	5.1	!	5.7	6.0	6.0
$NH_4H_2PO_4$	5.6	6.4	5.4	!	5.7	6.1	5.8
$(NH_4)_2SO_4$	5.6	6.1	5.8	!	5.7	5.9	5.6
Dried Blood	5.6	6.2	5.6	!	5.7	6.0	5.6
C. S. Meal	5.6	5.9	5.5	!	5.7	6.0	5.9
WORTHINGTON							
Soil	5.7	5.4	5.3	!	5.8	5.8	5.5
$NH_4H_2PO_4$	5.7	5.4	4.9	!	5.8	5.6	4.9
$(NH_4)_2SO_4$	5.7	5.4	4.9	!	5.8	5.6	5.1
Dried Blood	5.7	5.5	5.3	!	5.8	5.8	5.5
C. S. Meal	5.7	5.7	5.2	!	5.8	5.8	5.4

LEGEND

For Interpretation of Graphic Representation
of the Figures on the Following Pages.

FIGURES I - XI

NITRIFICATION-

TREATMENT	TOP-SOIL	SUB-SOIL
Soil	————	- - - - - - -
Soil and $NH_4H_2PO_4$	————	- - - - - - -
Soil and $(NH_4)_2SO_4$	————	- - - - - - -
Soil and Dried Blood	————	- - - - - - -
Soil and Cotton S. Meal	————	- - - - - - -

FIGURES I A - XI A

MAXIMUM NITRATE ACCUMULATION AND PLANT GROWTH

	TOP-SOIL	SUB-SOIL
Nitrate Accumulation		
Height of Plants		
Weight of Plants		

Figure I

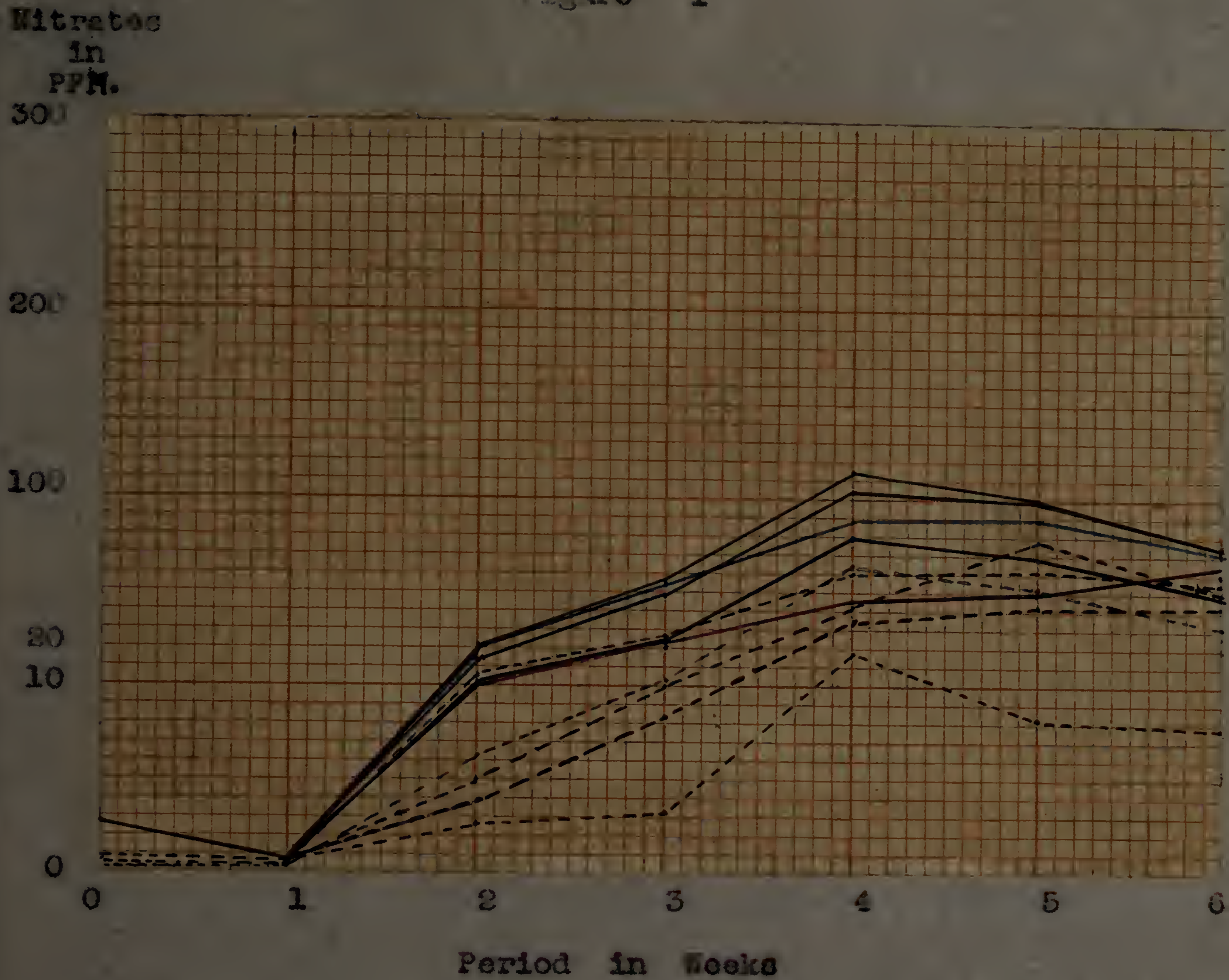


Table I

PPM of Nitrates formed in AGAWAM FINE SANDY LOAM AT 1 week intervals over a period of six weeks. Soils having been treated as shown.

Top Soil

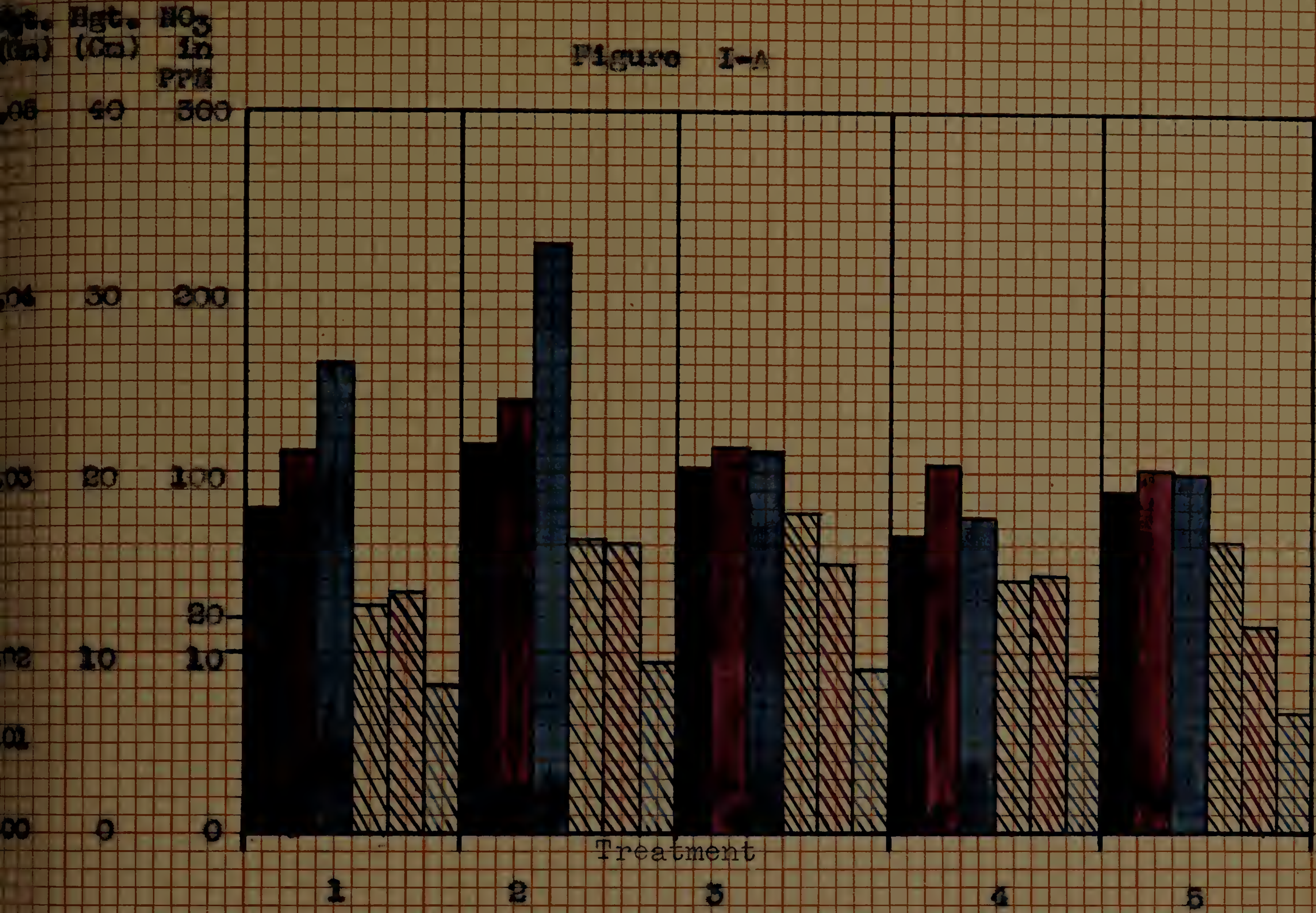
		Weeks					
Treatment	Initial	1st	2nd	3rd	4th	5th	6th
Soil	2.80	-1	10.60	26.25	80.00	68.20	47.43
$NH_4H_2PO_4$	2.80	-1	21.72	57.00	115.36	100.00	75.37
$(NH_4)_2SO_4$	2.80	-1	18.10	49.95	105.84	100.00	74.99
Dried Blood	2.80	-1	10.20	25.00	44.15	50.00	65.38
C. S. Meal	2.80	-1	20.00	55.50	88.88	89.05	71.23

Sub Soil

Soil	-1	-1	2.68	3.12	18.30	8.44	6.97
$NH_4H_2PO_4$	-1	-1	11.43	27.75	60.80	61.27	54.55
$(NH_4)_2SO_4$	-1	-1	5.10	10.00	43.55	78.00	50.00
Dried Blood	-1	-1	4.00	8.63	3[illegible].68	42.84	41.66
C.S. Meal	-1	-1	6.28	12.90	62.60	52.52	32.05

-1 = less than 1 PPM.

Figure I-A



Graphic representation of Table I-A and showing plant growth in proportion to Maximum Nitrate Accumulation.

Table I-A

Relative HEIGHT and WEIGHT of Barley plants grown in the Top-Soil and Sub-Soil of AGAWAM FINE SANDY LOAM. Soil having been treated as indicated.

	Treatment				
	1- Soil	2- $NH_4H_2PO_4$	3- $(NH_4)_2SO_4$	4- D. Blood	5 C. Meal
Top-Soil					
HEIGHT --- in centimeters	21.3	24.1	21.4	20.5	20.3
WEIGHT --- in grams	.0360	.0425	.0311	.0275	.0304
Sub-Soil					
HEIGHT	13.1	15.8	14.9	14.2	11.6
WEIGHT	.0145	.0182	.0179	.0174	.0136

Figure II

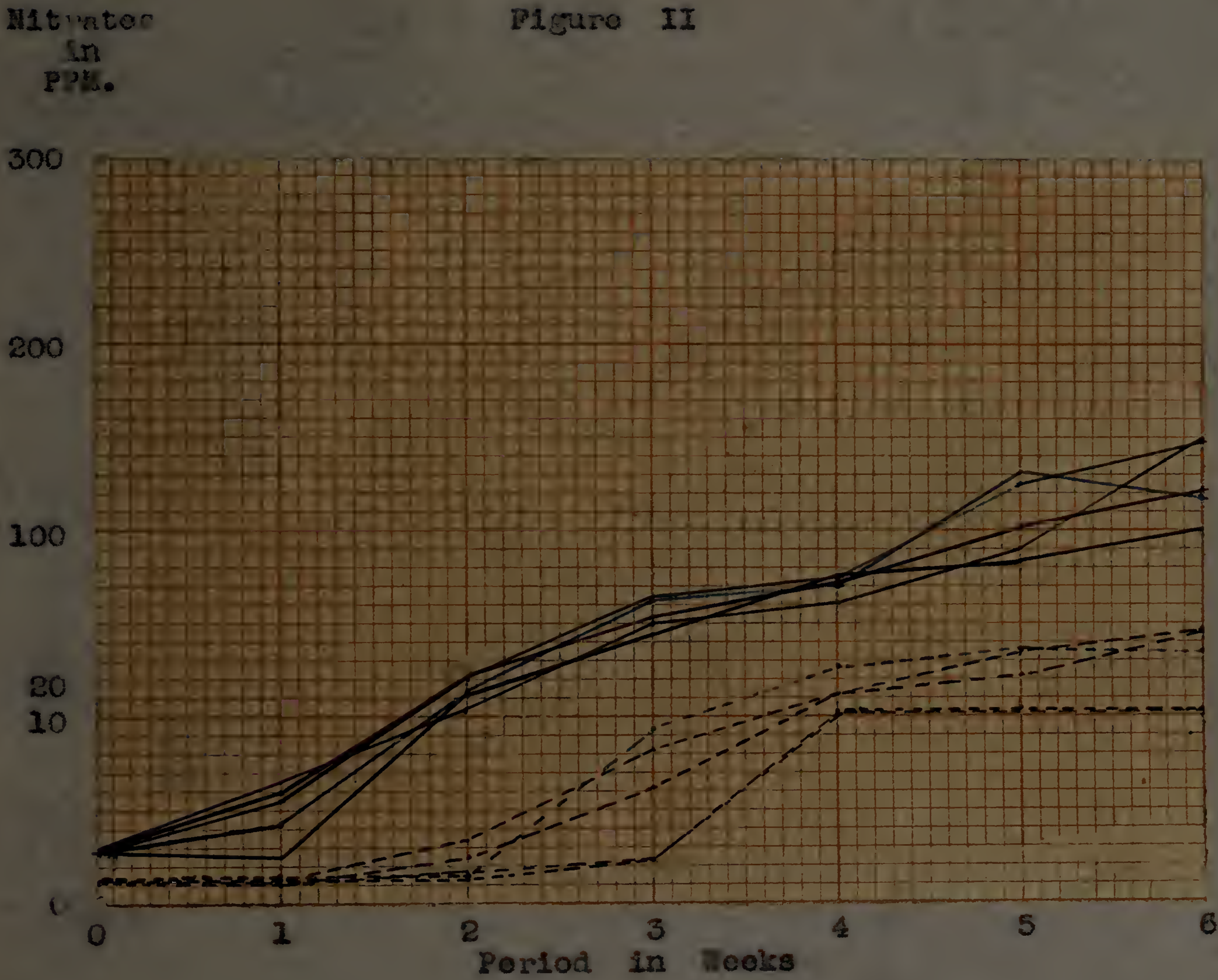
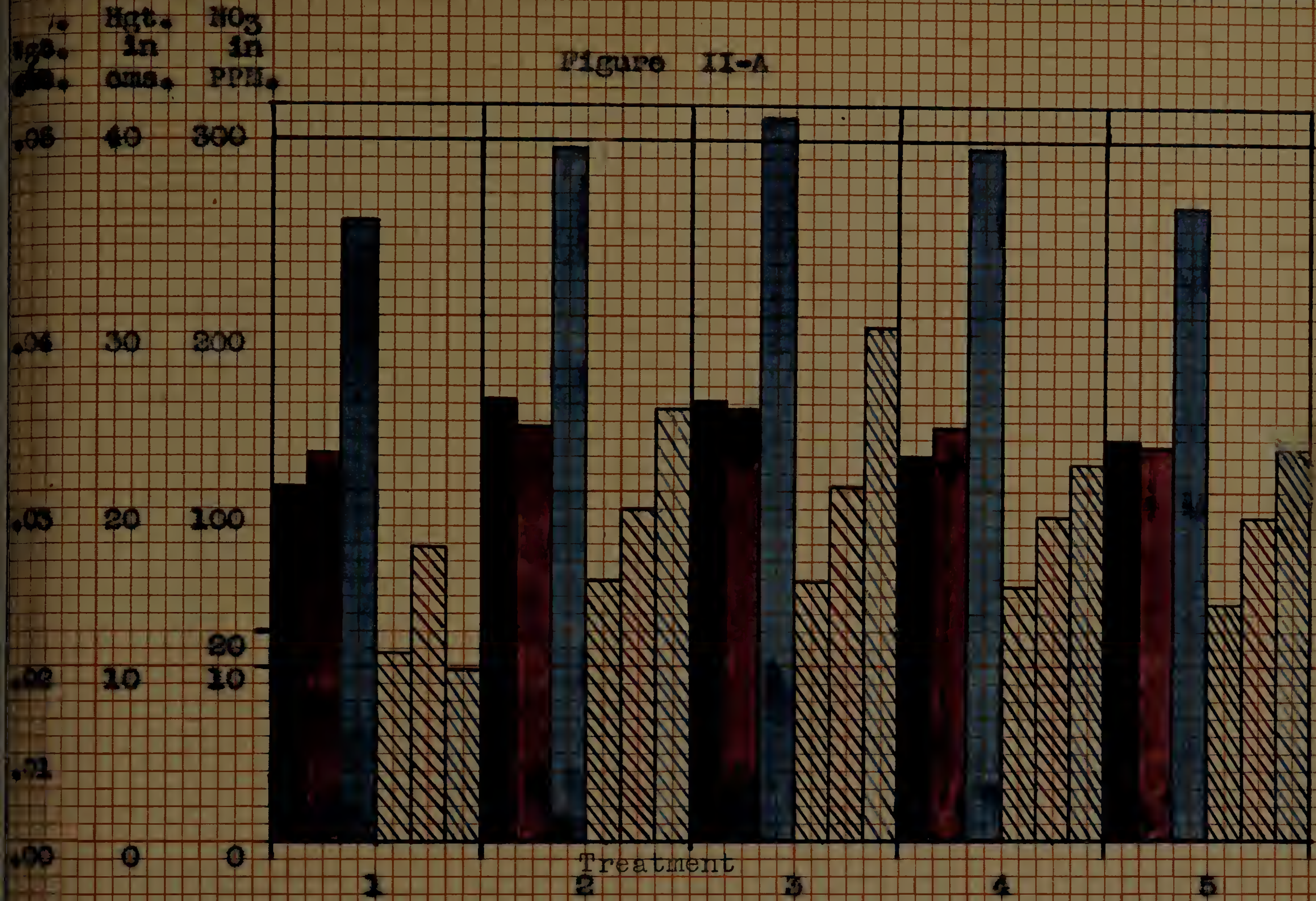


Table II

PPM of Nitrates formed at 1 week intervals during a six week period in CHESHIRE SANDY LOAM. Soils having been treated as shown.

Top-Soil							
		Weeks					
Treatment	Initial	1st	2nd	3rd	4th	5th	6th
Soil	2.78	2.50	16.50	44.05	76.80	83.50	100.00
$NH_4H_2PO_4$	2.78	5.60	22.40	64.50	75.00	125.00	148.00
$(NH_4)_2SO_4$	2.78	6.65	12.50	50.50	60.83	92.17	149.00
Dried Blood	2.78	6.00	22.40	53.80	72.00	102.13	122.00
C. S. Meal	2.78	4.15	17.82	63.65	70.20	132.56	119.50
Sub-Soil							
Soil	1.05	1.25	1.27	2.38	10.70	12.40	10.90
$NH_4H_2PO_4$	1.05	1.25	3.32	8.16	16.20	34.64	47.20
$(NH_4)_2SO_4$	1.05	1.14	1.57	2.37	10.00	12.40	45.15
Dried Blood	1.05	1.22	2.53	6.10	16.20	22.38	45.15
C. S. Meal	1.05	1.43	1.45	9.60	29.60	34.74	36.60

Figure II-A



Graphic representation of Table II-A and showing plant growth in proportion to Maximum Nitrate Accumulation.

Table II-A

Relative HEIGHT and WEIGHT of Barley plants grown in Top-Soil and Sub-Soil of CHESHIRE SANDY LOAM. Soils having been treated as indicated.

	Treatment				
Top-Soil	1- Soil	2- $NH_4H_2PO_4$	3- $(NH_4)_2SO_4$	4- D.Blood	5- C. Meal
HEIGHT----	22.15	23.43	24.84	23.59	22.65
WEIGHT----	.0458	.0496	.0515	.0495	.0468
Sub-Soil					
HEIGHT----	16.63	18.90	20.36	17.46	17.34
WEIGHT----	.0194	.0247	.0287	.0219	.0228

Nitrates
in
PPM.

Figure III

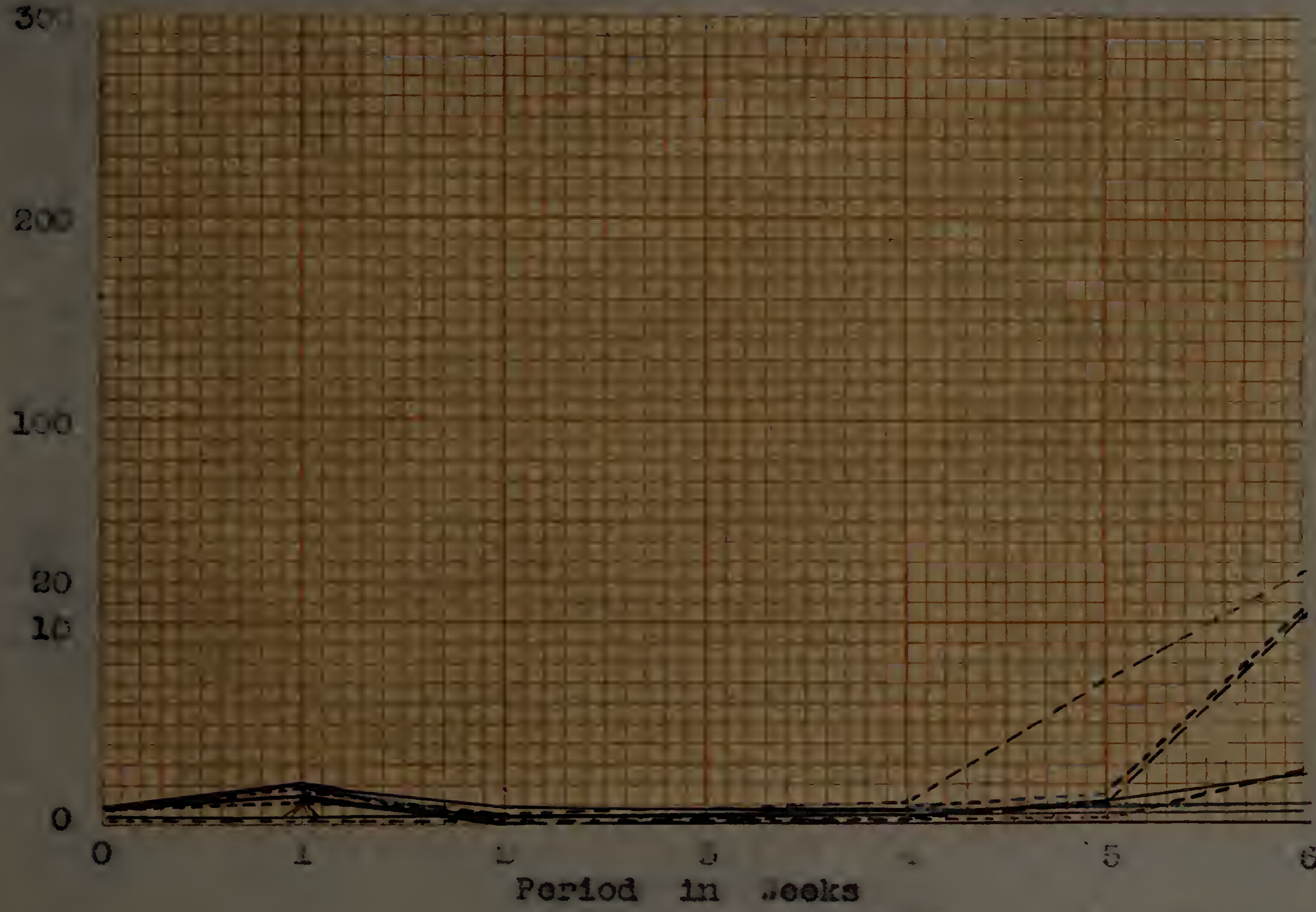


Table III

PPM of Nitrates formed in CHESHIRE FINE SANDY LOAM at 1 week intervals over a period of six weeks. Soils having been treated as shown.

Top-Soil

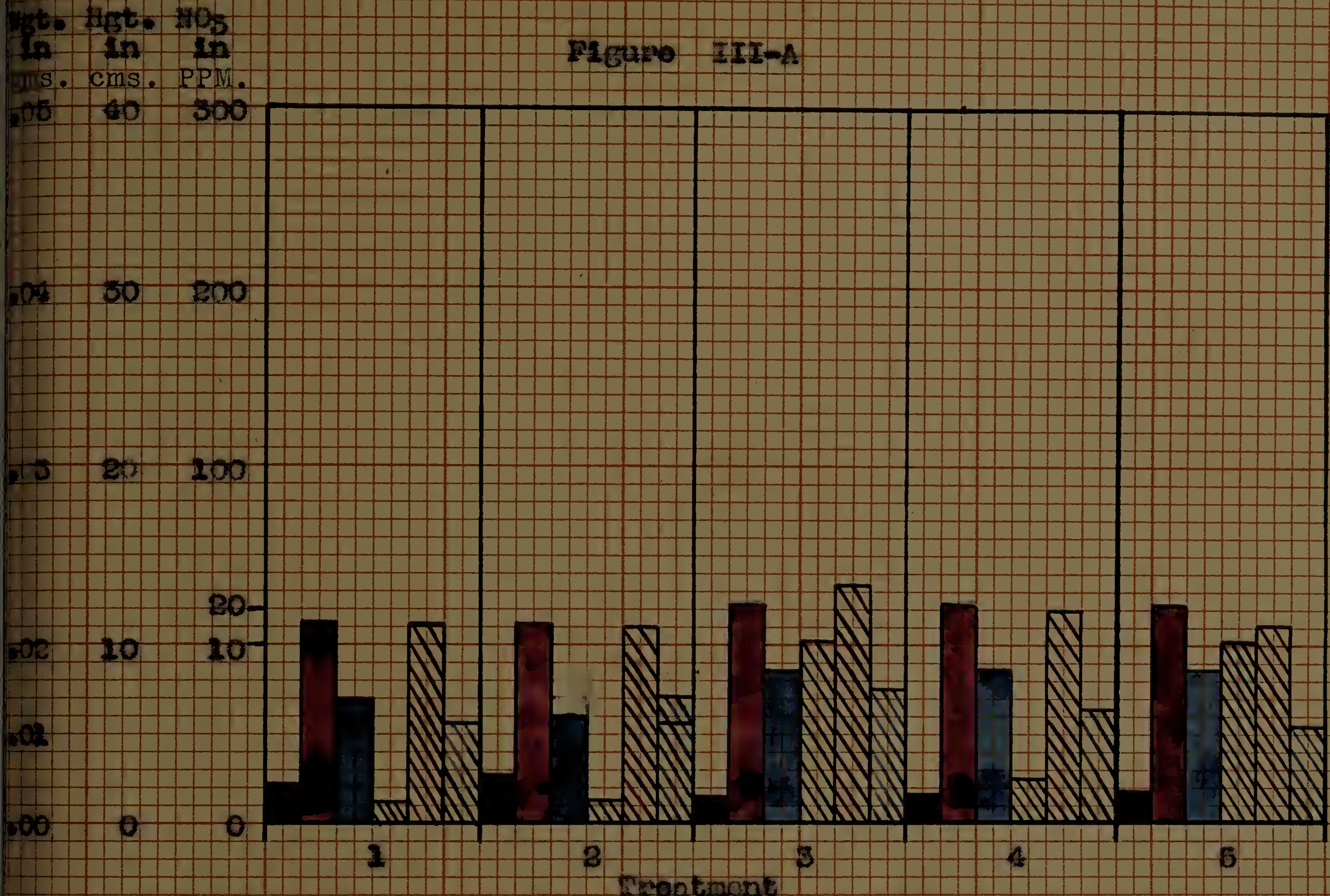
Treatment	Initial	1st	2nd	3rd	4th	5th	6th
Soil	-1	2.00	-1	-1	-1	No	NO
$NH_4H_2PO_4$	-1	1.19	-1	-1	-1	1.07	2.74
$(NH_4)_2SO_4$	-1	1.09	-1	-1	-1	-1	-1
Dried Blood	-1	1.44	-1	-1	-1	-1	-1
C. S. Meal	-1	1.89	-1	-1	-1	-1	-1

Sub-Soil

Treatment	Initial	1st	2nd	3rd	4th	5th	6th
Soil	-1	1.25	-1	-1	-1	No	No
$NH_4H_2PO_4$	-1	1.31	-1	-1	1.13	7.10	26.20
$(NH_4)_2SO_4$	-1	-1	-1	-1	-1	1.03	11.70
Dried Blood	-1	1.78	-1	-1	-1	-1	2.75
C. S. Meal	-1	1.34	-1	-1	-1	1.13	13.85

-1 = less than 1 PPM.

Figure III-A



Graphic representation of Table III-A and showing plant growth in relation to the Maximum Nitrate Accumulation.

Table III-A

Relative HEIGHT and WEIGHT of Barley plants grown in the Top-Soil and Sub-Soil of CHESHIRE FINE SANDY LOAM. Soils having been treated as indicated.

	Treatment				
	1-	2-	3-	4-	5-
Top-Soil	Soil	$NH_4H_2PO_4$	$(NH_4)_2SO_4$	D.Blood	C. Meal
HEIGHT----	11.40	11.25	12.39	12.41	12.41
WEIGHT-----	.0143	.0120	.0171	.0173	.0176
Sub-Soil					
HEIGHT----	11.09	13.17	13.41	12.13	11.21
WEIGHT----	.0106	.0141	.0143	.0129	.0112

Figure IV

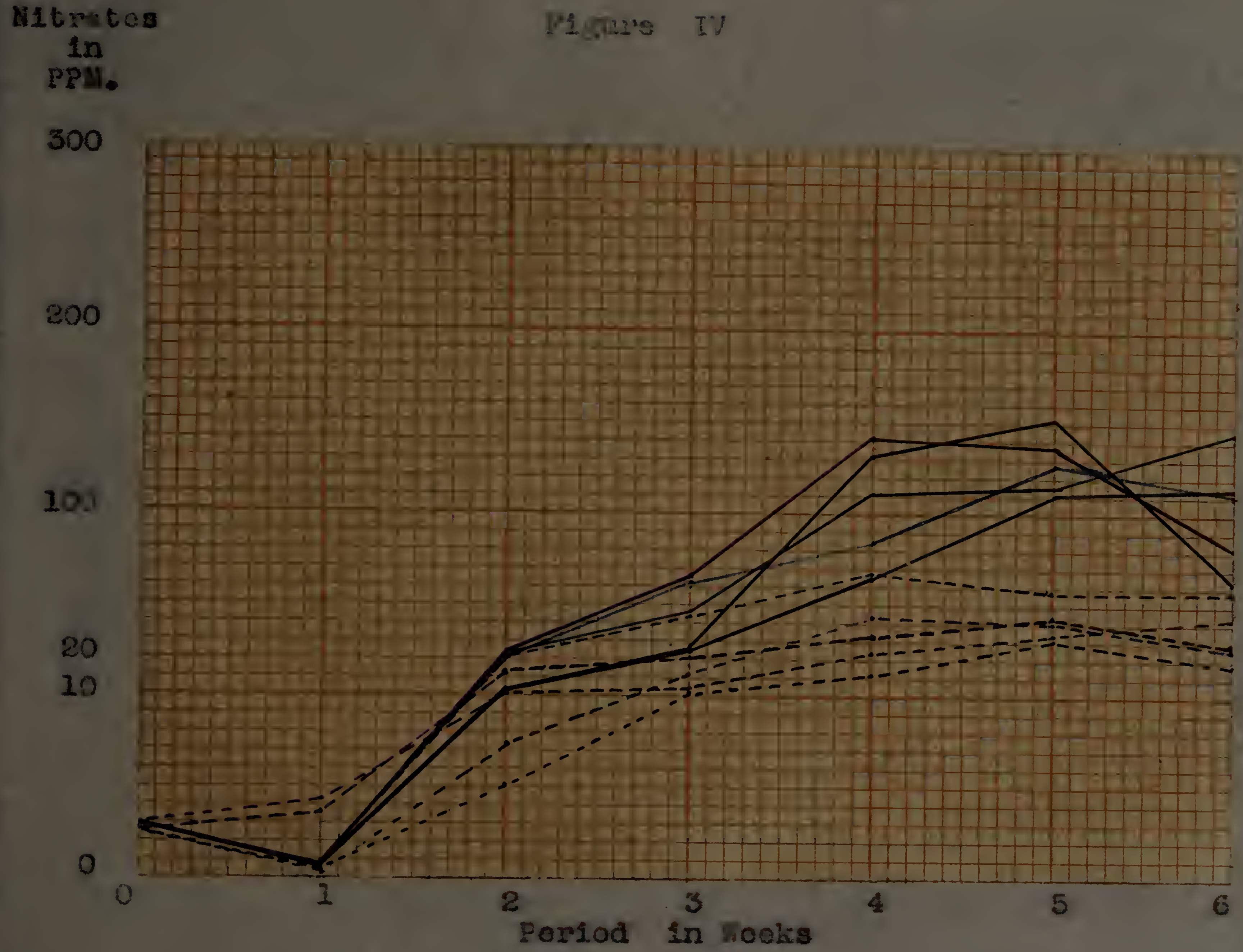


Table IV

PPM of Nitrates formed in GLOUCESTER FINE SANDY LOAM at 1 week intervals over a six week period. Soils having been treated as shown.

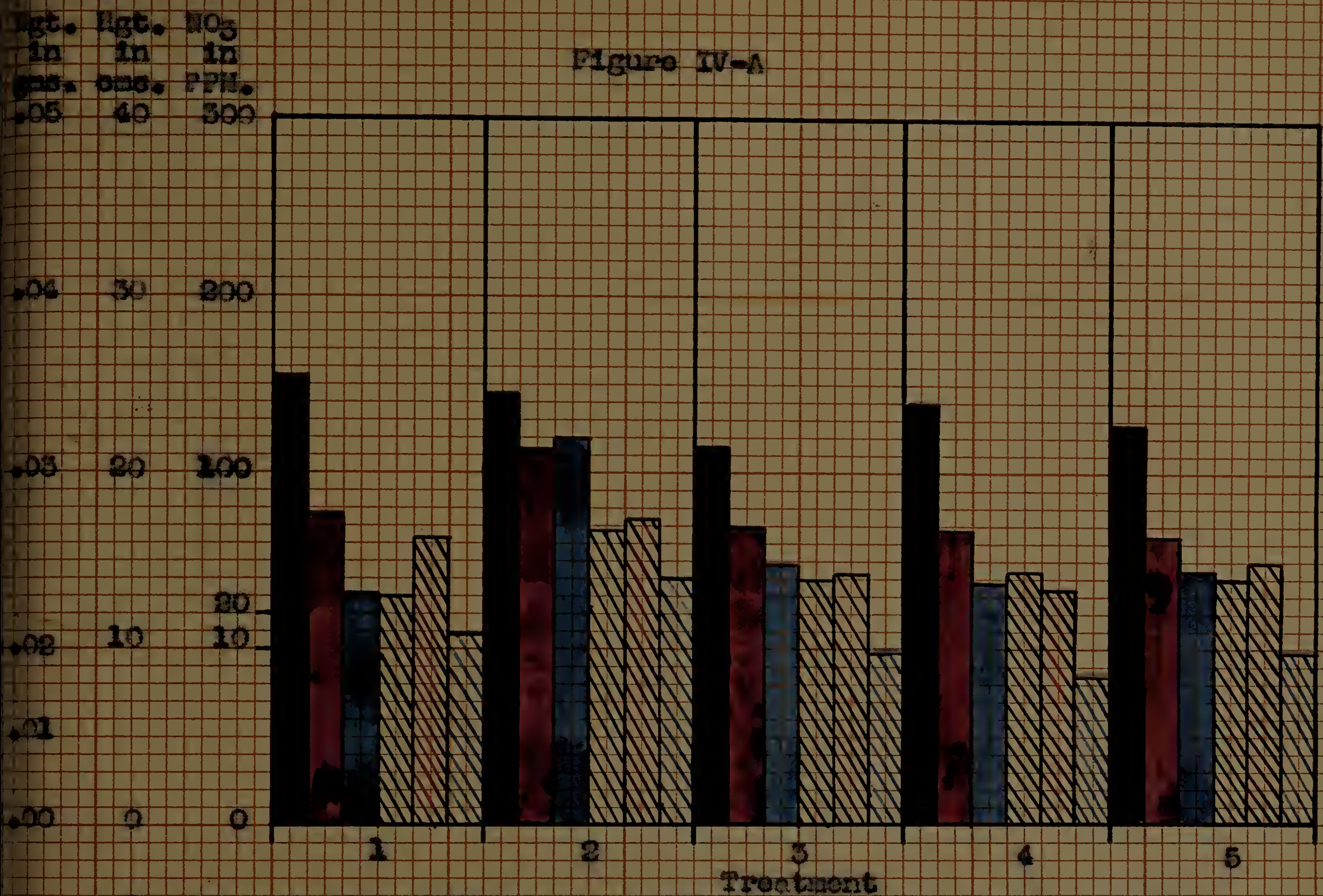
Top-Soil

Treatment	Initial	1st	2nd	3rd	4th	5th	6th
		Weeks					
Soil	3.00	-1	12.78	27.90	132.28	153.96	64.91
$NH_4H_2PO_4$	3.00	-1	21.15	45.45	111.11	115.37	144.45
$(NH_4)_2SO_4$	3.00	-1	12.62	25.40	66.96	111.10	115.38
Dried Blood	3.00	-1	24.30	67.00	142.09	137.52	81.11
C. S. Meal	3.00	-1	22.07	62.50	85.62	129.58	112.03

Sub-Soil

Treatment	Initial	1st	2nd	3rd	4th	5th	6th
Soil	2.90	-1	5.10	11.76	16.02	31.08	19.05
$NH_4H_2PO_4$	2.90	3.84	20.37	43.15	68.65	59.59	58.61
$(NH_4)_2SO_4$	2.90	4.08	10.55	12.10	24.66	33.64	41.66
Dried Blood	2.90	3.84	18.05	21.15	34.98	44.15	30.75
C. S. Meal	2.90	-1	7.25	17.65	43.90	40.00	27.75

Figure IV-A



Graphic representation of Table IV-A and showing plant growth in relation to the Maximum Nitrate Accumulation.

Table IV-A

Relative HEIGHT and WEIGHT OF Barley plants grown in the Top-Soil and the Sub-Soil of GLOUCESTER FINE SANDY LOAM. Soils having been treated as indicated.

	Treatment 1- Soil	2- $NH_4H_2PO_4$	3- $(NH_4)_2SO_4$	4- D. Blood	5- G. Meal
Top-Soil					
HEIGHT----	16.73	21.15	16.90	16.70	16.26
WEIGHT ---	.0229	.0323	.0247	.0236	.0242
Sub-Soil					
HEIGHT----	16.23	17.30	14.15	13.25	15.09
WEIGHT----	.0208	.0236	.0193	.0162	.0193

Figure V

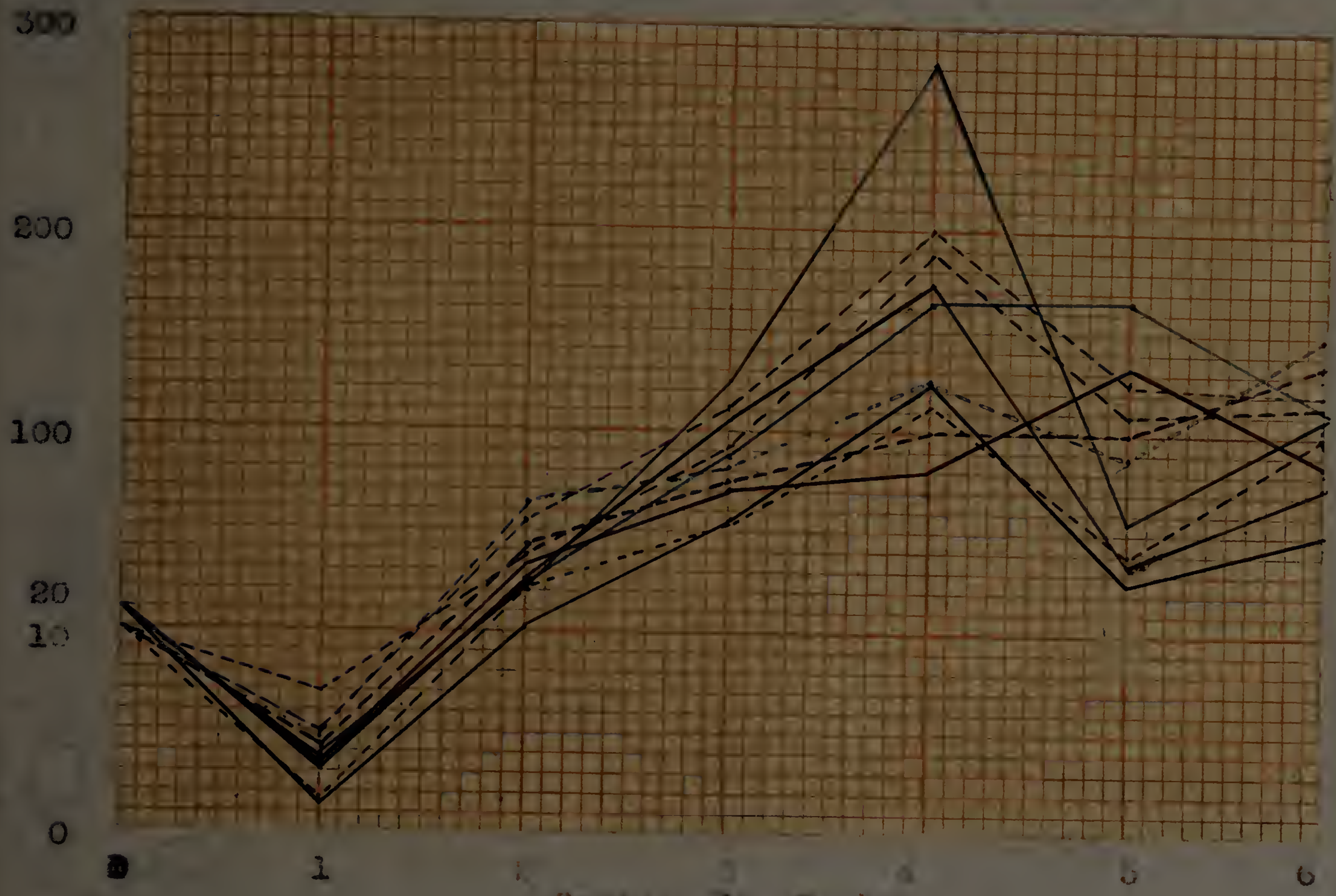
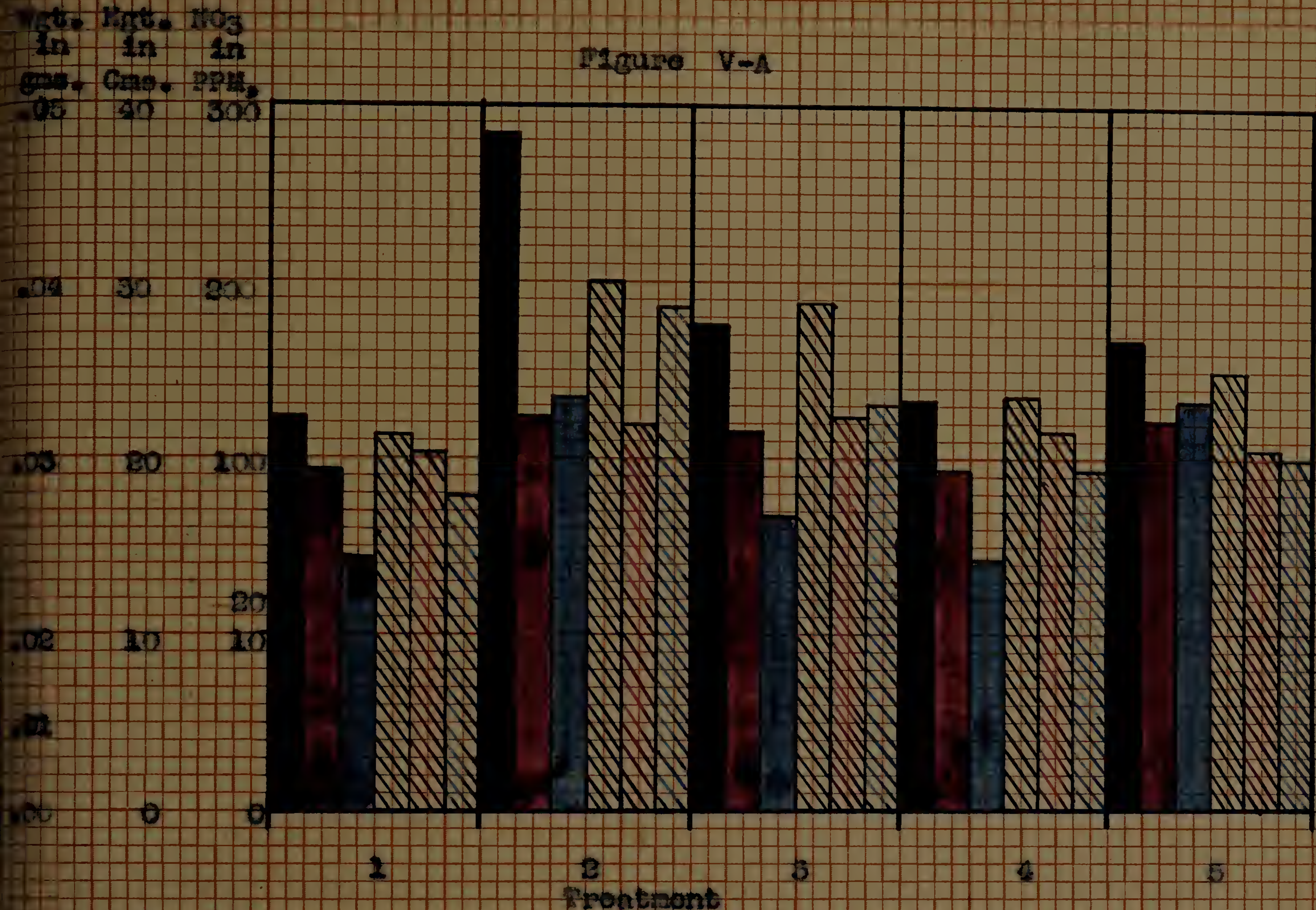


Table V

PPM of Nitrates formed in HADLEY SILT LOAM at 1 week intervals over a period of six weeks. Soils having been treated as shown.

Treatment	Initial	1st	2nd	3rd	4th	5th	6th
Top-Soil							
		Weeks					
Soil	15.00	1.58	11.50	56.10	125.00	26.65	50.00
$NH_4H_2PO_4$	15.00	3.66	23.25	125.00	281.67	55.52	107.14
$(NH_4)_2SO_4$	15.00	3.16	26.50	106.15	173.62	36.36	74.96
Dried Blood	15.00	3.40	31.25	70.30	82.75	133.36	85.71
C. S. Meal	15.00	3.16	35.25	87.65	165.66	169.07	115.39
Sub-Soil							
Soil	10.00	1.85	23.65	55.80	113.33	40.00	100.00
~~$NH_4H_2PO_4$~~	~~10.00~~	6.00	55.00	112.65	200.00	125.49	120.00
$(NH_4)_2SO_4$	10.00	7.24	37.50	95.12	189.15	110.58	115.38
Dried Blood	10.00	4.25	43.75	76.32	100.00	100.00	136.35
C. S. Meal	10.00	4.66	64.00	81.15	125.52	89.21	150.[illegible]

Figure V-A



Graphic representation of Table V-A and showing plant growth in relation to the Maximum Nitrate Accumulation.

Table V-A

Relative HEIGHT and WEIGHT of Barley plants grown in the Top-Soil and in the Sub-Soil of HADLEY SILT LOAM. Soils having been treated as indicated.

Treatment

	1- Soil	2- $NH_4H_2PO_4$	3- $(NH_4)_2SO_4$	4- D. Blood	5- C. Meal
Top-Soil					
HEIGHT----	19.27	22.50	21.21	19.07	22.05
WEIGHT----	.0244	.0333	.0266	.0244	.0330
Sub-Soil					
HEIGHT----	20.73	21.99	22.53	21.35	20.70
WEIGHT----	.0275	.0338	.0330	.0296	.0295

Figure VI

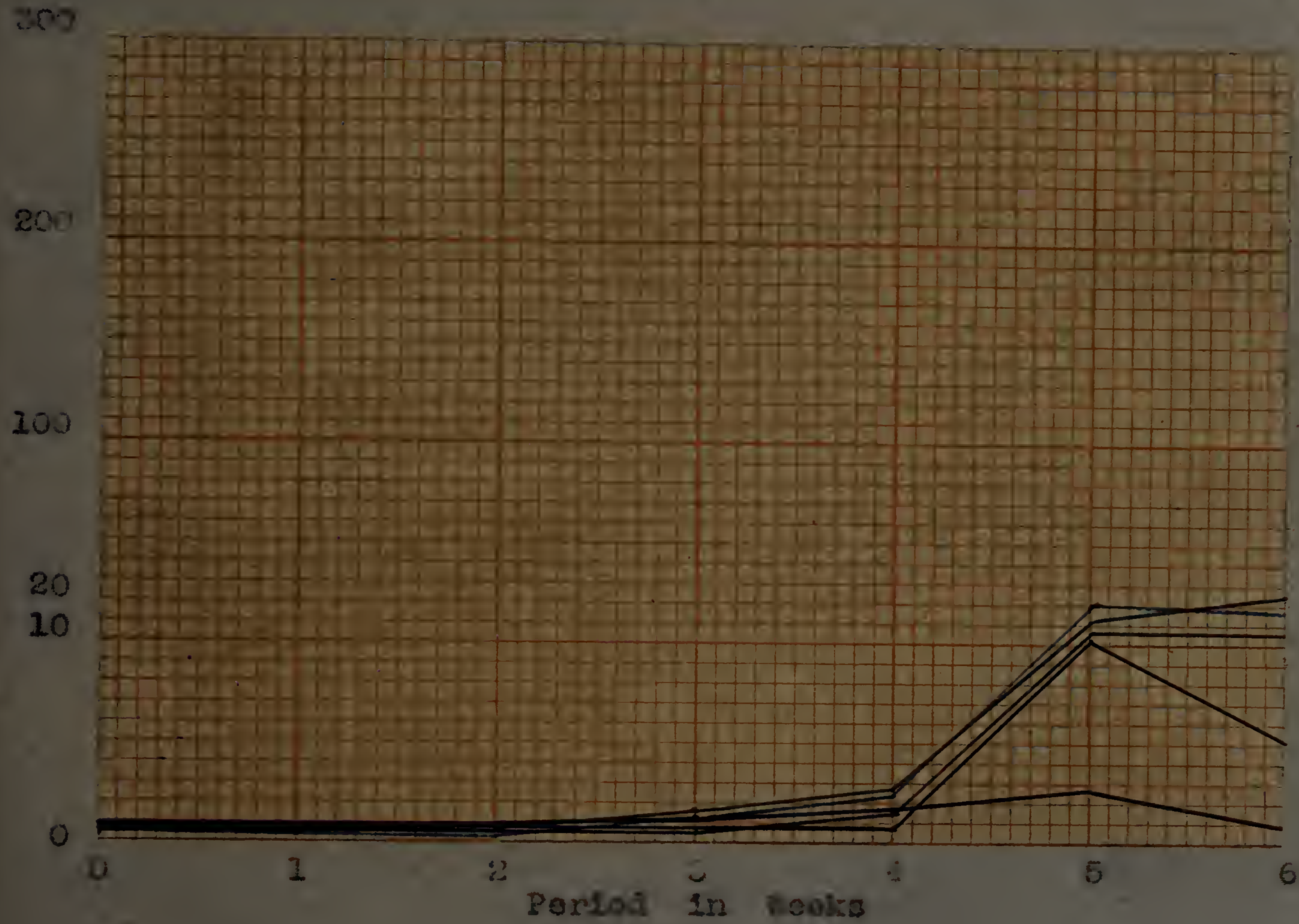


Table VI

PPM of Nitrates formed in HINKLEY GRAVELY SANDY LOAM at 1 week intervals over a period of six weeks. Soils having been treated as shown.

Top-Soil

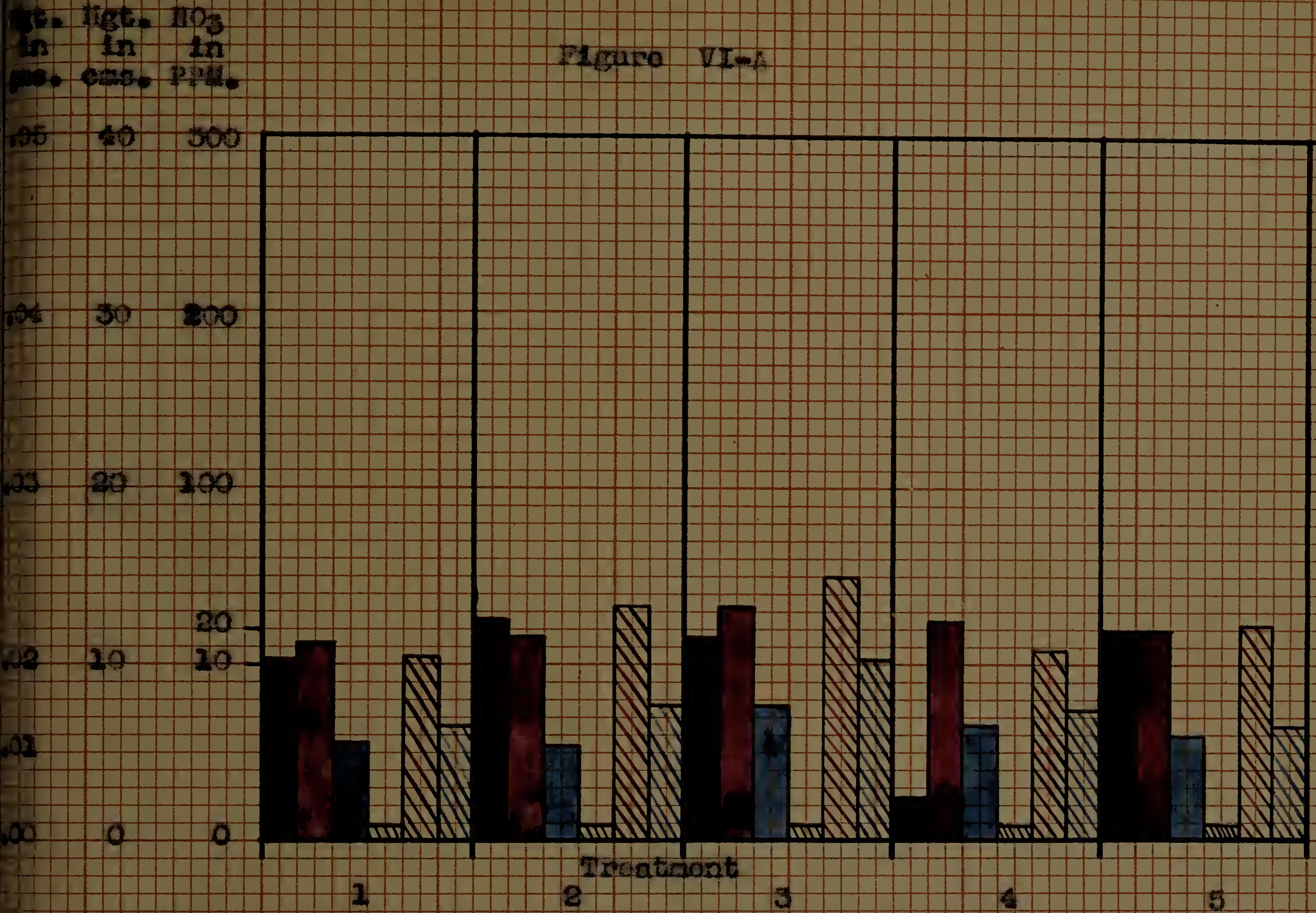
Treatment	Initial	Weeks 1st	2nd	3rd	4th	5th	6th
Soil	-1	-1	-1	-1	-1	11.10	5.52
$NH_4H_2PO_4$	-1	-1	-1	1.70	2.85	15.62	24.99
$(NH_4)_2SO_4$	-1	-1	-1	-1	1.50	12.07	17.22
Dried Blood	-1	-1	-1	1.05	1.75	2.70	-1
C. S. Meal	-1	-1	-1	1.45	2.35	20.83	18.60

Sub-Soil

Soil	No	No	No	No	-1	-1	No
$NH_4H_2PO_4$	No	No	-1	-1	-1	-1	-1
$(NH_4)_2SO_4$	No	NO	-1	-1	No	-1	-1
Dried Blood	No	No	-1	-1	-1	-1	-1
C. S. Meal	No	No	-1	-1	-1	-1	-1

-1 = less than 1 PPM.

Figure VI-A



Graphic representation of Table VI-A and showing plant growth in relation to the Maximum Nitrate Accumulation.

Table VI -A

Relative HEIGHT and WEIGHT of Barley plants grown in the Top-Soil and in the Sub-Soil of HINKLEY GRAVELLY SANDY LOAM. Soils having been treated as indicated.

	Treatment				
Top-Soil	1- Soil	2- $NH_4H_2PO_4$	3- $(NH_4)_2SO_4$	4- D. Blood	5- C. Meal
HEIGHT----	11.31	11.42	13.22	12.49	12.14
WEIGHT----	.0118	.0106	.0148	.0126	.0123
Sub-Soil					
HEIGHT----	10.75	13.66	15.06	11.18	12.81
WEIGHT----	.0128	.0163	.0208	.0146	.0161

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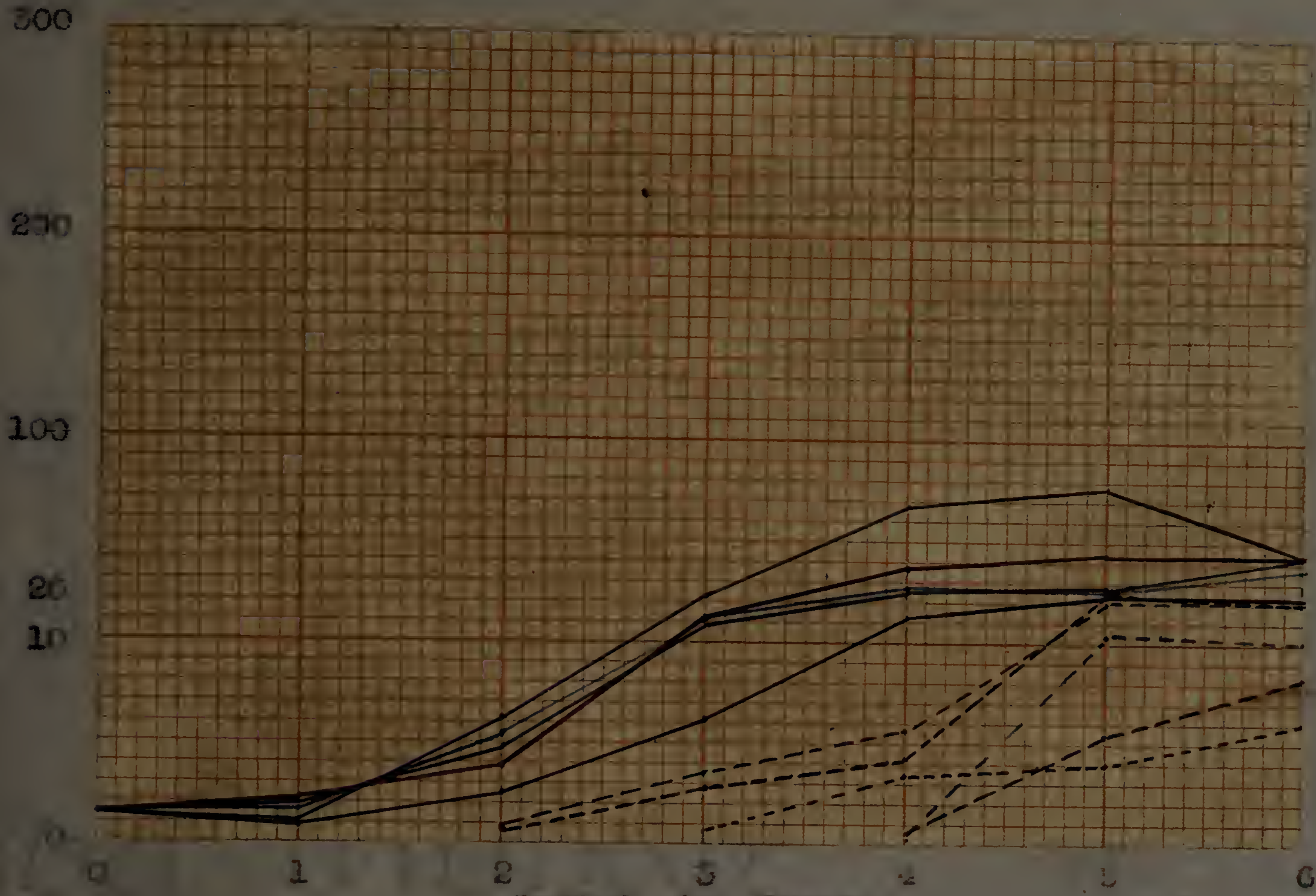
Nitrates in PPM.

Figure VII



Period in Weeks

Table VII

PPM of Nitrates formed in MERRIMAC SANDY LOAM at intervals. Over a period of six weeks. Soils having been treated as shown.

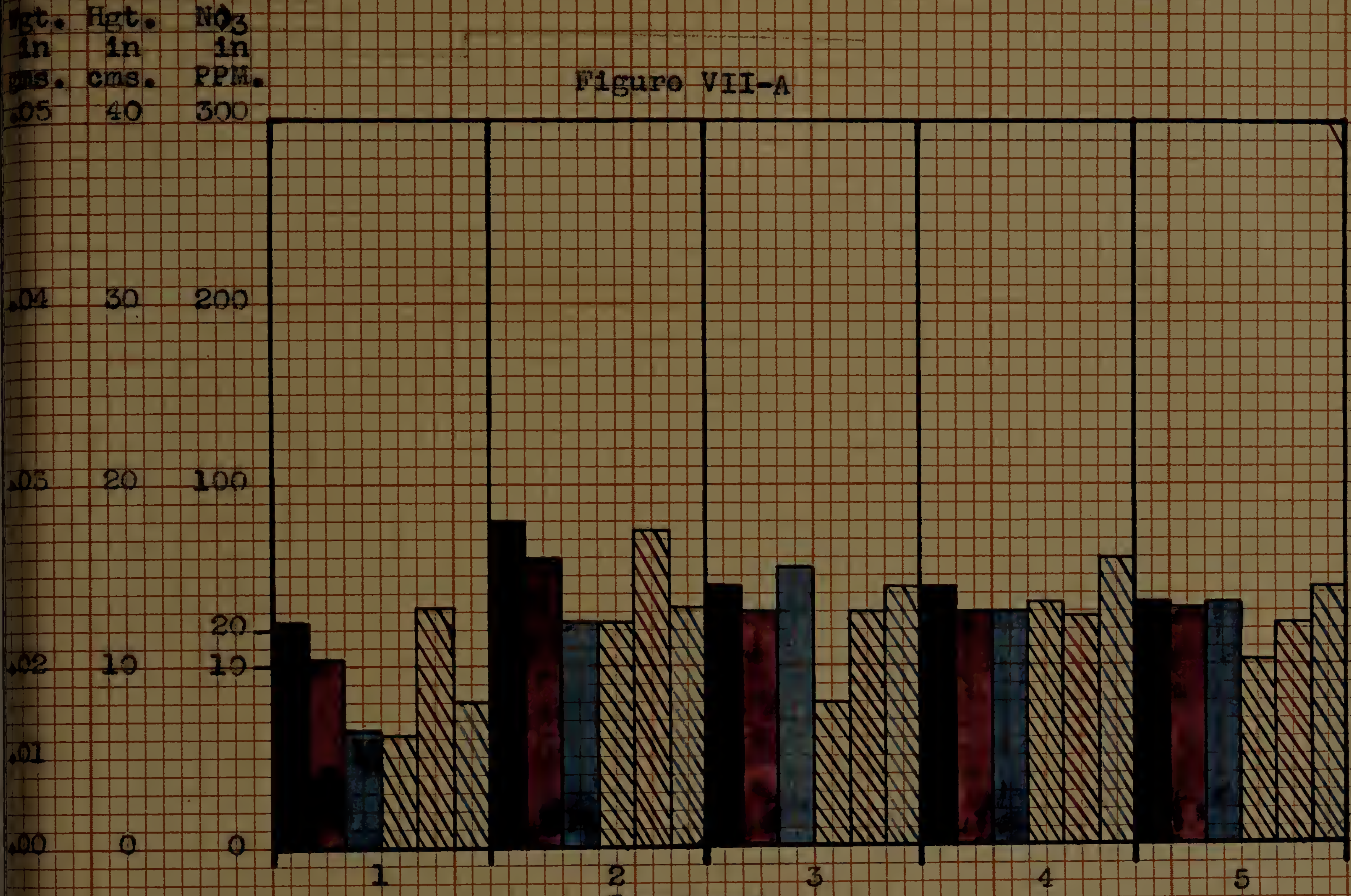
Top- Soil

Treatment	Initial	Weeks 1st	2nd	3rd	4th	5th	6th
Soil	1.66	-1	2.50	6.32	16.44	25.00	24.32
$NH_4H_2PO_4$	1.66	1.15	6.25	22.15	67.15	79.86	44.10
$(NH_4)_2SO_4$	1.66	2.00	4.96	13.00	24.07	27.75	44.10
Dried Blood	1.66	2.18	3.94	16.65	37.50	43.30	44.10
C. S. Meal	1.66	1.84	5.45	15.35	27.15	26.38	37.50

Sub-Soil

Soil	No	-1	-1	-1	3.40	4.00	6.00
$NH_4H_2PO_4$	No	-1	-1	3.55	5.94	20.96	22.50
$(NH_4)_2SO_4$	No	-1	-1	-1	-1	5.56	8.10
Dried Blood	No	-1	-1	2.72	4.11	27.70	23.16
C. S. Meal	No	-1	-1	-1	-1	11.34	10.00

Figure VII-A



Graphic representation of Table VII-A and showing plant growth in relation to the Maximum Nitrate Accumulation

Table VII- A

Relative HEIGHT and WEIGHT of Barley plants grown in the Top-Soil and in the Sub-Soil of MERRIMAC SANDY LOAM. Soils having bee treated as indicated.

	Treatment				
Top-Soil	1- Soil	2- $NH_4H_2PO_4$	3- $(NH_4)_2SO_4$	4- D.Blood	5- C/Meal
HEIGHT----	10.45	16.05	13.34	13.22	13.32
WEIGHT----	.0127	.0223	.0158	.0130	.0133
Sub-Soil					
HEIGHT----	13.09	17.64	13.23	12.80	12.66
WEIGHT----	.0164	.0230	.0145	.0163	.0144

Figure VIII

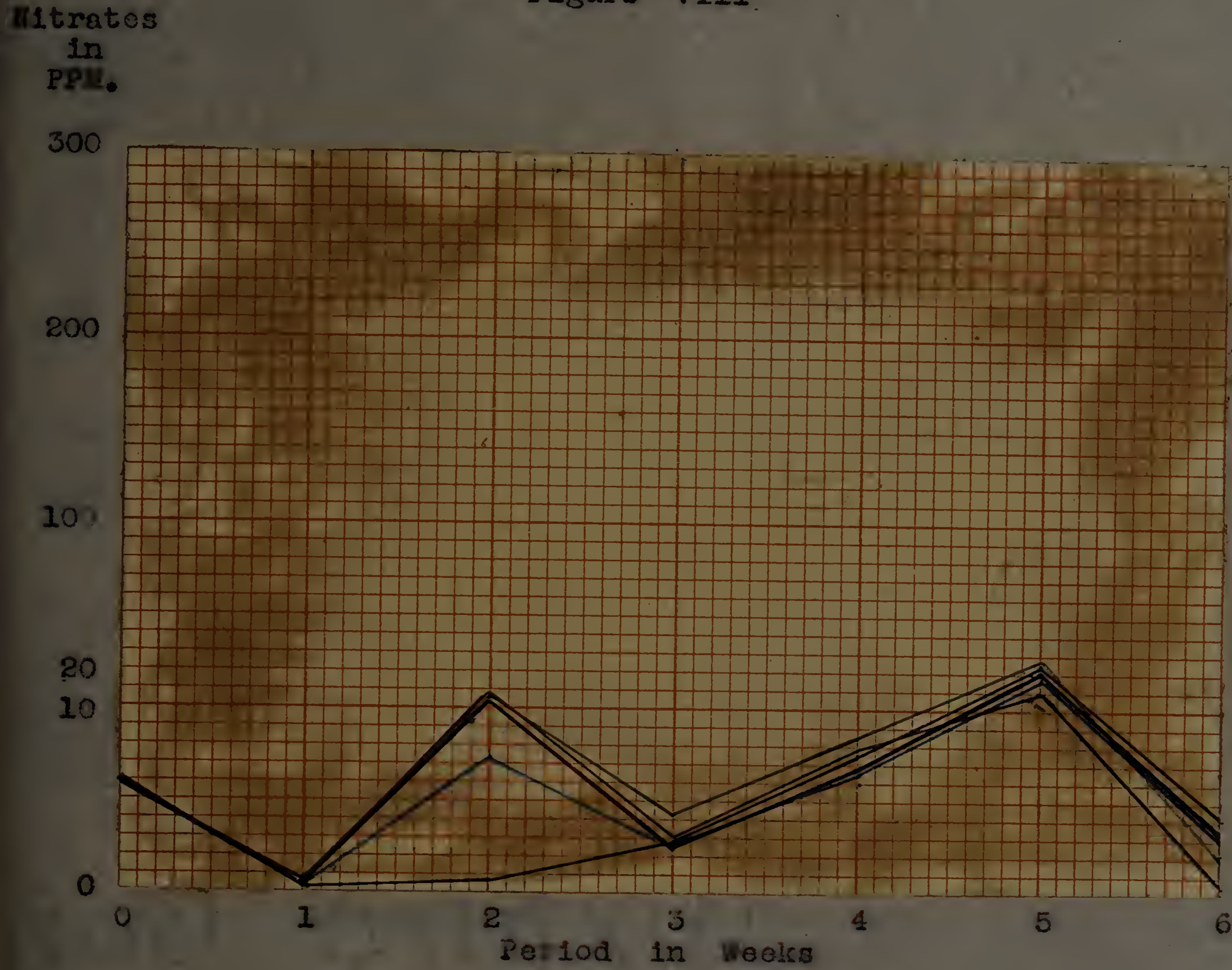


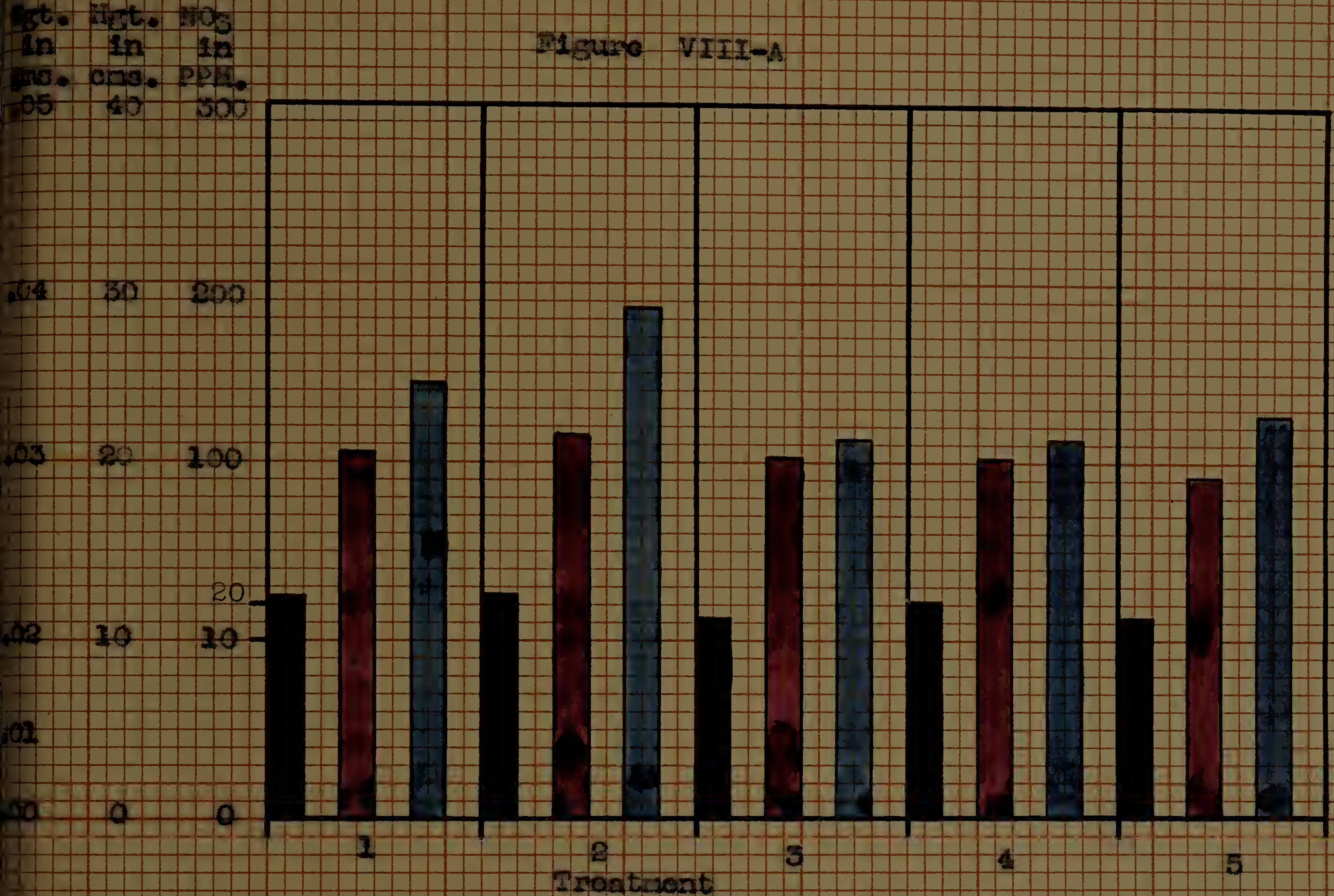
Table VIII

PPM of Nitrates formed in MUCK soil at 1 week intervals over a period of six weeks. Soils having been treated as shown.

Top-Soil

Treatment	Initial	1st	2nd	Weeks 3rd	4th	5th	6th
Soil	6.05	-1	-1	2.85	7.45	26.40	4.18
$NH_4H_2PO_4$	6.05	-1	11.55	4.10	8.55	27.99	2.14
$(NH_4)_2SO_4$	6.05	-1	12.30	3.00	7.62	15.19	-1
Dried Blood	6.05	-1	10.80	2.66	6.87	20.00	3.64
C. S. Meal	6.05	-1	7.20	2.68	6.75	17.55	3.12

Figure VIII-A



Graphic representation of Table VIII-A and showing plant growth in relation to the Maximum Nitrate Accumulation.

Table VIII-A

Relative HEIGHT and WEIGHT of Barley plants grown in Top-Soil and in the Sub-Soil of MUCK soil.
Soil having been treated as indicated.

Treatment

	1- Soil	2- $NH_4H_2PO_4$	3- $(NH_4)_2SO_4$	4- D.Blood	5- C.Meal
HEIGHT--	20.7	21.7	20.2	20.2	19.03
WEIGHT--	.0344	.0387	.0312	.0314	.0327

Figure IX

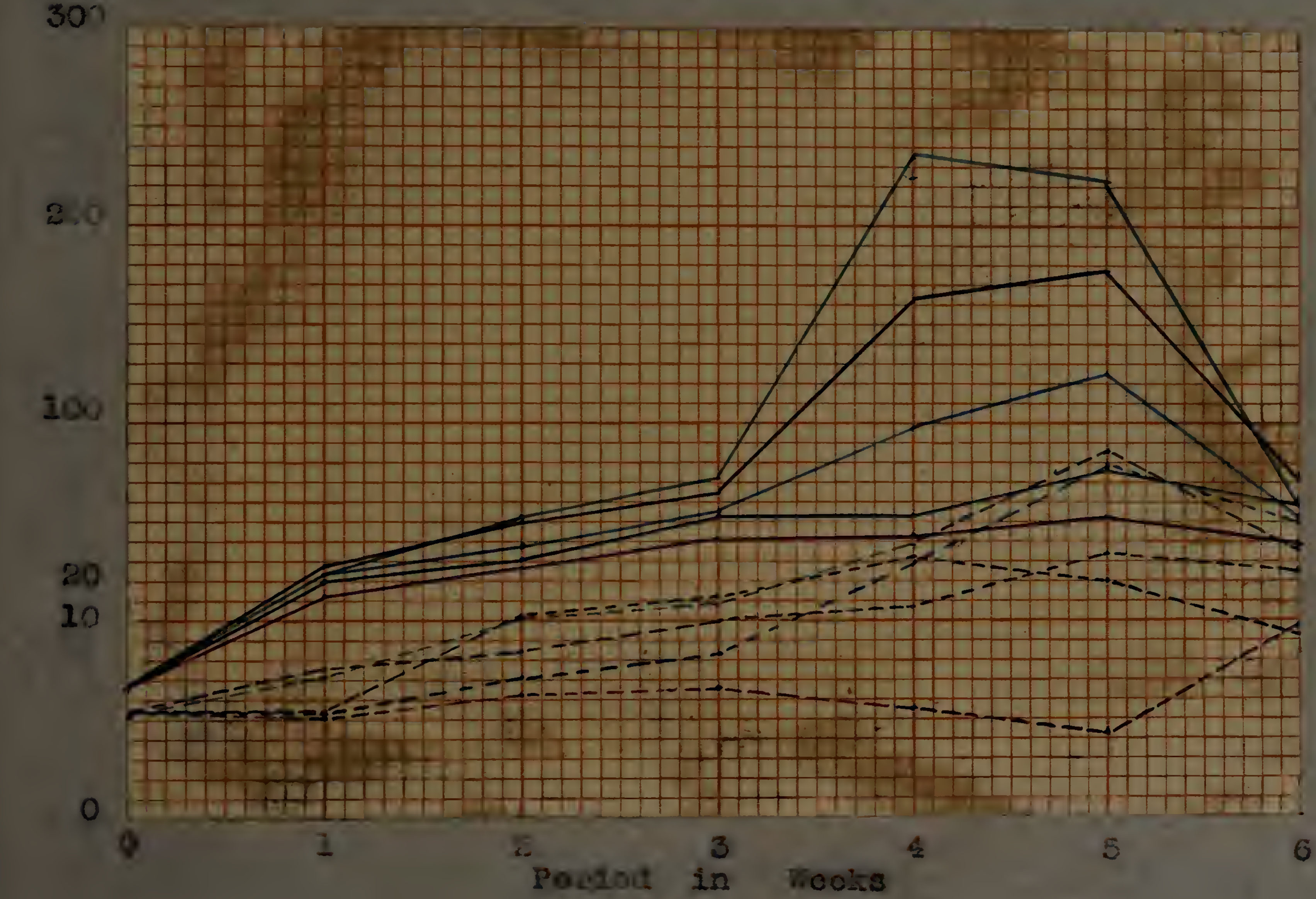


Table IX

PPM of Nitrates formed in SUFFIELD FINE SANDY LOAM at 1 week intervals over a six week period. Soils having been treated as shown.

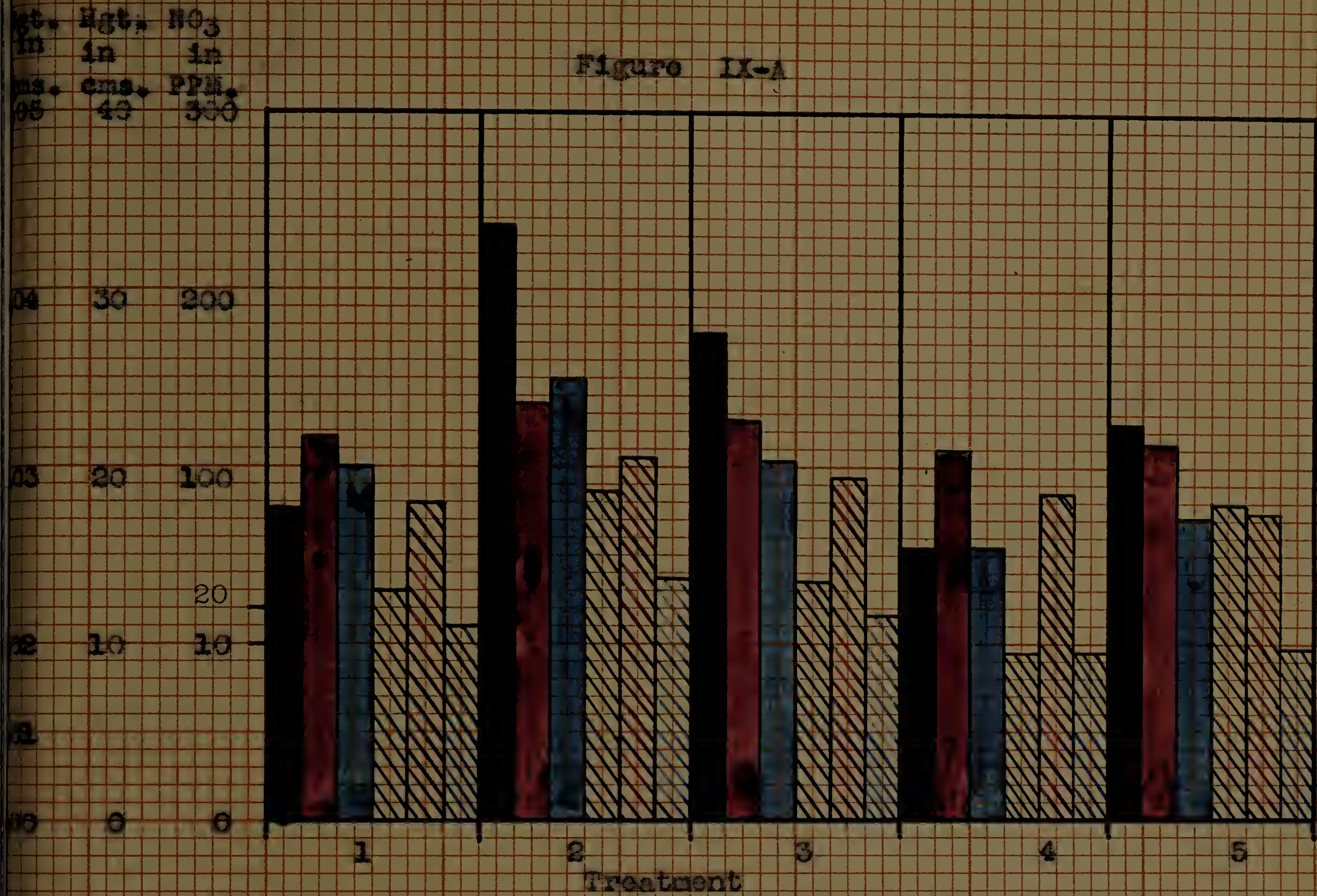
Top-Soil

Treatment	Initial	Weeks 1st	2nd	3rd	4th	5th	6th
Soil	6.83	20.00	32.17	52.25	53.55	77.74	59.55
$NH_4H_2PO_4$	6.83	21.00	53.25	71.30	235.83	222.22	59.55
$(NH_4)_2SO_4$	6.83	26.80	50.80	66.35	161.10	176.31	72.00
Dried Blood	6.83	18.26	28.65	40.25	43.59	52.98	39.00
C. S. Meal	6.83	21.00	38.35	56.75	98.20	125.00	55.50

Sub-Soil

Soil	6.52	6.57	11.75	17.56	33.80	20.28	9.27
$NH_4H_2PO_4$	6.52	7.09	10.15	13.12	39.36	85.00	58.72
$(NH_4)_2SO_4$	6.52	7.48	8.55	10.00	13.05	33.18	27.56
Dried Blood	6.52	5.20	6.25	6.70	5.55	4.05	9.68
C. S. Meal	6.52	6.50	7.10	8.35	30.00	80.00	50.00

Figure IX-A



Graphic representation of Table IX-A and showing plant growth in relation to Maximum Nitrate Accumulation.

Table IX-A

Relative HEIGHT and WEIGHT of Barley plants grown in the Top-Soil and in the Sub-Soil of SUFFIELD FINE SANDY LOAM. Soils having been treated as indicated.

	Treatment 1- Soil	 2- $NH_4H_2PO_4$	 3- $(NH_4)_2SO_4$	 4- D.Blood	 5- C.Meal
Top-Soil					
HEIGHT----	21.91	23.56	22.65	21.02	21.19
Weight----	.0300	.0351	.0307	.0252	.0271
Sub-Soil					
HEIGHT----	18.38	20.48	19.13	18.39	17.28
WEIGHT----	.0212	.0233	.0311	.0192	.0197

Nitrates
in
PPM.

Figure X

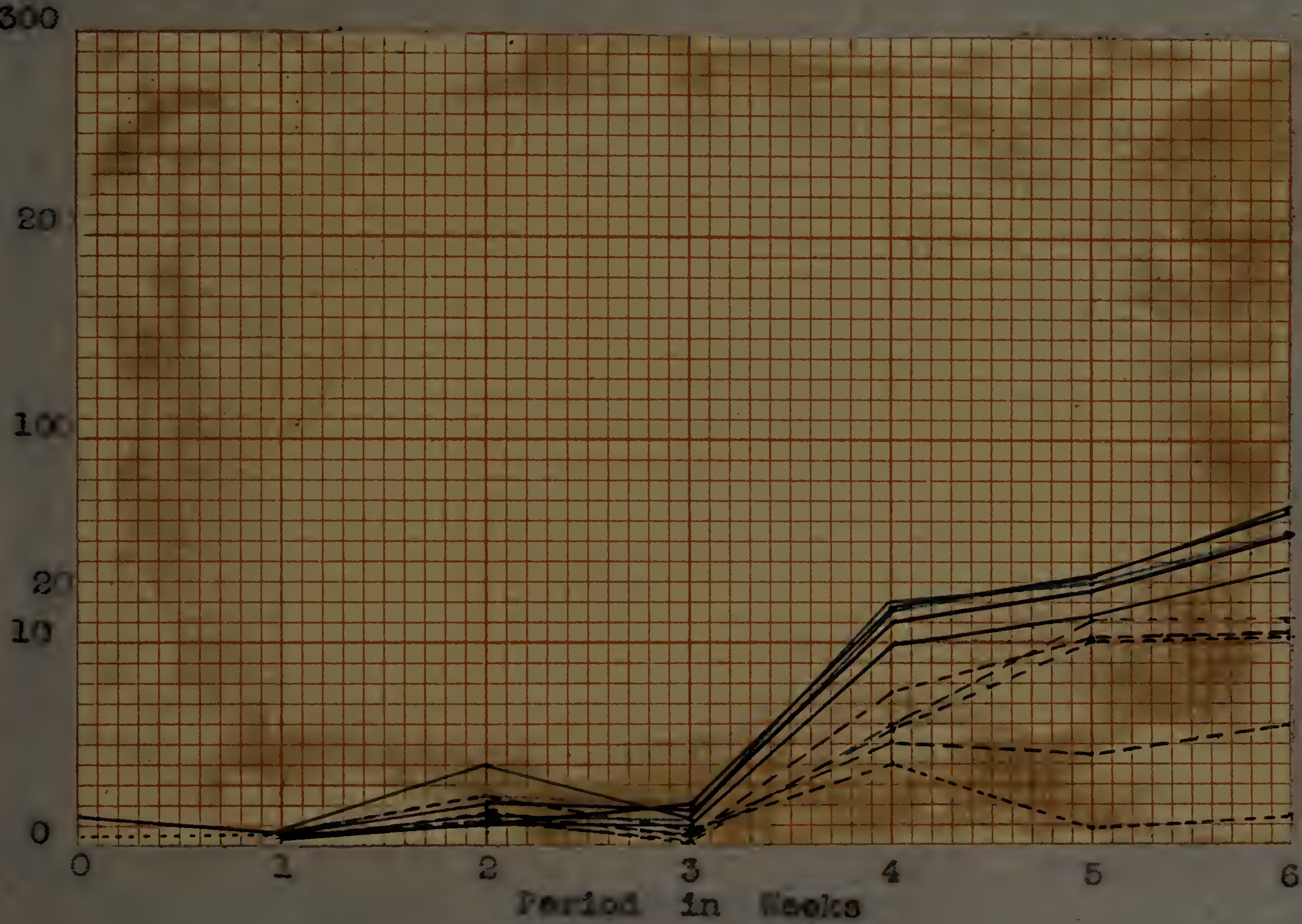


Table X

PPM of Nitrates formed in WEATHERSFIELD LOAM at 1 week intervals over a six week period. Soils having been treated as shown.

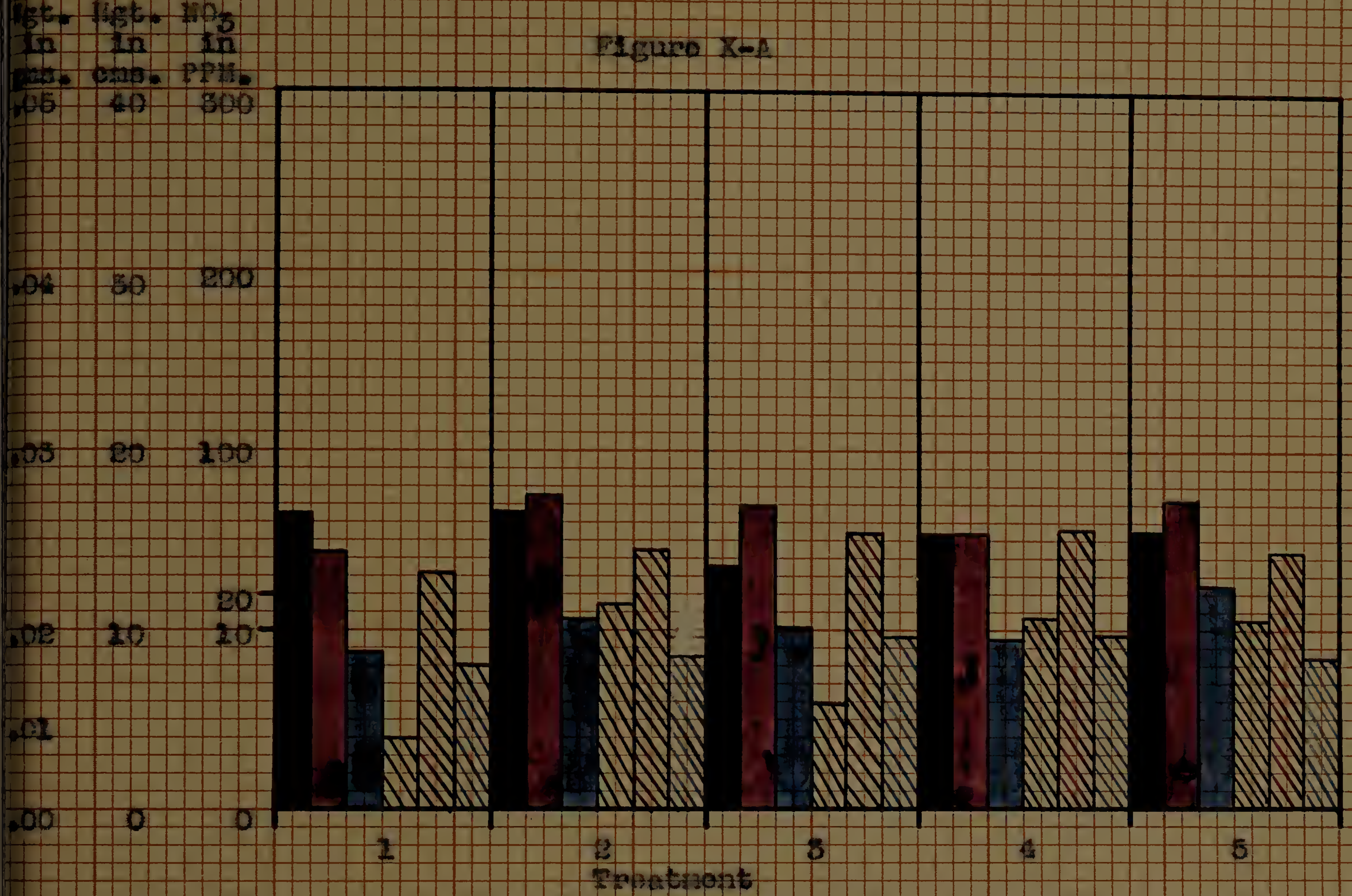
Top-Soil

Treatment	Initial	1st	2nd	3rd	4th	5th	6th
Soil	1.50	-1	1.03	2.00	18.10	32.80	66.00
$NH_4H_2PO_4$	1.50	-1	4.00	1.41	18.10	32.20	63.65
$(NH_4)_2SO_4$	1.50	-1	1.30	1.00	10.00	17.00	37.95
Dried Blood	1.50	-1	2.00	1.81	15.00	26.60	54.65
C. S. Meal	1.50	-1	1.25	1.23	20.00	30.20	54.90

Sub-Soil

Soil	-1	-1	2.61	-1	4.00	-1	1.58
$NH_4H_2PO_4$	-1	-1	1.25	-1	6.00	15.00	16.62
$(NH_4)_2SO_4$	-1	-1	1.89	-1	5.02	4.44	6.00
Dried Blood	-1	-1	1.80	-1	7.64	10.70	13.88
C. S. Meal	-1	-1	1.41	-1	5.90	12.18	14.42

Figure X-A



Graphic representation of Table X-A and showing plant growth in relation to the Maximum Nitrate Accumulation

Table X-A

Relative HEIGHT and WEIGHT of Barley plants grown in the Top-Soil and in the Sub-Soil of WEATHERSFIELD LOAM. Soils having been treated as indicated.

	Treatment 1- Soil	2- $NH_4H_2PO_4$	3- $(NH_4)_2SO_4$	4- D.Blood	5- C.Meal
Top-Soil					
HEIGHT----	14.65	17.61	17.06	15.75	17.42
WEIGHT----	.0176	.0217	.0200	.0187	.0226
Sub-Soil					
HEIGHT----	15.38	14.61	15.55	15.86	14.11
WEIGHT----	.0161	.0171	.0192	.0196	.0175

Nitrates in PPM.

Figure XI

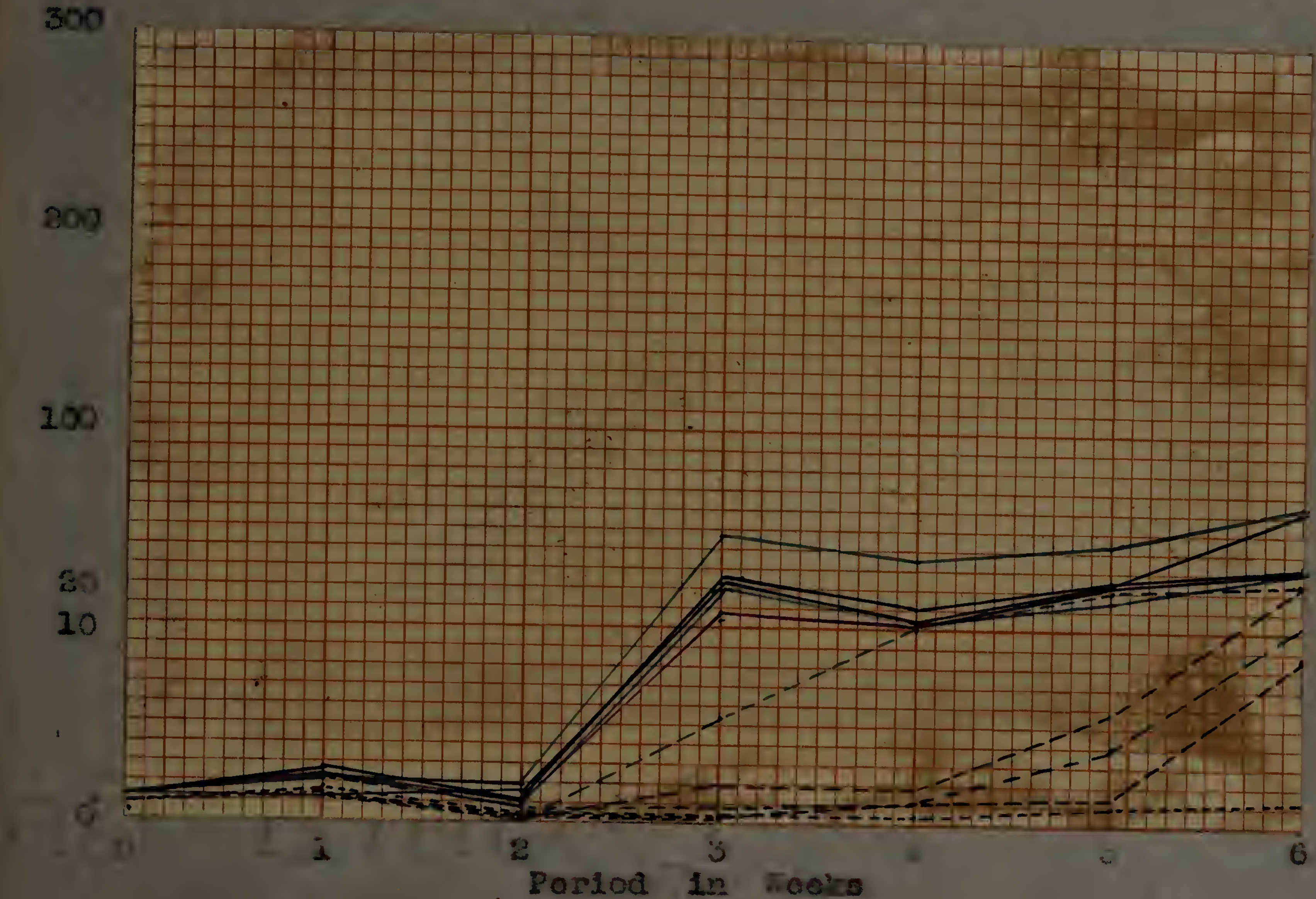
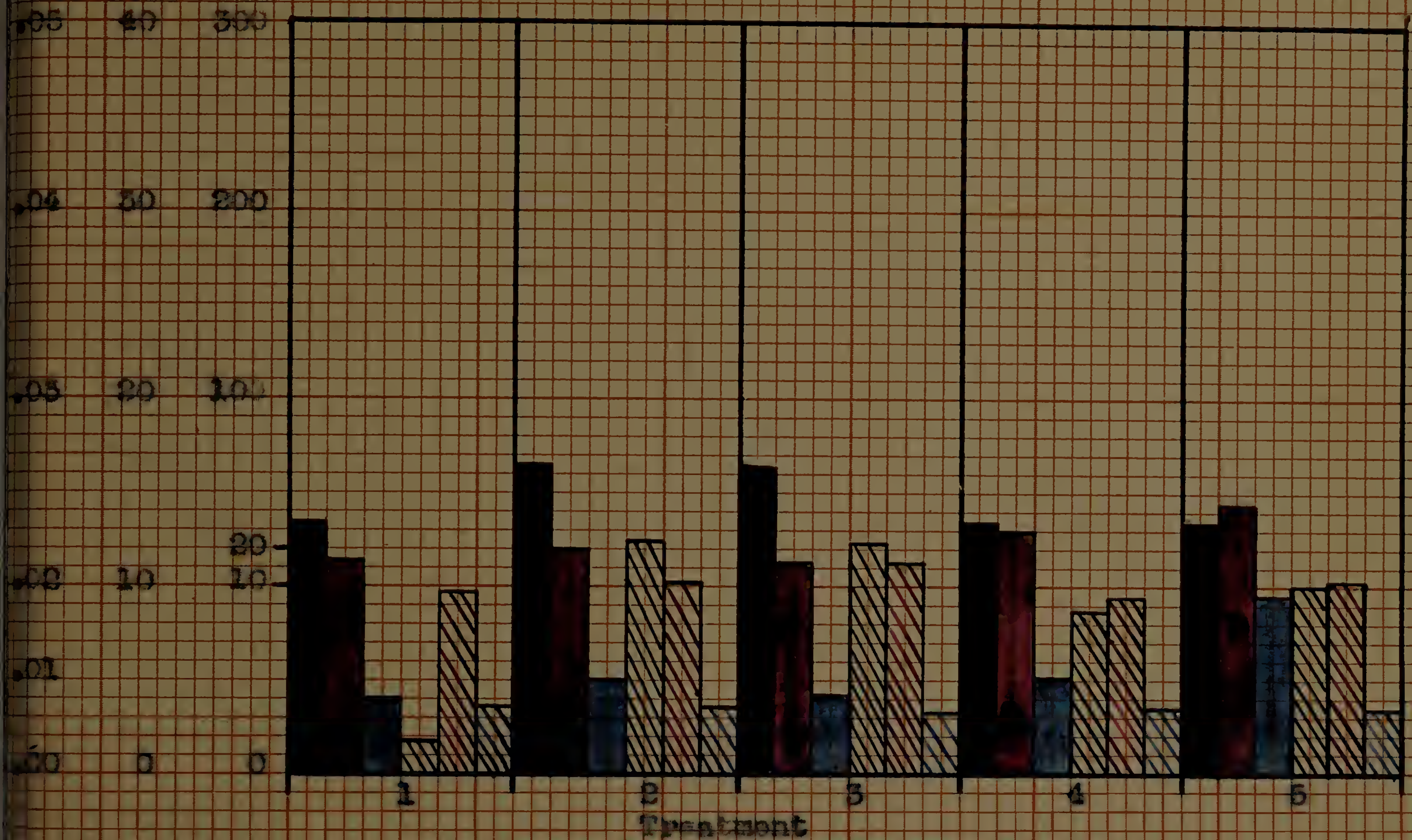


Table XI

PPM of Nitrates formed in WORTHINGTON LOAM at 1 week intervals over a period of six weeks. Soils having been treated as shown.

Treatment	Initial	1st	2nd	3rd	4th	5th	6th
Top-Soil				Weeks			
Soil	1.11	2.60	1.11	25.00	15.30	26.80	37.40
$NH_4H_2PO_4$	1.11	2.18	1.75	46.00	36.20	43.10	66.22
$(NH_4)_2SO_4$	1.11	1.15	1.46	23.85	12.50	25.33	63.42
Dried Blood	1.11	2.36	-1	14.25	11.70	25.11	35.15
C. S. Meal	1.11	2.35	1.64	20.95	12.86	18.78	35.09
Sub-Soil							
Soil	-1	1.87	-1	-1	-1	1.0[illegible]	1.22
$NH_4H_2PO_4$	-1	1.30	-1	5.35	10.80	20.00	24.20
$(NH_4)_2SO_4$	-1	1.07	-1	2.00	1.72	5.51	23.20
Dried Blood	-1	1.33	-1	-1	1.10	1.26	8.94
C. S. Meal	-1	2.25	-1	-1	1.00	5.00	11.19

Figure XI-A



Graphic representation of Table XI-A and showing plant growth in relation to Maximum Nitrate Accumulation

Table XI-A

Relative HEIGHT and WEIGHT of Barley plants grown in the Top-Soil and in the Sub-Soil of NORTHINGTON LOAM. Soils having been treated as indicated.

Treatment

Top-Soil	1- Soil	2- $NH_4H_2PO_4$	3- $(NH_4)_2SO_4$	4- D.Blood	5- G.Meal
HEIGHT----	11.47	12.12	11.45	13.00	14.54
WEIGHT ----	.0081	.0092	.0085	.0108	.0109
Sub-Soil					
HEIGHT----	9.86	10.01	11.15	9.76	10.22
WEIGHT----	.0074	.0070	.0064	.0070	.0070

"Perfect

S.A.

DISCUSSION OF EXPERIMENTAL RESULTS

The results obtained from the different topsoils and subsoils, with the exception of the Hadley silt loam, show a definite order of results. The moisture content of the topsoil was greater than that of the subsoil. It ranged from 3.4 per cent in the topsoil of the Weathersfield loam to 0.63 per cent in the topsoil of the Hadley silt loam. In the subsoils the moisture content ranged from 1.7 per cent in Weathersfield loam to 0.46 per cent in Merrimac sandy loam. The moisture-holding capacity was greater in the topsoil than in the subsoil. It varied from 70.3 per cent in Cheshire fine sandy loam to 28.8 per cent in Merrimac sandy loam. In the subsoil the range was from 59.9 per cent in Cheshire fine sandy loam to 27.7 per cent in the Merrimac sandy loam.

Loss on ignition of the soils showed a great variation in the soil types studied but, with the exception of Hadley silt loam, the topsoil showed a greater loss on ignition than did the subsoil. This can be understood because loss on ignition is very closely associated with the organic matter content of the soil, and organic matter is ordinarily more abundant in the topsoil than in subsoil. The loss on ignition varied in the topsoil from 8.3 per cent in Cheshire sandy loam to 1.84 per cent in Merrimac sandy loam. In the subsoil the range was from 4.7 per cent in Gloucester fine sandy loam to 0.48 per cent in Hinkley gravelly sandy loam. Cheshire fine sandy loam showed less loss on ignition (6.3 per cent) than did the Cheshire sandy loam (8.3 per cent); and yet the moisture-holding capacity of the Cheshire fine sandy is greater. From the results of the mechanical analysis the silt fraction of the fine sandy loam is 53 per cent as compared with 46 per cent for the sandy loam. In the Merrimac sandy loam the loss on ignition is 1.84 per cent, the silt fraction is 16 per cent and the moisture-holding capacity is 28 per cent.

It would seem from these data that the moisture-holding capacity of a soil corresponds closely to the organic matter content in combination with the silt fraction. Alteration of either will change the moisture-holding capacity.

In all soils, excepting Hadley silt loam, the total nitrogen content of the soil corresponds with the loss on ignition. Total nitrogen in the soils ranged from 2,056 ppm. in Cheshire sandy loam to 507 ppm. in Merrimac sandy loam, topsoils; in the subsoils the nitrogen content was from 784 ppm. in the Gloucester fine sandy loam to 74 ppm. in the Hinkley gravelly sandy loam.

In all soils, excepting Hadley silt loam, the pH value was higher in the subsoil than in the topsoil. The clay fraction was greater in the subsoil than in the topsoil. The occurrence of such a difference can probably be attributed to the result of leaching brought about by water. The basic elements have been translocated downward. The clay fraction has probably been somewhat increased in the subsoil as a result of the fine material having been leached from the topsoil.

The general characteristics of the topsoil and subsoil of the Hadley silt loam are in an order reverse to that of the characteristics of the topsoil and subsoil of the other soil types. In the Hadley silt loam the moisture-holding capacity, loss on ignition, and total nitrogen content are greater in the subsoil than in the topsoil. The pH of the topsoil is higher in the topsoil than in the subsoil. These differences in this soil type as compared with the other types may be due largely to the difference in the origin of the soil. Hadley silt loam is an alluvial soil and it has been derived from areas in the Berkshire range and farther north, even into New Hampshire and Vermont. The topsoil was deposited by the flood of 1936 and the present subsoil existed as topsoil before the flood. The subsoil while it served as surface soil was covered with vegetation and thus organic matter was able to accumulate. The pH value of the present topsoil is probably the result of the soil having been derived largely from limestone areas, the calcium carbonate being responsible for the higher basicity. Table 3 shows Hadley silt loam to be medium-high in calcium content.

In the nitrification studies Cheshire fine sandy loam was the only soil to show a greater nitrate accumulation in the subsoil than in the topsoil. However, in the subsoil of certain of the soils, under certain fertilizer treatments, nitrification was more efficient than in the topsoil of other of the soils to which nitrogen had been applied in the form of a different fertilizer.

The nitrate accumulation in these soils varied with the source of nitrogen; certain of the soil types accumulated more nitrates than did other soil types given nitrogen from the same source. When the source of nitrogen was changed the relation, as above stated, did not follow in the same order. The results show that when nitrification of the soil's own nitrogen was studied the nitrate accumulation was greatest in Gloucester fine sandy loam, the maximum being 153 ppm. the Hadley silt loam ranked second with 125 ppm. On the other hand, when the soils were treated with ammonium phosphate as a source of nitrogen, Hadley silt loam showed the greatest accumulation of nitrate (281 ppm.), and Suffield ranked second with an accumulation of 178 ppm. When ammonium sulphate was used as a source of nitrogen Suffield fine sandy loam lead with an accumulation of 178 ppm. and Hadley silt loam showed 173 ppm. When dried blood was used as the source of nitrogen Gloucester fine sandy loam showed the greatest efficiency among the soils, the maximum accumulation being 142 ppm. Hadley silt loam was second with 133 ppm. When cotton-seed meal was used Hadley silt loam accumulated the most nitrates (169 ppm.) and Gloucester fine sandy loam ranked second with an accumulation of 129 ppm.

Among the subsoils the Hadley silt loam showed the greatest nitrate accumulation under all treatments. Suffield fine sandy loam ranked second in nitrification of the native nitrogen and also when it was treated with ammonium phosphate. When the soils were treated with ammonium sulphate Hadley silt loam remained first with an accumulation of 189 ppm. but second place was taken by Agawam fine sandy loam, having accumulated 78 ppm.

When the soils were treated with dried blood the nitrate accumulation in the Hadley silt loam was 136 ppm. compared with 45 ppm. in the Cheshire sandy loam which ranked second. The nitrates in the Hadley silt loam when cotton-seed meal was used as a source of nitrogen was 150 ppm., and the Suffield fine sandy loam ranked second with 80 ppm. It can be seen from these data that each soil responded quite differently to different sources of nitrogen.

In Agawam fine sandy loam, (Table I) nitrate accumulation decreased during the first week, while through the second and third weeks it showed rapid accumulation, and the rise continued to a maximum after the fourth week. Results for the period shown indicate that ammonium phosphate was most readily nitrified. A total of 115 ppm. of nitrates accumulated from such treatment. In the subsoil ammonium sulphate gave best results. Seventy-eight ppm. of nitrate nitrogen accumulated under such treatment. This exceeds the accumulation in the topsoil when dried blood was used.

In Cheshire sandy loam Table II the topsoil showed a decidedly greater nitrifying efficiency than did the subsoil. There was a continuous increase in nitrate accumulation throughout the period, the maximum accumulations being obtained from the use of ammonium phosphate (149 ppm.) and ammonium sulphate (148 ppm.). The maximum accumulation in the subsoil (47 ppm.) was obtained when ammonium sulphate was employed.

Nitrate accumulation in Cheshire fine sandy loam Table III was exceedingly low throughout the period. After the fifth week the nitrate accumulation when ammonium phosphate was used had reached 7.1 ppm., and at the end of the sixth week the accumulation was only 26 ppm. When the topsoil was treated with ammonium phosphate nitrate accumulation reached a maximum of 2.7 ppm. Nitrification was better in subsoil than in the surface-soil, both, however, were very inefficient.

In the Gloucester fine sandy loam, Table IV, the nitrate content decreased during the first week but rose abruptly through the second, third, and fourth weeks. There was a variation in the time required to reach maximum accumulation of nitrates from each fertilizer. The untreated soil reached a maximum accumulation of 153 ppm. at the end of the fifth week. Ammonium-phosphate-treated soils were continuing to show increased accumulation at the end of the sixth week. This is the only instance in the topsoils, when treated with ammonium phosphate, that nitrate accumulation was not greatest. Inasmuch as nitrates are accumulating at the end of the sixth week it would seem that potential accumulation is greater in the ammonium-phosphate-treated soil than in the untreated Gloucester fine sandy loam. The topsoil, under any treatment, showed more efficient nitrification than did the subsoil.

From Table V it can be seen that Hadley silt loam showed an extremely high and rapid nitrifying capacity. There was a slight decrease in nitrate accumulation during the first week, but by the end of the fourth week the soil treated with ammonium phosphate showed an accumulation of 281 ppm. Ammonium phosphate applied to the subsoil brought about a greater nitrate accumulation than was obtained in the topsoil under any treatment other than ammonium phosphate. Applications of ammonium sulphate, and cotton-seed meal brought about a considerable increase in nitrification. Nitrification of dried blood did not reach a maximum nitrate accumulation until the fifth and sixth weeks.

The subsoil of Hinkleygravelly sandy loam (Table VI) showed no nitrate accumulation. The topsoil responded very slowly, and in no event did nitrate accumulation exceed 10 ppm. until the end of the fifth week. Response was best when ammonium phosphate was used, maximum nitrate accumulation being 25 ppm.

The topsoil of Merrimac sandy loam (Table VII) had relatively good nitrifying capacity. A steady increase continued for a period of five weeks when a maximum accumulation of 79 ppm. was reached. Nitrates did not accumulate in the subsoil until after three weeks, and then only as a result of the soil having been treated with ammonium phosphate, and dried blood.

Suffield fine sandy loam (Table IX) showed relatively high nitrifying efficiency. Nitrate accumulation increased from the first week to the fourth and fifth weeks. The soil responded favorably to treatments of ammonium phosphate, ammonium sulphate, and cotton-seed meal. Nitrate accumulation from these substances reached 236, 178, and 125 ppm. respectively. With dried blood the maximum accumulation was less than that obtained from the soil's own nitrogen.

In Wethersfield loam (Table X) nitrification was low until the fourth week; accumulation then continued through to the sixth week. Phosphate of ammonia brought about a nitrate accumulation of 66.6 ppm. This was higher than that obtained with treatments of ammonium sulphate, dried blood, or cotton-seed meal.

In the Worthington loam (Table XI) the topsoil showed a greater nitrate accumulation than did the subsoil. Ammonium phosphate gave a maximum nitrate accumulation of 66 ppm., and evident accumulation did not begin until, during or with, the third week. When ammonium phosphate was applied to the subsoil the nitrate accumulation at the end of the fourth and fifth weeks was comparable to that from ammonium sulphate, dried blood, and cotton-seed meal in the topsoil.

The results of nitrification and plant -growth are summarized in tabular form on pages 77 and 78. The response of nitrification, and plant growth in each definite soil type to each definite treatment is shown. These tables also show which treatment gave maximum plant growth and which fertilizer provided the greatest nitrifying efficiency.

The numbers, as used in the tables, indicate the ranking position of nitrification and plant growth from a definite treatment in a definite soil type. For example: in Agawam fine sandy loam, ammonium phosphate treatment provided greatest nitrate accumulation and also greatest plant height and plant weight.

Rank of Substances in relation to Their Nitrate Accumulation, and Influence on Height and Weight of Plants When Added to a Definite Soil Type.

Top Soil

Soil Type	Native Nitrogen			Ammonium Phosphate			Ammonium Sulphate			Dried Blood			Cotton-seed Meal		
	NO_3	Plant Ht.	Plant Wt.	NO_3	Plant Ht.	Plant Wt.	NO_3	Plant Ht.	Plant Wt.	NO_3	Plant Ht.	Plant Wt.	NO_3	Plant Ht.	Plant Wt.
Agawam	4*	3	2	1	1	1	2	2	3	5	4	5	3	5	4
Cheshire (s. l.)	5	5	5	1	3	2	2	1	1	4	2	3	3	4	4
Cheshire (f.s.l.)	2	4	4	1	5	5	5	3	3	4	2	2	3	1	1
Gloucester	1	3	5	2	1	1	5	2	2	3	4	4	4	5	3
Hadley	5	4	4	1	1	1	2	3	3	4	5	5	3	2	2
Hinkley	4	5	4	1	4	5	3	1	1	5	2	2	2	3	3
Merrimac	5	5	5	1	1	1	2	2	2	4	4	4	3	3	3
Muck	2	2	2	1	1	1	5	4	5	3	3	4	4	5	3
Suffield	4	3	3	1	1	1	2	2	2	5	5	5	3	4	4
Weathersfield	2	5	5	1	1	2	5	3	3	4	4	4	3	2	1
Worthington	3	4	5	1	3	3	2	5	4	4	2	2	5	1	1

* - Numbers represent rank of substance in respect to nitrification and influence on plant growth.

Subsoil

Soil Type	Native Nitrogen			Ammonium Phosphate			Ammonium Sulphate			Dried Blood			Cotton-seed Meal		
		Plant			Plant			Plant			Plant			Plant	
	NO_3	Ht.	Wt.	NO_3	Ht.	Wt.	NO_3	Ht.	Wt.	NO_3	Ht.	Wt.	NO_3	Ht.	Wt.
Agawam	5	4	4	3	1	1	1	2	2	4	3	3	2	5	5
Cheshire (s. l.)	5	5	5	1	2	2	2	1	1	3	3	4	4	4	3
Cheshire (f.s.l.)	5	5	5	1	2	2	3	1	1	4	3	3	2	4	4
Gloucester	5	2	2	1	1	1	4	4	4	2	5	5	3	3	3
Hadley	5	4	5	1	2	1	2	1	2	4	3	3	3	5	4
Hinkley	-	5	5	-	2	2	-	1	1	-	4	3	-	3	4
Merrimac	5	3	2	2	1	1	4	2	4	1	4	3	3	5	5
Suffield	4	4	2	1	1	1	3	2	3	5	3	5	2	5	4
Wethersfield	5	5	5	1	3	4	4	2	2	3	1	1	2	4	3
Worthington	5	4	1	1	3	3	2	1	5	4	5	2	3	2	4

Nitrification, in the soils studied, became more efficient when additional nitrogen had been added to the soil, it would seem that nitrification was greatly enhanced by the ammonium phosphate. All of the soils were relatively low in phosphorus, and additional nitrogen plus phosphorus stimulated bacterial growth and thus nitrification was increased.

In the subsoil nitrification responses were shown in soils treated with ammonium phosphate. In the case of Merrimac sandy loam, however, greater response was obtained when organic matter in the form of dried blood was added to the soil. This would seem to indicate a need for organic matter, probably as a source of energy. The subsoil of the Merrimac sandy loam contained considerable phosphorus so it is reasonable to assume that nitrogen applied to this soil in organic form is more readily nitrified than nitrogen of ammonium phosphate.

In most instances ammonium sulphate nitrified more readily than cotton-seed meal, dried blood, or the native nitrogen of the soil. Exceptions to this seem to be evident where the pH value of the soil normally was relatively low and increased acidity due to the ammonium sulphate caused an inhibition of the nitrifying organisms. In certain of the subsoils use of ammonium sulphate resulted in better plant growth than when ammonium phosphate was used. Certain of the topsoil responded in like manner.

In such instances nitrate accumulation was greater in soils treated with ammonium phosphate. This would seem to indicate that perhaps sulphur was exhibiting some effect upon plant growth.

Where the addition of organic matter brings about a decrease in nitrate formation, below that from native nitrogen of the soil itself, it would seem that perhaps the C:N ratio was so disturbed as to cause a temporary decline in nitrate accumulation and some denitrification.

Plant growth did not correlate with nitrification except in very few soils. It would seem that under the conditions in which the investigations were carried out that there was probably a deficiency in the soils of certain elements that the plant needed for growth. As stated above, it can be seen that in several instances, that plant growth was best in certain of the soils to which ammonium sulphate had been added.

It is evident that there is great variation in the response of these soils to different treatments, and variation in the same soil under varied treatment.

The maximum nitrate accumulation, and the maximum plant height and weight obtained from any soil regardless of treatment is on the following page. The total nitrogen content and the pH value is also listed.

Maximum Responses of Each Soil Type

Soil Type	pH	Total Nitrogen (ppm.)	Nitrification (ppm.)	Plant Height (cms.)	Plant Weight (gms.)
SILT LOAM					
Hadley	6.8	308	281	22.5	.038
FINE SANDY LOAM					
Suffield	5.9	1,624	235	23.5	.035
Gloucester	5.4	1,096	144	21.1	.032
Agawam	5.8	939	115	24	.042
Cheshire	5.9	1,312	26	13.4	.017
SANDY LOAM					
Cheshire	5.9	2,056	149	24.8	.051
Merrimac	5.4	507	79.8	16.05	.023
LOAM					
Weathersfield	5.6	1,649	66.6	17.6	.022
Worthington	5.7	1,228	66.2	14.5	.018
GRAVELLY SANDY LOAM					
Hinkley	5.2	934	24.9	15.0	.020
[illegible]					
MUCK	5.4	2,799	27.9	21.7	.038

Under the conditions studied, it would seem evident that, when maximum conditions of plant growth, and nitrification were obtained, that there is a definite correlation of these factors with soil type. In the soils considered it can be seen, however, that nitrate accumulation does not correlate with the total nitrogen content of those soils.

There is an evident correlation between nitrification and soil pH. The pH value of Hadley silt loam is 6.8 and in these soil types, as pH decreases, there is a definite decline in nitrate accumulation.

Further consideration of the pH values (Table 4) shows that in all samples of topsoil and subsoil, excepting Hinkley gravelly sandy loam, and the subsoil of Wethersfield loam, there was a definite decrease in pH value as nitrates accumulated. The formation of nitric acid in the soil was probably responsible for the decrease in pH. In the soils that showed an exception to this, nitrification was very low or completely lacking (and there was an increase in basicity). It seems probable that where little nitrate was accumulated there was a possibility that ammonification was going on and because of the presence of the ammonium-ions the basicity of the soil increased; consequently, the rise in the pH value.

Muck soil is an unusual soil in comparison with the other soil types. It can be seen that the soil examined was over one-half organic matter (Table 1) and it had a moisture-holding capacity of 250 per cent. The soil was unusual in its nitrification, and yet plants grew well. Throughout the course of the six weeks there was a varied rise and fall in the nitrate accumulation. The maximum accumulation did not exceed 28 ppm. It would seem that this would hardly be sufficient for the production of such vigorous plants as these were. On the other hand it is not known how rapidly the nitrates were absorbed from the soil cultures by the growing plants; perhaps the nitrates were removed by the plants before they were denitrified. The soil structure and physical condition of Muck soil under laboratory conditions was much different from that normally existing in the field. The moisture content was only 60 per cent of the moisture-holding capacity and the compact heavy condition of this soil had been altered. These factors alone, in an organic soil such as Muck, would seem sufficient to alter the inhibiting affect on plant growth.

There remains a great deal of work to be done in investigations of this type, but it is reasonable to believe that sufficient data and evidence have been presented here to show that apparently identical soils may vary one from another as do individuals. General recommendations regarding soil treatment and methods of soil management are of major importance, but soils should be considered individually, and specific suggestions regarding agricultural practices and systems of soil management should be made only after special consideration of each particular soil.

SUMMARY

1- Nitrification as influenced by soil type and source of nitrogen was studied in certain of the soils of Massachusetts. The soil types considered included Agawam fine sandy loam, Cheshire sandy loam, Cheshire fine sandy loam, Gloucester fine sandy loam, Hadley silt loam, Hinkley gravelly sandy loam, Merrimac sandy loam, Muck, Suffield fine sandy loam, Weathersfield loam, and Worthington loam. The sources of nitrogen were the native nitrogen of the soil, nitrogen from ammonium phosphate, ammonium sulphate, dried blood and cottonseed meal.

2- There was a definite relation between the soil organic matter content, silt and clay fraction, and the moisture holding capacity.

3- There was a definite correlation between the loss on ignition and the total nitrogen content of the soils.

4- Contrary to the results of Gainey (16) these soils, under virgin conditions, did not show a correlation between the total nitrogen content and nitrate accumulation.

5- Nitrifying efficieny was greatly increased by the addition of ammonium phosphate. In soils low in organic matter a better response was obtained from samples treated with an organic fertilizer. This would indicate a necessity for increase in the organic matter of the soils.

6- Nitrification was affected by soil reaction. Nitrification was most efficient in near neutral soils, and as the pH value decreased there was a definite decline in nitrate accumulation.

7- Plant growth did not correlate with nitrification under the different fertilizer treatments employed. This may have been due to the lack of certain necessary nutrient elements in soils that showed high nitrate accumulation. Certain soils showed responsive plant growth when ammonium sulphate rather than ammonium phosphate was supplied; yet nitrate accumulation was greater when ammonium phosphate was applied. This would seem to indicate a response of the plants to sulphur.

8- Plant growth and nitrate accumulation were affected by soil type. Nitrification was most efficient in light, mellow soils; silt loam, fine sandy loam, and sand y loam. Plant growth was best in sandy loam.

9- Different soil classes within a soil series gave different nitrification and plant growth responses with the treatments employed.

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Date May 17, 1938