THE EFFECT OF ALFALFA AND SUGAR BEET RESIDUES ON FOLLOWING CROPS

by

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INTRODUCTION

Historical records reveal that green manuring was practiced by the Chinese 3000 years ago.

The use of alfalfa (medicago sativa) as a green manure crop has long been in vogue in most of the countries where the plant exhibits normal growth. The quality of alfalfa (medic) has been recognized by the Latin writer Columella (De Re Rustica, second book, first century A. D.) who stresses the value of the plant as cattle food as well as green manure. And throughout the centuries that followed, alfalfa has figured among the best soil-improving plants.

When - according to historical records, of course - agriculture ceased to be an art and acquired the characteristics of a science, that is at the beginning of the seventeenth century, scientists became more concerned with the causes of the phenomena they observed. In the field of agriculture, the search for "causes" became more and more intense and the era of scientific experimentation was born.

Dealing with the influence of alfalfa on the following crops, various workers arrived at different conclusions according to the prevailing ambient factors. A certain number of those factors were identified and studied separately in order to secure an explanation for the discordant results obtained.

As research progressed, the value of certain factors became more and more conspicuous. It has been established that the quality of a plant for green manure depends upon both quantity and quality of material produced; that quantity is influenced by soil fertility, soil structure, climate; that quality is, in addition, a function of plant chemical composition. The chemical nature of a plant is, in turn, dependent upon the productivity level of the medium in which it grows and also upon the stage of maturity of the plant. The part played by climate in the rate of plant growth also comes into play as a determining factor.

In view of these praenotata, and in hope to secure more adequate information, the author has been interested in studying the effect of age of alfalfa plants when used as green manure under the climatic conditions that prevail in Michigan. In this study, the value of fertilized and unfertilized plants has been compared and also the most favorable growth stage of plants for plowing under has been investigated.

Along with alfalfa studies, some work on sugar beet (Beta saccharina) green residues used as green manure was undertaken in order to find out to what extent these residues could be returned to the field as a means of increasing soil productivity.

This report summarizes the studies on the subject and points out the conclusions that have been deducted.

REVIEW OF LITERATURE

This review of literature deals mostly with the history of legumes and the steps that have marked the progress of legume knowledge up to the present time. Wilson (103),* Fred (24) and Russell (72) give a rather detailed exposé of the matter and several references have been selected from their works.

Following this historical development, a general survey of the most representative experimental findings is given as corroborative argument towards the conclusions deduced from the experimental work herein reported.

Ancient Greek and Roman Agriculture.

That Leguminosae, even before the Christian era, were known to be soil-improving crops is made obvious by the writings of Latin authors such as Virgil, Varro, Cato, and Greek authors such as Xenophon, Theocritus. Fred (24) and Harrison (28) cite these writers and give a description of the agricultural situation that prevailed in those days of early history.

In regard to legumes, Columella (De Re Rustica, second book, first century A. D.) discusses the use of vetches, peas, beans, lupines, lentils and alfalfa (medic). Varro states that lupines should be turned

* Figures in parentheses refer to Bibliography, p. 131.

under as green manure when the plants are young and that the residues should be incorporated with the soil before they dry out. He gives good advice that still holds true as to the preparation of the seed-bed, the rate of seeding and the harvesting; he recognizes the outstanding value of medic (alfalfa) as green manure and as cattle food, saying that the crop can be harvested four and six times per annum and that one jugerum (2/3 acre) will support three horses for one year.

The death of Theodosius the Great, in 395, marked the fall and disintegration of the Roman Empire. With the Collapse of Rome, most arts, including Agriculture (which, at the time, was more an art than a true science) were soon forgotten and lost in the obscurity of the Dark Ages that followed. Moreover, the continuous wars of the Medieval period were nothing to favor the expansion of art or science. Now and again, however, a monk would copy the works of Columella, Virgil, Cato, Varro, and these copies would be deposited in libraries. During the entire period that ended with the fall of Constantinople, in 1453, the few writers, such as Palladius, Crescenzi and the various authors of the Geoponici, plagiarized the Roman and the Greek. The Roman agricultural literature was condensed into one volume around 1240 by a senator of Bologna, Petrus Crescentius (De Agricultura Vulgare. Augsburg, 1471).

Beginnings of Agricultural Science (XVIth century).

a) Principle of vegetation (1600-1750).

It was not until the Renaissance, in the sixteenth century, that agricultural literature came back to life.

As a general rule, up to 1700, most authors were inspired by the Roman and the Greek writers as to both form and substance. According to McDonald (58), in his "A gricultural writers", only 5 writers are to be found from 1200-1500; from 1500-1600, 12 authors; from 1600-1700, 63 authors; from 1700-1800, over 200 authors. The earliest writers published modest tracts, but later Markham, Hartlib, Bradley, Young, required from 10 to 20 volumes. As reported by Johnstone (37, 38), these writers would generally include Virgil's classical "O fortunatos nimium, sua si bona norint, Agricolas" (Ex Georgics, II, 458-459) and would praise the farmer by all kinds of flatteries. It would be mentioned, for instance, how the Roman senate ordered a Latin translation of the 28 books on agriculture written by the conquered Carthaginian general Mago; how Cincinnatus was called from the plow to become dictator. Later on, along with classical doctrines, consideration would be given to the possibility of agricultural practices varying with locality, and statements were issued that suggested the logic of a change in the absolute rules given by the Latin or Greek predecessors. The minds were open to research and people felt the need for more controlled knowledge. Olivier De Serres, in 1600, seems to be the first to have given importance to agriculture and might well be considered the Father of Agriculture of the Western World.

One of the first questions to be investigated was that of the principle of vegetation. Francis Bacon (5) in 1627, believed that water was the only plant food. And so did Van Helmont (31) and Boyle (14). Glauber (26), in 1656, and Mayow (57), in 1674, thought that saltpetre was the principle of vegetation. Woodward (110), in 1699, regarded earth as the sole plant nutrient. Tull (82), in 1731, summarizes the prevalent ideas of the time by saying that no one knew which really was the plant food: water, nitre, earth, air or fire.

As the search for the principle of vegetation was progressing, more and more became known about agricultural practices. Andrew Yarranton, in 1663, (The Great Improvement of Lands by Clover, or the Wonderful Advantage by Right Management of Clover) thought that clover improved the soil and was profitable to succeeding crops. He also advised to lime freely. John Worlidge, in 1681, (Systema Agriculturae. The Mystery of Husbandry Discovered) and Giles Jacob, in 1717, (The Country Gentleman's Vade-mecum), recommended that clover and rye grass be sown together to improve the soil and furnish better herbage for cattle.

At this time, no schools were to be found, although Columella (first century A. D.) had complained about not having any. In 1651, Samuel Hart proposed the establishment of schools for the teaching of Agriculture and outlined a program of studies. His requests were never granted. However, some serious consideration was now being given to Agriculture: in 1664, the Royal Society of London, founded in 1660, sent out to landlords a questionnaire bearing on agricultural practices. These reports can be found in Volume X of the classified papers of the Royal Society, and have been analyzed by Lennard (46) in 1932.

The answers to this inquiry were of scant scientific value. Those that answered the questions belonged to the well-educated class and did not know too much about farm practices. They were primarily interested in social activities, arts and literature, and their Greek and Latin quotations reveal that Rhetoric was more important in their reports than scientific accuracy. They seem to be more interested in making a good impression and their answers appear to be based more upon what they read than what they actually did. Nevertheless, mention is made of the use of the microscope, which indicates that some scientific interest was to be found.

b) Plant nutrients (1750-1850).

In 1757, as no one yet had solved the problem of the principle of vegetation, Home (34) tried to tackle the question by studying the mode of plant nourishment. His conclusions were that not only one, but several things, such as air, water, earth, salts and fire in a fixed state were taken in by plants. Other workers became interested in Home's conclusions and re-oriented their research according to the new goal. Wallerius (97), in 1761, basing himself on the principle "Nutritio non fieri potest a rebus heterogeneis, sed homogeneis", suggested humus as the "nutritiva" and the other soil constituents as "instrumentalia". De Saussure, in 1804, proved that plants respire, i.e. absorb oxygen and expel carbon dioxide, and that they take their carbon from the air. This work marks a turning point in the history of the young science of Agriculture and also marks the point of bifurcation from which Plant Physiology has originated and developed as a separate science. Priestly and Ingenhous claimed that plants used up molecular nitrogen, but De Saussure rejected the statement.

Neglecting the numerous scientific findings of De Saussure, Thaer published his "Grundsatze der rationellen Landwirtschaft" in 1809. Four years later, in 1813, Davy (22) launched his "Elements of Agricultural Chemistry". This book deals with chemistry, plant physiology and botany, and may be considered the first serious textbook on agriculture.

However, both Thaer's and Davy's books became the classical texts of the day. Davy, prior to Liebig, anticipated the value of mineral fertilizers and stressed the importance of ammonia as a source of nitrogen.

Establishment of Agriculture as a Science (XIXth century).

It was not until J.-B. Boussingault, the leading French chemist, started to experiment on his farm at Bechelbronn, Alsace, that true scientific agricultural research began. His farm became the first agricultural experiment station. He investigated the composition of various foods and the effect of climate on crops. Making use of De Saussure's analytical methods, he studied rotations in the field and in the greenhouse. In 1837, he turned to the question of atmospheric nitrogen absorption and issued the statement: "Azote may enter the living frame of plants directly (10)... The observations of vegetable physiologists are not generally favorable to this view". He reported his work in 1841 (23) but his findings on rotations and his balance sheets of crop nutrients were overlooked by the contemporaries.

The first survey of agricultural science was made by Liebig, the outstanding organic chemist of the time, for the British Association for the Advancement of Science. Liebig (48, 49) advanced the theory that plants could get nitrogen from the air in the form of ammonia which was carried down by rain, snow or dew into the soil, or even by direct absorption of ammonia by the leaves. He rejected nitrate as a possible source of nitrogen and claimed that the beneficial effect encountered with sodium nitrate fertilizer was due to the sodium ion. He also objected to the use of nitrogenous fertilizers, except to save time (50), and put forth the idea that the mineral constituents of the soil should be restored to it in order to maintain fertility. Liebig introduced the "Law of the Minimum", that has ever since remained classical.

The publication of Liebig's "Die Chemie in ihrer Anwendung auf Agricultur und Physiologie" marked the birth of popularized agriculture as an applied science. Following the volume, experiment stations were established and agricultural societies were formed, both in the Old and the New World. Professors wrote books for students and farmers; agriculture was being popularized for the first time.

Then originated a period of controversy among the various investigators, and as the dispute grew more bitter, so much more favored was research. De Saussure denied that plants absorbed gaseous nitrogen. The best chemists, such as Boussingault, Liebig, Gilbert, Ville, conducted experiments and published reports. Boussingault, in 1838, found that peas and clover could get nitrogen from the air, but not wheat. Ville, in France, shared Liebig's view on the non-necessity of nitrogen as fertilizer but denied the sole intake of ammonia nitrogen. Ville claimed that nitrogen was also absorbed in the molecular form from the atmosphere. This conclusion he reached after the French Academy of Science appointed a commission to study the question. The commission was composed of brilliant scientists such as Chevreul, Payen, Regnault, Decaisne, Peligot, Dumas, and they all agreed with Ville's theory (88). Liebig was not the only one opposed to the molecular intake of nitrogen by plants, as proposed by Boussingault and Ville; a whole group of other workers sided with Liebig, such as Cloez (18), who was Ville's co-worker, Harting (29) and Boussingault himself (11, 12), who had cast aside his previous theory of 1838.

Meanwhile, Lawes and Gilbert were studying the Rothamsted experiments, which they had set up in 1843 and which were based on the same principle as those of Boussingault. By 1855, they had reached interesting conclusions, such as regard the salt requirements of plants; the nitrogen requirements of non-legumes; the maintenance of soil fertility; the beneficial effect of fallowing due to the nitrogen increase of the soil. Later, in 1857, they showed that plots continuously cropped to legumes remained at high yields, whereas those continuously cropped to non-legumes without addition of organic fertilizer soon declined and remained at low yields. In 1861, after careful investigation they (42) arrived at conclusions opposing Ville's theory, i.e. that plants do not use atmospheric nitrogen.

These findings convinced all but Ville and a few of his followers. And even Ville himself (89), later on, in 1879, suggested applications of sodium nitrate or ammonium sulfate to non-leguminous plants, but not to legumes, a practice that was common on his farm, at Vincennes.

Along with the progress of chemistry, bacteriology, born from Pasteur, was rapidly growing as a child filled with hope and promise. Pasteur's diversified research lead him to emit the opinion that nitrification was a bacterial process. Schloesing and Muntz (73), in 1877, confirmed Pasteur's statement. Warington (98), in 1878, found that there were two stages in the process of nitrate formation and that two distinct organisms were involved: ammonia was first converted into nitrite and then into nitrate. But he did not succeed in identifying the organisms. It was Winogradsky (104) who isolated them in 1890 and called them Nitrosomonas and Nitrosococcus (nitrite formers) and Nitrobacter (nitrate former).

Following the conclusions of Lawes and Gilbert, in 1861, that plants did not use atmospheric nitrogen, the question remained closed and settled. But twenty years later, in 1881, the American workers stirred the still waters when O. W. Atwater came to the conclusion that peas obtained large quantities of nitrogen from the air, thus confirming forty years later Boussingault's findings. In a paper presented before the British Association for the Advancement of Science, he stated that legumes could use free nitrogen but that such an opinion was "contrary to the general belief and the results of the best investigators on the subject". Later, in 1885 (3) and 1886 (4), he recognized that both plant and bacteria might be responsible for nitrogen fixation, but did not succeed in solving the problem.

Once more, new series of experiments were outlined to reinvestigate the old question. Hellriegel (30) and Wilfarth came to the conclusion that the nodules formed by infection of the organisms were the cause of free nitrogen fixation. Wolff (108), in 1887, obtained results similar to those of Hellriegel and Wilfarth, but he disagreed with them in regard to the form of nitrogen absorbed. Wolff maintained that the nitrogen was obtained from atmospheric ammonia which diffused into the substrate and from free nitrogen fixed by the soil in the presence of calcium carbonate; that legumes had a greater evaporating power favoring more "pumping" (103) of soil nitrogen. He did not accept the idea of bacteria in the nodules and said that these nodules were the result and not the cause of better plant growth: they were storage organs. Gilbert (25), in 1887, explained the differences in behavior between legumes and non-legumes by the fact that legumes might simply have a greater extractive power for nitrogen in the soil and sub-soil.

Lawes and Gilbert remained skeptical before Hellriegel and Wilfarth's findings. After further experiments at Rothamsted they came to an agreement with the German workers, and in 1891 (41) finally accepted the conclusion reached by Hellriegel and Wilfarth that legumes fix free atmospheric nitrogen through the activity of a specific organism present in the nodules. The organism had been isolated by Beijerinck in 1888 and he called it Bacillus radicicola.

But, even though it has been established that legumes fix free atmospheric nitrogen through their nodules, other interrogation marks have appeared all around the subject of symbiotic nitrogen fixation: for example, do all legumes fix nitrogen? Do they always fix nitrogen, even if nodules are present? These questions have not yet been adequately answered.

No discussion of the mechanism of nitrogen fixation by symbiotic bacteria will be made here. Suffice it to say that several explanations have been proposed, among which the asparagine hypothesis, previously proposed by Pfeffer, the botanist, and others, and developed by Schulze and co-workers (71, 59, 103); the amino-acid hypothesis, first suggested by Boussingault and supported by Priaanischnikow (65), a student of Schulze; the aspartic acid hypothesis, supported by many contemporary authorities (15, 94, 93, 87). However, the three main hypotheses for symbiotic nitrogen fixation are: a) the ammonia hypothesis, supported by Winogradsky and others (105, 106, 107, 39, 40); b) the hydroxylamine hypothesis, more popular than the previous and defended by Blom (9), Virtanen (90, 91, 94), Virtanen and Arhimo (92) and others such as Lemoigne, Monguillon and Desveaux

(45), Michlin (61); c) the organic nitrogen hypothesis, suggested by the Wisconsin workers such as Orcutt (66), Umbreit and Burris (85) and others.

Which of these three main hypotheses is most probable? According to Wilson (103), Virtanen's hydroxylamine theory is most explanatory and most widely admitted under the present day knowledge of the subject. Further investigation is needed to supply workers with the true answer.

Alfalfa Material as Green Manure.

Whether or not the process by which nitrogen fixation takes place in alfalfa is discovered, this will not affect the value of the plant as green manure. From a more practical standpoint, some of the extensive work dealing with the value of alfalfa as green manure can be considered. Nearly every experiment station located in those areas naturally adapted to alfalfa production has done some work on the value of alfalfa as green manure, its influence upon the following crop or its effect upon a whole rotation.

As compared with non-legumes, there is general agreement on the superiority of alfalfa as green manure, provided the plant exhibits normal growth, i.e. that the circumambient conditions are favorable to its normal development. The list of experiments that support this statement is rather long and it is judged sufficient to mention the works of Lyon (51), Ripley (70), Gustafson (27), Lyon and Bizzell (53, 54), Sprague (77), and publications such as "Alfalfa in Michigan" (1), "Sugar Beets in Michigan" (79), that are representative of most of the work done along this line.

If we parallel alfalfa with other legumes, the comparison becomes much more difficult and the conclusions far less obvious. Apparently, from the literature, it seems that sweet clover*, either white or yellow, is a little better than alfalfa, as measured by the yields of following crops. Several investigators (21, 2) have come to this conclusion, although others (52, 53, 54) have found that alfalfa gave better results than sweet clover.

Many factors can be accounted as responsible for this divergence of opinions, such as climate, soil composition, amount of material produced, plant chemical composition, ability of one plant to do better than another on a given soil, and especially this factor of utmost importance: age of plant when turned under. The influence of these factors is easily recognized because of the intimate relationship that links them all to plant chemical composition.

A great deal of research has been carried on in regard to the effect of age of plants upon their manurial value when turned under. Lyon (51, 52) found that 1-year-old alfalfa gave just as good results as 2 or 3-year-old plants. Davis and Turk (21) showed that with advancing maturity the total potassium and calcium increased in sweet clover or alfalfa plants, tops and roots combined. It is stated in "Sugar Beets in Michigan" (79) that early spring plowing of alfalfa is best for sugar beets and that sweet clover should not exceed ten inches high when plowed under in the spring. Pieters (69) and Morrison (63) realized that as the alfalfa plant grows older its percentage of pro-

* White sweet clover: Melilotus alba.
Yellow sweet clover: Melilotus officinalis.

tein decreases while its percentage of fiber increases. According to Willard (101), the commonly accepted difference in protein content between alfalfa and red clover* is due largely, if not entirely, to the fact that alfalfa is usually cut earlier in the season and at an earlier stage of maturity. Martin (55) concludes that rye, oats and buckwheat benefit the soil most when turned under at the half-grown stage, because the more succulent the plant, the more rapid the decomposition and liberation of nitrates. Muntz (64) states that the value of a green manure is proportional to the rapidity with which nitrogen is converted into nitrates. Hutchinson and Milligan (35) and also Maynard (56) claim that the rate of nitrification decreases markedly with advancing age of the green material. White (99) working with crimson clover* as green manure found that the younger the plant, the more rapid the decay and greater the tomato yields. Waksman and Tenney (81) state: "The rapidity and nature of decomposition of plant residues under aerobic conditions depend primarily upon the chemical composition of the particular plant materials". According to Waksman, these most important chemical constituents are: 1- amount and nature of constituents soluble in cold water; 2- abundance of celluloses and hemicelluloses; 3- amount and nature of nitrogenous complexes; 4- abundance of lignins. Furthermore, the chemical composition of a plant varies with age and nutrition. Snider (76) points out that phosphorus applications increase the phosphorus content of alfalfa and that the phosphorus content of the plant will also vary with the date of cutting. Wiancko and Mulvey (102) say that sweet clover

* Red clover: Trifolium pratense.
  Crimson clover: Trifolium incarnatum.

as green manure in Indiana does best when plowed under the latter part of April the spring following its seeding. Davis and Turk (21) found that fertilized alfalfa contained more nitrogen, phosphorus and potassium in the tops and roots than did the unfertilized, and that fertilized alfalfa or sweet clover gave better results than did the unfertilized plant material when turned under for a proso crop. Davis (20) has found that fertilizing sweet clover causes an increase of nitrogen in the plant. Vandecaveye and Bond (86) found that fertilizers and climate will change the nitrogen, phosphorus and potassium content of alfalfa. A complete review of the literature on the effect of fertilizers upon the chemical composition of various crops is given by Beeson (7). Many other workers (96, 56, 35, 47, 32, 100) have found that the younger the plant turned under, the more rapid the chemical breakdown and liberation of beneficial nutrients.

Sugar Beet Green Residues (and Cane Trash) as Green Manure.

The literature dealing with the quality of sugar beet material as green manure is much less extensive than that dealing with legumes. The reason for this might be that sugar beets cannot be profitably grown as a green manure crop: the high cost of the work involved in producing sugar beets cannot be counterbalanced by the relatively low value of the fertilizers they contain. The question is different, however, when it comes to making use of the residues of a crop grown for other purposes, and in this respect some work has been done of which a succinct résumé will be given.

Woodman and Bee (109) studied the fertilizing value of sugar beet tops and concluded that they should be used as fertilizer on account of their appreciable nitrogen, phosphorus and potassium content. Tancré (80) also studied the manurial value of sugar beet leaves. Merkle (60) compared the rate of decomposition of sugar beet roots, sweede roots and rape tops. Sugar beet roots gave off the most carbon dioxide and in all cases the carbon dioxide production curves reached a peak at the end of two weeks incubation and then dropped abruptly to assume a practically identical and constant value along the X-axis (time). Daji (19) found that sugar beet tops had a beneficial effect on a barley crop. He secured better results when the tops were burried at once than when they were first allowed to decompose on the surface of the soil or were composted previous to turning under. Hirst and Greaves (33) conclude that the nitrogen content of sugar beet tops, on a dry basis, approximates that of first crop alfalfa, but that the phosphorus content is lower. Comparing tops and roots, they state that the tops account for 30 per cent of the green weight of the plant, 65 percent of the total nitrogen in the plant and 50 per cent of the total phosphorus; that the percentage of calcium and of magnesium is greater in the tops than in the roots; that phosphorus was increased in both tops and roots by fertilization, phosphorus being lower in the roots than in the leaves. Phosphorus in the total plant fertilized amounted to 4.8 pounds per acre; in the non-fertilized, 1.9 pounds. The nitrogen in fertilized tops was 64.6 pounds per acre; in the non-fertilized, 27.6 pounds. Sturgis (78) observes that cane trash caused a marked lowering of nitrates in the soil. The depressive effect lasted three months. Cane trash turned under in the fall, in Louisiana, had decomposed sufficiently by the following April to liberate available nitrogen. The addition of five pounds of inorganic nitrogen per ton of trash increased the rate of decomposition and insured available nitrogen.

PLAN OF INVESTIGATION

The research work reported in this paper was divided into three experiments:

I- Comparison of 1, 2 and 3-year-old alfalfa, fertilized and unfertilized, and harvested from the field at three different dates in the early spring.
Roots and tops were collected and used as green manure for a sugar beet crop in the greenhouse.

Nitrification studies were made on the alfalfa material in the laboratory.

II- Comparison of 4, 8, 9, 11 and 14 months old fertilized alfalfa grown in the greenhouse and used as green manure in the "same soil" and in "new soil", for sugar beets followed by barley in the greenhouse.

Nitrification studies were made on the alfalfa material in the laboratory.

III- Influence of field-harvested sugar beet tops and roots used as green manure for corn, barley and proso in the greenhouse, oats following the proso crop.

Nitrification studies were made on the sugar beet material in the laboratory.

A study of all soils receiving different treatments to establish, if possible, a correlation between the yields recorded and the percentage saturation of the soil colloids as regards both total and individual cations.

EXPERIMENTAL WORK

I- Comparison of 1, 2 and 3-year-old alfalfa, roots and tops, fertilized and unfertilized, harvested from the field at three different dates in the spring and turned under for a sugar beet crop in the greenhouse.

A- Greenhouse work.

a) <u>Sampling of alfalfa material</u>:

The alfalfa samples were taken from field plots on a Brookston clay loam, near Chesaning, Saginaw Co., Michigan, which is located in the central part of the State. The fertilizer applied to the alfalfa crop at seeding time was 0-12-12 at the rate of 1000 pounds per acre.

Areas in which a good stand was found were chosen to collect the samples. This was done in an attempt to gain uniformity in the number of plants per area. Three squares 3 X 3 feet were marked off and every plant within the squares was used for the triplicate sample. The whole plant was collected. The roots were dug up with a spade and as much soil as possible was shaken off. They were then separated from the tops (crowns always included with roots), washed clean under the tap and then rinsed with distilled water. After oven-drying at 80° C. until constant weights were obtained, both tops and roots were ground.

Samples of 1, 2 and 3-year-old plants, fertilized and unfertilized, were taken on April 17, April 27 and May 10, 1944. Tables 1, 2 and 3 contain the sampling data, and Table 4 summarizes all three. Fig. 1 affords a graphic representation of the data in Table 4.

b) Sugar beet crop:

The alfalfa material sampled was used as a green manure for sugar beets grown in the greenhouse. The set-up was as follows:

The beets were grown in two-gallon glazed jars containing 8 kilograms of Miami silt loam soil. The soil was passed through a 1-cm. mesh screen to remove pebbles and other débris. The alfalfa material was mixed with the top 6 inches of soil and distilled water added in sufficient quantity to bring the soil to a moisture content equal to that of its moisture equivalent as previously determined by the Bouyoucos method (13). The moisture equivalent so determined was 20.7 and, for practical purposes, moisture was maintained at 20 per cent of the air-dry weight of the soil: thus, the percentage of moisture in the jars was a trifle higher than the moisture equivalent. Three days elapsed before seeding.

The sugar beet seed used was U. S. 216. Eight seeds per jar were planted on June 20, 1946. Distilled water was added to the jars whenever necessary, and once a week they were brought up to their 20 per cent moisture weights. The jars were placed at random and moved occasionally.

All treatments were triplicated. In mixing alfalfa material with the soil, the field top/root ratios have been maintained and a constant

Table 1.- Alfalfa sampled on APRIL 17, number of plants per sample and yields of tops and roots per sample and per acre.

Field sample No.	Age of plants	0-12-12 lbs per acre	Plants per 9sq.ft.	Roots* gms.per 9sq.ft.	Roots lab. No.	Tops* gms.per 9sq.ft.	Tops lab. No.	Roots* lbs per acre	Tops* lbs per acre
1	1-yr.	1000	220	91.1		31.0			
2	"	"	221	86.8	R-I	28.1	T-I		
3	"	"	205	74.7		35.9			
Sum			646	252.6		95.0		899	338
4	"	0	214	87.0		31.2			
5	"	0	205	70.0	R-II	28.6	T-II		
6	"	0	164	76.8		25.0			
Sum			583	233.8		84.8		832	302
7	2-yr.	1000	51	211.5		0			
8	"	"	64	156.2	R-III	0	-		
9	"	"	55	158.5		0			
Sum			170	526.2		0		1872	0
10	"	0	63	154.1		0			
11	"	0	58	224.6	R-IV	0	-		
12	"	0	58	190.0		0			
Sum			179	568.7		0		2023	0
13	3-yr.	1000	64	245.5		0			
14	"	"	81	320.5	R-V	0	-		
15	"	"	48	174.9		0			
Sum			193	740.9		0		2635	0
16	"	0	44	189.3		0			
17	"	0	64	257.2	R-VI	0	-		
18	"	0	60	210.0		0			
Sum			168	656.5		0		2335	0

* Oven-dry weights.

amount, 60 grams of air-dry plant material per jar, incorporated with the soil. This amount represents approximately 7.5 tons of air-dry material (tops plus roots) per acre. It is difficult to calculate the

Table 2.- Alfalfa sampled on APRIL 27, number of plants per sample and yields of tops and roots per sample and per acre.

Field sample No.	Age of plants	0-12-12 lbs per acre	Plants per 9sq.ft.	Roots* gms.per 9sq.ft.	Roots lab. No.	Tops* gms.per 9sq.ft.	Tops lab. No.	Roots* lbs per acre	Tops* lbs per acre
19	1-yr.	1000	163	61.1		41.7			
20	"	"	208	60.6	R-VII	32.5	T-VII		
21	"	"	179	42.4		29.6			
Sum			550	164.1		103.8		584	369
22	"	0	194	72.6		31.8			
23	"	0	190	50.5	R-VIII	26.7	T-VIII		
24	"	0	145	60.4		33.8			
Sum			529	183.5		92.3		653	328
25	2-yr.	1000	60	137.0		24.1			
26	"	"	87	201.0	R-IX	30.9	T-IX		
27	"	"	100	209.9		34.9			
Sum			247	547.9		89.9		1949	320
28	"	0	60	216.2		33.7			
29	"	0	80	160.8	R-X	25.2	T-X		
30	"	0	99	169.5		25.2			
Sum			239	546.5		84.1		1944	299
31	3-yr.	1000	50	236.2		14.0			
32	"	"	72	232.7	R-XI	8.2	T-XI		
33	"	"	62	200.0		4.9			
Sum			184	668.9		27.1		2379	96
34	"	0	83	280.0		9.3			
35	"	0	37	152.6	R-XII	5.3	T-XII		
36	"	0	76	192.7		13.1			
Sum			196	625.3		27.7		2224	99

* Oven-dry weights.

quantity of green material corresponding to the grams of air-dry material because the conversion factor from dry to green weight varies with the age of the plant, the date of harvest and the fertilizer applied.

Table 3.- Alfalfa sampled on MAY 10, number of plants per sample and yields of tops and roots per sample and per acre.

Field sample No.	Age of plants	0-12-12 lbs per acre	Plants per 9sq.ft.	Roots* gms.per 9sq.ft.	Roots lab. No.	Tops* gms.per 9sq.ft.	Tops lab. No.	Roots* lbs per acre	Tops* lbs per acre
37	1-yr.	1000	73	44.2		50.8			
38	"	"	73	45.6	R-XIII	51.6	T-XIII		
39	"	"	73	42.8		50.0			
Sum			219	132.6		152.4		472	542
40	"	0	109	56.1		58.2			
41	"	0	95	52.2	R-XIV	55.6	T-XIV		
42	"	0	63	33.5		44.1			
Sum			267	141.8		157.9		504	562
43	2-yr.	1000	78	163.4		54.4			
44	"	"	74	161.5	R-XV	68.6	T-XV		
45	"	"	58	135.1		43.7			
Sum			210	460.0		166.7		1636	593
46	"	0	54	160.0		69.3			
47	"	0	57	114.5	R-XVI	50.2	T-XVI		
48	"	0	59	129.3		59.7			
Sum			170	403.8		179.2		1436	637
49	3-yr.	1000	83	233.0		42.7			
50	"	"	85	227.3	R-XVII	41.4	T-XVII		
51	"	"	55	175.0		36.8			
Sum			223	635.3		120.9		2260	430
52	"	0	58	164.2		47.4			
53	"	0	68	222.1	R-XVIII	45.1	T-XVIII		
54	"	0	71	205.9		29.9			
Sum			197	592.2		122.4		2106	435

* Oven-dry weights.

Moreover, the two components, roots and tops, vary independently. Green tops weighed from 2.9 to 3.7 times as much as air-dry tops, the mean being 3.2. Green roots weighed approximately twice as much as air-

Table 4.- Summary of data for alfalfa harvested on APRIL 17, APRIL 27 and MAY 10.

Age of plants	Sampling date	Roots, lbs/acre* fert.	Roots, lbs/acre* unfert.	Tops, lbs/acre* fert.	Tops, lbs/acre* unfert.	Roots+tops, lbs/acre* fert.	Roots+tops, lbs/acre* unfert.
1-yr.	April 17	899	832	338	302	1237	1134
2-yr.	"	1872	2023	0	0	1872	2023
3-yr.	"	2635	2335	0	0	2635	2335
1-yr.	April 27	584	653	369	328	953	981
2-yr.	"	1949	1944	320	299	2269	2243
3-yr.	"	2379	2224	96	99	2475	2323
1-yr.	May 10	472	504	542	562	1014	1066
2-yr.	"	1636	1436	593	637	2229	2073
3-yr.	"	2260	2106	430	435	2690	2541
1-yr.	April 17	899	832	338	302	1237	1134
"	April 27	584	653	369	328	953	981
"	May 10	472	504	542	562	1014	1066
2-yr.	April 17	1872	2023	0	0	1872	2023
"	April 27	1949	1944	320	299	2269	2243
"	May 10	1636	1436	593	637	2229	2073
3-yr.	April 17	2635	2335	0	0	2635	2335
"	April 27	2379	2224	96	99	2475	2323
"	May 10	2260	2106	430	435	2690	2541

* Oven-dry weights.

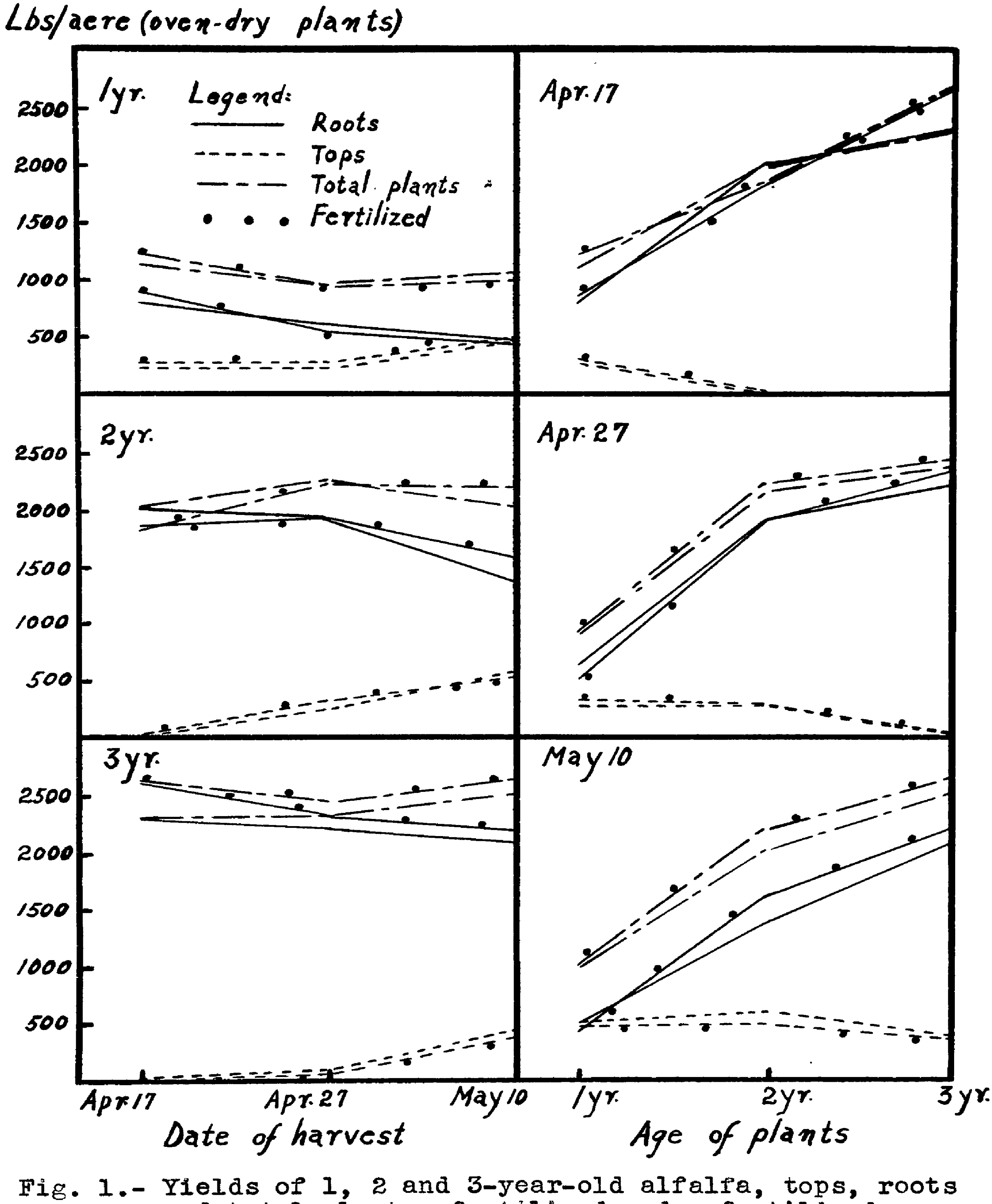

Fig. 1.- Yields of 1, 2 and 3-year-old alfalfa, tops, roots and total plants, fertilized and unfertilized, harvested at various dates in the spring.

Table 5.- Outline of various soil treatments preceding the sugar beet crop.

Jar No	Alfalfa material turned under			
	Top/root ratios in gms.	Date of harvest	Age, previous treatment	Symbols used
1-2-3	T,16.4; R,43.6	April 17	1-yr. fert.	A-17;1Y; F.
4-5-6	T,16.0; R,44.0	"	" unfert.	A-17;1Y;UNF.
7-8-9	T, 0 ; R,60.0	"	2-yr. fert.	A-17;2Y; F.
10-11-12	T, 0 ; R,60.0	"	" unfert.	A-17;2Y;UNF.
13-14-15	T, 0 ; R,60.0	"	3-yr. fert.	A-17;3Y; F.
16-17-18	T, 0 ; R, 60.0	"	" unfert.	A-17;3Y;UNF.
19-20-21	T,23.2; R,36.8	April 27	1-yr. fert.	A-27;1Y; F.
22-23-24	T,20.1; R,39.9	"	" unfert.	A-27;1Y;UNF.
25-26-27	T, 8.4; R,51.6	"	2-yr. fert.	A-27;2Y; F.
28-29-30	T, 8.0; R,52.0	"	" unfert.	A-27;2Y;UNF.
31-32-33	T, 2.3; R,57.7	"	3-yr. fert.	A-27;3Y; F.
34-35-36	T, 2.5; R,57.5	"	" unfert.	A-27;3Y;UNF.
37-38-39	T,32.1; R,28.4	May 10	1-yr. fert.	M-10;1Y; F.
40-41-42	T,31.6; R,28.4	"	" unfert.	M-10;1Y;UNF.
43-44-45	T,15.9; R,44.1	"	2-yr. fert.	M-10;2Y; F.
46-47-48	T,18.4; R,41.6	"	" unfert.	M-10;2Y;UNF.
49-50-51	T, 9.6; R,50.4	"	3-yr. fert.	M-10;3Y; F.
52-53-54	T,10.3; R,49.7	"	" unfert.	M-10;3Y;UNF.
55-56-57	Checks.			

Table 6.- Yields and sucrose content of sugar beets following the turning under of alfalfa. Figures give sum of triplicates.

Alfalfa turned under*	Tops, gms.		Green roots, gms.	Total sucrose	
	Green	Air-dry		%**	Gms.
A-17;1Y; F.	469.2	89.2	369.4	14.0	51.7
A-17;1Y;UNF.	433.8	83.8	229.8	14.4	33.1
A-17;2Y; F.	335.0	75.0	305.0	15.6	47.6
A-17;2Y;UNF.	306.4	65.4	309.4	14.6	45.2
A-17;3Y; F.	326.6	63.6	239.8	15.6	37.1
A-17;3Y;UNF.	321.4	69.4	247.0	15.0	37.1
A-27;1Y; F.	416.2	76.2	237.6	15.1	35.9
A-27;1Y;UNF.	452.2	81.2	191.0	14.9	28.5
A-27;2Y; F.	323.6	61.6	194.4	15.4	29.9
A-27;2Y;UNF.	355.4	67.4	167.6	14.6	24.5
A-27;3Y; F.	320.4	67.4	280.8	15.7	44.1
A-27;3Y;UNF.	276.6	66.6	251.2	14.7	36.9
M-10;1Y; F.	341.5	94.8	285.0	15.0	42.7
M-10;1Y;UNF.	359.9	68.9	283.1	15.8	44.7
M-10;2Y; F.	342.2	60.2	251.4	13.6	34.2
M-10;2Y;UNF.	399.8	78.8	249. 4	15.9	39.6
M-10;3Y; F.	310.2	61.2	274.6	14.7	36.2
M-10;3Y;UNF.	287.0	63.0	251.6	14.4	36.2
Checks	115.4	25.4	104.1	12.4	12.9

* See symbols, table 5.
** Average of triplicates.

Table 7.- Sugar beet yields of roots and of total sucrose following the various soil treatments with alfalfa. Figures give sum of triplicates.

Alfalfa turned under		Beet roots* after alfalfa		Total sucrose* after alfalfa	
Age	Sampling date	Fert.alf.	Unfert.alf.	Fert. alf.	Unfert. alf.
1-yr.	April 17	369.4	229.8	51.7	33.1
2-yr.	"	305.0	309.4	47.6	45.2
3-yr.	"	239.8	247.0	37.4	37.1
1-yr.	April 27	237.6	191.0	35.9	28.5
2-yr.	"	194.4	167.6	29.9	24.5
3-yr.	"	280.8	251.2	44.1	36.9
1-yr.	May 10	285.0	283.1	42.7	44.7
2-yr.	"	251.4	249.4	34.2	39.6
3-yr.	"	274.6	251.6	40.4	36.2
1-yr.	April 17	369.4	229.8	51.7	33.1
"	April 27	237.6	191.0	35.9	28.5
"	May 10	285.0	283.1	42.7	44.7
2-yr.	April 17	305.0	309.4	47.6	45.2
"	April 27	194.4	167.6	29.9	24.5
"	May 10	251.4	249.4	34.2	39.6
3-yr.	April 17	239.8	247.0	37.4	37.1
"	April 27	280.8	251.2	44.1	36.9
"	May 10	274.6	251.6	40.4	36.2

* Grams.

dry roots. Based on these data, 60 grams of dry material composed of 0 grams of tops and 60 grams of roots is equivalent to 0 grams of green tops and 120 grams of green roots per jar (15 tons of green material per acre). In comparison with these figures, 60 grams of dry material composed of 31.6 grams of tops and 28.4 grams of roots would be equivalent to 101.1 grams of green tops and 56.8 grams of green roots per jar (19.75 tons of green material per acre).

Perhaps it would have been better to have used a quantity of alfalfa material in the pots equal to or double the amount actually harvested from the plots. Thus, the quantity would have varied in the different pots according to the yields in the field. At the time, however, it was deemed advisable to use the same quantity of material in each pot.

In Table 5 are recorded the quantities of top and root material added to the various jars before the beets were planted.

When the beet plants were 3 inches tall, they were thinned to 4 plants per jar, and when they had reached a height of 6 inches, they were further thinned to 2 plants per jar. The strongest plants were saved.

The sugar beets grew normally. No nitrogen deficiency symptoms were noticed, except in the checks where the tops were a yellowish brown and much less developed than in all other jars.

On December 18, 1946, the beets were harvested after six months growth. The tops (with the crowns) were separated from the roots, and tops and roots were weighed separately. The tops were put aside to dry, and later on the air-dry weights of the tops were recorded. The percentage of total sucrose was determined immediately after harvest. A description of the method used is given along with the other laboratory procedures. Table 6 contains the yields of the sugar beet crop and Fig. 3 affords a graphic comparison of the beet root yields with the nitrogen accumulation in the soils.

B- Laboratory work.

a) Sucrose analysis:

The percentage of total sucrose in the sugar beets was determined by the hot water digestion method as described in "Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists", 5th ed., 1940, p. 516. This method makes use of the saccharimeter with a 400-mm. polarizing tube. However, instead of using basic $Pb(CH_3COO)_2$ as a clarifying agent, as provided for in the method, basic $Pb(NO_3)_2$ consisting of a mixture in equal volumes of a 50% solution of $Pb(NO_3)_2$ and a 5% solution of NaOH was substituted. In these tests, 10 ml. of basic $Pb(NO_3)_2$ was used as a clarifying agent.

The sampling of the sugar beet is of utmost importance since the sucrose is not evenly distributed throughout the whole root. The most representative sample is obtained from a V-shaped slice cut lengthwise of the beet and the wide edge at the beet's surface.

Each sample consisted of the six beets from the three jars which received the same treatment. On each composite sample, two determinations were made. Therefore, two 25-gm. samples were taken from each lot of six beets. All the saccharimeter readings of the duplicate determinations agreed within 0.2% sucrose, except in A-17;2Y;UNF. (see Table 6) where the duplicates showed a difference of 0.4%. This slight discrepancy was overlooked.

b) Nitrification studies of the alfalfa material used as green manure:

The alfalfa material used as green manure was submitted to nitrification studies in the laboratory.

Two grams of air-dry ground alfalfa material were mixed (tops and roots separately) with 100 grams of air-dry Wisner soil in a glass tumbler and distilled water was added to bring the soil to a moisture content equal to its moisture equivalent. The moisture equivalent was 19.7, as determined by the Bouyoucos method (13). To simplify the subsequent calculations, it was considered as being 20.0 and calculated on an air-dry basis. All treatments were quadruplicated, 2 duplicates serving for the 4-week incubation period and 2 for the 8-week period. The tumblers were covered with lids containing 2 holes for aeration and were set in a dark locker in the laboratory. The tumblers were weighed every week and brought up to their respective weights with distilled water.

At the end of the incubation period, nitrate and ammonia nitrogen were extracted from the soils with a 4% KCl solution. The soils were allowed to soak 12 hours in the salt solution; the liquid was then filtered out and distilled (Kjeldahl method) into a 4% solution of H_3BO_3. Titrations were made with N/10 H_2SO_4 using bromphenol blue as an indicator.

The incubation was started on March 30, 1945, and ended on April 27, 1945 (4-week period) and on May 25, 1945 (8-week period).

Chemical determinations made on the Wisner soil used in the incubation studies revealed the following*: pH value, 7.48; total adsorbed phosphorus, 10.0 p.p.m.; acid-soluble phosphorus, 162.5 p.p.m.; total adsorbed + acid-soluble phosphorus, 172.5 p.p.m.; exchangeable potassium, 0.094 m.e. per 100 grams (73.3 lbs/acre); exchangeable magnesium, 0.123 m.e. per 100 grams (29.8 lbs/acre); exchangeable + free calcium, 17.172 m.e. per 100 grams (6890 lbs/acre); exchange capacity, 10.665 m.e. per 100 grams; magnesium/exchange capacity, 1.15%; potassium/exchange capacity, 0.88%; potassium/magnesium ratio (m.e. basis), 0.76.

The results of this nitrification study are shown in Tables 8, 9, 10, 11, and are graphically presented in Fig. 2.

After studying the rate of nitrification of alfalfa material as related to its chemical composition at various stages of maturity, the data were used to compute the amounts of nitrogen produced in the soils growing the sugar beets. Knowing the amounts of nitrogen produced by 1 gram of root and 1 gram of top material of a given sample, it is easy to calculate the amounts produced by any given quantity of top or root material of an identical sample. So, respecting the relative amounts of tops and roots turned under for the beet crop, the figures shown in Table 12 were obtained. They represent the calculated quantities of nitrogen formed in the soils during the growth of the crop. Fig. 3 compares the yields of the beets with the amounts of nitrogen produced in the soils.

c) <u>Study of soils</u>:

In a search for correlations which might exist between the contents of various nutrients present in the soil and the yields

* See paragraph "Study of soils".

Table 8.- Mgms. of nitrogen accumulated during a 4-week incubation period in 100 gms. of soil receiving 2.0 gms. of alfalfa material.

Alfalfa incubated*	Alfalfa tops			Alfalfa roots		
	NH_4-N	NO_3-N	$(NH_4+NO_3)N$	NH_4-N	NO_3-N	$(NH_4+NO_3)N$
A-17;1Y; F.	2.58	21.00	23.58	1.27	22.79	24.06
A-17;1Y;UNF.	1.15	26.17	27.32	1.22	17.64	18.86
A -17;2Y; F.	0	0	0	1.83	11.67	13.50
A-17;2Y;UNF.	0	0	0	2.45	14.41	16.86
A-17;3Y; F.	0	0	0	1.33	8.30	9.63
A-17;3Y;UNF.	0	0	0	1.41	10.64	12.05
A-27;1Y; F.	1.60	27.15	28.75	1.62	13.22	14.84
A-27;1Y;UNF.	0.88	25.77	26.65	3.09	15.25	18.34
A-27;2Y; F.	5.71	31.29	37.00	1.37	8.78	10.15
A-27;2Y;UNF.	15.53	25.51	41.04	1.58	8.01	9.59
A-27;3Y; F.	8.44	25.91	34.35	1.41	7.50	8.91
A-27;3Y;UNF.	3.42	28.85	32.27	1.60	7.14	8.74
M-10;1Y; F.	1.11	23.52	24.63	0.80	8.95	9.75
M-10;1Y;UNF.	2.10	22.96	25.06	1.12	7.41	8.53
M-10;2Y; F.	0.77	29.75	30.52	1.01	7.25	8.26
M-10;2Y;UNF.	3.04	30.38	33.42	1.15	10.91	12.06
M-10;3Y; F.	1.32	23.72	25.04	1.22	6.86	8.08
M-10;3Y;UNF.	1.15	29.53	30.68	1.60	6.61	8.21
Checks	(See 8-week incubation, table 9)					

* See symbols, table 5.

Table 9.- Mgms. of nitrogen accumulated during an 8-week incubation period in 100 gms. of soil receiving 2.0 gms. of alfalfa material.

Alfalfa incubated*	Alfalfa tops			Alfalfa roots		
	NH_4-N	NO_3-N	(NH_4-N+NO_3)N	NH_4-N	NO_3-N	(NH_4+NO_3)N
A-17;1Y; F.	9.85	28.92	29.77	0.74	23.72	24.46
A-17;1Y;UNF.	1.06	28.28	29.34	0.85	22.20	23.05
A-17;2Y; F.	0	0	0	0.83	16.06	16.89
A-17;2Y;UNF.	0	0	0	0.85	15.72	16.57
A-17;3Y; F.	0	0	0	0.81	11.37	12.18
A-17;3Y;UNF.	0	0	0	0.73	13.80	14.53
A-27;1Y; F.	0.95	29.54	30.49	0.66	16.06	16.72
A-27;1Y;UNF.	0.99	26.82	27.81	1.25	18.24	19.49
A-27;2Y; F.	1.43	36.20	37.63	0.84	12.03	12.87
A-27;2Y;UNF.	2.24	38.25	40.49	0.85	12.42	13.27
A-27;3Y; F.	1.22	34.43	35.65	0.80	10.96	11.76
A-27;3Y;UNF.	1.13	32.84	33.97	0.71	9.79	10.50
M-10;1Y; F.	0.84	24.11	24.95	0.73	12.68	13.41
M-10;1Y;UNF.	0.78	25.77	26.55	0.73	13.45	14.18
M-10;2Y; F.	0.81	30.21	31.02	0.83	11.51	12.34
M-10;2Y;UNF.	0.92	33.07	33.99	0.85	10.86	11.71
M-10;3Y; F.	0.92	27.09	28.01	0.78	10.05	10.83
M-10;3Y;UNF.	0.85	29.60	30.45	0.74	10.04	10.78
Check	NH_4-N: 0.83; NO_3-N: 1.34; (NH_4+NO_3)N: 2.17					

* See symbols, table 5.

Table 10.- Mgms. of nitrogen accumulated during a 4-week incubation period in 100 gms. of soil receiving 2.0 gms. of alfalfa material. A summary of table 8.

Alfalfa incubated*	Tops $(NH_4+NO_3)N$		Roots $(NH_4+NO_3)N$	
	Fertilized	Unfertilized	Fertilized	Unfertilized
A-17;1Y.	23.58	27.32	24.06	18.86
A-17;2Y.	0	0	13.50	16.86
A-17;3Y.	0	0	9.63	12.05
A-27;1Y.	28.75	26.65	14.84	18.34
A-27;2Y.	37.00	41.04	10.15	9.59
A-27;3Y.	34.35	32.27	8.91	8.74
M-10;1Y.	24.63	25.06	9.75	8.53
M-10;2Y.	30.52	33.42	8.26	12.06
M-10;3Y.	25.04	30.68	8.08	8.21
1Y;A-17	23.58	27.32	24.06	18.86
1Y;A-27	28.75	26.65	14.84	18.34
1Y;M-10	24.63	25.06	9.75	8.53
2Y;A-17	0	0	13.50	16.86
2Y;A-27	37.00	41.04	10.15	9.59
2Y;M-10	30. 52	33.42	8.26	12.06
3Y;A-17	0	0	9.63	12.05
3Y;A-27	34.35	32.27	8.91	8.74
3Y;M-10	25.04	30.68	8.08	8.21

* See symbols, table 5.

Table 11.- Mgms. of nitrogen accumulated during an 8-week incubation period in 100 gms. of soil receiving 2.0 gms. of alfalfa material. A summary of table 9.

Alfalfa incubated*	Tops $(NH_4+NO_3)N$		Roots $(NH_4+NO_3)N$	
	Fertilized	Unfertilized	Fertilized	Unfertilized
A-17;1Y.	29.77	29.34	24.46	23.05
A-17;2Y.	0	0	16.89	16.57
A-17;3Y.	0	0	12.18	14.53
A-27;1Y.	30.49	27.81	16.72	19.49
A-27;2Y.	37.63	40.49	12.87	13.27
A-27;3Y.	35.65	33.97	11.76	10.50
M-10;1Y.	24.95	26.55	13.41	14.18
M-10;2Y.	31.02	33.99	12.34	11.71
M-10;3Y.	28.01	30.45	10.83	10.78
1Y;A-17	29.77	29.34	24.46	23.05
1Y;A-27	30.49	27.81	16.72	19.49
1Y;M-10	24.95	26.55	13.41	14.18
2Y;A-17	0	0	16.89	16.57
2Y;A-27	37.63	40.49	12.87	13.27
2Y;M-10	31.02	33.99	12.34	11.71
3Y;A-17	0	0	12.18	14.53
3Y;A-27	35.65	33.97	11.76	10.50
3Y;M-10	28.01	30.45	10.83	10.78

* See symbols, table 5.

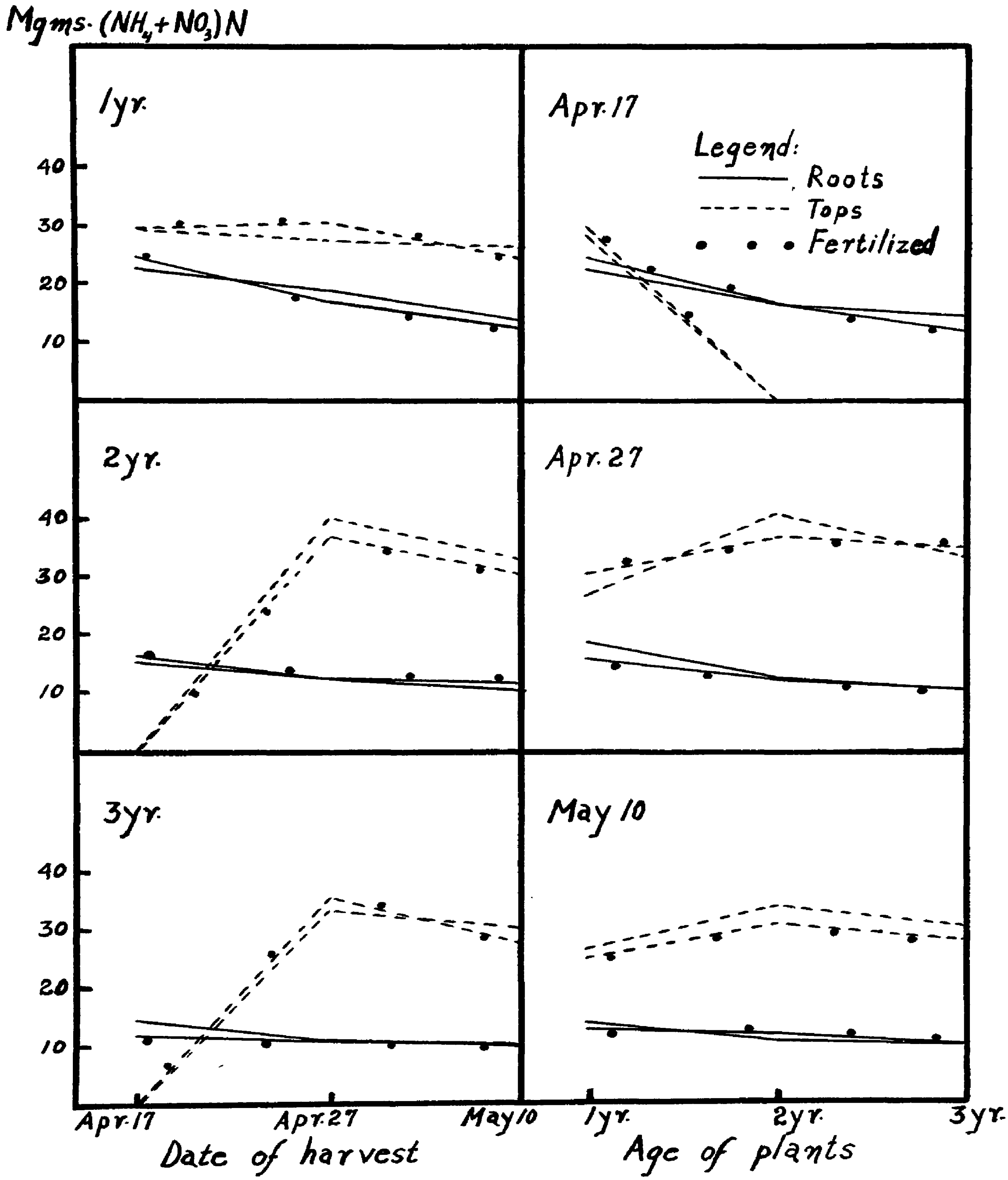

Fig. 2.- Mgms. of N accumulated during an 8-week period in 100 gms. of soil receiving 2.0 gms. of 1, 2 or 3-year-old fertilized or unfertilized alfalfa tops and roots harvested at various dates in the spring.

Table 12.- Calculated mgms. of nitrogen produced during an 8-week incubation period in soils growing sugar beets and receiving 60 gms. of alfalfa material with varying top/root ratios. See ratios, table 5.

Alfalfa incubated*	Tops $(NH_4+NO_3)N$		Roots $(NH_4+NO_3)N$		Total plants $(NH_4+NO_3)N$	
	Fert.	Unfert.	Fert.	Unfert.	Fert.	Unfert.
A-17;1Y.	244.0	234.7	533.2	506.9	777.2	741.6
A-17;2Y.	0	0	506.4	496.8	506.4	496.8
A-17;3Y.	0	0	365.4	435.6	365.4	435.6
A-27;1Y.	353.6	279.4	307.6	388.6	661.2	668.0
A-27;2Y.	158.0	161.9	331.8	344.8	489.8	506.7
A-27;3Y.	41.0	42.4	339.3	301.9	380.3	344.3
M-10;1Y.	400.3	419.3	186.9	201.4	587.2	620.7
M-10;2Y.	246.6	312.6	272.1	243.4	518.7	556.0
M-10;3Y.	134.4	156.8	272.7	267.9	407.1	424.7
1Y;A-17	244.0	234.7	533.2	506.9	777.2	741.6
1Y;A-27	353.6	279.4	307.6	388.6	661.2	668.0
1Y;M-10	400.3	419.3	186.9	201.4	587.2	620.7
2Y;A-17	0	0	506.4	496.8	506.4	496.8
2Y;A-27	158.0	161.9	331.8	344.8	489.8	506.7
2Y;M-10	246.6	312.6	272.1	243.4	518.7	556.0
3Y;A-17	0	0	365.4	435.6	365.4	435.6
3Y;A-27	41.0	42.4	339.3	301.9	380.3	344.3
3Y;M-10	134.4	156.8	272.7	267.9	407.1	424.7

* See symbols, table 5.

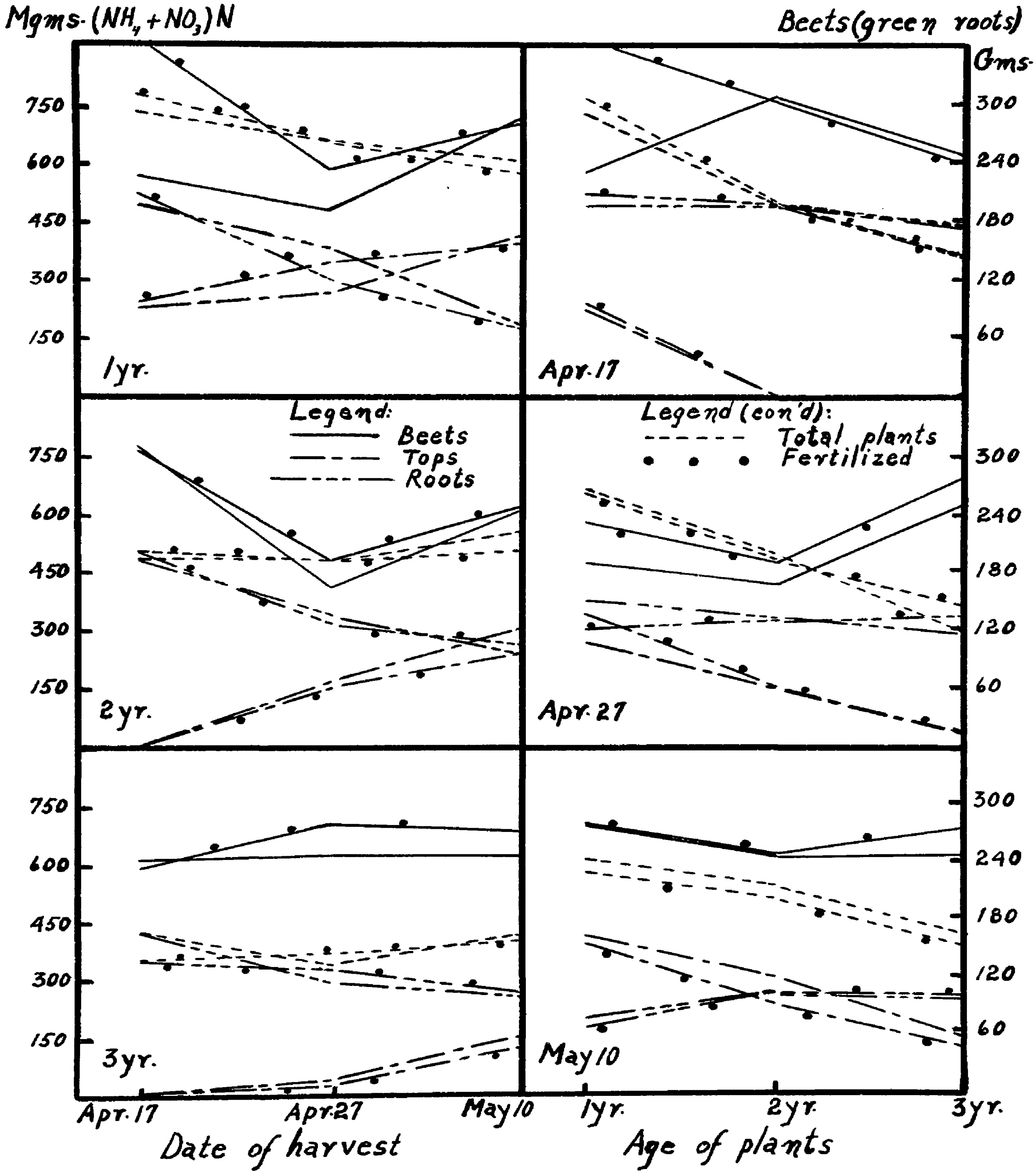

Fig. 3.- Sugar beet yields and calculated amounts of N produced in 8 weeks per 100 gms. of soil by the various quantities of alfalfa tops and roots turned under as green fertilizer.

of the crop, all soils were submitted to a rather complete chemical analysis. An attempt was made to correlate the percentage base saturation and the crop yields. A study of different cation ratios as found in the soils was also undertaken and all the data secured are presented in tabular form in Tables 13 and 13a, and in graphic form in Figs. 3, 4 and 5. Representative soil samples were taken from each jar in the greenhouse and passed through a 0.84 mm. sieve. All three soil samples corresponding to a given treatment were well mixed and two sub-samples taken from them. These two sub-samples were considered as duplicate samples in all the chemical analytical work.

The pH value of the soils was obtained with the Macbeth pH-meter. The soils were soaked 12 hours in H_2O previous to the determinations. A 1:1 soil-water ratio was used, i.e. 15 grams of soil - 15 grams of water. Duplicate determinations were made and since the duplicates checked within 0.1 pH unit, the arithmetic mean of the duplicates was recorded. The difference between the true mean of H-ion concentrations and the apparent arithmetic mean when the variations in pH values are so small is not significant.

Two phosphorus fractions were determined after the Bray and Kurtz method (16), using NH_4F for extracting the total adsorbed phosphorus and HCl for the acid-soluble phosphorus. Readings were made with the Evelyn photoelectric colorimeter and the results were expressed in terms of p.p.m. in the soil.

The exchange capacity, the exchangeable potassium, calcium and magnesium were determined by the Peech method (67) - a microanalytical method - using centrifuge and spectrophotometer. In this work, the Evelyn photoelectric colorimeter was used. A slight modification was

Table 13.- pH value, phosphorus, potassium, calcium and magnesium content of the soils before and after the beet crop.

Soil treatment	pH	P (p.p.m. in soil)			K		Ca		Mg	
		1**	2**	3**	M.e. per 100 gms.	Lbs per acre	M.e. per 100 gms.	Lbs per acre	M.e. per 100 gms.	Lbs per acre
Before crop; untreated	6.16	45.0	132.5	177.5	0.136	106.6	5.589	2242	0.141	34.1
After crop; treated*										
A-17; 1Y; F.	5.32	42.5	140.0	182.5	0.170	133.2	5.184	2080	0.097	23.7
A-17; 1Y; UNF.	5.37	40.0	197.5	237.5	0.162	126.5	4.860	1950	0.097	23.7
A-17; 2Y; F.	5.45	35.0	127.5	162.5	0.132	103.2	5.022	2015	0.092	22.4
A-17; 2Y; UNF.	5.56	35.0	130.0	165.0	0.119	93.2	4.941	1982	0.094	22.8
A-17; 3Y; F.	5.47	37.5	160.0	197.5	0.136	106.6	5.670	2275	0.110	26.6
A-17; 3Y; UNF.	5.74	35.0	135.0	170.0	0.125	97.6	5.022	2015	0.106	25.7
A-27; 1Y; F.	5.69	42.5	167.5	210.0	0.153	119.9	4.212	1690	0.103	24.9
A-27; 1Y; UNF.	5.59	45.0	185.0	230.0	0.145	113.2	5.346	2145	0.108	26.2
A-27; 2Y; F.	5.51	35.0	147.5	182.5	0.106	83.2	4.698	1885	0.085	20.7
A-27; 2Y; UNF.	5.64	35.0	147.5	182.5	0.132	103.2	5.589	2242	0.116	28.1
A-27; 3Y; F.	5.50	40.0	117.5	157.5	0.136	106.6	4.941	1982	0.090	22.0
A-27; 3Y; UNF.	5.62	35.0	147.5	182.5	0.132	103.2	5.751	2307	0.101	24.5
M-10; 1Y; F.	5.74	47.5	122.5	170.0	0.221	173.2	5.508	2210	0.111	27.0
M-10; 1Y; UNF.	5.69	50.0	172.5	222.5	0.204	159.8	4.860	1950	0.097	23.7
M-10; 2Y; F.	5.80	42.5	135.0	177.5	0.148	115.3	5.508	2210	0.113	27.5
M-10; 2Y; UNF.	5.66	40.0	195.0	235.0	0.166	129.9	5.427	2177	0.111	27.0
M-10; 3Y; F.	6.01	35.0	152.5	187.5	0.136	106.6	5.508	2210	0.115	27.9
M-10; 3Y; UNF.	5.95	37.5	167.5	205.0	0.123	96.6	5.427	2177	0.113	27.5
Check	6.10	37.5	175.0	212.5	0.123	96.6	5.022	2015	0.110	26.6

* See symbols, table 5.
** 1, adsorbed; 2, acid-soluble; 3, adsorbed+acid-soluble.

Table 13a.- Exchange capacity, percent base saturation, per cent saturation of individual cations, cation ratios of the soils before and after the beet crop.

Soil treatment	Exc. cap. m.e./100 gms.	% base sat.	Percentage of exc. cap.			Cation ratios(m.e. basis)		
			Ca	Mg	K	Ca/Mg	Ca/K	K/Mg
Before crop; untreated	8.875	61.6	63.0	1.59	1.53	39.6	41.1	0.96
After crop; treated*								
A-17; 1Y; F.	11.000	49.5	47.1	0.88	1.54	53.4	30.5	1.75
A-17; 1Y; UNF.	10.375	49.3	46.8	0.93	1.56	50.1	30.0	1.67
A-17; 2Y; F.	11.250	46.6	44.6	0.82	1.17	54.6	38.0	1.43
A-17; 2Y; UNF.	10.665	48.3	46.3	0.88	1.12	52.6	41.5	1.27
A-17; 3Y; F.	11.375	52.0	49.8	0.97	1.20	51.5	41.7	1.24
A-17; 3Y; UNF.	10.830	48.5	46.4	0.98	1.15	47.4	40.2	1.18
A-27; 1Y; F.	10.500	42.5	40.1	0.98	1.46	40.9	27.5	1.48
A-27; 1Y; UNF.	10.375	54.0	51.5	1.04	1.40	49.5	36.9	1.34
A-27; 2Y; F.	11.000	44.4	42.7	0.77	0.96	55.3	44.3	1.25
A-27; 2Y; UNF.	10.750	54.3	52.0	1.08	1.23	48.2	42.3	1.14
A-27; 3Y; F.	11.250	45.9	43.9	0.80	1.21	54.9	36.3	1.51
A-27; 3Y; UNF.	11.875	50.4	48.4	0.85	1.11	56.9	43.6	1.31
M-10; 1Y; F.	10.750	54.3	51.2	1.03	2.06	49.6	24.9	1.99
M-10; 1Y; UNF.	9.500	54.3	51.2	1.02	2.15	50.1	23.8	2.10
M-10; 2Y; F.	10.375	55.6	53.1	1.09	1.43	48.7	37.2	1.31
M-10; 2Y; UNF.	11.875	48.0	45.7	0.93	1.40	48.9	32.7	1.49
M-10; 3Y; F.	10.000	57.6	55.1	1.15	1.36	47.9	40.5	1.18
M-10; 3Y; UNF.	9.750	58.1	55.7	1.16	1.26	48.0	44.1	1.09
Check	9.250	56.8	54.3	1.19	1.33	45.6	40.8	1.12

* See symbols, table 5.

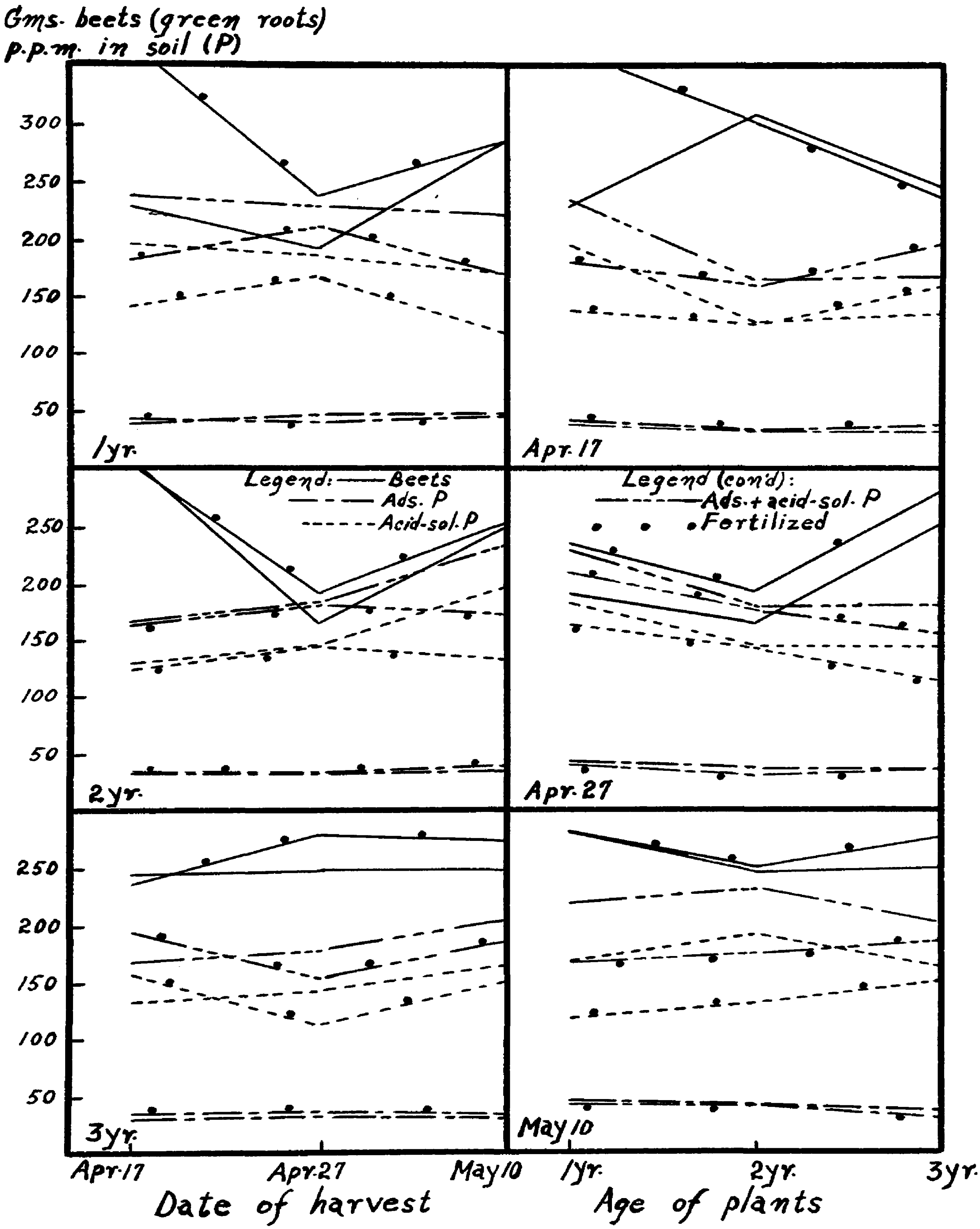

Fig. 4.- Sugar beet yields and the amounts of phosphorus in the soils after the crop.

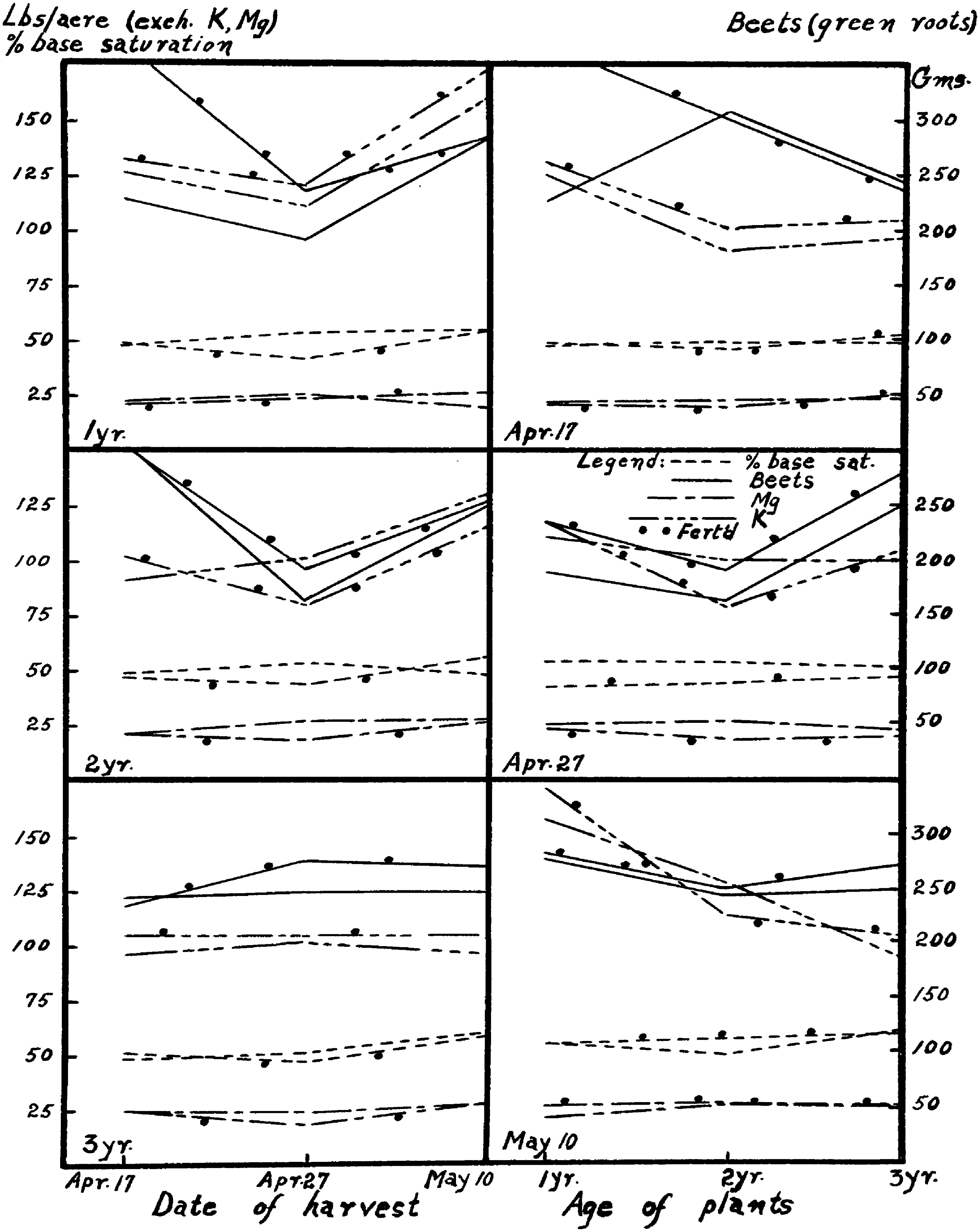

Fig. 5.- Sugar beet yields and the amounts of K, Mg, and % base saturation of the soils after the crop.

introduced in determining the exchangeable cations: instead of heating the NH_4CH_3COO extract to 400° C. to destroy organic matter, a larger quantity of a mixture of HNO_3 and HCl was added.

In calculating the percentage base saturation, potassium, calcium and magnesium only were considered, since the quantities of sodium and manganese were negligible in the soils used in the experimental work.

C- Discussion of results.

The manurial value of the alfalfa under study has been measured by means of the beet crop that followed. Since the beet yields reflect the quality of the alfalfa turned under, Table 7 (Fig. 3) describes the various effects of the alfalfa material as green manure.

A study of Table 7 (Fig. 3) shows that the 1 and 2-year-old plants produced the highest yields when turned under on April 17, and the lowest, on April 27, the 1-year-old plants being superior. The 3-year-old plants proved most beneficial when turned under on April 27, and the least beneficial on April 17. When turned under on May 10, the 1-year-old alfalfa gave best results, and the 2-year-old plants, the poorest results.

The value of unfertilized alfalfa followed the same trend as that of the fertilized, with one exception: the 1-year-old plants, instead of giving best results when turned under on April 17, gave best results when turned under on May 10. The unfertilized material, as compared with the fertilized, gave lower corresponding results in every case, except in the case of the 3-year-old plants turned under on April 17 which gave higher results in beet root yields only, and the 2-year-old plants turned under on May 10 which gave better sucrose yields.

Comparing all alfalfa plants, fertilized and unfertilized, those that gave best results in beet root and sucrose yields were the 1-year-old plants fertilized and turned under on April 17. Next, in decreasing order, came the 2-year-old plants, either fertilized or unfertilized (difference not significant) also turned under on April 17. The alfalfa that gave the poorest results was the 2-year-old plant material, unfertilized, turned under on April 27, followed by the 1-year-old, unfertilized plants turned under on the same date.

It is interesting, however, to observe (Table 6) that the alfalfa that gave the poorest results, i.e. the 2-year-old, unfertilized, turned under on April 27, still produced 161 per cent of the amount of roots and 190 per cent of the amount of sucrose found in the checks.

The sugar beets which were grown in pots that had received alfalfa material contained more sucrose than did those grown in the check pots, but there were no differences as affected by the various treatments as compared to each other. See Table 6.

As an aid in the explanation of the differences in beet yields as affected by the incorporation of the various alfalfa plants, nitrification studies were undertaken in the laboratory. A study of Table 11 (Fig. 2) reveals that all fertilized tops caused the greatest nitrate production with the April 27 material, and the lowest with the May 10 material. The unfertilized tops followed the same trend (except in the case of 1-year-old tops, which gave best results with the April 17 material), but in some cases gave higher figures than the corresponding fertilized alfalfa. The roots, fertilized or unfertilized, gave highest nitrate production with the April 17 material, and lowest with the May 10 material. Here again, the unfertilized material sometimes gave better results than did the corresponding fertilized material. These data are in perfect agreement with those of Davis and Turk (21), who came to identical conclusions.

Viewed from the date angle, the April 17 fertilized tops nitrified most rapidly with the 1-year-old plants; the April 27 and May 10 nitrified most rapidly with the 2-year-old plants and slowest with the 1-year-old. The unfertilized tops followed the same trend as did the fertilized, except that sometimes the figures were higher than for the corresponding fertilized material. The fertilized roots of all the harvests, either April 17, April 27 or May 10, nitrified most rapidly with the 1-year-old plants, and slowest with the 3-year-old plants. The unfertilized roots followed the same general trend as did the fertilized, but sometimes gave higher figures than did the corresponding fertilized roots.

Considering all top material incubated, the most nitrate was obtained from the 2-year-old unfertilized plants of April 27, the corresponding fertilized plants having produced slightly less. The least nitrate was obtained from the 1-year-old fertilized plants of May 10, the corresponding unfertilized plants having produced slightly more. Comparing all root material, the most nitrate was obtained from the 1-year-old fertilized plants of April 17, the corresponding unfertilized having produced a little less. The least nitrate came from the 3-year-old fertilized or unfertilized plants of May 10.

In all cases, as expected, the tops showed faster nitrification than did the corresponding roots; but whenever the unfertilized tops nitrified faster than the fertilized, it did not follow that the corresponding unfertilized roots nitrified faster than did those that were fertilized.

Before attempting to correlate the nitrogen release from the alfalfa material with the beet yields, it is to be remembered that varying amounts of tops and roots were turned under in the different treatments. To get an approximate idea of the amounts of nitrate liberated by these various amounts of tops and roots, calculations of the amounts of nitrate formed in the greenhouse jars have been based on the data secured from the laboratory tumblers.

In laboratory nitrification tests, only the quality of the alfalfa material affected nitrate production; here, both quantity and quality are taken into account. This is why the greatest amount of nitrate produced by the total plants is found neither where it was when considering tops alone nor roots alone. Considering only the quality of tops (Table 11, Fig. 2), the April 27 material nitrified most rapidly, and the highest results were obtained with the 2-year-old plants. However, due to the increase in top growth in the field from April 17 to May 10, (Table 12, Fig. 3) this latter material (May 10) produced the most nitrate, and the 1-year-old plants produced more than the 2 or 3-year-old plants. The root material harvested April 17 nitrified more rapidly than that harvested at later dates (Table 11, Fig. 2). The highest yields of nitrate were obtained from the 1-year-old plants. Contrary to the performance of tops, the roots decreased slightly in weight from April 17 to M ay 10 (Table 4, Fig. 1). This slight decrease in weight along with a marked decrease in rate of nitrification resulted in the April 17 roots being first in quantity of nitrate produced (Table 12, Fig. 3).

Although the roots were inferior to the tops so far as quantity of nitrate production was concerned, a glance at Table 12 (Fig. 3) reveals that, for an 8-week incubation period, they were more important than the tops in nitrate production, for the mere reason that quantity superseded quality. This explains why the 1-year-old material of April 17 gave so much better results. As seen previously (Table 11, Fig. 2), the quality (as regards chemical nature) of tops was best with the 2-year-old material on April 27; the quality of roots was best with the 1-year-old material on April 17. Adding the factor quantity to the factor quality (Table 12, Fig. 3), the best calculated results in nitrification studies for the tops were obtained from the 1-year-old material on May 10, and for the roots, with the 1-year-old material on April 17. Combining all factors, quality and quantity of roots and tops (Table 12, Fig.3), the best results were obtained from the 1-year-old plants of April 17. The roots and not the tops were responsible for this greater nitrate production. The increase in nitrate production of the tops through quantity, on May 10, was less than the decrease in nitrate production of the roots at the same date. The balance was in favor of the 1-year-old alfalfa plant turned under on April 17. The fertilized plants were superior to those unfertilized.

Fig. 3 shows that any correlation between beet yields and the calculated nitrate production of the material turned under, either tops, roots or total plants, is far from being satisfactory, except for the material turned under on April 17, May 10, and the 3-year-old plants, in which cases a fair correlation exists. This lack of correlation may be attributed to the fact that laboratory nitrification studies were carried out in a different soil which did not have the same microflora and nitrifying power as did the soil in which the beets were grown.

As seen in Fig. 4, no correlation seems to exist between the beet yields and the amounts of various forms of phosphorus found in the soils after the crop. Fig. 5 shows no correlation between the amounts of exchangeable magnesium, but shows a fair correlation between the exchangeable potassium and the beet yields. It also indicates that differences in the percent base saturation were not sufficient to influence the beet yields.

However, Table 13 indicates that the pH value of the soils was lower after the beet crop, and it decreased more where alfalfa had been turned under than it did in the checks. This was probably due to the action of organic acids liberated by the decomposition of the alfalfa material or by greater crop removal of bases.

The adsorbed and acid-soluble phosphorus (Table 13) was lower in the checks after the beet crop than in the original soil, but in certain treatments where alfalfa was turned under it was higher after the beet crop. This might indicate that some phosphorus was rendered soluble by the action of plant root excretions or was added by the alfalfa material. Phosphorus seems to have been present in sufficient quantities to furnish all that was needed by the sugar beets.

Potassium (Table 13) was lower in the checks after the beet crop than in the original soil. The amounts of potassium brought to the soil by the addition of alfalfa or solubilized by the action of organic acids varied quite a lot, although a fair correlation (Fig. 5) was found to exist between the yields and the amounts of exchangeable potassium in the soils after the beet crop.

Magnesium was used up by the beets, and, contrary to the results obtained with phosphorus and potassium, the addition of alfalfa did not increase the magnesium content of the soils as measured after the crop (Table 13, Fig. 5).

The base exchange capacity of the soils (Table 13a) was slightly increased through addition of alfalfa material, and the percent base saturation of the soils was lower after than before the beet crop. The percent saturation of calcium and magnesium was lower after the crop, but this did not always hold true for potassium.

II- Comparison of 4, 8, 9, 11 and 14 months old fertilized alfalfa grown in the greenhouse and turned under in "same soil" and in "new soil" for a sugar beet crop in the greenhouse.

<u>Note</u>: The terms "same soil" and "new soil" refer respectively to the soil that has grown the alfalfa and to soil identical to the first, but which has not grown the plant.

A- Greenhouse work.

a) <u>Growing the alfalfa</u>:

The alfalfa material to be used as green manure was grown in the greenhouse, in 2-gallon glazed jars containing 8 kilograms of Miami silt loam soil. This soil is identical to that used in part one to grow the sugar beet crop, and was sieved and brought up to its optimum moisture content, at seeding time, as previously described. The experiment was planned to give alfalfa of 5 different ages with 8 replicates for each given age of the plant. Thus, 40 jars were filled with soil, 8 were seeded and the remainder set aside until needed. Four grams (1000 lbs/acre) of 2-16-8 fertilizer were applied to each jar at the time of planting the seed (Hardigan C3911-D175). Inoculation of the soil was not judged necessary for it was supporting a good alfalfa stand in the field from which it had been taken. The dates of sowing of the alfalfa and the age-to-be of the plants at harvest when turned under as green manure are shown in Table 14.

The seeding of each set of 8 jars was done when the plants in the preceding set blossomed. At each seeding, all the tops of each set of

Table 14.- Outline of greenhouse set-up to secure alfalfa of 5 different ages.

Seeding date	Jars seeded	Remarks	Age-to-be of plants when turned under.
Jan. 12/44	8	-	14 months
Apr. 11/44	8	Tops cut in previous set	11 "
Jun. 7/44	8	" " " 2 previous sets	9 "
Jul. 28/44	8	" " " 3 " "	8 "
Nov. 22/44	8	" " " 4 " "	4 "
On March 23/45, roots and tops in all jars collected and weighed.			

jars were cut, weighed and discarded. On March 23, 1945, when the alfalfa last sown had blossomed, all plant material in all jars was collected and weighed, tops and roots (crowns always included with roots) separately. Table 15 gives the yields of plant material harvested at various dates.

b) Growing the sugar beets:

After cutting up ($\frac{1}{2}$ inch) and mixing well, tops and roots separately, the plant material in each set of 8 replicates, 4 grams of tops and 4 grams of roots corresponding to each of the 5 alfalfa samples were put aside for nitrification studies. Then, the soil of 4 of the 8 jars corresponding to each alfalfa sample was discarded and the pots were refilled with "new soil". The quantity of alfalfa material (roots and tops separately) corresponding to a given treatment (8 replicates) was then divided into 8 equal portions which were turned under in

Table 15.- Grams of green and air-dry alfalfa in a total of 8 replicates, planted and harvested at given dates and to be used as green manure.

Seeding date	Date of harvest										
	Apr.11/44 tops		Jun.7/44 tops		Jul.28/44 tops		Nov.22/44 tops		March 23/45		
									tops		roots.
	Gr.	Dry	Gr.	Dry	Gr.	Dry	Gr.	Dry	Gr.	Dry	dry
Jan.12/44	242	65.1	406	135.1	387	130.0	343	101.9	274	92.0	164
Apr.11/44			195	56.7	455	157.0	341	98.5	251	86.0	188
Jun. 7/44					315	100.0	269	81.1	290	92.0	198
Jul.28/44							182	50.7	228	76.0	124
Nov.22/44									211	66.0	76

each of the quadruplicates of both "same soil" and "new soil" treatments. In addition, quadruplicate checks were set up consisting of "new soil" receiving no alfalfa material. The amounts of alfalfa material, tops and roots, added to the jars of both soils were as indicated in Table 16.

On April 23, 1945, the alfalfa material was mixed with the top six inches of the soils, and the jars were brought up to their optimum moisture levels with distilled water. The checks were also brought to their optimum moisture content. Two weeks later, on May 7, 1945, sugar beets were sowed at the rate of 8 seeds of U. S. 216 par jar. The jars were randomized and occasionally moved around.

When the beets were 3 inches tall, they were thinned out to 4 plants per pot, and later, when they were 6 inches high, were further thinned to 2 plants per jar. The weakest plants were always discarded.

Table 16.- Grams of air-dry alfalfa material turned under per jar in both "same soil" and "new soil" as green manure for sugar beets.

Age of plants turned under	Plant material turned under per jar in both soils		
	tops	roots	total plants
4 months	7.7	9.0	16.7
8 "	9.0	15.0	24.0
9 "	11.0	24.2	35.2
11 "	10.2	23.0	33.2
14 "	11.0	20.0	31.0

A contact insecticide was used to control the aphids. At least once a week the jars were weighed and brought up to their respective optimum moisture weights. The plants grew normally but showed slight nitrogen deficiency symptoms as maturity approached.

Shortly before the beets were harvested, it was noticed that the rate of percolation of added water was quite different in some of the jars. After closer observation, it was found that, in general, the jars containing the "same soil" exhibited a slower rate of percolation than did those containing the "new soil". The water added remained on the surface of the "same soil" much longer than it did on the "new soil". It was thought, therefore, that the structure of the two soils was different, and an attempt was made to measure, by means of aggregate analysis, any eventual size-variation in the structural units of the soils. At the time of harvesting the beet crop, the soil samples were taken and the results of this aggregate analysis are given later.

The beet crop was harvested on November 10, 1945, when the beets were

Table 17.- Sugar beet yields following the turning under of alfalfa of 5 different ages. Figures give sum of four replicates.

Age of alfalfa turned under	Green plants, gms.		App. pur. coef.*	Sucrose, gms.		
	Tops	Roots		%*	Total	Avail.
			"Same soil"			
4 months	264.2	423.9	0.857	15.3	64.9	55.6
8 "	238.0	272.0	0.868	16.0	43.5	37.8
9 "	289.8	279.8	0.928	15.8	44.2	41.0
11 "	248.2	255.8	0.825	16.0	40.9	33.8
14 "	248.7	177.9	0.828	14.3	25.4	21.1
			"New Soil"			
4 "	363.8	666.3	0.892	17.0	113.3	101.0
8 "	385.8	668.7	0.884	16.3	109.0	96.4
9 "	352.3	727.8	0.889	15.0	109.2	97.0
11 "	378.0	634.0	0.870	15.7	99.5	86.6
14 "	384.5	661.6	0.890	16.9	111.8	99.5
Check	257.8	422.0	0.895	15.1	63.7	57.0

* Mean of four replicates.

approximately 6 months old. Tops and roots were weighed separately and sucrose determinations made within three days after harvest. (See laboratory work). The top, root and sucrose yields of the sugar beets are given in Table 17.

Following the beet crop, the soils were sampled for laboratory study and these results are found in the report of the laboratory work.

To further study the residual effect of the alfalfa turned under,

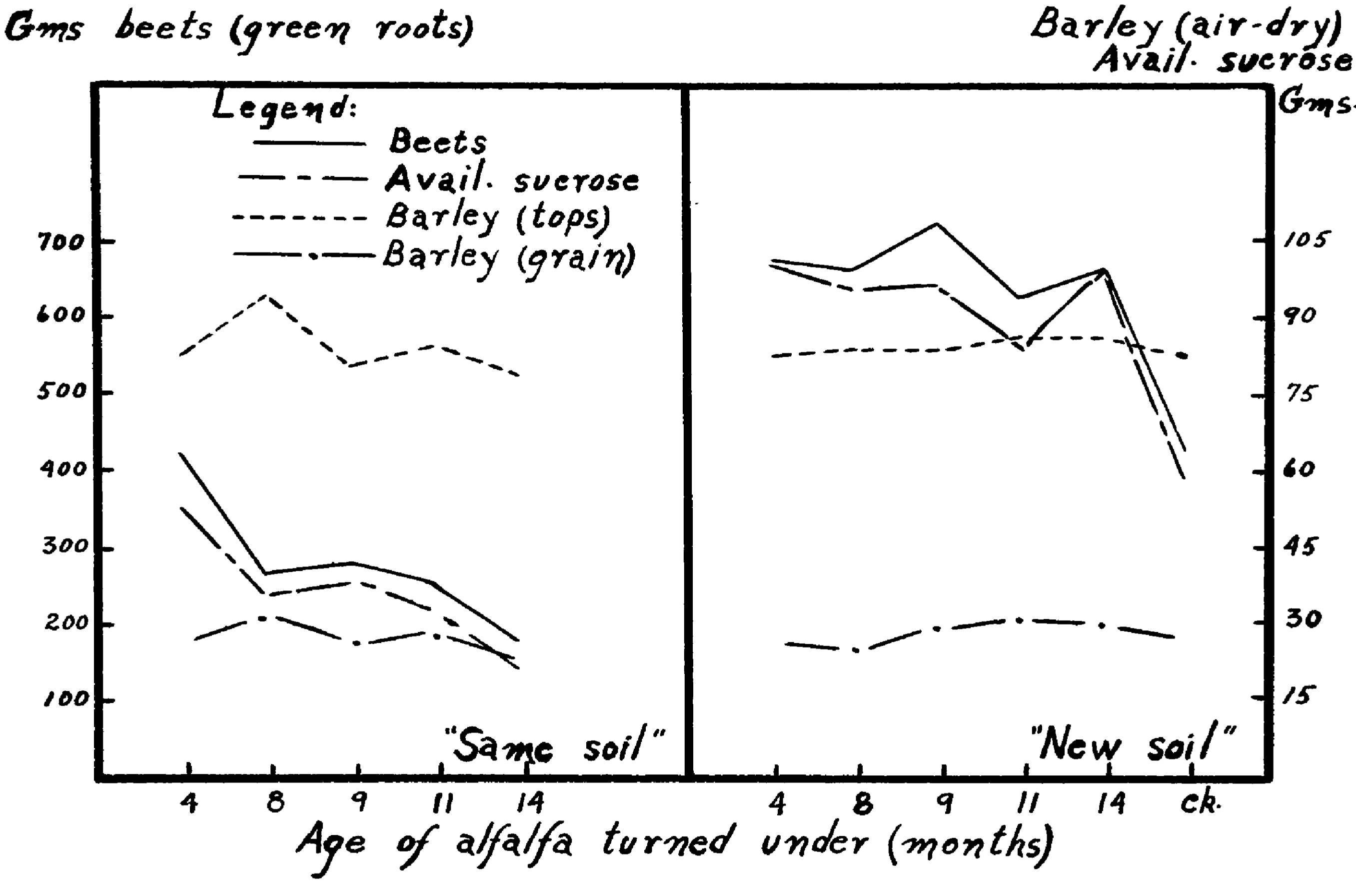

Fig. 6.- Sugar beet and sucrose yields following alfalfa turned under at various stages of maturity. Yields of barley following the beets.

Table 18.- Barley yields following the sugar beet crop. Figures give sum of four replicates on an air-dry basis.

Age of alfalfa turned under for the beets	Total plant, grams.	Straw, grams.	Grain, grams.
	"Same soil"		
4 months	83.2	56.0	27.2
8 "	94.0	61.1	32.9
9 "	82.9	55.6	27.3
11 "	85.1	55.1	30.0
14 "	80.0	55.7	24.3
	"New soil"		
4 "	83.2	55.8	27.4
8 "	85.5	58.8	26.7
9 "	84.3	53.7	30.6
11 "	87.1	54.7	32.4
14 "	87.1	56.0	31.1
Check	83.3	55.2	28.1

the sugar beets were followed by a barley crop.

After loosening the soils in the jars, a 4-16-8 fertilizer was added at the rate of two grams per jar (500 lbs/acre). Twenty seeds of Bay barley were planted in each pot on January 18, 1946. When the plants reached a height of 6 inches, they were thinned to 15 plants per jar.

On April 27, 1946, the barley was harvested. The yields are recorded in Table 18.

Following the barley crop, the soils were sampled and studied in the laboratory. The results of these tests are presented in the discussion on the laboratory work.

In another attempt to determine the effects of age of alfalfa when turned under as green manure at various stages of growth, an experiment was set up similar to the preceding one, but a little more involved. Here again, alfalfa was grown in the greenhouse and turned under as before in the "same soil" and in a "new soil". This time, however, another factor was introduced. Fertilizer was added to some of the jars and some were left unfertilized. Only two ages of alfalfa were involved, 3 months and 6 months. The plants were grown exactly as described in the preceding experiment, in identical soil, with same fertilizer, i.e. 2-16-8, at the rate of 4 grams per jar (1000 lbs/acre). In this final experiment, the seed wa s treated with C eresan. Alfalfa was planted in 12 jars on June 29, 1946, and in 12 others, on September 30, 1946. At this same date, the tops in the first group of jars were harvested, weighed and discarded. On December 30, 1946, all plant material, tops and roots, was collected, weighed and saved for green manure. Table 19 summarizes the yields of tops and roots at harvest time.

In each set of 12 replicates the alfalfa was cut up ($\frac{1}{2}$ inch), well mixed, tops and roots separately, and 12 equal portions of tops and of roots were turned under. These portions were, for the older plant (6 months): tops, 10.2 grams, roots, 16.6 grams; for the younger plant (3 months): tops, 8.0 grams, roots, 9.1 grams, all on an air-dry basis. Consequently, each jar to which either older or younger plant material was added received these same amounts of roots and tops. In both cases, the

Table 19.- Grams of green and air-dry alfalfa material in each of 12 replicates, sowed and harvested at given dates and to be used as green manure.

Seeding date	Date of harvest					
	Sept. 30/46 tops		Dec. 30/46			
			Tops		Roots	
	Green	Dry	Green	Dry	Green	Dry
June 29/46	17.9	6.7	26.8	10.3	33.2	16.9
	23.4	9.2	31.0	10.8	33.2	15.1
	18.4	7.1	27.6	10.2	34.4	19.3
	19.8	7.8	31.3	11.1	31.6	17.2
	23.4	8.0	31.3	11.0	33.9	17.1
	21.8	7.1	33.6	9.6	40.1	18.0
	22.8	7.9	30.7	10.3	30.5	15.4
	18.6	6.1	28.3	8.7	23.5	12.1
	20.4	7.4	31.4	11.1	30.5	17.3
	21.7	7.0	30.7	9.7	29.6	17.5
	24.7	9.3	30.2	11.4	32.9	18.4
	20.4	7.0	26.2	8.9	28.5	15.9
Sum	253.3	90.6	359.1	123.1	381.9	200.2
Sept. 30/46			32.9	10.7	21.8	11.7
			35.4	10.5	21.6	11.6
			25.7	7.3	16.9	7.8
			21.6	5.8	13.2	6.2
			26.6	8.2	19.3	10.2
			24.4	7.3	17.4	9.1
			17.3	5.5	13.4	6.4
			27.0	8.8	21.2	9.1
			21.3	7.0	20.8	10.8
			27.0	8.6	14.9	7.0
			29.0	8.1	21.2	10.2
			25.2	8.3	17.4	9.3
Sum			313.4	96.1	219.1	109.4

soil in 6 of the 12 jars was discarded and replaced by "new soil". Each treatment was triplicated and the set-up is illustrated in Table 20.

Sugar beets were sown on January 2, 1947, and the plants grew well up to the age of 3 months, i.e. up to April 1, 1947, when nitrogen deficiency symptoms were noticed in the jars having received the younger alfal-

Table 20.- Outline of greenhouse set-up to study the effect of 3 and 6 months old alfalfa turned under as fertilizer.

Age of alfalfa turned under	Soil used	2-16-8, grams	Symbol for treatment
3 months	"New soil"	2	3, N, F.
"	"	0	3, N, UNF.
"	"Same soil"	2	3, S, F.
"	"	0	3, S, UNF.
6 months	"New soil"	2	6, N, F.
"	"	0	6, N, UNF.
"	"Same soil"	2	6, S, F.
"	"	0	6, S, UNF.
Check	"New soil"	0	Check

fa material. Three weeks later, nitrogen deficiency symptoms were observed in the jars to which the older alfalfa had been incorporated. In all treatments the deficiencies were more pronounced in the unfertilized pots. The first week of May 1947, nitrate nitrogen determinations were made in soils and the results can be found in Table 27.

The beets were harvested on June 23, 1947, after 6 months growth and tested for sucrose the following day. Yields and sucrose contents are to be found in Table 21. At the time the beets were harvested, soil samples were collected for laboratory investigation. (See further, laboratory work).

Table 21.- Yields and sucrose content of sugar beets following the turning under of 3 and 6 months old alfalfa in "same soil" and "new soil", fertilized and unfertilized. Figures give sum of triplicates.

Soil treatment	Tops, gms.		Green roots, grams	Total sucrose	
	Green	Dry		%**	grams
3, N, F.	288.5	50.5	318.1	14.2	45.2
3, N, UNF.	229.0	43.0	216.2	15.9	34.4
3, S, F.	191.4	32.4	194.0	16.3	31.6
3, S, UNF.	170.6	28.6	190.2	15.5	29.5
6, N, F.	303.7	58.7	336.0	14.9	50.1
6, N, UNF.	274.6	53.6	279.1	15.8	44.1
6, S, F.	232.7	39.7	208.0	15.0	31.2
6, S, UNF.	176.8	34.8	174.2	15.1	26.3
Check	163.8	27.8	189.1	15.3	28.9

* See symbols, table 20.
** Mean of triplicates.

B- Laboratory work.

a) Test for sucrose:

Sucrose in the sugar beets was determined according to the method and procedure described in part one, laboratory work. In one instance (beets following alfalfa of 5 different ages), the apparent purity coefficient was determined in order to compute the amounts of available sucrose. Since the saccharimeter reading gives the percentage of total sucrose, and the Brix reading, the specific gravity of the extract (sucrose plus salts), the ratio saccharimeter reading/Brix reading gives the apparent purity coefficient of the sugar. Consequently, the weight of roots multiplied by the percentage of total sucrose (saccharimeter reading) will give the amount of total sucrose, and the amount of total sucrose multiplied by the apparent purity coefficient will give the quantity of available sucrose.

b) Soil aggregate analysis:

The methods used to study soil aggregate relationships are more or less adequate. No one method of approach to the question has been officially recognized as being of more value than another when applied to the study of soils in general or to the study of all problems of soil structure. In some cases, one method will be more adapted to the study of one aspect of the problem, while the same method may be of little value in studying some other aspect.

Regardless of the method used, two points are of vital importance in performing any soil aggregate analysis. These two points regard the sampling of the soil and are: first, the number of replicate samples used; second, the treatment given the sample before submitting it to the analysis. Both these preliminary steps should be given the greatest attention for they have a direct and decisive bearing on the results obtained.

To determine the state of aggregation of the soils under study, use has been made of the wet sieve method, consisting of a nest of sieves vertically agitated in a water bath for a period of 20 minutes. An electric motor was geared so as to cause 30 lowerings of the sieves per minute. The soil was placed on the upper large sieve and allowed to crumble under the disintegrating action of the mass of water. When up, the upper sieve screen was ½ inch above water level; when down, ½ inch below water level. A 50-gram moist soil sample was used, and moisture was determined in the soil from which the sample was taken in order to state results on an oven-dry basis. All jars had been brought up to their weights (20% moisture) two days previous to sampling. After a 20-minute shake, each sieve content was washed into a separate beaker. The soil was then evaporated to dryness and oven-dried at 110° C. for 24 hours. The weight of the soil collected on each sieve (thus representing a given fraction) was determined and expressed in percentage of the oven-dry weight of the sample.

If one will realize the rather broad range of variations found in the structural units of a given soil, it will be easy to conceive that a representative analysis can be obtained only by multiplying the number of replicate samples. It has been found in the course of this study that no significance could be attached to the results secured from one sample or from the mean of two replicates. This is the reason why, in this analysis, two soil samples were collected from each of the four jars corresponding to a given treatment, thus affording eight replicate soil samples per treatment. In preparing the sample, the soil was gently passed through a 1-cm. mesh screen, the clumps being broken by means of a sharp pencil. This allowed the soil to be completely exposed to the erosive action of water and erased the difficulty encountered when the clump is too large to favor its entire compenetration by water. The sieves used were of the following mesh: 2.0 mm., 1.0 mm., 0.5 mm., 0.25 mm. and 0.1 mm. They permitted the separation of the respective structural fractions: >2.0 mm., 2.0-1.0 mm., 1.0-0.5 mm., 0.5-0.25 mm., 0.25-0.1 mm. The fraction <0.1 mm. was not determined because it had been judged of no practical importance in this particular study.

The state of aggregation of the soil primary particles was expressed as follows:

$$\text{State of aggregation} = \sum \Big[\%\ \text{aggregates} \Big]_{a}^{b}$$

where

$$a = 0.1 \text{ mm.}$$

$$b > 2.0 \text{ mm.}$$

The results of this aggregate analysis are given in Table 22.

c) Nitrification studies:

Portions of the alfalfa material of 5 different ages that **was** turned under for sugar beets were put aside for nitrification studies in the laboratory. The soil used and the methods followed were the same as already described in part one. However, instead of using 2.0 grams of plant material per 100 grams of soil, as previously, 1.0 gram only was used. Tables 23 and 24 give the results obtained, and both are summarized in Table 25. Nitrification was started on January 17, 1946, and ended on February 14, 1946 (4-week period) and on March 14, 1946 (8-week period).

Based on the nitrogen produced in 8 weeks in 100 grams of soil by

Table 22.- The state of aggregation of the "same soil" as compared to that of the "new soil", while beets were growing after turning under alfalfa.

Soil treatment (alfalfa turned under)	Size of aggreg. in mm.	"Same soil" %aggregates	"Same soil" State of aggreg.	"Same soil" Soil moist. %	"New soil" %aggregates	"New soil" State of aggreg.	"New soil" Soil moist. %
4 months	>2.0	5.3			10.8		
	2.0-1.0	5.5 } 20.5			8.3 } 29.2		
	1.0-0.5	9.7			10.1		
	0.5-0.25	21.5			19.4		
	0.25-0.1	22.3	64.3	14.3	18.9	67.6	12.3
8 "	Idem	5.4			13.2		
		6.8 } 18.4			8.7 } 31.3		
		6.2			9.4		
		19.0			19.4		
		22.0	59.4	14.2	19.5	70.3	14.1
9 "	"	4.9			12.4		
		4.7 } 16.7			8.7 } 30.5		
		7.1			9.4		
		19.3			20.4		
		21.1	57.1	14.9	20.5	71.5	10.5
11 "	"	5.2			11.5		
		5.5 } 17.8			8.3 } 29.2		
		7.1			9.4		
		18.1			19.9		
		21.2	57.1	14.4	21.0	70.3	11.1
14 "	"	5.6			12.1		
		6.8 } 20.0			9.0 } 31.8		
		7.6			10.7		
		21.1			19.0		
		19.6	60.7	15.4	19.2	70.1	12.4
Check	"	-			11.9		
		-			8.5 } 30.2		
		-			9.8		
		-			18.8		
		-	-	-	18.2	67.3	14.0

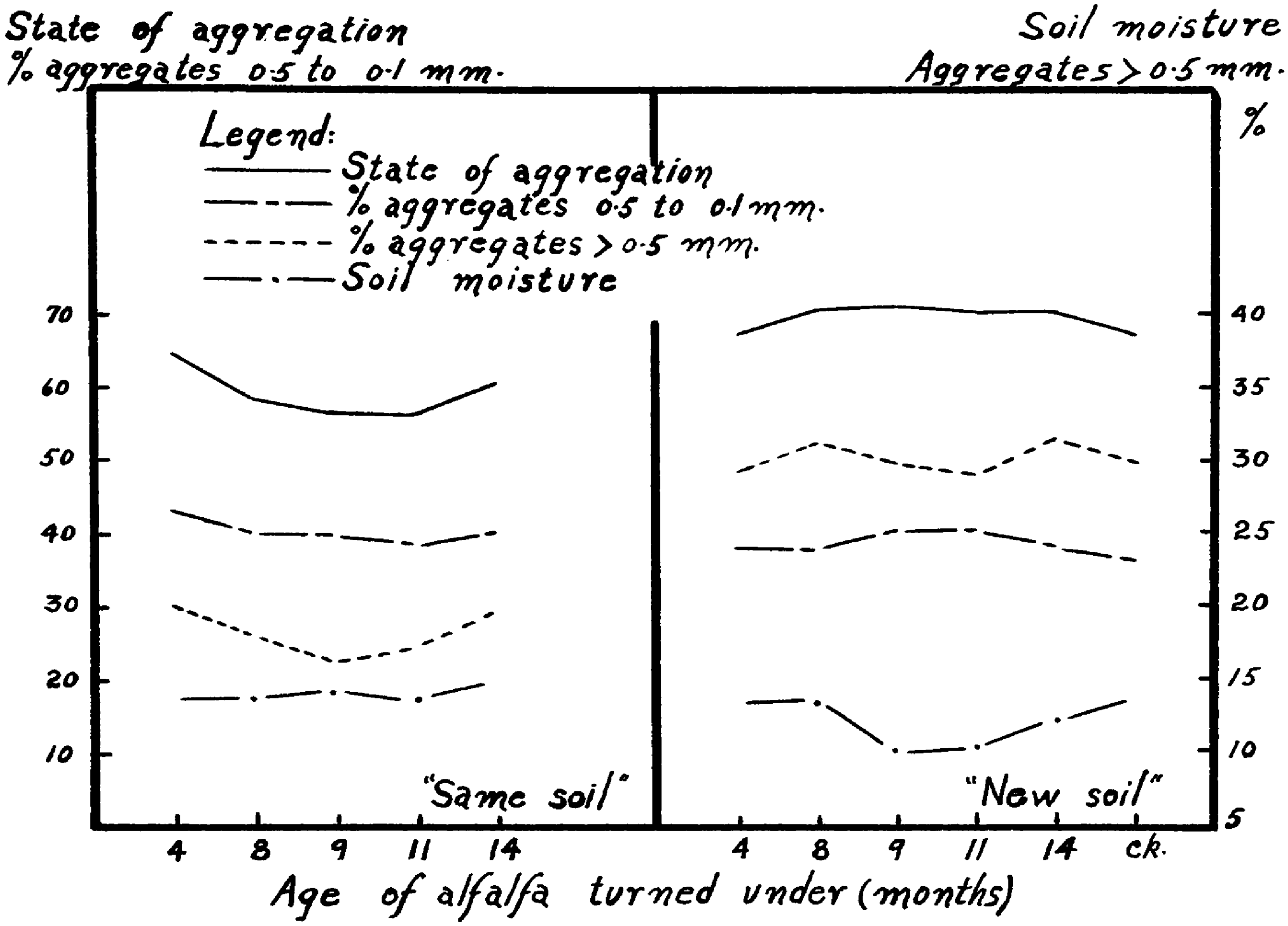

Fig. 7.- State of aggregation, % of larger and smaller aggregates and moisture content of "same soil" and "new soil" growing the sugar beets following the alfalfa turned under at various stages of maturity.

Table 23.- Milligrams of nitrogen accumulated during a 4-week period in 100 grams of soil receiving 1.0 gram of alfalfa material.

Age of alfalfa incubated	Roots			Tops		
	NH_4-N	NO_3-N	$(NH_4+NO_3)N$	NH_4-N	NO_3-N	$(NH_4+NO_3)N$
4 months	0.98	3.48	4.46	0.94	9.24	10.18
8 "	1.42	5.38	6.80	1.00	9.80	10.80
9 "	1.26	4.60	5.86	0.94	8.70	9.64
11 "	1.17	4.82	5.99	1.06	7.50	8.56
14 "	1.29	4.40	5.69	0.94	10.32	11.26
Check	(See 8-week period, table 24)					

Table 24.- Milligrams of nitrogen accumulated during an 8-week period in 100 grams of soil receiving 1.0 gram of alfalfa material.

Age of alfalfa incubated	Roots			Tops		
	NH_4-N	NO_3-N	$(NH_4+NO_3)N$	NH_4-N	NO_3-N	$(NH_4+NO_3)N$
4 months	0.80	9.38	10.18	0.94	8.84	9.78
8 "	1.07	9.38	10.45	0.87	6.96	7.83
9 "	0.87	10.04	10.91	0.87	6.30	7.17
11 "	0.80	8.18	8.98	0.87	6.28	7.15
14 "	0.80	7.50	8.30	0.87	9.78	10.65
Check	NH_4-N: 0.80; NO_3-N: 1.39; $(NH_4+NO_3)N$: 2.19					

Table 25.- Milligrams of $(NH_4+NO_3)N$ accumulated during a 4 and an 8-week period in 100 grams of soil receiving 1.0 gram of alfalfa material. A summary of tables 23 and 24.

Age of alfalfa incubated	4-week period		8-week period	
	Roots	Tops	Roots	Tops
4 months	4.46	10.18	10.18	9.78
8 "	6.80	10.80	10.45	7.83
9 "	5.86	9.64	10.91	7.17
11 "	5.99	8.56	8.98	7.15
14 "	5.69	11.26	8.30	10.65

1.0 gram of top and 1.0 gram of root material in the laboratory studies, the amounts of nitrogen produced from the alfalfa turned under in the greenhouse jars were calculated and are presented in Table 26.

The alfalfa material of 2 different ages, i.e. 3 and 6 months old, turned under as green manure for sugar beets, was not incubated in the laboratory. The soils in the greenhouse jars were sampled when the beet plants had grown 4 months (April 29, 1947, i.e. 2 months before harvest) and were analyzed for nitrate nitrogen.

A 50-gram moist soil sample was taken from each of the three replicates and the percentage of moisture in each jar was determined in order to base the results on dry soil. Ammonia and nitrate nitrogen was determined immediately after sampling, according to the method mentioned in part one, laboratory work. An exception, however, is to be noted. The nitrogen was distilled into N/10 H_2SO_4 and titrated with N/10 NaOH, using methyl red as the indicator. The results are found in Table 27.

One week before sampling the soils for these nitrogen determinations,

Table 26.- Milligrams of nitrogen accumulated in the laboratory in 100 grams of soil by 1.0 gram of alfalfa tops and 1.0 gram of roots, and calculated milligrams of nitrogen produced by the corresponding material in greenhouse jars (8-week period).

Age of alfalfa incubated	$(NH_4+NO_3)N$ produced in lab.		Calculated $(NH_4+NO_3)N$ produced in jars		
	Tops	Roots	Tops*	Roots*	Total plants
4 months	9.78	10.18	75.3	91.6	166.9
8 "	7.83	10.45	70.5	156.7	227.2
9 "	7.17	10.91	78.9	264.0	342.9
11 "	7.15	8.98	72.9	206.5	279.4
14 "	10.65	8.30	117.1	166.0	283.1

* See table 16.

i.e. on April 22, 1947, plant tissue tests were made on the beet leaves to confirm the nitrogen deficiency symptoms observed. In all cases the tests for nitrate nitrogen with diphenylamine were negative.

d) Study of soils:

The methods and procedures used in the study of soils are found in part one, laboratory work. Tables 28, 28a, 29, 29a, 30 and 30a contain the results of the various soil analyses.

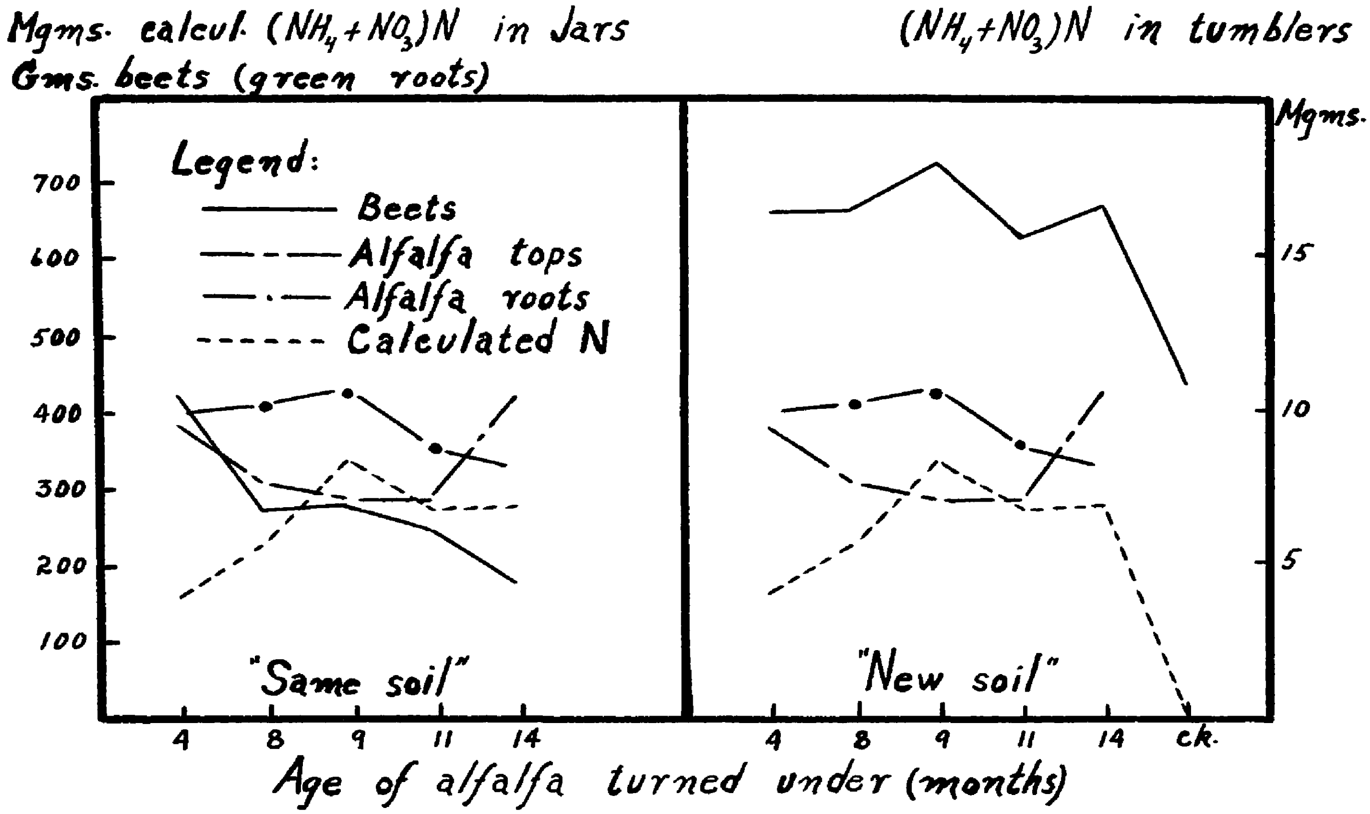

Fig. 8.- Sugar beet yields and amounts of N produced in 8 weeks in 100 gms. of soil receiving 1.0 gm. of alfalfa, tops and roots, and calculated amounts of N per 100 gms. of soil produced by the various quantities of alfalfa turned under in the greenhouse jars.

Table 27.- Milligrams of nitrogen per 100 grams of soil (oven-dry basis) growing sugar beets 4 months old, after turning under of alfalfa material.

Soil treatment*	Milligrams of nitrogen		
	NH_4-N	NO_3-N	$(NH_4+NO_3)N$
3, N, F.	0.49	0.03	0.52
3, N, UNF.	0.47	0.00	0.47
3, S, F.	0.42	0.00	0.42
3, S, UNF.	0.74	0.21	0.95
6, N, F.	0.76	0.18	0.94
6, N, UNF.	0.53	0.00	0.53
6, S, F.	0.54	0.00	0.54
6, S, UNF.	0.48	0.03	0.51
Check	0.49	0.00	0.49

* See symbols, table 20.

C- Discussion of results.

Here again, a glance at Table 17 (Fig. 6) will indicate that the youngest alfalfa turned under caused the highest yields of sugar beet roots with the highest sucrose content of any grown in the "same soil". Although the youngest alfalfa material also produced beets with the highest sucrose content in the "new soil", it failed to cause the highest yields of roots. There was not a general decrease in yields as the age of the plant increased, as was true with the beets grown in the "same soil".

Table 28.- pH value, phosphorus, potassium, calcium and magnesium contents of the original soil and the soil after the beet crop that followed the turning under of alfalfa. (Same data for soil before the barley crop)

Soil treatment (age of alfalfa turned under)	pH	P (p.p.m. in soil)			K		Ca		Mg	
		1*	2*	3*	m.e.per 100gms.	lbs per acre	m.e.per 100gms.	lbs per acre	m.e. per 100 gms.	lbs per acre
Original soil	6.46	42.5	145.0	187.5	0.136	106.6	5.751	2307	0.097	23.7
After beet crop					"Same soil"					
4 months	6.63	61.0	14.0	75.0	0.106	83.2	6.480	2600	0.116	28.1
8 "	6.60	60.0	26.0	86.0	0.099	77.3	5.832	2340	0.118	28.7
9 "	6.48	53.7	26.2	79.9	0.102	79.9	5.670	2275	0.116	28.1
11 "	6.40	57.5	167.5	225.0	0.089	69.3	5.832	2340	0.120	29.1
14 "	6.31	47.5	132.5	180.0	0.094	73.3	5.913	2372	0.104	25.3
					"New soil"					
4 "	6.63	45.0	75.0	120.0	0.111	86.6	6.318	2535	0.118	28.7
8 "	6.82	45.0	181.2	226.2	0.130	102.0	5.994	2405	0.118	28.7
9 "	6.89	50.0	180.0	230.0	0.123	95.9	6.156	2470	0.110	26.6
11 "	6.53	50.0	190.0	240.0	0.108	84.3	6.318	2535	0.118	28.7
14 "	6.58	57.5	125.0	182.5	0.119	93.2	6.318	2535	0.116	28.1
Check	6.68	49.0	112.2	161.2	0.132	103.2	6.480	2600	0.122	29.6

* 1, adsorbed; 2, acid-soluble; 3, adsorbed + acid-soluble.

Table 28a.- Exchange capacity, percent base saturation, percent saturation of individual cations, cation ratios of the original soil and the soil after the beet crop that followed the turning under of alfalfa. (Same data for soil before the barley crop)

Soil treatment (age of alfalfa turned under)	Exc. cap. m.e. per 100 gms.	% base sat.	Percentage of exc. cap.			Cation ratios (m.e. basis)		
			Ca	Mg	K	Ca/Mg	Ca/K	K/Mg
Original soil	9.250	64.7	62.2	1.05	1.47	59.3	42.3	1.40
After beet crop				"Same soil"				
4 months	10.100	66.4	64.2	1.15	1.05	55.9	61.1	0.91
8 "	9.665	62.6	60.3	1.22	1.02	49.4	58.9	0.84
9 "	9.750	60.4	58.1	1.19	1.05	48.9	55.6	0.88
11 "	10.000	60.4	58.3	1.20	0.89	48.6	65.5	0.74
14 "	10.330	59.2	57.2	1.01	0.91	56.9	62.9	0.90
				"New soil"				
4 "	10.100	64.8	62.5	1.17	1.10	53.5	56.9	0.94
8 "	9.165	68.1	65.4	1.29	1.42	50.8	46.1	1.10
9 "	8.830	72.4	69.7	1.25	1.39	56.0	50.0	1.12
11 "	9.900	66.1	63.8	1.19	1.09	53.5	58.5	0.91
14 "	9.500	69.0	66.5	1.22	1.25	54.5	53.1	1.03
Check	9.750	69.1	66.5	1.25	1.35	53.1	49.1	1.08

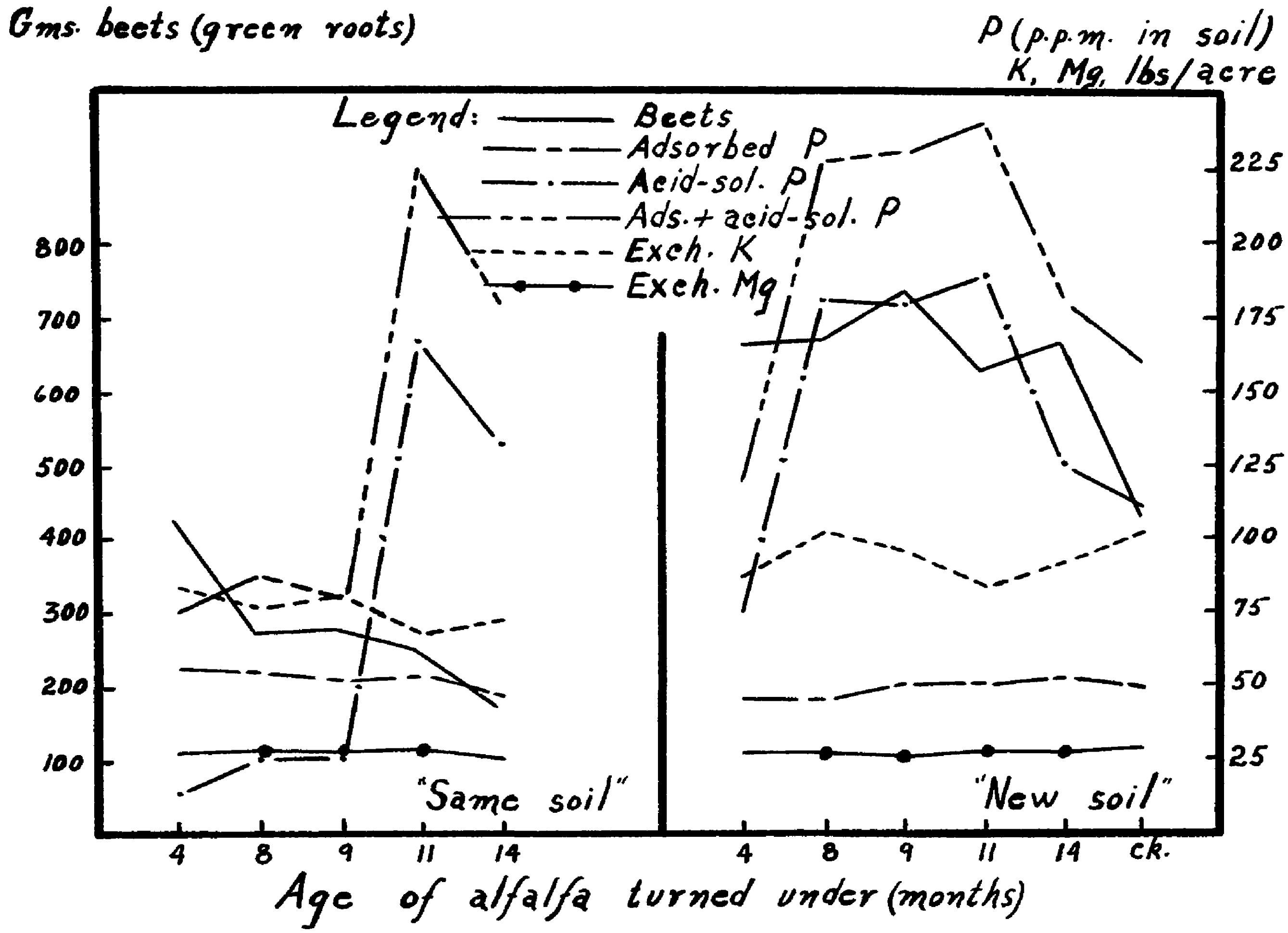

Fig. 9.- Sugar beet yields following alfalfa turned under at various stages of maturity, and P, K and Mg contents of the soils after the crop.

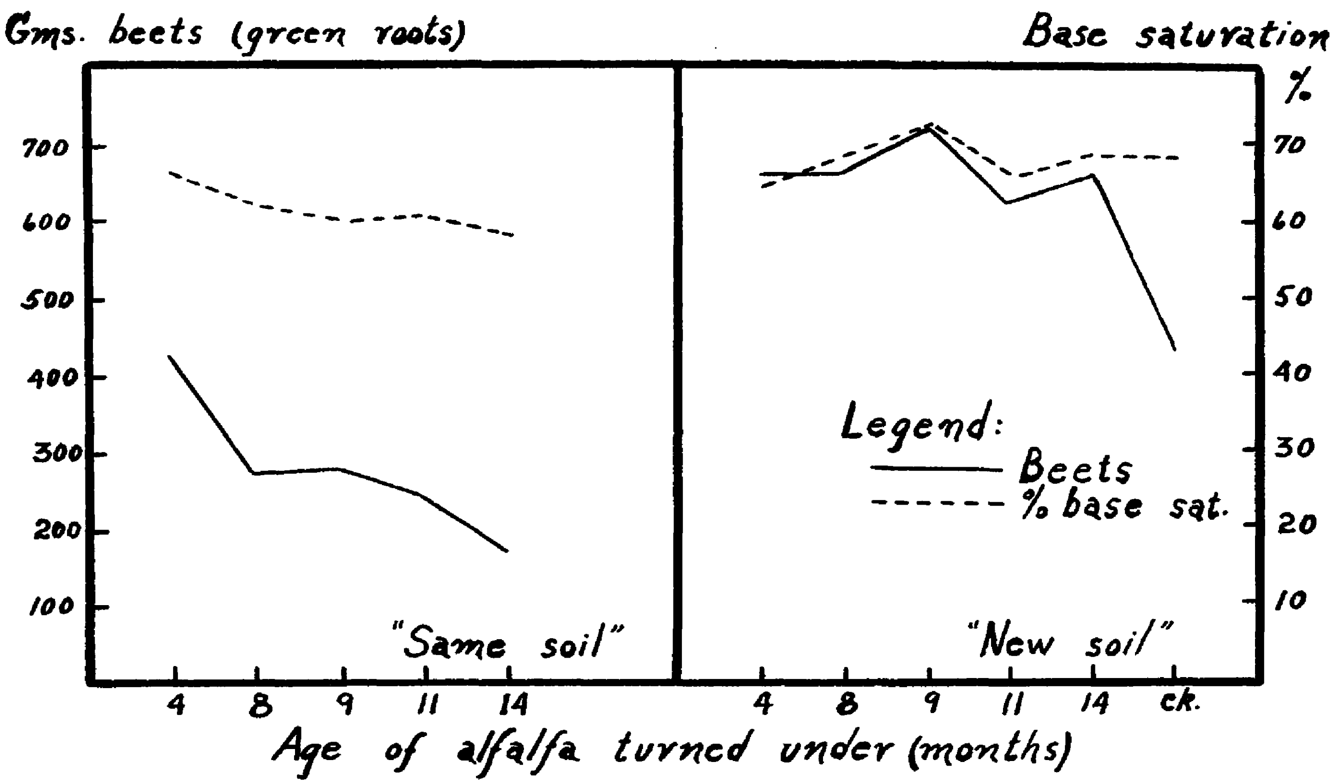

Fig. 9a.- Sugar beet yields following alfalfa turned under at various stages of maturity and % base saturation of the soils after the crop.

Table 29.- pH value, phosphorus, potassium, calcium and magnesium contents of the soil after the barley crop.

Soil treatment (age of alfalfa turned under)	pH	P (p.p.m. in soil)			K		Ca		Mg	
		1*	2*	3*	m.e. per 100 gms.	lbs per acre	m.e. per 100 gms.	lbs per acre	m.e. per 100 gms.	lbs per acre
"Same soil"										
4 months	6.48	65.0	40.0	105.0	0.072	56.6	5.427	2177	0.115	27.9
8 "	6.42	60.0	52.5	112.5	0.106	83.2	6.804	2730	0.125	30.4
9 "	6.23	57.5	77.5	135.0	0.094	73.3	6.156	2470	0.118	28.7
11 "	6.30	57.5	120.0	177.5	0.096	75.4	6.075	2437	0.116	28.1
14 "	6.32	47.5	115.0	162.5	0.079	62.1	5.346	2145	0.122	29.6
"New soil"										
4 "	6.72	50.0	40.0	90.0	0.068	53.3	5.670	2275	0.118	28.7
8 "	6.95	50.0	50.0	100.0	0.094	73.3	5.371	2151	0.125	30.4
9 "	7.00	52.5	47.5	100.0	0.102	79.9	5.776	2314	0.130	31.5
11 "	6.59	52.5	52.5	105.0	0.072	56.6	5.346	2145	0.108	26.2
14 "	6.45	55.0	50.0	105.0	0.089	69.9	6.966	2795	0.129	31.3
Check	6.85	50.0	40.0	90.0	0.074	57.7	5.751	2307	0.111	27.0

* 1, adsorbed; 2, acid-soluble; 3, adsorbed + acid-soluble.

Table 29a.- Exchange capacity, percent base saturation, percent saturation of individual cations, cation ratios of the soils after the barley crop.

Soil treatment (age of alfalfa turned under)	Exc. cap. m.e. per 100 gms.	% base sat.	Percentage of exc. cap.			Cation ratios (m.e. basis)		
			Ca	Mg	K	Ca/Mg	Ca/K	K/Mg
				"Same soil"				
4 months	9.165	61.2	59.2	1.25	0.79	47.2	75.4	0.63
8 "	10.000	70.3	68.0	1.25	1.06	54.4	64.2	0.85
9 "	9.750	65.3	63.1	1.21	0.96	52.2	65.5	0.80
11 "	9.500	66.2	63.9	1.22	1.01	52.4	63.3	0.83
14 "	8.875	62.5	60.2	1.37	0.89	43.8	67.7	0.65
				"New soil"				
4 "	9.165	63.9	61.9	1.29	0.74	48.0	57.1	0.58
8 "	9.165	61.0	58.6	1.36	1.03	43.0	56.6	0.75
9 "	9.750	61.6	59.2	1.33	1.05	44.4	76.2	0.78
11 "	9.250	59.7	57.8	1.17	0.78	49.5	74.2	0.67
14 "	12.625	56.9	55.2	1.02	0.70	54.0	78.3	0.69
Check	9.250	64.2	62.2	1.20	0.80	51.8	77.7	0.67

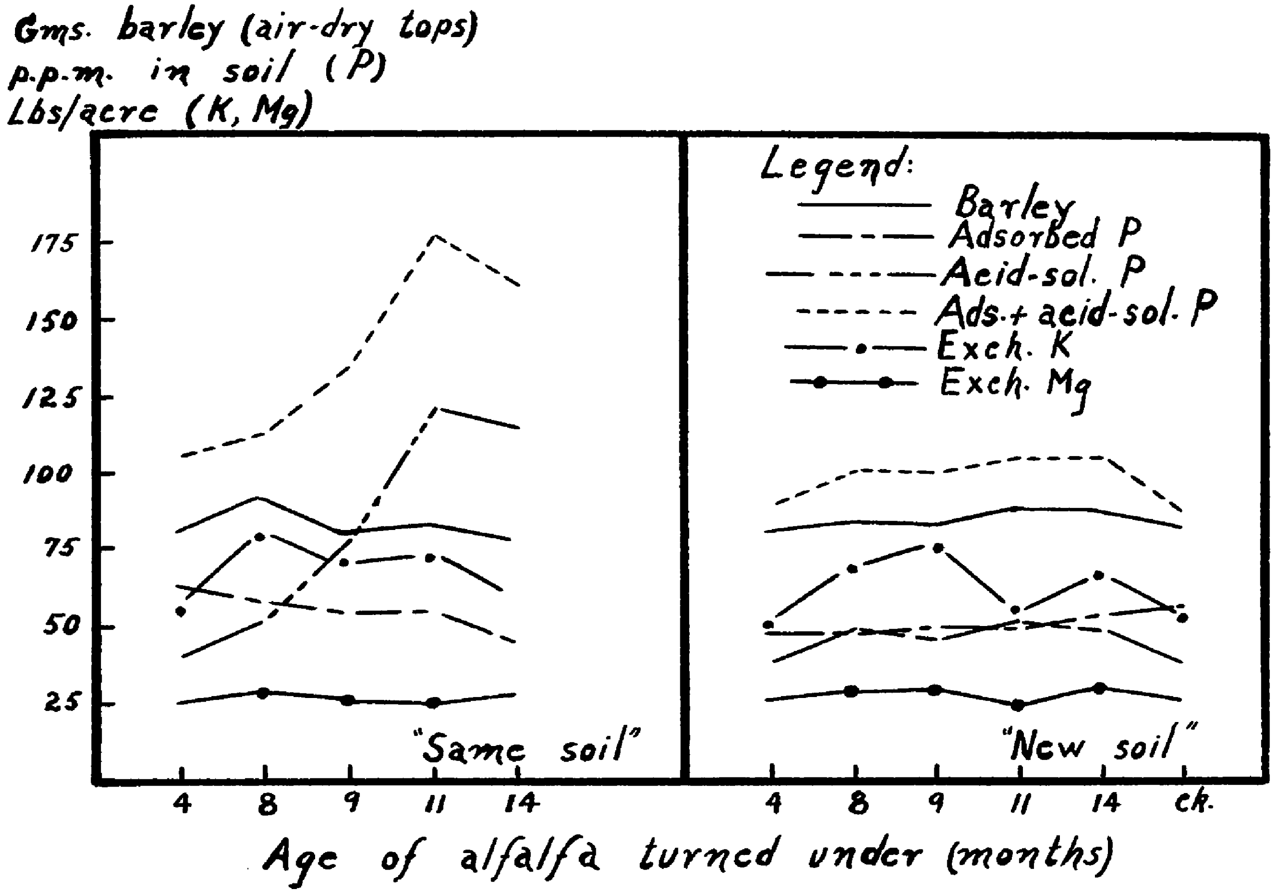

Fig. 10.- Barley yields after the sugar beets that followed alfalfa turned under at various stages of maturity, and P, K and Mg contents of the soils after the barley crop.

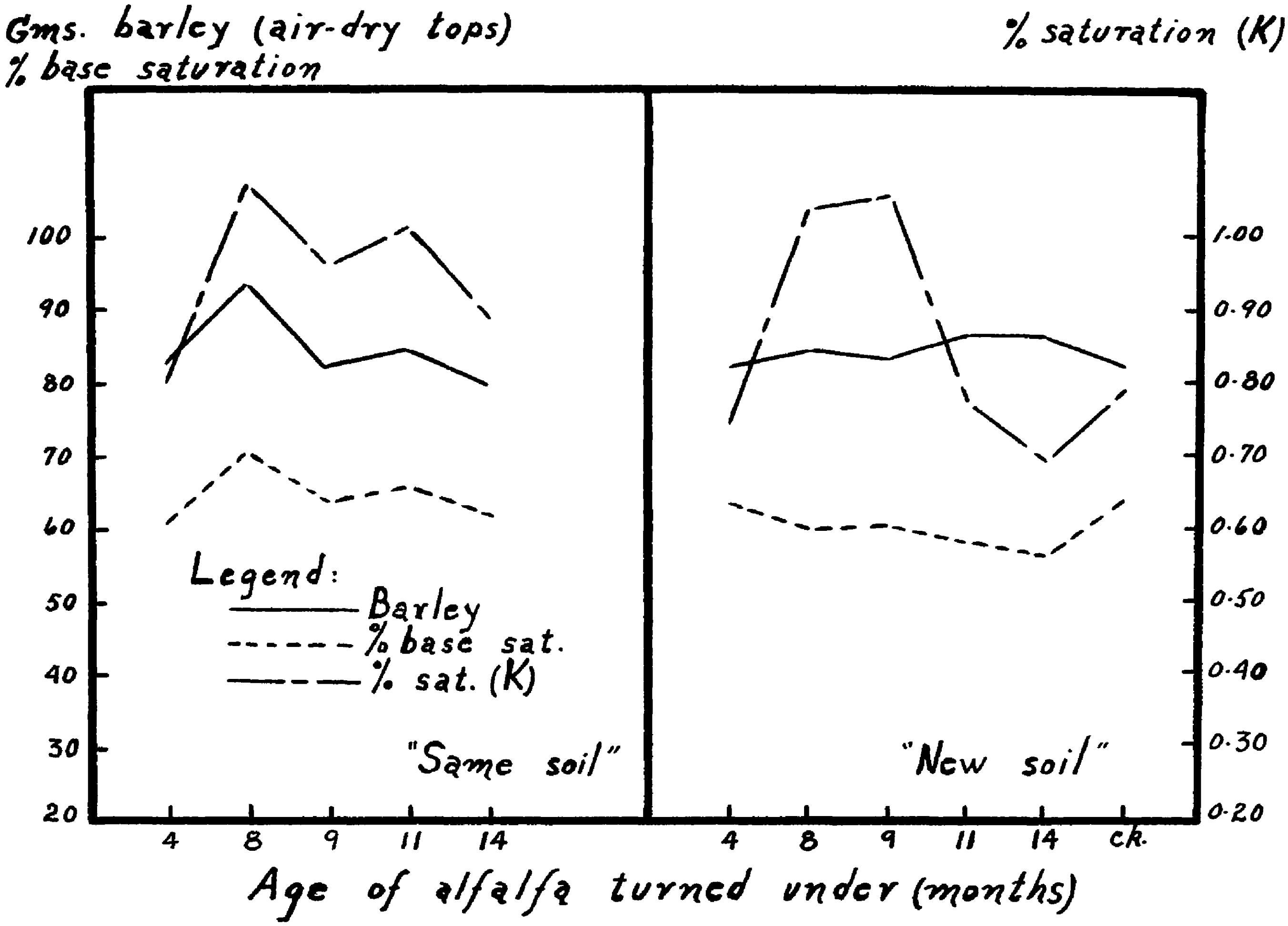

Fig. 10a.- Barley yields after the sugar beets that followed alfalfa turned under at various stages of maturity, % base saturation and % saturation of K for the soils after the barley crop.

Table 30.- pH value, phosphorus, potassium, calcium and magnesium contents of the soils after harvest of 3 and 6 months old alfalfa (before beets) and after the beet crop.

Soil treatment	pH	P (p.p.m. in soil)			K		Ca		Mg	
		1*	2*	3*	m.e. per 100 gms.	lbs per acre	m.e. per 100 gms.	lbs per acre	m.e. per 100 gms.	lbs per acre
After 3 months old alfalfa	5.85	65.0	182.5	247.5	0.136	106.6	5.297	2125	0.120	29.1
After 6 months old alfalfa	5.90	57.5	185.0	242.5	0.096	75.4	4.941	1982	0.116	28.1
After beets**										
3, N, F.	6.03	42.5	92.5	135.0	0.091	71.0	5.913	2372	0.106	25.8
3, N, UNF.	6.12	42.5	75.0	117.5	0.089	69.9	5.427	2177	0.110	26.6
3, S, F.	5.85	61.0	84.0	145.0	0.098	76.6	5.832	2340	0.120	29.1
3, S, UNF.	6.02	55.0	75.0	130.0	0.085	66.6	5.670	2275	0.125	30.4
6, N, F.	5.92	49.0	58.5	107.5	0.077	59.9	5.913	2372	0.110	26.6
6, N, UNF.	5.95	40.0	52.5	92.5	0.091	71.0	5.832	2340	0.113	27.5
6, S, F.	5.89	57.5	168.7	226.2	0.116	90.6	7.290	2925	0.128	31.0
6, S, UNF.	6.03	55.0	125.0	180.0	0.094	73.3	5.670	2275	0.113	27.5
Check	5.98	38.7	51.2	89.9	0.082	63.9	5.589	2242	0.115	27.9

* 1, adsorbed; 2, acid-soluble; 3, adsorbed + acid-soluble.
** See symbols, table 20.

Table 30a.- Exchange capacity, percent base saturation, percent saturation of individual cations, cation ratios of the soils after harvest of 3 and 6 months old alfalfa (before beets) and after the beet crop.

Soil treatment	Exc. cap. m.e. per 100 gms.	% base sat.	Percentage of exc. capacity			Cation ratios (m.e. basis)		
			Ca	Mg	K	Ca/Mg	Ca/K	K/Mg
After 3 months old alfalfa	9.750	59.9	54.3	1.23	1.39	44.1	38.9	1.13
After 6 months old alfalfa	9.250	55.7	53.4	1.25	1.04	42.6	51.5	0.83
After beets**								
3, N, F.	8.250	74.1	71.7	1.28	1.10	55.8	65.0	0.86
3, N, UNF.	9.500	59.2	57.1	1.16	0.94	49.3	61.0	0.81
3, S, F.	9.165	66.0	63.6	1.31	1.07	48.6	59.5	0.82
3, S, UNF.	7.625	77.1	74.4	1.64	1.11	45.4	66.7	0.68
6, N, F.	8.500	71.8	69.6	1.29	0.91	53.7	76.8	0.70
6, N, UNF.	9.665	62.4	60.3	1.17	0.94	51.6	64.1	0.80
6, S, F.	9.500	79.3	76.7	1.35	1.22	56.9	62.8	0.91
6, S, UNF.	7.875	74.6	72.0	1.43	1.19	50.2	60.3	0.83
Check	9.625	60.1	58.1	1.19	0.85	48.6	68.2	0.71

* See symbols, table 20.

In the "same soil", there existed a fair correlation between the yields of beets and the age of the plants turned under. A regular decrease in yields was obtained as the age of the alfalfa material increased. A slight break in the curve for the 8 months old alfalfa in the "same soil", as seen in Fig. 6, was probably due to a delay in the decomposition of the alfalfa, because this same 8 months old alfalfa greatly increased the yields of barley that followed the beet crop (Fig. 6). Since the quadruplicate beet yields agreed closely, it is presumed that the particular chemical composition of the alfalfa at that growth stage may have been responsible for the break in the curve, although no indication of this was obtained from the nitrification studies in the laboratory (Fig. 8, Table 26). Of course, the nitrification studies were conducted in "new soil".

According to 8-week incubation tests in the laboratory, the highest nitrate production was obtained with the 9 months old roots and the 14 months old tops (Table 26, Fig. 8). The same was true for the calculated amounts of nitrate produced in greenhouse jars for the same period. When the total plants were turned under, the 9 months old material caused the highest nitrate production. This again shows the more important part played by the roots in nitrate production when the plant is turned under. No correlation existed between the yields of beets and the calculated nitrate produced in the greenhouse jars in the "same soil" (Fig. 8), but a good correlation did exist between the yields of beets and the calculated nitrate production in the "new soil", although here no correlation was found between the yields of beets and age of alfalfa turned under. This points out anew that the nitrate production obtained in nitrification studies with "new soil" does not always represent what actually happens in the "same soil", when the plant material is turned under.

It is not strange that beet yields on the "new soil" were higher than those obtained on the "same soil" because the latter had grown the alfalfa crops, and nutrients had been lost in the cuttings discarded. Moreover, the "new soil" had benefited by the addition of alfalfa plant material which raised its fertility level still higher. It is of interest to note (Table 17, Fig. 8) that the yields obtained in the "same soil" with the 4 months old alfalfa and those obtained in the checks are practically identical. This is not surprising since in both instances no mineral constituents and no nitrate had been taken from or added to the soils when the beets were planted. (The absence of root nodules in these 4 months old alfalfa plants was an indication that no symbiotic nitrogen fixation took place).

Another reason for the higher yields on the "new soil" is that the soil was in a more granular condition. Table 22 or Fig. 7 give an indication of these rather significant differences in soil structure. The average state of aggregation for the "same soil" was found to be 59.7 per cent; for the "new soil", 69.5 per cent. The "same soil" contained 18.7 per cent aggregates larger than 0.5 mm., while the "new soil" contained 30.4 per cent. It will be noticed that the change in size of structural units in both soils occurred in those particles larger than 0.5 mm., those smaller than 0.5 mm. remained unaffected. L. S. Robertson* has obtained similar data working with similar soil (Miami silt loam) under field conditions. He found that the secondary particles smaller than 0.5 mm. were stable.

* Assistant Professor, Soils Dept. Private communication.

Tiulin, quoted by Baver (6), sustains that only those aggregates smaller than 0.25 mm. remain stable. His results agree rather closely with those obtained in this laboratory.

This lower state of aggregation in the "same soil" is attributed to several factors: first, the time during which the soils have been potted; second, the involuntary poundings that inevitably occur when the jars are weighed and set back unto the tables, in a moist condition. Through time, these cumulative pounding effects exert a decisive action. Third, the watering of the jars when brought up to their weights. The general procedure is to add at once the required quantity of water. This submerges the soil in a certain depth of water, and the soil colloidal material is brought into suspension. As the water percolates through the soil, this colloidal matter is deposited as a coat more or less permeable and seals off the jar. This sealing effect is more effective in the heavier soils. This is why Lehr (44), also working with beets, made use of a special pot with a sand "collar" all around the soil to preserve the soil structure when water was added. The better structure in the "new soil" means less compaction, more aeration, better nitrification and plant tissue breakdown. Lawton (43), working with corn, and Smith (74), working with sugar beets, both in greenhouse jars, found that compaction of the soils in the jars reduced the yields of corn and beets, respectively.

The third reason for higher yields in the "new soil" is taken from the work of Smith and Humfeldt (75). In comparative studies with "same soil" and "new soil", they found no differences in the amount or rapidity of CO_2 production, but great differences in the microflora and NO_3 production which was twice as high in the "new soil", i.e. soil not having grown the plant. They recommend that the soil that grows the crop be used for green manure experiments when a study of the crop to be turned under is desired.

This would explain the lack of correlation between nitrate production, as found in the laboratory, and crop yields in the "same soil", and the existence of such a correlation in the "new soil" (Figs.3, 8, 11, 12, 13). The results obtained with nitrification in soils that had not grown the crop did not apply to soils having grown the crop turned under.

Fig. 9 shows there was no correlation between the beet yields and the amounts of various forms of phosphorus, or between beet yields and the amounts of exchangeable potassium or magnesium in the soils after the crop. Here again, phosphorus seemed to change forms in the soils either as a result of the growth of the beets or the decomposition of the organic matter. After the beet crop, potassium and calcium were lower in the "same soil" than in the "new soil"; but in both soils, calcium and magnesium were higher after the crop than in the original soil. (Table 28).

This again may be explained by the solubilizing effects of root excretions, and these effects might be expected to be greater as the volume of the soil penetrated by the roots is smaller. Therefore, these seemingly exaggerated variations would not be expected to occur under field conditions.

The percent base saturation (Fig. 9a), on the other hand, appears to be correlated with the beet root yields in both "same soil" and "new soil". The discrepancy observed in the "new soil" for the check is probably due to nitrogen becoming a limiting factor in plant growth. The percent base saturation was higher in the "new soil".

The barley that followed the beet crop (Table 18, Fig. 6) supplied valuable information. It is interesting to note (Fig. 6) that the barley yields in the "same soil" were affected by the residual effect of the alfalfa turned under for the beets, while no such thing happened in the "new soil". In the "new soil" the alfalfa material apparently decomposed faster (higher nitrate production, higher beet yields) and no after-effects were observed in the barley yields, except with the 14 and 11 months old alfalfa treatments where a slight increase in barley yields corresponded to a slight residual effect of the alfalfa.

This, once more, shows that decomposition of plant material is not the same in "same soil" as in "new soil".

The only correlations that existed were those between barley yields and percent base saturation or percent saturation of the potassium ion after the crop in the "same soil" (Fig. 10a), and between barley yields and exchangeable potassium after the crop in the "same soil" (Fig. 10).

For reason of concision, just a few remarks concerning the 3 and 6 months old alfalfa turned under for sugar beets. Table 21 points out three main facts: first, the superiority of the 6 months old alfalfa as affecting beet root yields when turned into the "new soil"; second, the superiority of the 6 months old alfalfa turned into the "same soil" with addition of fertilizer; third, the superiority of the 3 months old alfalfa turned into the "same soil" without addition of fertilizer.

Comparing the 3 and 6 months old alfalfa turned into the "same soil" without a fertilizer supplement, and considering that one and a half times as much 6 months as 3 months old plants was turned under, it is obvious that the value (quantity X quality) of the latter is superior. In like manner, comparing the 3 months and 6 months old alfalfa turned into the "same soil" but with addition of fertilizer in both cases, one may see the effect of improved quality (fertilizer added) along with increased quantity (6 months old alfalfa) upon the yields.

As for the 6 months old alfalfa in the "new soil", with or without addition of fertilizer, the higher results obtained over the younger plant are explained by the greater ease of breakdown (greater nitrate production) of the plant material when turned into "new soil".

That the "new soil" or "same soil" which received 3 or 6 months old alfalfa and fertilized should have given better results than the same without fertilizer is not surprising, and the results are shown in Table 21. However, that the " new soil" which received 3 or 6 months old alfalfa without fertilizer should have given better results than the "same soil" receiving the same kind of alfalfa with fertilizer is surprising. The results are found also in Table 21.

In order to explain why sugar beets grown on the 3 months old alfalfa turned into the "same soil" or the "new soil" showed nitrogen deficiency sooner than did those grown on 6 months old alfalfa, two things may be assumed: first, that symbiotic nitrogen fixation by bacteria might be the cause. Virtanen (95) states that in the interior of young leguminous nodules is found a red pigment (hemoglobin). In certain less favorable conditions (more advanced growth, defectuous light intensity), a brown (methemoglobin) or even a green pigment replaces the red. Nodules formed on cloudy days are brown. If soya plants are kept in complete darkness for two or three days, the nodules become brown, then turn green if the conditions remain unchanged; with peas, this green pigment appears much sooner. The green pigments fix no nitrogen; the brown fix much less nitrogen than the red. "Our results... make it possible to estimate approximatively the nitrogen-fixing efficiency of root nodules in cultivated soils simply by watching the colour of the nodules on the plane of intersection. If the colour is red, the activity is high; if the colour is brown, the activity is lower... if... green, the activity is nil and the nitrogen fixation irrevocably at an end".

No nodules were noticed on the 3 months old alfalfa roots, and very few small ones on the older plants. Unfortunately, no examination of the nodules was made. According to Fred (Wisconsin), small nodules do not fix nitrogen, and Reid, Leonard, Rabu, quoted by Wilson (103), found that nodulation was reduced or inhibited during fall or winter.

The second possible explanation of the earlier nitrogen deficiency on beets grown on 3 months old alfalfa is that the younger plant material decomposed faster and liberated its nitrogen sooner, especially in the "new soil" unfertilized, where the first nitrogen deficiency symptoms were found. Moreover, the lesser quantity of this younger alfalfa turned under was more rapidly exhausted. In all treatments, however, four months after the seeding of the beets, nitrate was absorbed as it was formed, but the rate of production was too low to satisfy the requirements of the growing beet crop (Table 27).

In spite of the fact that no symbiotic nitrogen fixation took place in the 3 months old alfalfa plants, these proved a better fertilizer than the 6 months old, which most probably did fix some nitrogen during the summer season. But, since nitrogen was given the beet plants at an earlier stage of growth, this resulted in better yields than as much or even more nitrogen given to them later on.

Incidentally, no correlation was found to exist between the solar radiation (direct plus diffuse) received on a horizontal surface and expressed in gram-calories per square centimeter and the time necessary to bring the alfalfa to the blossom stage. The rapidity with which the alfalfa blossoms is more related to the length of daylight.

Tables 30 and 30a contain the data for soil chemical tests, and it will be noted that no correlation is to be found between the beet yields and the various nutrients found in the "new soil" after the crop. In the "same soil", however, phosphorus, exchangeable potassium and magnesium in the fertilized treatments, and the percent base saturation in all treatments, correlate to some extent with the beet yields.

It remains obvious that age, chemical nature and rate of decomposition of plant material are closely interrelated, as shown by Tenney and Waksman (81), and a long list of workers cited in the Review of Literature, at the beginning of this report. With advancing maturity of the plant, there is an increase in lignin, cellulose, hemicellulose, and a decrease in nitrogen and, especially, water-soluble substances, which slows down the nitrate formation.

The varying results produced by green manures are partly related to the chemical constituents of the plants as influenced by many factors that have been discovered. Some of these changes in plant chemical composition as influenced by soils or fertilizers are given by Millar (62).

This work, therefore, confirms the expected results that 1-year-old alfalfa is better than 2 or 3-year-old alfalfa when turned under as green manure for the following crop, and that the younger the spring growth of this 1-year-old material at plowing under time, the better the results.

III- Influence of field-harvested sugar beet tops and roots used as green manure for corn and barley in the greenhouse.

A- Greenhouse work.

The sugar beet material was collected from the field, dried and ground, tops and roots separately. The crowns were included with the tops. Both crops, barley and corn, were grown in two different soils, viz., a Wisner loam and a Napanee clay loam. The soils were prepared and put into the jars as described in part one for sugar beets, and the pots used were identical to those therein mentioned. The moisture equivalents, as determined by the Bouyoucos suction method (13), were 29.4 for the Wisner and 32.4 for the Napanee soil (considered as 29 and 32, respectively). The jars were kept at these percentages of moisture. The experiment was set up in quadruplicate according to the outline given in Table 31 for barley in Wisner soil. This set-up was replicated for corn in the same soil, and then the whole repeated for both crops in Napanee soil.

Sixteen grams of air-dry beet material per jar are equivalent to two tons of dry or ten tons of green material per acre, assuming the water content of beet tops and roots to be 80 per cent. The beet residues were incorporated with the top 6 inches of the soils. After the barley and the corn were planted in both Wisner and Napanee soils, the jars were brought up to their optimum moisture contents and set at random in the greenhouse. They were moved around occasionally. Bay barley was seeded

Table 31.- Outline of greenhouse set-up to study the effect of beet material as green manure for barley in Wisner soil.

Jars used	Grams of beet material per jar		Symbol for treatment
	Tops	Roots	
4	16.0	0	T
4	16.0	16.0	T+R
4	0	0	Check

on February 7, 1946, and thinned out to 15 plants per jar when it reached 6 inches tall. M-36B corn was also planted and thinned out to 4 plants per jar when it attained 6 inches in height, and to 2 plants when it was 12 inches high.

Insects were controlled by the contact insecticide already mentioned.

The barley and the corn came up well and the plants appeared to be in excellent condition. On March 7, 1946, however, four weeks after seeding, the corn in Napanee soil exhibited nitrogen deficiency symptoms in all jars, and soon afterwards phosphorus and potassium deficiency symptoms, while the corn in Wisner soil was growing normally. One week later, March 15, 1946, those deficiencies ha d become so severe that the plants were menaced. In an attempt to alleviate this critical situation, phosphorus and potassium were applied in the form of KH_2PO_4 in aqueous solution, at the rate of 1 gram of the salt per jar. This represents an application of 190 pounds of muriate of potash (50%) and 720 pounds of superphosphate (20%) per acre. Three days later, a remarkable difference was observed in all the corn plants: those leaves that were but slightly affected (nitrogen deficiencies) recovered, although those that showed more advanced symptoms (phosphorus and potassium deficiencies) remained as they were. But the plant as a whole became greener and just as healthy looking as those in Wisner soil.

This leads to the belief that nitrogen was the first limiting factor in plant growth. Nitrogen deficiencies appeared first, then phosphorus and potassium deficiencies followed. Phosphorus might well have accentuated the release of soil nitrogen by stimulating bacterial activity. When phosphorus and potassium were applied, the plants regained their vigor and also nitrogen became more abundant, most probably due to the fact that increased bacterial activity caused a greater release of soil nitrogen.

On April 3, 1946, one month later than in Napanee, the corn in Wisner soil showed nitrogen and potassium deficiencies in all jars. The leaves were not so green as they had been the previous week, especially in the four replicates which received beet tops and roots, where a marked nitrogen deficiency was obvious.

Here again, nitrogen seems to have been the first limiting factor. Although potassium deficiency symptoms appeared at the same time as nitrogen deficiency symptoms, it is to be expected that the nitrogen shortage was cause of the observed lack of potassium: the fact that nitrogen deficiencies appeared to be more severe where more potassium had been applied (adding of tops and roots to soils) is an indication that potassium was not the first limiting element.

On the other hand, the corn in Napanee soil at the same date was doing well. No phosphorus, potassium or nitrogen deficiencies were suspected, and this corn was then greener than that on the Wisner soil.

On April 20, 1946, the corn in Wisner soil was affected with severe nitrogen, phosphorus and potassium deficiencies in all jars, especially in those having received tops and roots, where nitrogen was particularly lacking. Diphenylamine tests for nitrogen revealed the complete absence of nitrate in the pale-green leaves of all plants.

In Napanee soil, the need for nitrogen was general, but more pronounced where tops and roots had been turned under. The checks, in addition, showed a potassium deficiency.

On April 27, 1946, nitrogen, phosphorus and potassium deficiencies were striking in the corn in Wisner soil. To save the threatened plants, phosphorus and potassium were applied at the rate of 1 gram of KH_2PO_4 per jar, as had been done for the corn in Na panee soil, on March 15. But here, the corn did not respond to the application of fertilizer.

One week later, Ma y 6, 1946, all corn plants of both soils were desperately afflicted with nitrogen, phosphorus and potassium deficiencies and beyond all hope of recovery. The corn in Wisner soil had not responded to the application of phosphorus and potassium, and the corn in Napanee was in no better condition. Nitrogen had become the limiting factor in all jars. The corn plants were allowed to stand until harvest, which was on May 25, 1946. The yields of corn in both soils are shown in Table 32.

In contrast to the behavior of corn, barley exhibited quite different features in both soils. The barley grew much better than the corn and did not show any deficiency symptoms, except where, in both soils, beet tops and roots had been turned under. In those jars, a few of the bottom leaves were either pale-green or yellowish in color; but the remainder of the plant was of a dark green. The barley was harvested at

Table 32.- Grams of air-dry barley and corn grown in Wisner and Napanee soils after the turning under of sugar beet tops and roots. Figures give sum of quadruplicates.

Beet material turned under	Wisner soil		Napanee soil	
	Total tops	Grain	Total tops	Grain
For barley:				
Tops	165.8	53.2	144.4	41.1
Tops+roots	145.2	50.8	130.4	29.6
Checks	148.6	52.2	133.1	32.5
For corn:				
Tops	235.3	0	253.6	0
Tops+roots	243.3	0	272.9	0
Checks	195.1	0	234.4	0

maturity, on May 25, 1946, and the yields are recorded in Table 32.

Following harvest, the soils in all jars were sampled for laboratory tests. See Tables 38 and 38a.

Nitrification studies were also made of the beet material turned under, and these results are found in Table 36.

To further investigate the effects of sugar beet tops and roots when turned under as green manure, the preceding experiment was supplemented with another in which the beet material was allowed to decompose 3 months before the seeding of a crop. Various chemical fertilizers were also added to the decomposed beet residues at seeding time in an attempt to study the nitrogen tie-up wherever it occurred.

A Brookston loam was put into jars as previously described for the sugar beet crop. The moisture equivalent of this soil was 33.7, as

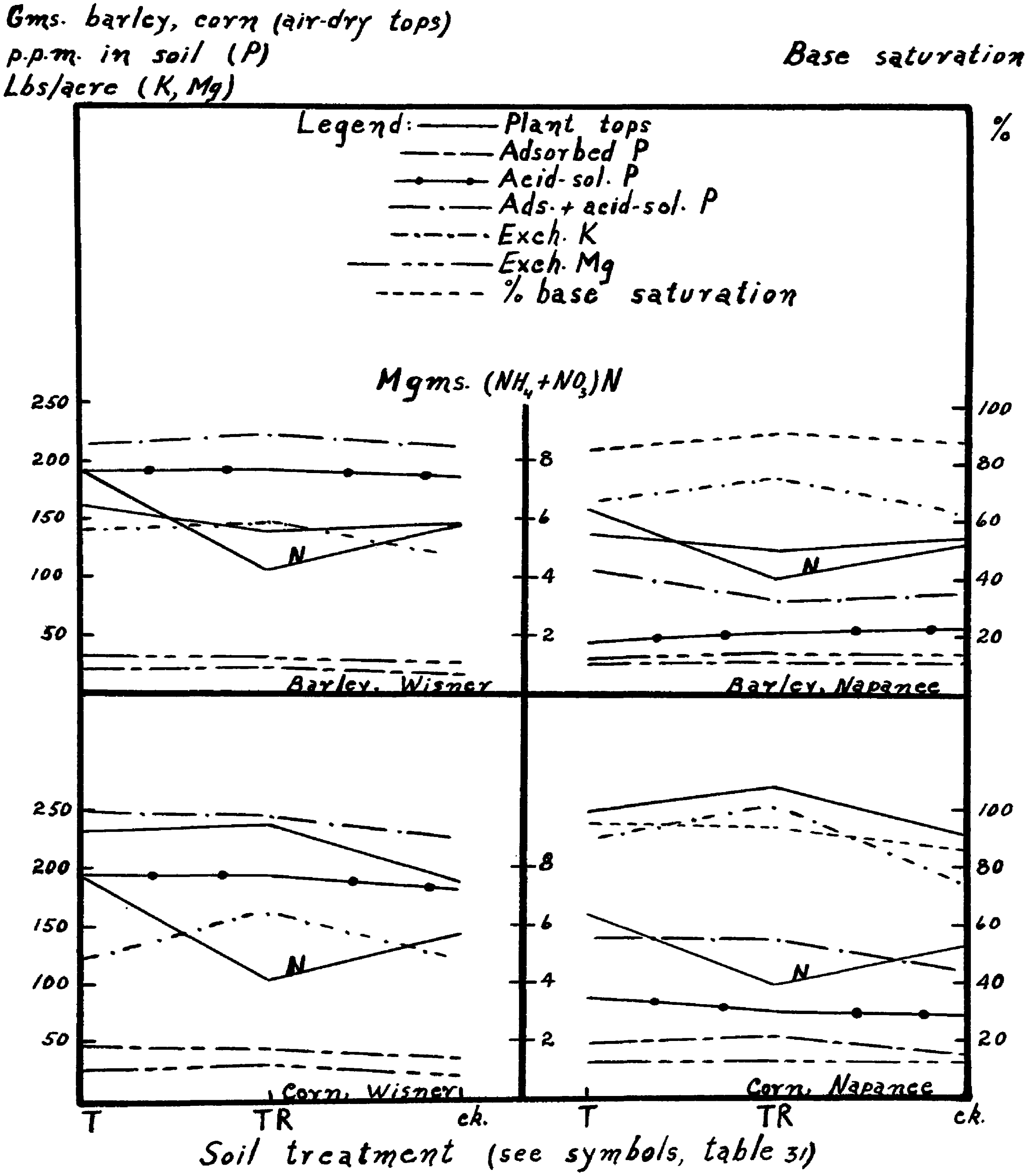

Fig. 11.- Yields of barley and corn in Wisner and Napanee soils, amounts of P, K, Mg, % base saturation of the soils after the crops, and amounts of N produced in 8 weeks in 100 gms. of the soils receiving beet tops (T, 2 gms.) and beet tops and roots (TR, 2 gms. of each).

determined by the Bouyoucos method (13). To simplify the calculations (done on an air-dry basis to bring the soils up to their optimum moisture contents) it was considered as being 33. Sugar beet tops and roots identical to those used in the preceding experiment were incorporated with the top 6 inches of the soil in each jar, and the jars brought up to their correct moisture contents on June 22, 1946. The soil in all jars, including the checks, was kept moist for 3 months, i.e. until September 21, 1946, when proso millet (also called Hog millet, Brown Corn millet) of the Yellow Manitoba variety was planted. The amounts of beet tops and roots turned under were the same as those used previously: 16 grams of air-dry tops and 16 grams of air-dry roots, each 16-gram portion representing 2 tons of dry and 10 tons of green material per acre. The fertilizers applied at seeding were: phosphorus, in the form of superphosphate 20%, at the rate of 4 grams per jar (1000 pounds per acre); potassium, in the form of muriate of potash 50%, at the rate of 2 grams per jar (500 pounds per acre); nitrogen, in the form of nitrate of soda 16%, at the rate of 4 grams per jar (1000 pounds per acre). The treatments were triplicated, the jars randomized and moved around once a week. An outline of the experimental set-up is found in Table 33.

Twenty proso seeds were planted in each jar. Nearly all of the 20 seeds germinated in each case; but when the plants reached 2 or 3 inches in height, damping off took place. None of the 3 replicates corresponding to treatments T+P (beet tops+P) and TR+P (tops and roots+P) showed any sign of damping off. The disease was found to exist in all other jars and was particularly bad in those having received tops plus N-P-K and tops and roots plus N-P-K; it was also severe in the checks with and without N-P-K fertilizer.

Table 33.- Outline of greenhouse set-up to study the effects of decomposed sugar beet tops and roots as green manure for proso.

Beet material turned under	Fertilizer used at seeding	Symbol used for treatment
Tops	None	T
"	N	T+N
"	P	T+P
"	K	T+K
"	N-P-K	T+N-P-K
Tops+roots	None	TR
"	N	TR+N
"	P	TR+P
"	K	TR+N-P-K
Tops at seeding	None	T at S
Tops+roots at seeding	"	TR at S
Checks	N-P-K	Checks+N-P-K at S
Checks	None	Checks

The plants in all pots were adjusted to 15 per jar, the dead plants being replaced by surplus ones from other jars. One week later, more plants had died, and this time were replaced by new seed. The following week, the new seed had germinated, but the plants were again affected with damping off. After this third attempt, it was decided to discontinue reseeding and to grow the crop regardless of the uneven distribution of plants in the jars.

Six weeks after sowing the proso, November 6, 1946, the soils in all jars were sampled and tested for ammonia nitrogen and nitrate nitrogen. Results are given in Table 37.

The jars or the individual plants that remained unaffected by the microbial infestation exhibited normal growth. The fact that, in all cases, the 3 replicates showed exceptionally good agreement as regards the number and height of plants affords a good reason to conclude that the particular treatment was responsible for the phenomena observed. Apparently, phosphorus alone did not prevent damping off; it seems rather as if the ratio P/N + K was the determining factor. Aliis verbis, phosphorus must be in excess over the other nutrients to exert its beneficial action. R. L. Cook*, Professor of soil fertility at Michigan State College, has observed that, when sugar beets were grown with small applications of commercial fertilizer, damping off was of common occurrence; but, as the years have passed and fertilizer applications have been greatly increased, this disease has become less common. If we consider that phosphorus fertilizer was always applied in excess of the plant's requirements and that it is not lost by leaching, it may be assumed that this P/N+K ratio in the soil has grown larger and to an extent favorable to the preventing of damping off. It is said that phosphorus favors the development and increases the vigor of the root system. In the proso crop, the most abundant root growth was found where phosphorus had been applied in excess over nitrogen and potassium. (See Table 34).

Shortly before harvesting the proso, pictures were taken of the crop. Plates 1, 2 and 3 show the effects of various soil treatments on

* Private communication.

Plate 1.- Proso following the turning under of sugar beet material. 1, tops, 3 months decomposition; 2, tops at planting; 3, tops and roots, 3 months decomposition; 4, tops and roots at planting; 5, tops, 3 months decomposition, plus N-P-K at planting; 6, check plus N-P-K at planting.

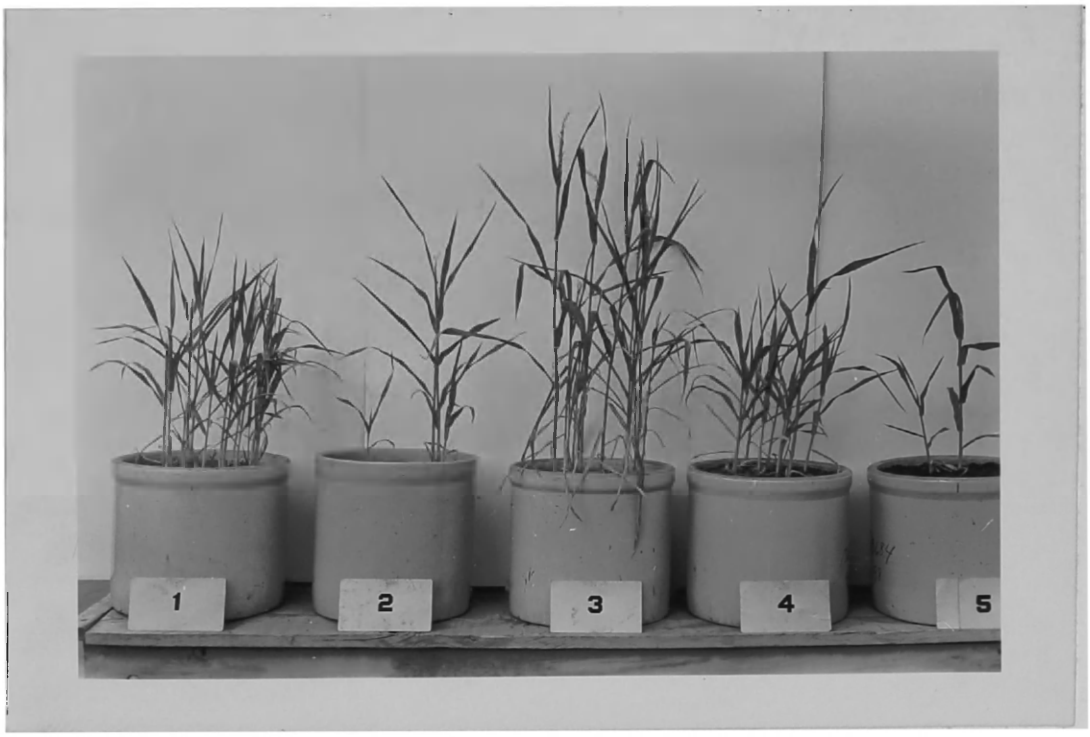

Plate 2.- Proso sown 3 months after the turning under of sugar beet tops and roots. 1, no fertilizer; 2, N; 3, P; 4, K; 5, N-P-K. (Fertilizer added at seeding time)

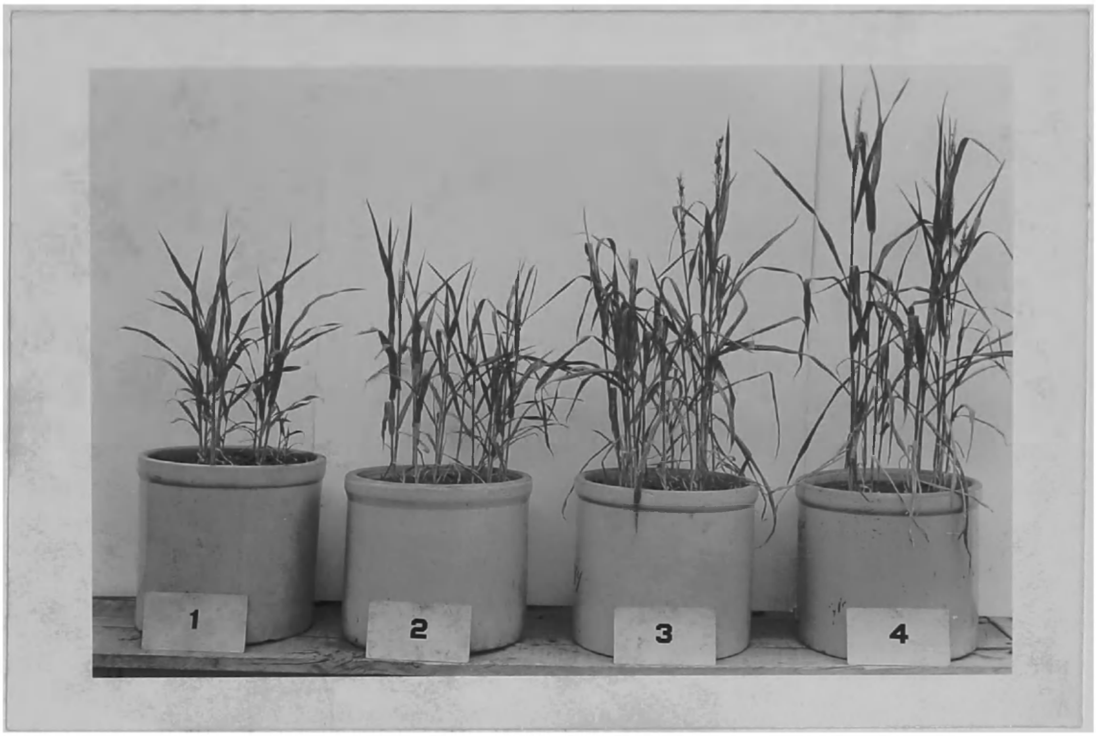

Plate 3.- Proso sown 3 months after the turning under of sugar beet material. 1, tops; 2, tops and roots; 3, tops plus P; 4, tops and roots plus P. (Fertilizer added at seeding time)

Table 34.- Yields of proso following the turning under of decomposed sugar beet residues. Figures give sum of triplicates.

Soil treatment*	Proso yields, in grams		
	Green tops	Air-dry tops	Air-dry roots
T	45.6	11.1	8.2
T+N	37.0	10.0	6.1
T+P	91.8	29.8	10.8
T+K	51.6	13.6	4.8
T+N-P-K	38.0	10.0	3.8
TR	64.2	18.2	5.0
TR+N	26.6	7.6	3.8
TR+P	85.2	28.2	9.1
TR+K	53.9	13.9	3.9
TR+N -P-K	21.2	5.2	2.7
T at S	66.2	16.2	4.8
TR at S	58.4	12.4	4.9
Ck.+N-P-K at S	22.2	5.2	2.0
C hecks	25.6	6.6	1.6

* See symbols, Table 33.

the proso crop.

At harvest, January 6, 1947, the roots were removed, washed, dried and weighed. Table 34 gives the proso yields along with the weights of the roots. Obviously, the soils where phosphorus had been added in excess over nitrogen and potassium gave the best results as concerns height, number of plants (no damping off) and root development.

Slight nitrogen deficiencies appeared on the check plants and in

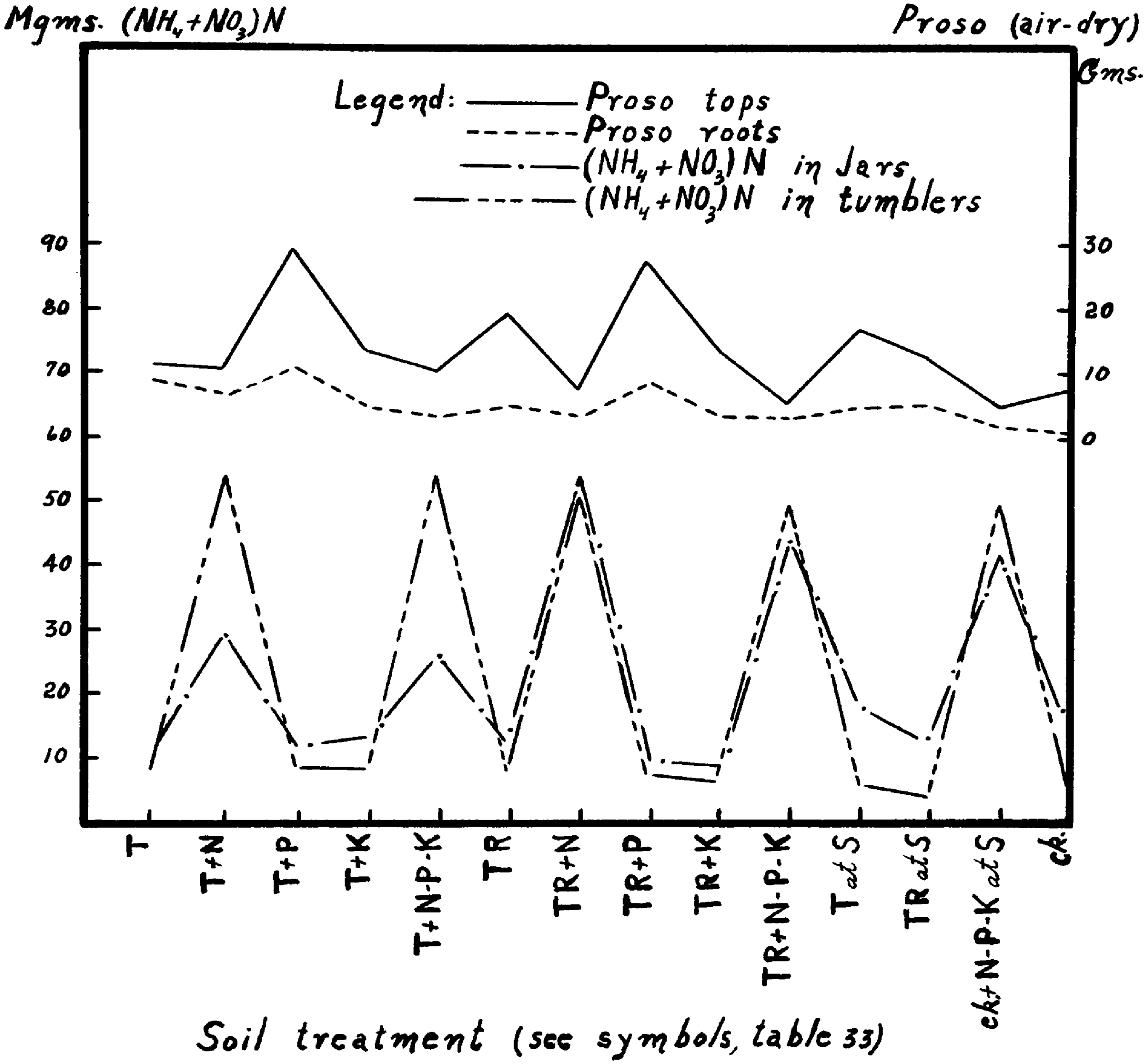

Fig. 12.- Proso yields and amounts of N per 100 gms. of soil 6 weeks after adding fertilizers and seeding proso (jars), and 6 weeks after adding fertilizers (tumblers); beet material was added 3 months before fertilizers were applied.

Table 35.- Yields of oats following proso. Figures give sum of triplicates.

Soil treatment* (for proso)	Oat yields, in grams (air-dry basis)		
	Total tops	Grain	Straw
T	227.6	82.7	144.9
T+N	295.4	103.8	191.6
T+P	247.3	84.9	162.4
T+K	230.7	86.2	144.5
T+N-P-K	298.1	105.5	192.6
TR	221.7	73.9	147.8
TR+N	315.5	103.3	212.2
TR+P	235.4	72.9	162.5
TR+K	223.8	73.8	150.0
TR+N-P-K	333.4	113.5	219.9
T at S	207.4	74.0	133.4
TR at S	183.7	52.8	130.9
Ck.+N-P-K at S	295.3	109.7	185.6
Checks	204.6	68.3	136.3

* See symbols, Table 33.

those jars where tops and roots had been turned under at seeding.

Soils were sampled at harvest time and analyzed for mineral constituents. For results, see Tables 39 and 39a.

Nitrification studies of this sugar beet material used as green manure were also made in the laboratory, and the results can be found in Table 37.

Following the proso crop, Huron oats were seeded on January 27, 1947,

Table 36.- Milligrams of nitrogen accumulated in 100 grams of soil receiving 2.0 grams of beet tops or roots (or 4.0 grams of tops+roots) during a 4 and an 8-week incubation period.

Beet material incubated	Wisner soil			Napanee soil		
	NH_4-N	NO_3-N	$(NH_4+NO_3)N$	NH_4-N	NO_3-N	$(NH_4+NO_3)N$
4-week period:						
Tops	0.56	5.39	5.95	0.21	4.99	5.20
Roots	0.56	0.77	1.33	0.35	0.42	0.77
Tops+roots	0.42	1.42	1.84	0.56	1.26	1.82
Checks	0.21	4.11	4.32	0.42	3.83	4.25
8-week period:						
Tops	0.49	7.42	7.91	0.35	6.09	6.44
Roots	0.49	1.75	2.24	0.42	1.26	1.68
Tops+roots	0.42	4.06	4.48	0.42	3.50	3.92
C hecks	0.28	5.74	6.02	0.49	4.88	5.37

at the rate of 20 seeds per jar. When the plants reached 6 inches in height, they were thinned to 15. The oats grew well and no damping off occurred.

After 10 weeks growth, i.e. on April 7, 1947, deficiency symptoms were noticed, and plant tissue tests revealed that potassium was high in all plants, but phosphorus and nitrogen abundant in those plants only to which nitrogenous or phosphatic fertilizer had been applied, either alone or as part of a complete fertilizer. In all other plants, phosphorus tests were low and tests for nitrogen (nitrate) were blank.

These oats were harvested on May 24, 1947, and the yields appear in Table 35.

The soils, after harvest, were sampled for laboratory investigation, and the results of the various analyses are found in Tables 40 and 40a.

B- Laboratory work.

a) Nitrification studies:

The sugar beet material turned under as green manure for barley and corn was incubated in the laboratory. Use was made of soils identical to those that grew these crops in the greenhouse, viz., Wisner and Napanee. The procedure followed is described in part one, laboratory work, with the exception that the moisture maintained in the tumblers was 29 per cent (Wisner) and 32 per cent (Napanee), figures in accord with the moisture equivalents of the soils as determined by the Bouyoucos method (13). Also, nitrogen was distilled into N/10 H_2SO_4 and titrated with N/10 NaOH, using methyl red as the indicator.

Two grams of either tops or roots were incubated in 100 grams of soil. When both tops and roots were incubated together, 2 grams of each were used. Nitrification started on November 6, 1946, and ended on December 4, 1946 (4-week period), and on January 3, 1947 (8-week period). Results are given in Table 36.

When the proso crop in the greenhouse was 6 weeks old (November 4, 1946), and the beet material had been decomposing for $4\frac{1}{2}$ months (since June 22, 1946), the soils were sampled and tested for nitrogen. The sampling and testing were performed as described in part two, laboratory work, c). Table 37 gives the results obtained.

A laboratory nitrification study was also made of this same beet

Table 37.- Milligrams of nitrogen per 100 grams of soil in jars growing proso and in laboratory tumblers, 6 weeks after adding fertilizer and seeding (jars), and 6 weeks after adding fertilizer (tumblers); in both cases, after 4½ months decomposition of the beet material.

Soil treatment*	Greenhouse jars			Laboratory tumblers		
	NH_4-N	NO_3-N	$(NH_4+NO_3)N$	NH_4-N	NO_3-N	$(NH_4+NO_3)N$
T	2.57	7.89	10.46	0.35	9.10	9.45
T+N	3.54	26.24	29.78	0.28	53.13	53.41
T+P	3.70	9.41	13.10	0.35	9.52	9.87
T+K	3.22	10.59	13.81	0.35	8.54	8.89
T+N -P-K	3.22	23.18	26.40	0.77	52.15	52.92
TR	3.06	9.82	12.88	0.42	7.84	8.26
TR+N	5.71	48.88	54.59	0.28	51.17	51.45
TR+P	1.18	8.90	10.08	0.28	7.70	7.98
TR+K	1.03	8.70	9.73	0.28	7.14	7.42
TR+N -P-K	1.51	43.85	45.36	1.05	48.02	49.07
T at S	1.01	18.14	19.15	0.35	7.42	7.77
TR at S	1.03	12.84	13.88	1.19	3.65	4.84
Ch.+N-P-K at S	1.34	40.58	41.93	3.92	46.20	50.12
Checks	2.43	13.04	15.47	0.42	5.53	5.95

* See symbols, Table 33.

material which had been turned under and allowed to decay 3 months before seeding. The laboratory study simulated the greenhouse set-up. Identical Brookston soil was used. Two grams of either tops or roots (4 grams of tops plus roots) were mixed with 100 grams of soil in glass tumblers. The soils in the tumblers were brought up to their optimum moisture contents

(November 6, 1946) and kept so for 3 months (until February 6, 1947). At the close of this period, the various fertilizers were added to the soils and incubation continued for 6 weeks. The beet material/soil ratio and the beet material/fertilizer ratio were the same in the tumblers as in the greenhouse jars, except that in the tumblers it was magnified ten times. The quantities of fertilizer used per tumbler were 0.5 grams of nitrate of soda 16%; 0.5 grams of superphosphate 20%; 0.25 grams of muriate of potash 50%.

At the end of 6 weeks (March 20, 1947), nitrogen was determined in each of the duplicates according to the method described in part one, laboratory work, b), with the exception that ammonia nitrogen was distilled into N/10 H_2SO_4 and titrated with N/10 NaOH, using methyl red as the indicator. The results are found in Table 37 along with those obtained from tests in the greenhouse jars.

In comparing both laboratory results and data secured from tests in the jars, it should be remembered that in the jars, following the 3 months decomposition, proso had been growing and absorbing nutrients for 6 weeks, whereas in the tumblers, following the 3 months decomposition, nitrogen accumulated for 6 weeks.

b) Study of soils:

The soils were submitted to chemical analyses before receiving the various treatments and also after cropping. The methods used are those described in part one, laboratory work, c). Data for the soils analyzed are given in Tables 38, 38a, 39, 39a, 40 and 40a.

Table 38.- pH value, phosphorus, potassium, calcium and magnesium contents of the original soils and the soils after the barley and corn crops that followed the turning under of beet residues in Wisner and Napanee soils.

Soil treatment (beet residues)	pH	P (p.p.m. in soil)			K		Ca		Mg	
		1**	2**	3**	m.e.per 100gms.	lbs per acre	m.e.per 100gms.	lbs per acre	m.e.per 100gms.	lbs per acre
__Wisner__, original soil	7.30	30.0	177.5	207.5	0.142	141.9	-*	-*	0.141	34.2
__After barley__										
Tops	7.67	25.0	192.5	217.5	0.182	142.0	-	-	0.141	34.4
Tops+roots	7.66	27.5	197.5	225.0	0.191	149.2	-	-	0.141	34.2
Checks	7.64	25.0	190.0	215.0	0.153	119.9	-	-	0.138	33.5
__After corn__										
Tops	7.52	52.5	200.0	252.5	0.159	124.3	-	-	0.134	32.5
Tops+roots	7.67	50.0	200.0	250.0	0.217	169.8	-	-	0.153	37.2
Checks	7.53	47.5	187.5	235.0	0.165	128.7	-	-	0.118	28.7
__Napanee__, original soil	7.35	32.5	102.5	135.0	0.213	166.5	17.010	6825	0.125	30.4
__After barley__										
Tops	7.42	30.0	47.5	77.5	0.217	169.8	18.792	7540	0.137	33.4
Tops+roots	7.53	30.0	55.0	85.0	0.244	190.9	19.764	7930	0.141	34.2
Checks	7.50	32.5	57.5	90.0	0.208	162.5	19.521	7832	0.141	34.2
__After corn__										
Tops	7.49	52.5	92.5	145.0	0.293	229.1	20.817	8352	0.141	34.2
Tops+roots	7.39	57.5	82.5	140.0	0.329	257.5	21.060	8450	0.141	34.2
Checks	7.47	42.5	77.5	120.0	0.251	196.5	20.169	8092	0.141	34.1

* Soil containing free calcium.

** 1, adsorbed P; 2, acid-soluble P; 3, adsorbed + acid-soluble P.

Table 38a.- Exchange capacity, percent base saturation, percent saturation of individual cations and cation ratios of the original soils and the soils after the barley and corn that followed the turning under of beet residues in Wisner and Napanee soils.

Soil treatment (beet residues)	Exc. cap. m.e. per 100gms.	% base sat.	Percentage of exc. cap.			Cation ratios (m.e. basis)		
			Ca	Mg	K	Ca/Mg	Ca/K	K/Mg
Wisner, original soil	17.165	-*	-*	0.82	0.82	-*	-*	1.01
After barley								
Tops	17.500	-	-	0.81	1.04	-	-	1.29
Tops+roots	18.000	-	-	0.78	1.06	-	-	1.35
Checks	17.830	-	-	0.77	0.86	-	-	1.11
After corn								
Tops	17.600	-	-	0.76	0.90	-	-	1.19
Tops+roots	18.500	-	-	0.83	1.17	-	-	1.42
Checks	18.100	-	-	0.65	0.91	-	-	1.40
Napanee, original soil	22.000	78.8	77.3	0.57	0.97	136.1	79.9	1.70
After barley								
Tops	22.600	84.7	83.1	0.61	0.96	137.2	86.6	1.58
Tops+roots	22.000	91.6	89.8	0.64	1.11	140.2	81.0	1.73
Checks	22.400	88.7	87.1	0.63	0.93	138.4	93.8	1.47
After corn								
Tops	22.165	95.9	93.9	0.64	1.32	147.6	71.0	2.08
Tops+roots	22.665	95.0	92.9	0.62	1.45	149.4	64.0	2.33
Checks	23.330	88.1	86.4	0.60	1.08	143.0	80.3	1.78

* Soil containing free calcium.

Table 39.- pH value, phosphorus, potassium, calcium and magnesium contents of the original soil and the soils after the proso crop that followed the turning under of beet residues. Same data for soils before the oat crop.

Soil treatment* (beet residues)	pH	P (p.p.m. in soil)			K		Ca		Mg	
		1**	2**	3**	m.e. per 100gms.	lbs per acre	m.e. per 100gms.	lbs per acre	m.e. per 100gms.	lbs per acre
Original soil	6.45	35.0	85.0	120.0	0.191	149.2	14.418	5785	0.141	34.2
After proso:										
T	6.21	40.0	197.5	237.5	0.273	213.1	14.904	5980	0.132	32.1
T+N	6.17	40.0	155.0	195.0	0.256	199.8	15.066	6045	0.132	32.1
T+P	6.16	62.5	115.0	177.5	0.251	196.5	15.714	6305	0.136	32.9
T+K	6.11	35.0	160.0	195.0	0.285	223.1	14.580	5850	0.132	32.1
T+N-P-K	6.03	65.0	92.5	157.5	0.298	233.1	14.904	5980	0.136	32.9
TR	6.27	40.0	97.5	137.5	0.239	186.5	13.608	5460	0.134	32.5
TR+N	6.19	37.5	117.5	155.0	0.247	193.1	15.066	6045	0.134	32.5
TR+P	6.22	70.0	140.0	210.0	0.256	199.8	14.742	5915	0.136	32.9
TR+K	6.22	37.5	95.0	132.5	0.311	243.1	13.446	5395	0.132	32.1
TR+N-P-K	6.07	65.0	62.5	127.5	0.311	243.1	15.066	6045	0.134	32.5
T at S	6.35	35.0	85.0	120.0	0.234	183.1	14.256	5720	0.129	31.3
TR at S	6.47	37.5	87.5	125.0	0.230	179.8	14.094	5655	0.137	33.4
Ck.+N-P-K at S	6.00	57.5	75.0	132.5	0.264	206.5	15.714	6305	0.132	32.1
Checks	6.16	35.0	92.5	127.5	0.226	176.5	14.742	5915	0.136	32.9

* See symbols, Table 33.
** 1, adsorbed P; 2, acid-soluble P; 3, adsorbed + acid-soluble P.

Table 39a.- Exchange capacity, percent base saturation, percent saturation of individual cations, cation ratios of the original soil and the soil after the proso crop that followed the turning under of beet residues. Same data for soils before the oat crop.

Soil treatment* (beet residues)	Exc. cap. m.e. per 100 gms.	% base sat.	Percentage of exc. cap.			Cation ratios (m.e. basis)		
			Ca	Mg	K	Ca/Mg	Ca/K	K/Mg
Original soil	19.875	74.2	72.5	0.71	0.96	102.2	75.5	1.35
After proso:								
T	20.250	75.6	73.6	0.65	1.35	112.9	54.6	2.07
T+N	21.000	73.6	71.7	0.63	1.22	114.1	58.8	1.94
T+P	20.250	79.5	77.6	0.67	1.24	115.5	62.6	1.85
T+K	21.000	71.4	69.4	0.63	1.36	110.4	51.2	2.16
T+N-P-K	21.250	72.2	70.1	0.64	1.40	109.6	50.0	2.19
TR	21.625	64.6	62.9	0.62	1.10	101.5	56.9	1.78
TR+N	20.750	74.4	72.6	0.65	1.19	112.4	61.0	1.84
TR+P	20.500	73.8	71.9	0.66	1.25	108.4	57.6	1.88
TR+K	20.250	68.6	66.4	0.65	1.54	101.9	43.2	2.36
TR+N-P-K	20.750	74.7	72.6	0.65	1.50	112.4	48.4	2.32
T at S	21.750	67.2	65.5	0.59	1.08	110.5	60.9	1.81
TR at S	21.500	67.3	65.5	0.64	1.07	102.9	61.3	1.68
Ck.+N-P-K at S	21.500	74.9	73.1	0.61	1.23	119.0	59.5	2.00
Checks	21.500	70.2	68.6	0.63	1.05	108.4	65.2	1.66

* See symbols, Table 33.

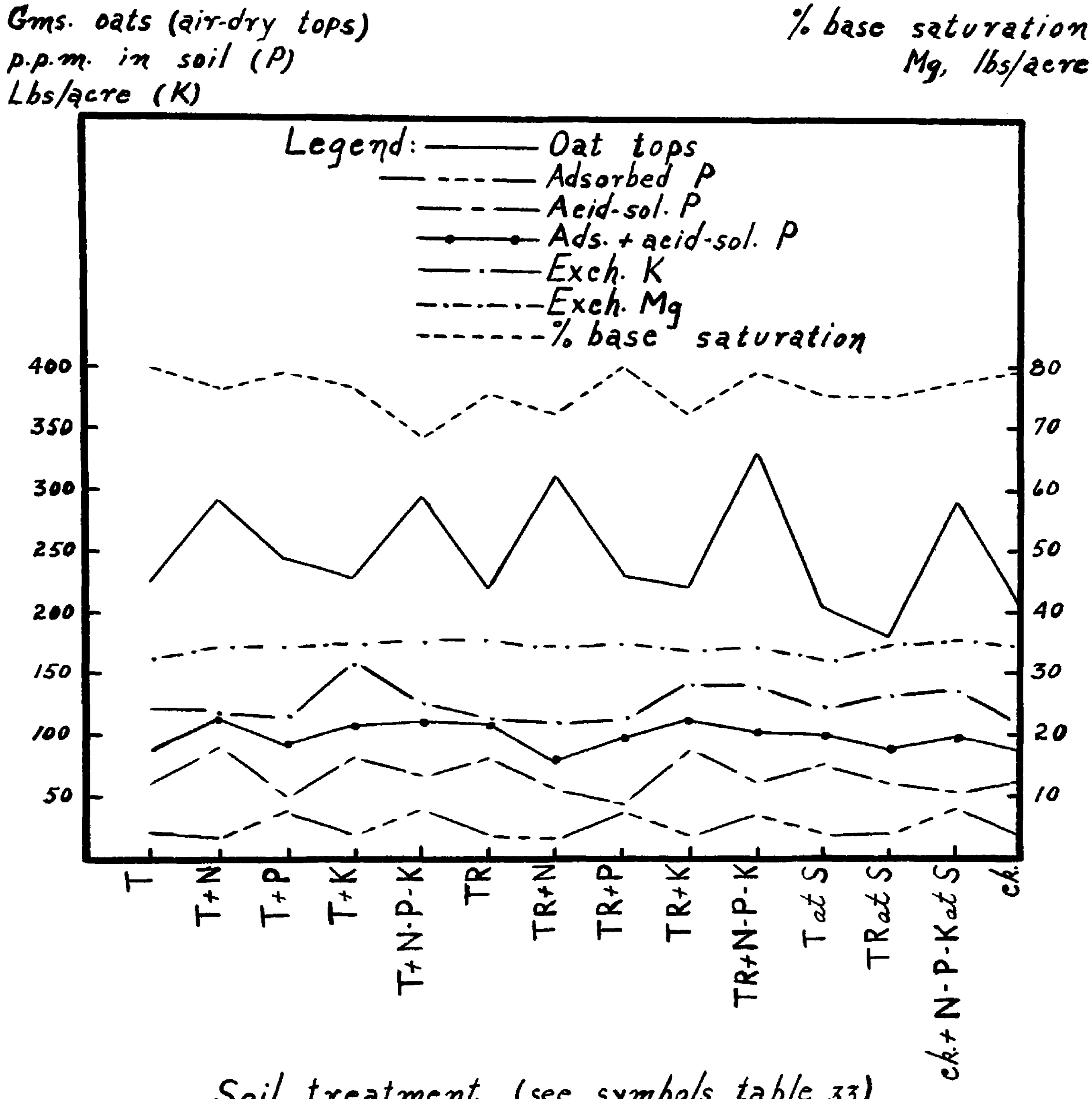

Fig. 13.- Oat yields following proso, amounts of P, K and Mg and % base saturation of the soils before the oat crop (or after the proso).

Table 40.- pH value, phosphorus, potassium, calcium and magnesium contents of the soils after the oats that followed the proso crop.

Soil treatment* (beet residues turned under for proso)	pH	P (p.p.m. in soil)			K		Ca		Mg	
		1**	2**	3**	m.e. per 100 gms.	lbs per acre	m.e. per 100 gms.	lbs per acre	m.e. per 100 gms.	lbs per acre
T	6.45	26.0	65.0	91.0	0.158	123.2	15.390	6175	0.137	33.4
T+N	6.54	23.7	95.0	118.7	0.157	122.5	15.390	6175	0.143	34.6
T+P	6.13	42.5	55.0	97.5	0.153	119.9	15.795	6337	0.144	35.1
T+K	6.46	25.0	86.6	111.6	0.208	162.5	15.552	6240	0.144	35.1
T+N-P-K	6.19	45.0	71.6	116.6	0.166	129.9	13.446	5395	0.150	36.3
TR	6.47	24.0	88.5	112.5	0.148	115.3	15.066	6045	0.148	36.0
TR+N	6.78	21.6	60.8	82.4	0.145	113.2	14.580	5850	0.144	35.1
TR+P	6.32	41.0	59.0	100.0	0.150	117.2	15.309	6142	0.147	35.8
TR+K	6.47	24.0	93.5	117.5	0.187	146.5	14.499	5817	0.141	34.2
TR+N-P-K	6.31	40.0	67.5	107.5	0.187	146.5	16.038	6435	0.144	35.1
T at S	6.43	25.0	80.0	105.0	0.162	126.5	15.066	6045	0.137	33.4
TR at S	6.48	24.0	67.0	91.0	0.174	135.9	14.742	5915	0.144	35.1
Ck.+N-P-K at S	6.23	42.5	59.1	101.6	0.179	139.9	15.633	6272	0.148	36.0
Checks	6.44	23.7	66.2	89.9	0.140	109.2	15.795	6337	0.144	34.9

* See symbols, Table 33.

** 1, adsorbed P; 2, acid-soluble P; 3, adsorbed + acid-soluble P.

Table 40a.- Exchange capacity, percent base saturation, percent saturation of individual cations, cation ratios of the soils after the oats that followed the proso crop.

Soil treatment* (beet residues turned under for proso)	Exc. cap. m.e. per 100 gms.	% base sat.	Percentage of exc. cap.			Cation ratios (m.e. basis)		
			Ca	Mg	K	Ca/Mg	Ca/K	K/Mg
T	19.625	79.9	78.4	0.70	0.80	112.3	97.4	1.15
T+N	20.500	76.5	75.1	0.70	0.77	107.6	98.0	1.10
T+P	20.250	79.5	78.0	0.71	0.76	109.7	103.2	1.06
T+K	20.500	77.6	75.9	0.70	1.01	108.0	74.8	1.44
T+N-P-K	20.000	68.8	67.2	0.75	0.83	89.6	81.0	1.11
TR	20.250	75.9	74.4	0.73	0.73	101.8	101.8	1.00
TR+N	20.500	72.5	71.1	0.70	0.71	101.2	100.5	1.01
TR+P	19.500	80.0	78.5	0.75	0.77	104.1	102.1	1.02
TR+K	20.250	73.2	71.6	0.70	0.92	102.8	77.5	1.33
TR+N-P-K	20.500	79.8	78.2	0.70	0.91	111.4	85.8	1.30
T at S	20.250	75.9	74.4	0.68	0.80	110.0	93.0	1.18
TR at S	19.875	75.8	74.2	0.72	0.87	102.4	84.7	1.21
Ck.+N-P-K at S	20.500	77.8	76.3	0.72	0.87	105.6	87.3	1.21
Checks	20.250	79.4	78.0	0.71	0.69	109.7	112.8	0.97

* See symbols, Table 33.

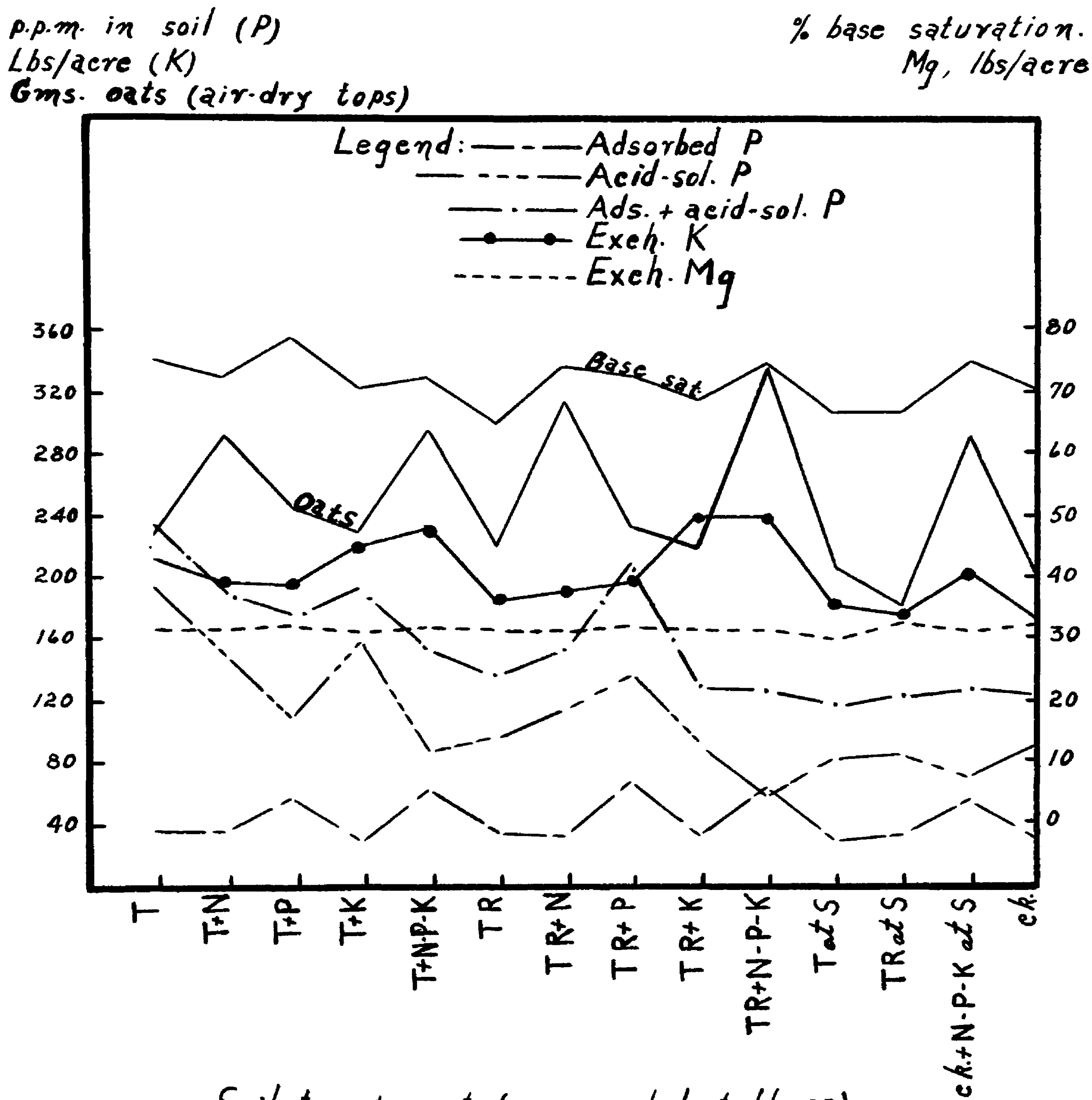

Fig. 14.- Oat yields following proso, and amounts of P, K and Mg and % base saturation of the soils after the oat crop.

C- Discussion of results.

The sugar beet green residues turned under as green manure produced different effects according to the crop grown. Table 32 (Fig. 11) shows that on barley, in both Wisner and Napanee soils, the beet tops had a beneficial effect, while the tops and roots turned under had a detrimental effect. On the other hand, corn, on both soils, produced the highest yields following the incorporation of tops and roots. The turning under of tops alone caused higher yields than those produced in the check pots. The corn on both soils failed to grow normally, whereas the barley grew well.

These differences in barley yields are easy to explain. It may be seen from Table 36 (Fig. 11) that beet tops caused better nitrification than did the checks, but beet roots were so detrimental that, even mixed with an equal quantity of tops, the pots into which they were mixed produced less nitrate than did the checks. Turk (83), studying the nitrogen tie-up by soybean plants, found that the roots were the cause of the nitrogen shortage in the soil when they were turned under at an advanced stage of maturity. The rate of decomposition of the plant parts was, in decreasing order: tops, tops and roots, roots.

A mere consideration of the chemical composition of sugar beets also leads to that conclusion. Carlson (17) gives the following figures, on a dry basis: sugar beet tops, 2.0% nitrogen; 0.2% phosphorus; 2.5% potassium; sugar beet roots, 0.7% nitrogen; 0.1% phosphorus; 0.7% potassium. These figures may vary a trifle with the nature of the soils and the fertilizer applied to the beet crop, as shown by Tyson (84) and Hirst and Greaves (33), but they represent fair averages.

Now, considering the corn yields, the picture is reversed. The only apparent explanation is to be found in the phosphorus and potassium that have been added during the growth of the corn. Had these fertilizers not been applied, the corn would have died sooner. Besides, the plants in the poorest condition when the fertilizer was applied were those plants having received beet tops and roots. As mentioned previously, it is probable that the phosphorus and potassium fertilizer added stimulated bacterial activity and caused a temporary increase in plant material breakdown or in nitrate production. The old saying that corn does well in undecomposed manure might be recalled, but it affords no explanation of scientific character.

That barley has done better than corn seems to be due to the fact that it requires only one third the nitrogen required by corn (8).

The chemical analyses of the soils after the corn crop (Table 38, Fig. 11) showed that phosphorus and potassium were much more abundant where beet tops and roots had been turned under. In no way was there a correlation with corn yields. It is more probably due to the action of CO_2 evolved that solubilized these soil constituents, but which were not taken in by the plants.

Except for nitrogen in the barley crop on both soils, no other correlation is found in Fig. 11 between yields and soil constituents.

The proso yields following the turning under of decomposed beet material (Table 34, Fig. 12) do not represent the true fertility of the soils, because damping off occurred among the proso plants, and the yields reflect the effect of the disease. With only two treatments did damping off fail to occur and those two treatments were where phosphorus alone was added (1000 pounds per acre) along with tops or tops and roots. This resistance of the plants to the disease is well illustrated in Fig. 12 where the two peaks for proso yields correspond to the treatments mentioned. The weights of the roots correspond fairly well to the weights of the tops. Since this question has been treated previously, please refer to the paragraph dealing with the greenhouse work for additional comments.

Of more value is the nitrification study of beet material in laboratory tumblers. Fig. 12 is impressive with its peaks, each one corresponding to an addition of nitrogen to the beet material incubated. Several observations can be made (Table 37). After $4\frac{1}{2}$ months decomposition, the results were as follows:

The beet tops proved beneficial as compared to the checks. Tops turned under at seeding time were less effective than were those allowed to decompose, but were more effective than the checks or tops and roots turned under at seeding time. Tops and roots together were detrimental as compared with the checks. Tops alone plus nitrogen were better than tops and roots plus nitrogen, thus denoting the still nocive effect of the roots after 4 months decomposition. The same holds true for tops plus N-P-K and tops and roots plus N-P-K. Tops without the addition of fertilizer were better than tops and roots without fertilizer.

After 7 months decomposition, and as measured by the oat yields that followed proso (Table 35, Fig. 14), it was found that the picture remained unchanged. Oat yields were in accord with the nitrate accumulated in laboratory tumblers during $4\frac{1}{2}$ months decomposition (Table 37, Fig. 12). An exception is found: tops plus nitrogen after $4\frac{1}{2}$ months were better than tops and roots plus nitrogen. After 7 months, the reverse was true, thus indicating that the injurious effects of roots had disappeared after the longer period of decomposition. The same holds true for tops plus N-P-K and tops and roots plus N-P-K. In other words, after 7 months decomposition, tops and roots plus nitrogen were more effective than tops plus nitrogen, while tops and roots alone were still inferior to tops alone, but were better than the checks.

Tenney and Waksman (96) show that a minimum of 1.7 per cent nitrogen is required in the plant material to supply microbes with their needs, although this rule might be limited by the nature of the material. They (81) showed that addition of nitrogen hastens the breakdown of carbonaceous substances.

Beet tops contain 2.0% nitrogen and do not exert any detrimental action; the beet roots contain but 0.7% nitrogen and their depressive effect is striking. The mixture in equal portions of tops and roots contains 1.3% nitrogen and the injurious effect is apparent.

The study of the soils before the oat crop (Tables 39, 39a, Fig. 13) shows that the additions of potassium along with the beet material produced peaks in the exchangeable potassium curve, and the additions of phosphorus similarly affected the adsorbed phosphorus curve, although no correlation with yields was obtained. The percent base saturation is correlated with the oat yields only where beet root material is turned under. The same holds true after the crop, but the correlation is very weak.

It remains that sugar beet tops, when turned under, will increase the nitrogen content of the soil and will benefit the following crop. Sugar beet roots have a pronounced depressive effect on nitrate accumulation in soils. Beet tops and roots in equal amounts will also be injurious after 8 weeks, but favorable after 4 months, although less favorable than tops alone. At the end of 7 months, tops alone are still better than tops and roots, unless nitrogen is added. In this case, the reverse is true.

Remarks on soils:

The correlation between percent saturation of the soil colloids and the crop yields, logically stressed by Parker and Pate, Hull, and by Pierre (68), who quotes these authors, was not supported by the results of this study. It should be expected that the percent BASE SATURATION should correlate with yields only when all other factors affecting plant growth are favorable. It has been reported (36) that the nature of the complementary cation will affect the ease of release of a given cation of a given percent saturation.

In this study, due to the fact that nitrogen often became the limiting factor in plant growth, the percent saturation of total as well as individual cations failed to show any relationship with the crop yields. It remains true, however, that for soils with different exchange capacities, the percent saturation has and will yield helpful information as compared with data obtained for exchangeable cations.

SUMMARY AND CONCLUSIONS

A comparative study was made of the manurial value of alfalfa at various stages of maturity, and of sugar beet green residues.

Total alfalfa plant samples 1, 2 and 3 years old, fertilized and unfertilized, were collected from the field on April 17, April27 and May 10, and were incorporated into soils for a sugar beet crop in the greenhouse.

Alfalfa 4, 8, 9, 11 and 14 months old was grown in the greenhouse. At blossom time of the first alfalfa sowed (14 months old plants), the tops were cut and discarded, and another group of plants were sowed (11 months old plants). When the last plants sowed (4 months old plants) blossomed, all plants (tops and roots) were harvested and incorporated into the "same soil" (having grown the alfalfa) and into "new soil" (identical soil, not having grown the alfalfa) for a sugar beet crop in the greenhouse.

Alfalfa 3 and 6 months old was also grown in similar manner and incorporated into the "same soil" and into "new soil", with and without addition of 2 grams of 2-16-8 fertilizer per jar (500 pounds per acre) at seeding of the sugar beets.

A study of sugar beet green residues used as green manure was also conducted in the greenhouse with grain crops.

Nitrification studies were made on the plant material used as green manure, and soil chemical analyses were made to supplement the information secured from the various crops grown.

The experimental data lead to the following conclusions:

1.- As regards quality, an 8-week incubation period shows that alfalfa tops of 1, 2 and 3-year-old plants from the April 27 harvest produced the most rapid rate of nitrification, with the 2-year-old unfertilized plants proving best. The roots from the April 17 harvest nitrified most rapidly, and the rate decreased markedly from the April 17 to the May 10 harvest, and from the 1 to the 3-year-old plants.

2.- As regards quality and quantity combined (calculated nitrification of total amount of material, based on 8-week incubation tests), the 1-year-old unfertilized tops of May 10 and the 1-year-old fertilized roots of April 17 produced the most nitrate. Considering the total plant (tops and roots), the 1-year-old fertilized plants of April 17 caused the greatest accumulation of nitrate.

3.- The highest sugar beet yields were obtained with the 1-year-old fertilized alfalfa of April 17.

4.- Fertilized alfalfa (tops or roots) generally nitrified more rapidly than the corresponding unfertilized alfalfa, although exceptions were noted.

5.- Considering either quality alone, or quality and quantity combined (calculated nitrification of total amount of material, based on 8-week incubation tests) of the 4, 8, 9, 11 and 14 months old alfalfa grown in the greenhouse, the tops of the 14 months old and the roots of the 9 months old plants proved best. Considering the total plants, the 9 months old plants resulted in the greatest accumulation of nitrates in the soil.

6.- Comparing the 4, 8, 9, 11 and 14 months old alfalfa, the 4 months old plant resulted in the highest sugar beet yields on the "same soil", where a decrease in yield paralleled an increase in age of alfalfa incorporated. In "new soil", the highest yields followed the incorporation of the 9 months old alfalfa, and a correlation existed between the calculated nitrification of the total alfalfa and the beet yields.

7.- The state of soil aggregation in the "new soil" (soil potted for a shorter period) was better than in the "same soil" (soil potted for a longer period). The change occurred in aggregates larger than 0.5 millimeters, the smaller ones remained unaffected.

8.- The 3 months old alfalfa proved a better fertilizer than the 6 months old alfalfa for sugar beets in the "same soil", but in "new soil" the 6 months old alfalfa was better. The 3 or 6 months old alfalfa without addition of fertilizer in "new soil" was better than the 3 months old with addition of fertilizer in the "same soil".

9.- Although sugar beet tops had a beneficial effect on the following crops when incorporated with soil at seeding time, they gave better results after 3 months decomposition. Beet roots had a depressive effect, even when mixed with an equal portion of tops.

10.- After 4 months decay, however, a mixture of equal parts of sugar beet tops and roots proved beneficial, although less beneficial than were tops alone, even when, in both cases, nitrogen had been added at the beginning to aid decomposition.

11.- At the end of 7 months, sugar beet tops and roots without nitrogen were still inferior to tops alone; but when nitrogen had been added at the beginning, tops and roots proved better than tops alone.

12.- Nitrification studies with soils not having grown the crop to be turned under gave results that did not apply to the soils that grew the crop. In "new soil", nitrification is much more rapid than in the "same soil".

13.- The percent saturation of total or individual soil cations in only a few cases exhibited any correlation with the yields of the crops grown.

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