Unless there are special qualities of a soil proposed for sugar beets, our recommendations are for a 5 year rotation to include clover the second year preceding beets, with a heavy manure application on the crop preceding the beets. If the mineral elements are low, then fertilizers are recommended to build up those elements near the deficiency level. Clover and manure can supply most of the Nitrogen needed, but the Phosphate level in Ontario soils is usually so low as to need special application of superphosphate, in addition to the "balanced" fertilizer recommended to go in with the seed. Potash applications do not usually show much response in the beet crop, but the plants use it to a degree which merits some addition to the soil growing beets.

Cooperative field experiments are placed in various localities each year and these act as demonstrations of fertilizer benefit as well as furnish data on the field response of sugar beets to the analyses under test. We feel that much still remains to be done in persuading farmers to stop burning straw, to adopt better rotations and apply more fertilizer for this special cash crop. The general production can be raised much higher apart from disease control, and more productive seed types, if the proper fertilizer analyses are used in the proper quantities and put in the right place.

THE EFFECT OF SOIL STRUCTURE ON SUGAR BEET GROWTH

by
R. B. Farnsworth and L. D. Baver1/

The sugar beet producing region of Ohio is located in the northwestern quarter of the state. The sugar beet enterprise is, however, concentrated in the Maumee Basin or the old Glacial Lake Plain. The soils of this area are of lacustrine and glacial origin and are mostly of a very heavy nature.

The Paulding, Toledo, and Brookston series comprise the major soil groups of the area (I). The Paulding constitutes a large portion of the flat area west of central Henry and Putnam counties, and nearly all of Paulding county. The soil is principally a heavy clay, exhibits a high moisture-holding capacity, and has a high organic matter content. The Toledo clay is almost as heavy as the Paulding, has almost the same content of organic matter, and is highly retentive of moisture. This clay with the associated classes: silty clays, silty clay loams, and clay loams make up the soils of the beet producing area of eastern Lucas, north central Sandusky, and Ottawa counties.

The Brookston soils overspread the area eastward from the Paulding soil and intersperse the area of the Toledo soils. They are less heavy than the Paulding clay, slightly gritty but almost as dark. The principal soil classes, in addition to the clay, are silty clay loam, silty clay, and silt loam. Throughout the above areas are several light-colored soils ranging from sandy to heavy with respect to texture.

During the last few years evidence has been brought out which indicates that beet yields in these areas are frequently limited by unfavorable physical conditions of the soil. In a recent publication (II) data from the Agricultural Statistics of the U.S.D.A. were presented which show a gradual decrease in acre

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yield of beets in Ohio from an early date in the enterprise to the present. The equivalent decrease was approximately three to four tons per acre; whereas several western states showed a continued increase of one and a half to two tons per acre during the same period. Extensive use of commercial fertilizers on beets in the Ohio territory has failed in many areas to bring about an increase in acre yield.

The physical condition of the soil is of primary importance in the production of a suitable yield of any crop. It is of especial importance in regions where the soils are of an extremely heavy nature.

With the advent of commercial fertilizers the idea developed in many sections of the country that a "cure all" was now available for plant deficiencies and there need be no great concern over the old idea that the fertility elements of the soil would one day become depleted. The rousing interest in plant nutrients was so very marked that the importance of the physical condition of the soil was crowded somewhat into the background.

The physical condition of a soil is referred to by the farmer when he states that his land is in a poor, or in a good state of tilth. His interests seem to lie in the nutrient content of the soil rather than in the factors which may have been responsible for the state of tilth.

The soil system is composed of three phases -- solid particles, air and water. The solid phase is made up of various sized particles. It is the arrangement of these particles, that is, the way they are "put together" in the soil, that greatly determines the air-water relationships of a particular soil. This arrangement of soil particles, the size and shape of the aggregates, is known as soil structure.

The term "soil structure" is more or less descriptive and as such is not capable of being expressed by any specific measurement or number. Measurements of the physical properties of the soil, which are dependent upon structure, can be made and any of these measurements can be used as an index of soil structure. Measurements of soil aggregation, macro- or microstructure, may be used as an index of soil structure. Other measurements that have been used as indices of soil structure are volume weight, total porosity, capillary and non-capillary pore space, and air movement, the pull on the drawbar of a tillage implement, and penetrometric measurements, that is, the force required to press a sharpened instrument into the soil.

The development of an ideal root system of a plant is dependent upon the existence of the proper air-water relationships in the soil. In this case porosity, non-capillary and capillary pore space, and drainage are important factors.

Recent investigations in some newer concepts of how plants feed point out the necessity of a well-developed root system. Root-soil contact is of major importance in plant growth and a well-developed root-system consequently results in a better root-soil contact and a more economical use of fertility elements. If a soil cannot supply the proper air-water relationships the development of the plant roots will be affected. It is often that many soils have a very low percentage of non-capillary pore space and the capillary pore space is filled with water a large portion of the time. The consequent result of such a condition is poor root development, insufficient aeration of the plant roots, a small amount of root-soil contact, an uneconomical utilization of fertility elements, and a low crop yield.

The optimum plant growth is obtained when there is present in the soil sufficient nutrients and a proper air-water relationship. A suitable physical condition of the soil is important for optimum growth of any plant. In the case of where the root itself is the crop the physical condition of the soil is of utmost importance.

Clay soils ordinarily have a non-capillary porosity of 5 to 10 percent. This has, in the past, in Northwestern Ohio, been sufficient for growth of sugar beets. With an already relatively low non-capillary porosity it is reasonable to believe that very much of a decrease in this porosity would affect plant growth. German investigators have reported that optimum conditions for sugar beet growth in their country were obtained in soils containing a non-capillary pore space of about 15 to 20 percent. A high non-capillary porosity is made possible by a high organic matter content and a stable aggregation of soil particles.

The investigations in this particular problem were carried out on the Northwestern Test Farm at Holgate, Ohio, and on privately-owned farms in the lake plains area.

Earlier investigations (III) on soil changes in these areas show that after from 50 to 75 years of cropping there has been a 48 percent loss in soil nitrogen. Virgin soils originally weighing 65.5 pounds per cubic foot, in the upper foot, now weigh 81.7 pounds. The organic matter content has been reduced from 66 tons per acre to 44. Total pore space has decreased from 60.3% to 50.5.

It is evident that the removal of the organic matter has resulted in the compaction of the soil and a loss of pore space. When a soil becomes compacted not only is there a loss in total pore space but the non-capillary porosity through which air and water readily move is greatly decreased. In some cases the change in total porosity may not be large but the loss of non-capillary pore space (an increase in capillary pore space) is sufficient to affect plant growth. Recent investigations substantiate the above results and show the marked effect these changes are having upon sugar beet growth.

In the fall of 1938 the conditions of a field at Paulding, Ohio, were studied. One-half of the beets had been planted on a continuously-cropped soil. The other half had been planted on land which had been in pasture for eight years, and in corn in 1937. Fertilization and other treatments throughout the summer had been the same. Soil samples were taken at different depths, a stand count was made, and actual yields taken on each half of the field. The following results were obtained:

Table I

CULTIVATED SOIL

Depth of soil sample (inches)	Total pore space (%)	Non-capillary porosity (%)	Apparent sp. gr. (gms./cc)	Beets/ 100 ft.	Actual yield (T/A)
0 - 3	64.0	4.2	.94	55	5.2
3 - 6	62.6	1.9	1.06		
12 - 15	50.8	.87	1.23		

Table I (continued)

PASTURE SOIL

Depth of soil sample (inches)	Total pore space (%)	Non-capillary porosity (%)	Apparent sp. gr. (gms./cc)	Beets/ 100 ft.	Actual yield (T/A)
0 - 3	72.0	6.3	.77	56	8.9
3 - 6	69.2	4.1	.83		
12 - 15	57.5	1.85	1.16		

Table I and figure 1 show that the pasture soil is much less compact than the cultivated soil. The amount of non-capillary pore space is larger and to a depth of 15 inches the pasture soil is much better drained and better aerated. The difference in beet yield is 3.7 tons per acre in favor of the pasture soil.

When experimental work was begun at Holgate the beet production on the farm for the past several years had been about 1.5 to 3 ton per acre. In few instances the yield had been slightly higher.

The effects of soil structure on sugar beet growth were studied. Attempts were made to change the structural conditions by additions of organic matter by various systems of cropping. Manure was also added in different amounts and placed at different depths. A part of the experimental results will be presented in this paper.

In 1937 all plots were planted to corn. In 1938 the following set up was arranged to be planted to beets in 1939.

A - Beets following corn
B - Beets following soy beans (on some plots the crop was removed for hay, on others the beans were plowed under in the fall)
C - Beets following alfalfa
D - Beets following sweet clover
E - Beets following soy beans with manure additions (the entire crop of beans was plowed under in the fall. In the spring 5, 10, and 20 ton amounts of manure were incorporated in the surface three inches of the soil, throughout the plow layer, and under at six inches.)
F - Beets following soy beans, the entire crop of beans was plowed under in the fall and the beets were planted on ridges of from 2 to 8 inches high.

Actual yields were determined on all plots and sugar analyses were made. The percentage of loss in stand was determined by making a stand count after the beets were blocked and thinned and then counting the number of beets harvested from each plot. Total porosity and non-capillary pore space were determined. The results of these investigations are shown in tables II, III and IV.

Table II - The Effect of Crop and Treatment on Yield, Sugar Content, and Percentage Loss of Beets

Number of plots	Crop or Treatment	Yield (T/A)	Sugar Content (%)	Loss in stand (%)
A - 3	Corn	1.54	15.50	48.3
B - 9	Soy beans	3.10	16.55	35.4
C - 18	Alfalfa	3.73	16.32	20.16
D - 5	Sweet clover	4.93	16.80	20.3
E -	Soy beans with additions of manure			
12	5 T. manure*	5.98	16.24	14.3
12	10 T	7.06	16.28	15.6
12	20 T.	7.58	16.23	12.2
F - 24	Soy beans with beets on 2 to 8" ridges	10.12	17.32	17.3

(*) The yield is the combined average of all plots. That is, organic matter additions in the surface, throughout the plow layer, and under at 6 inches are averaged together.

Table III - The Effect of Incorporating Different Amounts of Organic Matter at Different Depths on Yield of Beets
(Soy beans - entire crop plowed under plus organic matter)

	Beet Yield (Tons/Acre)		
	Depth of Organic Matter Incorporation		
Amount of Organic matter Added	In Surface 3 inches	Throughout Plow Layer	Under at 6 inches
0	4.41	4.41	4.41
5 Ton of manure	6.01	6.70	5.20
10 "	7.50	6.60	6.60
20 "	7.75	7.70	8.12

Table IV - The Effect of Non-capillary Porosity on Yield and Sugar Content of Beets
(Practices used in effecting porosity changes)

Cultural practices	Apparent sp.gr. (gms./cc.soil)	Total pore space (%)	N.C.P. (%)	Yield (T/A)	Sugar content (%)
Beets following:					
Corn	1.13	55.2	2.66	1.54	15.5
Soy beans (plowed under)	1.13	57.2	4.03	4.41	16.01
Soy beans under with					
5 T. manure in surface	1.03	57.0	5.86	5.00	16.18
10 "	1.03	59.6	6.20	7.75	16.24
20 "	.94	64.5	6.43	10.02	16.74
Ridging 4"	.96	59.3	7.35	11.01	18.35
8"	1.05	58.3	7.54	15.20	18.20

The data in the Tables show a wide difference in beet yield as obtained on plots receiving different cultural treatments. The beet yield following two years of corn was 1.54 tons per acre. The non-capillary pore space of the soil was 2.66% of the total volume. The sugar content was 15.5%; during the season 48.3% of the beets originally on the plots was lost. Beets following soy beans, alfalfa, and sweet clover gave more favorable yields than those following corn. For example the yields after corn were 1.54 tons per acre, after soy beans, 4.41 tons, after alfalfa 3.73, and after sweet clover 4.93 tons per acre. The non-capillary porosity of the soil on the corresponding plots was 2.66%, for corn, and 4.03% for soy beans. Organic matter additions, and ridging of land on which soy beans had been plowed under gave very favorable results. Yields as high as 15 tons per acre were obtained on the ridged plots.

In Table II the yields on the organic matter plots are an average of all plots whether or not the organic matter had been applied only in the surface, throughout the plow layer, or under at 6 inches. The yield on the ridged plots is an average of 24 plots which had been ridged from 2 to 8 inches. In Table IV the yield from the corresponding treatments is that from plots of a specific treatment.

It is not to be understood that any single one of the above methods of treatment is a remedy for the condition existing in the beet-producing area. The ridges in conjunction with organic matter proved especially effective this year. One particular reason for the effectiveness of ridges may be seen in the fact that at Holgate the rainfall in June and July was 8.46 inches and 7.35 inches respectively. The ridged plots were prepared in the fall and the beets were planted after a minimum amount of seed-bed preparation in the spring. This afforded full use of the soil granulation resulting from freezing and thawing during the winter.

Table III shows the relative effectiveness of organic matter additions in different amounts at different depths. Applications of 5, 10, and 20 tons gave increased yields. The 5-ton application was more effective when placed in the surface or throughout than when placed entirely under. This may be attributed to the fact that there is a necessity of keeping the surface layer of soil open. If the surface is closed by the beating action of rain the permeability of the soil to air and water is limited. Ten ton of manure in the surface was more effective than when placed under or throughout the plow layer. The 20-ton application in the surface was the most effective of the surface applications but did not give the results that were obtained when the 20 tons were placed entirely under. Twenty tons of manure under at 6 inches may facilitate drainage and also leave sufficient organic matter throughout the surface to keep the soil open.

Table IV shows the value of a high percentage of non-capillary pore space in these soils. Soils with a non-capillary porosity of 6½ percent to 7½ percent gave favorable yields. An increase in non-capillary pore space resulted in an increase in sugar content as well as an increase in yield. An increase in the non-capillary porosity of a soil means that there will be present in the soil less carbon dioxide and more oxygen. The presence of oxygen promotes respiration of the plant, greater growth, and more efficient sugar production.

The deterioration of the soil structure in this area has resulted after years of cropping during which time very little, if any, organic matter has been returned to the land. It is reasonable to believe that it will be

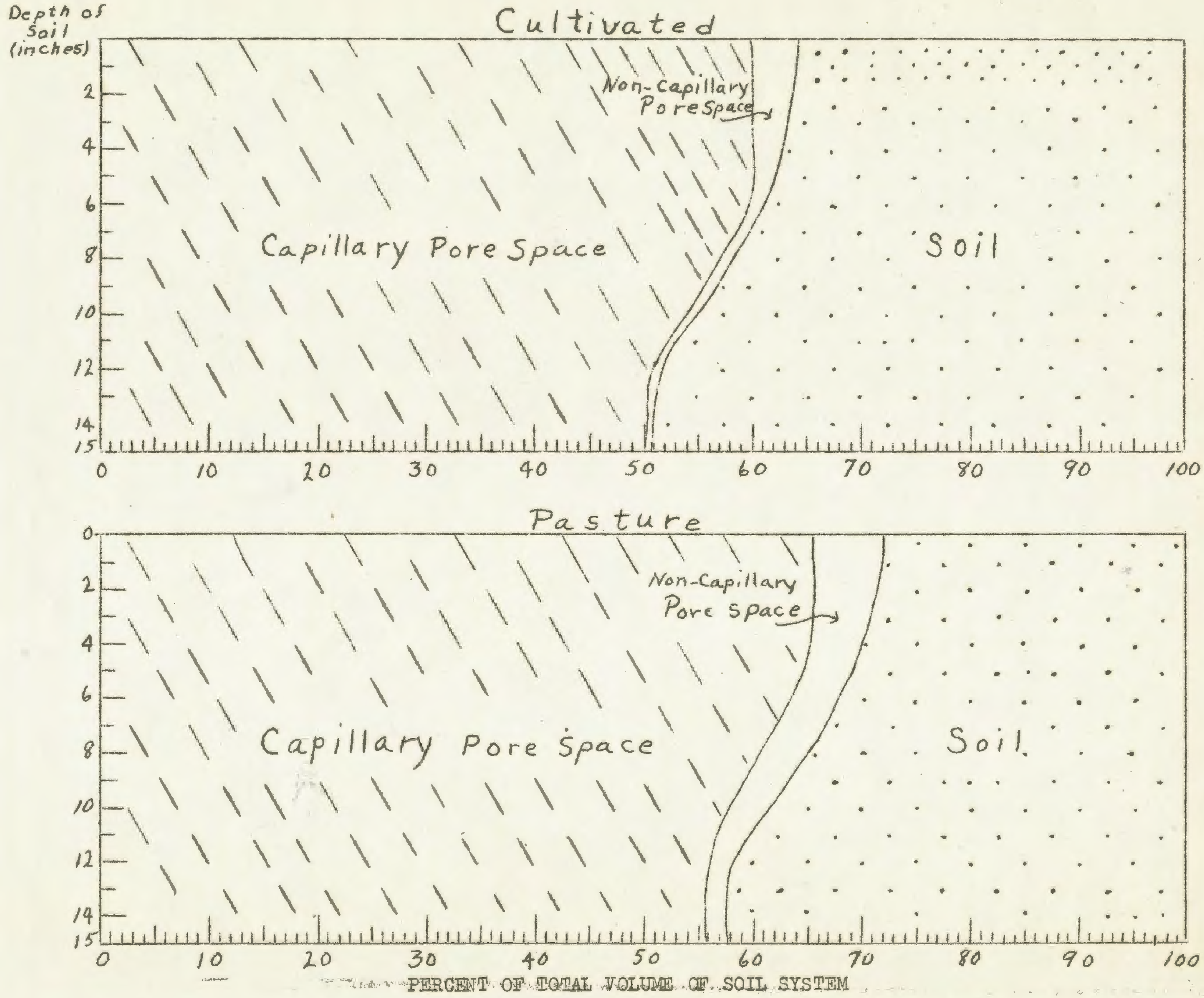
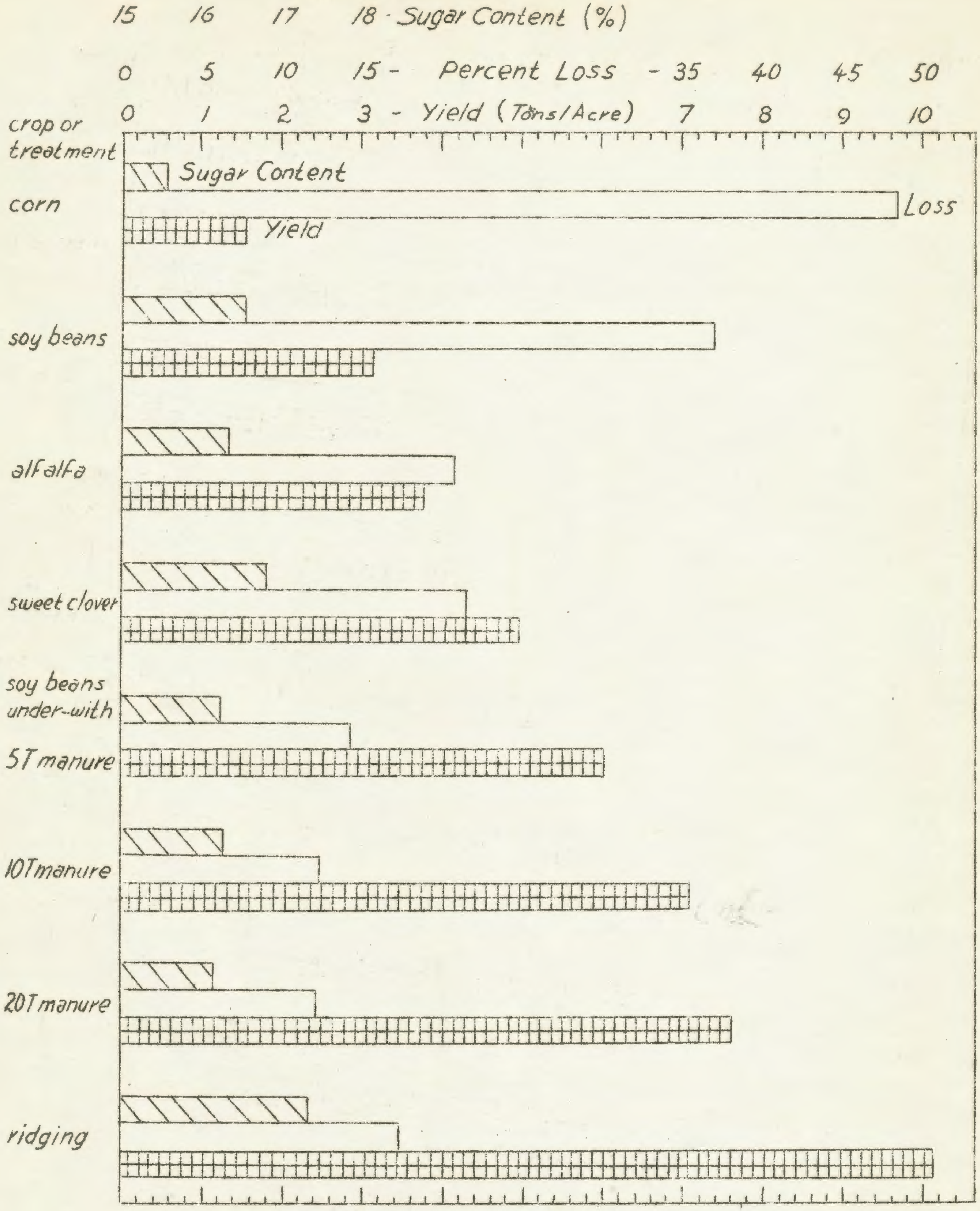


Figure 1 (See Table I)

FIGURE 2 (See Table II)

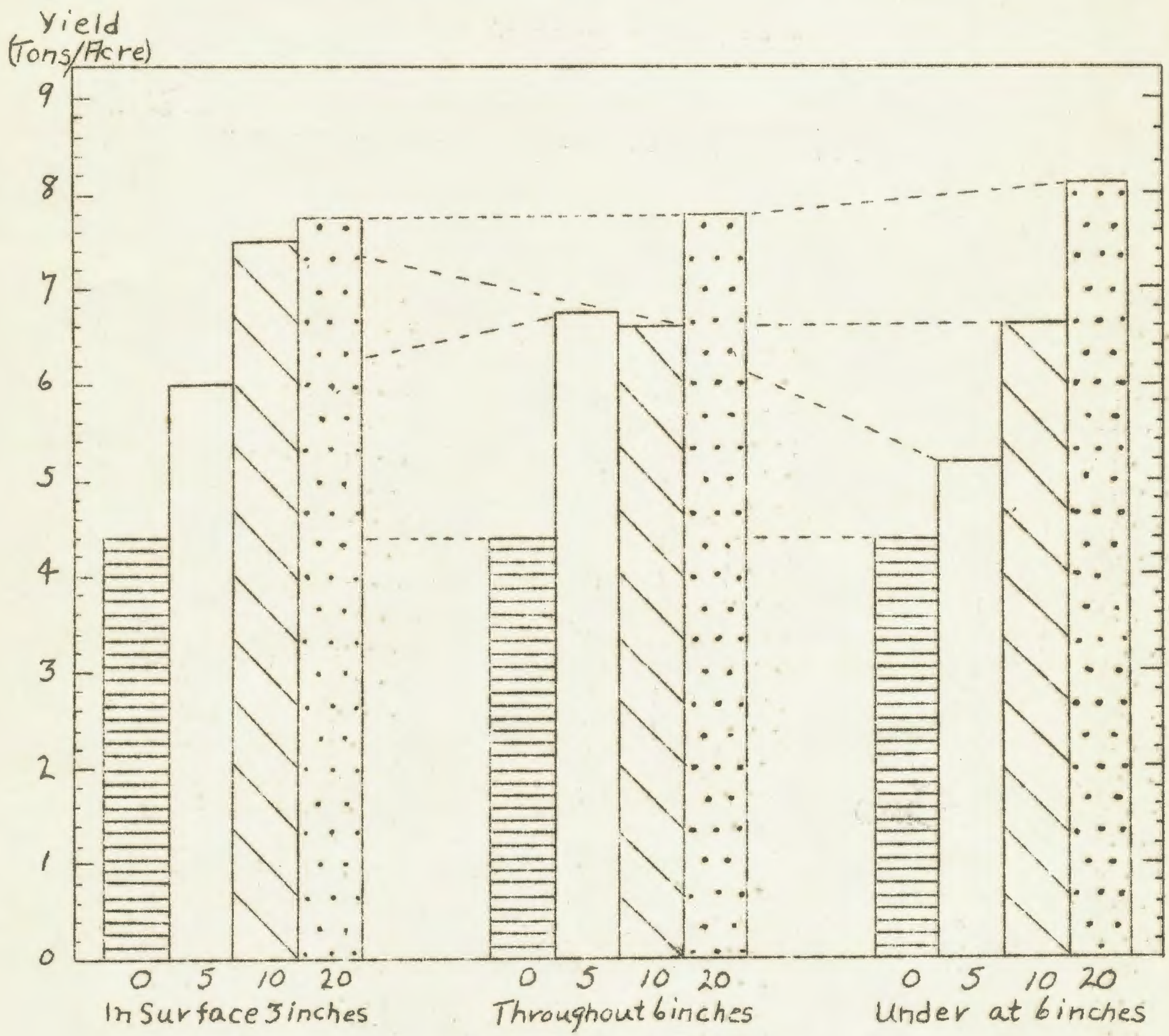


Effect of Crop and Treatment on Yield, Sugar Content and Loss.

Figure 3 (See Table III)

The Effect of Amount and Depth of Organic Matter

Incorporation on Beet Yield

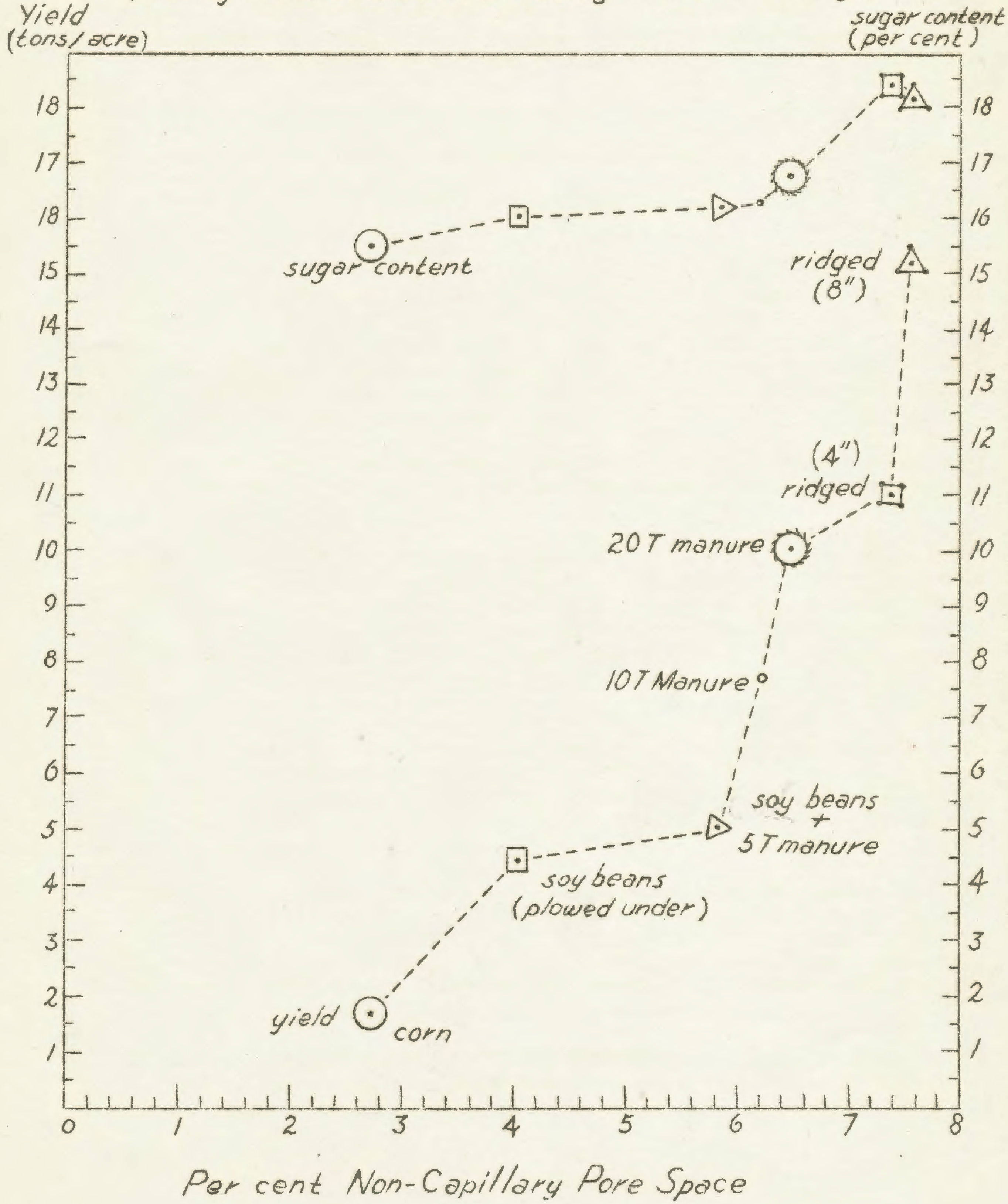


Organic Matter Incorporation
(Tons/Acre)

FIGURE 4 (See Table IV

Effect of N.C.P. on Yield and Sugar Content

(*Showing Practice used in effecting N.C.P. change*)



impossible in one, two, or perhaps several years to restore an entirely suitable structure to this soil. It is evident however, that organic matter in the form of residues, manure, and green manure crops can be used which will give satisfactory beet yields through their effects on the soil structure.

References:

I. J. A. Slipher, E. P. Reed, et al - Sugar Beet Production in Ohio - Agri. Ext. Bul. 194, Ohio State University.

II. R. B. Farnsworth, Soil Physics Studies on Sugar Beets, Proceedings A. S. S. B. T. Eastern United States and Canada, 1939. Page 52.

III. R. M. Salter et al - Our heritage, the soil. Agri. Extension Bul. No. 175. Ohio State University, pages 5-7.

"AGRICULTURE IN IRAN"

G. H. Siegumfeldt

Notes made from an illustrated lecture given by Dr. G. H. Siegumfeldt of Denmark at the Agronomy Section of the American Society of Sugar Beet Technologists. Dr. Siegumfeldt is on the staff of the University of Copenhagen and is associated with the Danish Beet Seed Company, as plant breeder. His company is supplying beet seed to Iran and he has several months there each year as Agricultural Adviser to the Shah.

"Iran consists of ten provinces, each one of which is ruled over by a Shah, and the most powerful of these Shahs used to rule over the other Shahs.

"Once, when the Darius dynasty ruled over Iran, it was a great country, which ruled over most the world, known at that time. The country itself was not as big as it is today. The rulers lived in the province of Pars or Fars as it was called and resided in the most beautiful palace the world ever has seen. Persepolis was destroyed about 3000 years ago by Alexander the Great, who at that time killed King Darius the Great and his entire family.

"Iran was also in other respects a great country. It was the cradle of agriculture. It was the Persians, under the rule of the great kings, who went out and taught the Babylonians by the Eurphrates and Tigris Rivers how to cultivate and irrigate the land. They also taught the Egyptians in the Valley of the Nile.

"Iran is the native home of many of our fruits, such as peaches, apricots, almonds and pistachios. The first wine was made in Iran and theirs is still a leading type of wine. Iran is likewise the homeland of alfalfa. History tells us that the Roman Caesars obtained their heavy horses from Persia where the horses grew so large, because they fed on the alfalfa which grew wild on the plains, where these horses pastured.

"Today agriculture in Iran is in the same stage of development as it was a thousand years ago. However, during the past five years and by command of the present ruler, His Majesty Shah Pahlevi of Iran, efforts have been