Lectures on
Soil Organic Matter

by

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Foreword

To my friends and the friends of the subject.

In this manuscript are some unpublished results and therefore only for friends and not to use for publication.

I would enjoy having any comments on this material.

W. Flaig

Acknowledgments

This manuscript came about as a result of the kind invitation of Prof. Dr. W. H. Pierre, Head, Department of Agronomy, to give lectures about soil biochemistry. I am very thankful for this opportunity.

I would like to express my best thanks also to my colleague, Prof. Dr. Lloyd Frederick, who stood by me helpfully at all times during the writing of these lectures in the English language and I appreciate his suggestions during our many discussions.

Without the help of his co-workers, Messrs. McIntosh Sims, Horton, Brown, and of the secretaries, Mrs. McLaughlin, Misses Sansgaard and Zart, it would not have been possible to mimeograph the lectures. Also to these, many thanks.

June, 1959

W. Flaig

SOIL ORGANIC MATTER

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Considerations in the decomposition of organic matter

The last lectures served to get a survey of the manner in which the humification of plant residues depends upon the climatic conditions, the soil type and the biological activity. It will be necessary to give this in more detail. One may have the opinion that this has been done too intensively. But, I must repeat that the processes of the decomposition of plants and the formation of humic substances are complicated. It is necessary to bear in mind this fact, especially if chemical studies are used to help elucidate them.

If a chemist wants to find the chemical composition of natural products, he tries to isolate them. By decomposition reactions he splits the compounds off. Fragments help to reconstruct the chemical constitution. But only if he succeeds to resynthesize the product and by comparison, if there are no longer differences between the natural and synthesized compounds, their constitutions are confirmed.

The way to elucidate the chemical constitution is only possible if the substances which are investigated crystallize. The next question must be therefore, are the humic substances crystallized? Today none are known. Are crystallized substances in humus? Can crystallized compounds be isolated out of the soil? Only the last question can be answered, but not the first. How do these crystallized compounds help to find the composition of humic substances?

The humic substances consist not only of low but also of higher molecular components. High molecular substances usually do not crystallize. The chemical composition but not the constitution of the polysaccharides or polypeptones could be elucidated for instance by hydrolysis. What changes exist in the case of higher molecular humic substances? There are few; not all high molecular substances can be hydrolyzed. Other chemical operations must be done for elucidating their constitutions.

Favorable circumstances allow us to isolate fragments with a recognizable chemical constitution. Can we expect such definite substances in the case of humic acids? The examples of formation of humus under different climatic conditions in different soil types and under different biological activities teach us that the possibility is extremely small. The composition, for instance, of lignin in the different plants varies. The different conditions in the soils due to climate and therefore the existing biological activity do not effect only different speed of reactions but also their directions. These considerations do not concern only the lignin but also all other components, which can take part in the reactions in soils. At first, we think about which kind of compounds offer eventually the largest possibilities for the formation of humic acids. Do we know them? I believe we have good suggestions. Therefore it must be studied 1) how they are formed by decompositio of residues of dead organisms, 2) which a re their reactive groups, 3) which are the principles of combination of the same kind of compounds or of these with the aid of others.

The first step of the investigation of formation of humus must be the study of decomposition.

The rate of a chemical reaction depends mainly upon:

a) the temperature (climatic conditions)
b) the concentration

In our case other factors are also important.

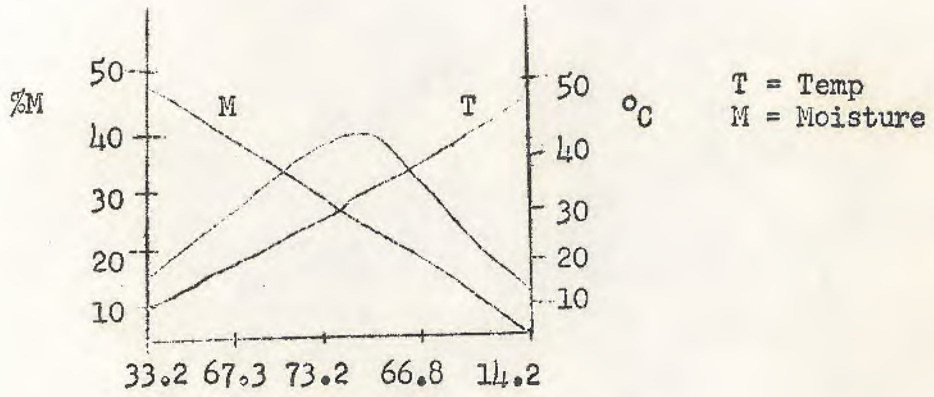
pH value reaction in homogeneous or heterogeneous medium

Catalysts, presence or absence

Reaction among absorbed or unabsorbed substances

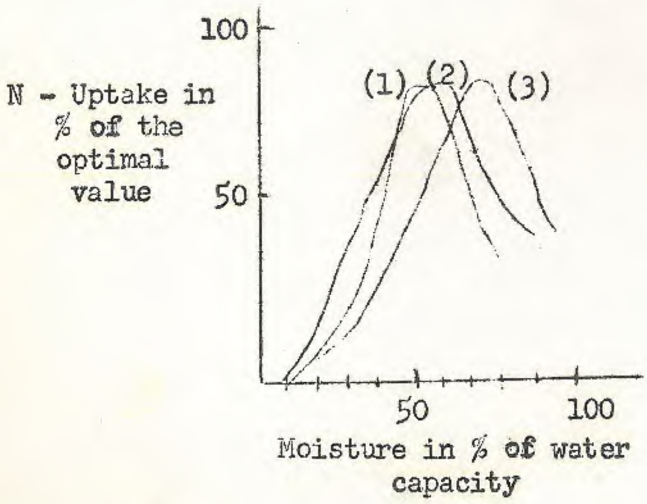
The most convenient way to study the decomposition of organic substances is to measure the last oxidation product, which is CO_2.

Wollny in 1886 determined the liberation of CO_2 when organic substances were decomposed. He found the relationship between temperature and humidity and CO_2 evolution.



Amount of CO_2 in mg.

At the same time, Kostytschew (1886) also studied this relationship and could confirm the results of Wollny (1886). In similar kinds of investigations he also showed that with decreasing temperature and moisture, the CO_2 evolved reaches a maximum and then decreases.



25 years later Greaves and Carter (1920) determined the biological activity in soils with different contents of soil moisture. These experiments were made in the laboratory. Twenty-two different soils have been used, which had a different composition of humus and mineral parts. The intensity of the nitrification (1) ammonification (2) and fixation of nitrogen (3) depends on the soil moisture.

Waksman and Gerretsen (1831) determined the speed of decomposition of straw at two different temperatures and moisture content of 66-80%. The amount of the residues gets smaller as the time of rotting and temperature increases.

If one calculated the temperature coefficient Q_{10}, it decreases with the increasing temperature.

S 1 K/690

Decomposition (rate velocity) of straw. (Waksman and Gerretsen, 1931). Variants with mineral fertilizing

Temperature °C	Comparison of the Initial amount with that which has decomposed (In %)				Temperature coefficient at 80% moisture	
	In the case of 66% moisture		In the case of 80% moisture		after 105 days	after 273 days
	105 days	273 days	105 days	273 days		
7	27.3	35.7	23.2	36.3	-	-
18	46.8	50.5	53.3	60.8	2.3	1.62
27	55.9	64.7	62.4	70.1	1.16	1.15
37	60.2	70.0	68.0	76.4	1.09	1.09

Since this time, very many experiments have been made with more or less the same results. The methods used have been also different.

One of these experiments shall be mentioned (H. Kroept, Zeitschr. f. Pflanzern. Düng und Bodenkunde: (1956)) because we need later on some of these data.

In laboratory work, different organic substances have been incorporated into two soil samples.

S 2 714

Composition of Organic Substances

Number	Substance	% Ash	% C	% N	C:N
1	Starch	0.6	46.4	0.02	2322.0
2	Gelatin	2.8	46.0	14.20	3.24
3	Peptone	2.5	50.6	13.61	3.72
4	Nutrient Broth	50.5	24.2	7.36	3.28
5	Barley Straw	5.7	42.7	0.64	67.1
6	Oat straw	8.0	43.40	0.43	100.7
7	Wheat straw	9.2	39.20	0.70	56.0
8	Rye straw	5.6	42.20	0.39	109.3
9	Rape straw	7.8	39.4	0.91	43.4
10	Maize straw	7.7	39.9	0.59	67.2
11	Field Bean Straw	10.2	39.5	2.22	17.8
12	Pea straw	13.4	41.8	3.15	13.3
13	Alfalfa Hay	9.4	41.8	2.88	14.5
14	Green rape	52.8	22.6	1.98	11.4
15	Young white clover	18.6	43.6	2.83	15.4
16	Beech Leaves	24.5	45.0	0.79	57.2
17	Pine Needle Litter	26.3	46.0	1.24	36.8

The content of carbon and nitrogen varies. The C/N ratio ranges from 3 to 100. These substances have been gound to sizes <0.5 mm and mixed with the soils. Every sample has the same content of 0.25% C. The moisture was 60% of the water holding capacity. The temperature of incubation was 25° C.

S 3 716

The course of decomposition by adding different organic substances

	Loam Soil	Sandy Soil
0.2 mm fraction	33.2%	14.9%
C-content ( )	1.04%	0.96%
N-content (Kjeldahl)	0.130%	0.078%
C/N	8.0	12.3
pH (KCl)	6.9	4.6
P_2O_5 } in Lactic acid	14 mg	1.2 mg
K_2O } Extract	20 mg	11 mg

The properties of the soils have been different in clay-content and also in content of carbon, nitrogen and pH.

S 4 717

C evolved as CO_2 in Percent of added carbon

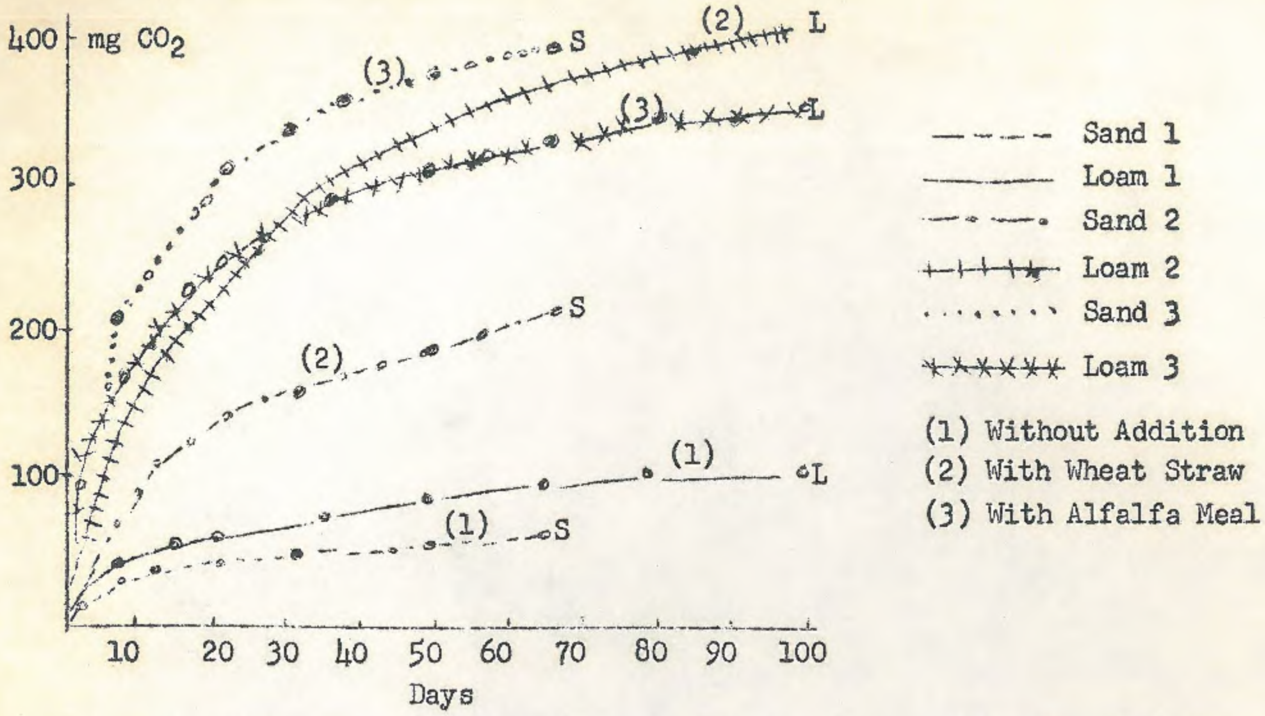
	65 Days		99 Days
Substance	Sandy Soil	Loam Soil	Loam Soil
Barley Straw	53.5	78.9	86.0
Oat Straw	53.4	74.4	83.5
Wheat Straw	46.6	81.6	91.2
Rye Straw	50.1	81.0	89.9
Rape Straw	52.0	78.8	86.2
Green Rape	65.4	73.9	79.5
White Clover	60.4	67.7	73.4
Pea Straw	75.6	63.8	69.1
Alfalfa Hay	85.3	73.0	78.9
Beech Leaves	43.4	49.0	58.7
Pine Needles	26.6	35.0	41.2

Between 50 and 80% of the added carbon could be determined as CO_2 after 2 months. After 99 days, the speed of decomposition decreases.

This diagram shows that not only the composition of organic substances but also the properties of the soils had an effect on the development of CO_2. The closer the C/N ratio of the soils, the less the differences are. The ground straw of alfalfa decomposed with nearly the same speed in sand as in loam.
(Diagram on next page)

S 5 718

Decomposition rate of ground alfalfa and wheat-straw in two different soils



Course of Decomposition of Alfalfa and Wheat Straw in 2 Different Soils

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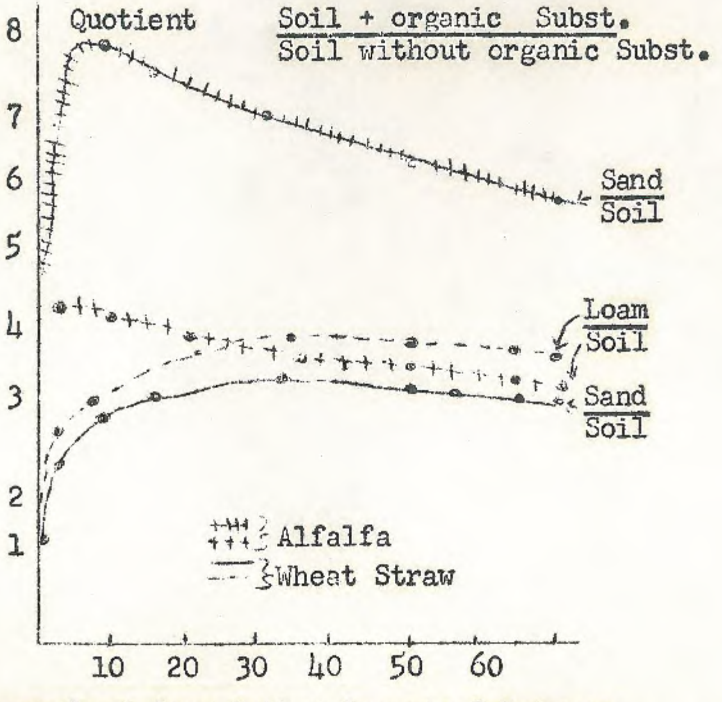
Quotient of CO_2 Evolution



Quotient of CO_2-evolved from Soil + Organic Substance
Soil without added Organic Substance

The soils without organic substances also evolve CO_2. If one forms the quotient of the CO_2 evolution

$$Q = \frac{\text{soil + organic substances}}{\text{soil without organic substances}}$$

The diagram shows the increasing of the transformation of the organic substances.

In sand the increase of transformation is high by incorporating of ground alfalfa, while straw decomposes slowly. The curves have a large difference.

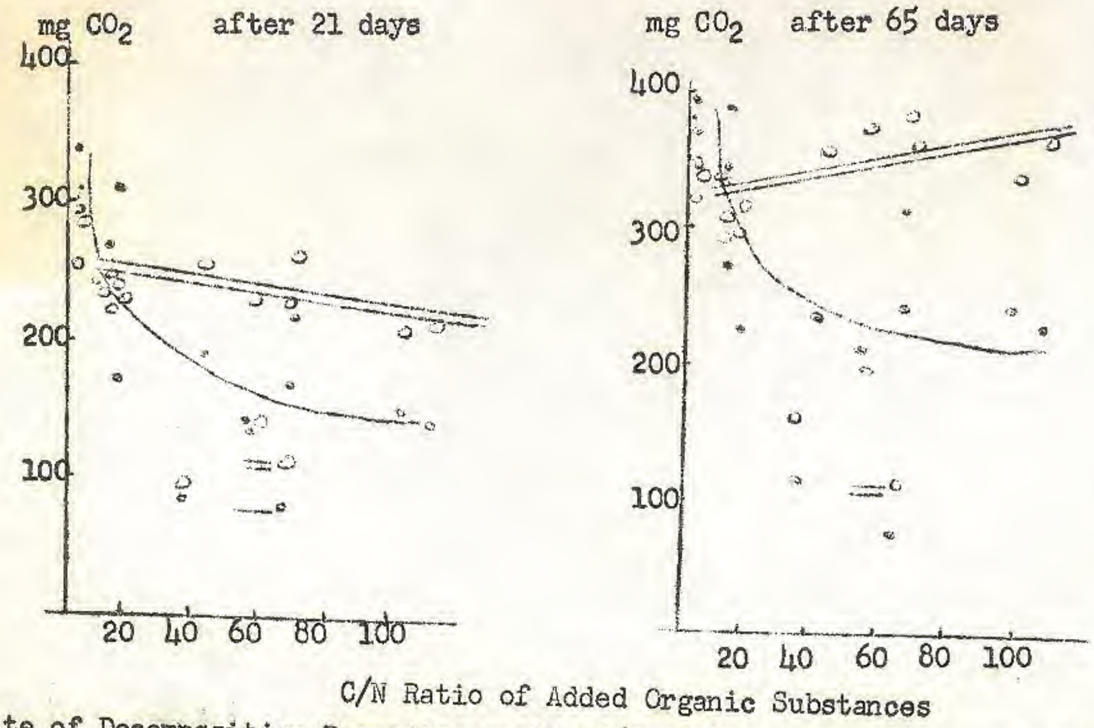
In loam the correspondent curves are closer together. At the beginning the ground alfalfa produces a larger amount of CO_2 but later on the wheat straw releases more.

The composition, the C/N ratio especially, of the organic substances does not play such an important role for the rate of decomposition in loam as in the sand.

In this connection, the nitrogen content of the soils must be considered. The sand has a lower content of carbon and nitrogen, the C/N ratio is larger than in the loam.
Generally the organic substances with a lower C/N ratio decompose more rapidly as the nitrogen in organic combination can be liberated (compare wheat straw in sand and in loam).

If the content of nitrogen in the organic substances, for instance alfalfa, is relatively high the nitrogen in the soil has not the same effect on the decomposition. The rate of decomposition is in both cases high at the beginning. At this time, the easily available nitrogen of the organic substances takes part in the reactions. Later, the rate of decomposition decreases to that of organic substances with lower content of nitrogen. The next diagram may explain these facts more in detail.

S 7 720



Rate of Decomposition Depending on the C/N ratio of Added Organic Substances

These are all different substances with C/N ratios from 1 to 100 plotted against the amount of CO_2 evolved after 21 and 65 days; it can be noticed that the C/N ratio is indeed the dominant factor for the decomposition in sand in both cases. The evolution of CO_2 increases with the smaller C/N ratio. Some of the points are relatively far away from the curves. These belong to substances such as leaves of trees, needles of spruce, etc. Because we will not talk about the decomposition of residues in forests, I will mention a paper of W. Wittich (Untersuchungen über den Verlauf den Strewzersetzungen auf einem Boden mit starker Regenwurmtätigkeit Schriftenveihe der forstl. Fakultät, Universität Göttingen, 9 (1953). He found also that organic substances of this kind decompose more slowly than one would suggest according to the C/N ratio. It may be that not only the conditions of temperature or moisture are important but also some substances which are formed during decomposition of forest litter. Several reasons support this.

In contrast to the results of experiments in sand, the points of the measurements in loam are nearly on straight lines which are more or less horizontal. In this case the amount of CO_2 evolved after 21 and 63 days depends approximately upon the amount of added organic substances and not upon the C/N ratio.

The process of decomposition of organic matter can be influenced by fertilizers, for instance. In connection with different other considerations, we discuss the data which are interesting.

The acid sand soil was investigated, which needed according to the soil analysis 15 dz CaO/ha and phosphorus acid. For the experiment $CaCO_3$ and potassium phosphate has been added to the soil sample.

S 8 721

Influence of fertilizing with limestone (chalk) and phosphate on the amount of decomposition

	Fertilization per ha.			
	None	15 dz CaO	15 dz. CaO 150 kg. P_2O_5	30 dz. CaO 150 kg. P_2O_5
	Mg CO_2 after 28 days			
Soil	51.4	67.0	59.3	81.7
Soil + Wheat straw	168.0	223.0	206.6	221.2
Soil + Alfalfa meal	245.4	291.1	270.9	272.1

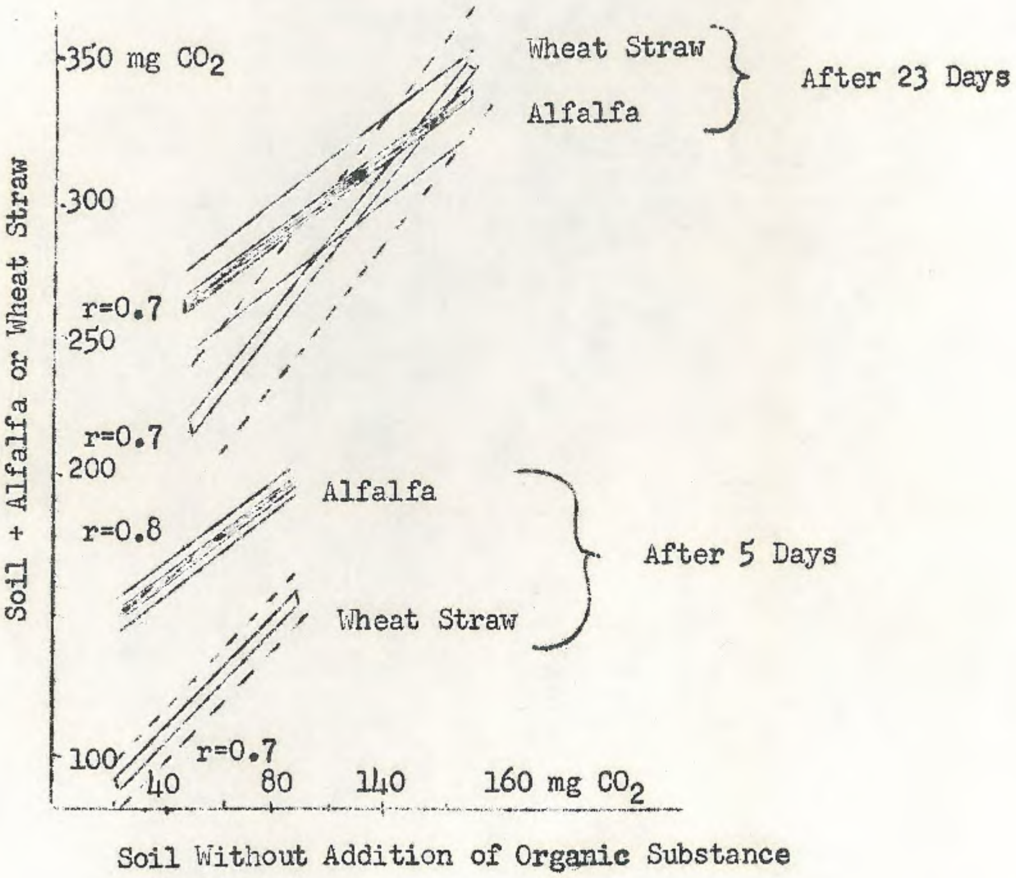
The required amount of 15 dz CaO/ha increased the evolution of CO_2 most. The inhibiting effect for the decomposition of organic matter has been the acid reaction. The pH (in water and in KCl) were lowered 0.2-0.4 during the decomposition independent of the C/N ratio.

The first example has shown that the decomposition is influenced by the properties of the soil. Therefore, a number of 28 soils of cultivated land have been investigated in the same manner. The properties of the soils were:

Particle size $< 2\ \mu$	7.2 - 44%
Content of carbon	1.23 - 5.35%
Content of nitrogen	0.12 - 0.58%
C/N ratio	7.3 - 10.3
pH value	4.8 - 7.1
CO_2-evolution in 23 days	
Soil control	46.1 - 148.6 mg.
Soils with wheat straw	168.7 - 327.3 mg.
Soils with alfalfa	227.0 - 320.5 mg.

The soils varied not much in their properties. Among them there had not been, for instance, podzolic soils.

S 9 722



Relation between the respiratory quotient of different soils and the velocity with which these organic substances decompose

The results are summarized:

1) Soils, which show a higher respiration without organic substances, decompose the added organic materials more rapidly.

2) At the beginning the alfalfa evolves more CO_2 than wheatstraw. The former is more rich in nitrogen. But after 3 weeks, the differences are smaller between alfalfa and straw than at the first measurement. Some soils decompose wheatstraw faster than alfalfa.

In a similar way as before, the experiment was calculated. It has been found that the nitrogen content of the organic substances in the soil have some influence on the rate of decomposition. In the following, the different relations between nitrogen contents of the organic substance and some soil properties are given:

Content of particles $< 2\mu$	r = -0.3
% C	r = -0.4
% N (Kjeldahl)	r = -0.4
mg % Nitrate nitrogen in the soil at beginning	r = -0.4
mg % Ammonia-nitrogen in the soil at beginning	no relation
pH (KCl)	r = -0.5
mg P_2O_5; mg K_2O, respectively	no relation

The mentioned correlation coefficients only show a weak relation.

It has been surprising that neither the humus content nor the amount of nitrogen of the organic substances have a very large influence. C and N content influences the rate of decomposition in this way, that the importance of the nitrogen-content in the added substances is reduced in the case of high nitrogen content in the soil.

The nitrogen content in humus is not always available at the beginning of the experiments. Therefore nitrate and ammonia nitrogen has been determined. It could be shown that the difference of the contents of ammonia nitrogen in the soils is not very large. The contents of nitrate nitrogen varies more. Higher contents of nitrate nitrogen effects a relatively more rapid decomposition of straw.

The pH value of the soils is one of the most important factors. The more acid the soils are, the more nitrogen the organic materials must contain for rapid decomposition.

As an example of how different soils can evolve CO_2, depending on the pH value and the ratio of different ions, I will show two tables, one is more interesting for chemical considerations, the other more for microbiological.

S 10 692

The decomposition intensity of organic substances in soil with different contents of Ca++ and H+. Evolved CO_2-amounts in Mg from 100 g soil, when 0.75 g of plant residues were incorporated. (Kononowa, 1937)

Sampling Date	Weakly Podzolized Soil*				Normal Chernozem*			
	3.8	5.2	7.1	8.4	3.8	5.8	6.8	8.4
1 month	430.6	622.0	834.9	909.3	339.0	602.2	838.1	1042.9
2 months	252.8	417.6	346.7	299.6	169.4	279.6	237.6	267.6
3 months	140.6	144.6	107.0	117.0	100.4	111.6	106.2	103.6
Total	824.0	1184.2	1288.6	1325.9	608.8	993.4	1181.9	1414.1

*)In the soil sample, the Ca++ was only partly exchangeable as compared to the H+.

100 g soil samples were mixed with 0.75 g plant residues. The mixture was moistened and incubated. The evolution of CO_2 was then measured in monthly periods. The influence of pH is higher in weakly podzolized soils than in normal chernozems. Calcium ions play an important part for the formation of humus. The soils which have the best structure, such as chernozems, have a relatively high content of calcium ions. A large amount of humic acids is present as calcium salts in this type of soils. By the investigation of different authors it has been shown that $CaCO_3$ has a favorable affect on the decomposition of fresh plant materials. It may be that the decreasing of the concentration of H+ in the soils is one of the reasons. The oxidation rate of phenols depends upon the pH-value. Later on we will discuss more about this fact.

The exchangeable sodium has an influence on the humus formation. Tschishewski (1933) and Kononowa (1940) could show that small amounts of Na+ increased the rate of decomposition of organic substances. There are two reasons for this effect. First, the increase of pH and second, partly increasing of the dispersity of humic substances. By this fact, they are more available for the microorganisms. The increased dispersity deteriorates the soil properties.

S 11 693

The decomposition intensity of organic substances in soil with different contents of Ca++ and Na+. Evolved CO_2-Amounts in Mg per 100 g of soil, when 0.75 g. of plant residues were added. (Kononowa, 1937)

Sampling Date	Ca++ 58.3 m val. No Na+, pH = 7.4	Ca++ 50.3 m val. Na+ 6.0 m val. pH = 7.86	Ca++ 44.3 m val. Na+ 14 m val. pH = 8.22
1 month	1268.2	1252.4	1238.1
2 months	295.2	538.9	627.7
3 months	96.9	254.5	233.7
Total	1660.3	2045.8	2099.5

The monthly measurements show that with the increasing content of sodium ions the decomposition is also increased. Otherwise the decomposition depends also upon the pH. Calcium ions have only been partly exchanged.

To use CO_2 evolution as a value for soil activity, it is necessary to measure it with dynamic and not static methods. There are several reasons why this is so:

1) Normally the cultivated lands have a good aeration. Most of the processes are aerobic. Carbon dioxide is the last metabolic product.

2) Also carbon dioxide has several effects on the dynamics of the soil and on plant growth.

3) In contrast to other metabolic products which are gaseous, CO_2 is not accumulated in the soil. Surely, a part of carbon dioxide is dissolved in soil water for a short time and combined as carbonate or dicarbonate. It can be supposed that the influence of these chemical and physical factors do not reduce the determination of respiration curves. Source of carbon dioxide formed in the soils are the processes of life.

4) The method of the determination of CO_2 with an infrared absorption recorder allows to work under natural conditions and continuously.

With soil respiration one determines a sum of effects. Temperatures and moisture are important factors. Other influences suchas fertilizing, soil management and others can be determined as far as they overlap the other factors.
Table 1
Both curves are nearly analagous. The different influences of air-temperature, soil temperature, soil humidity, and rainfall could be seen.

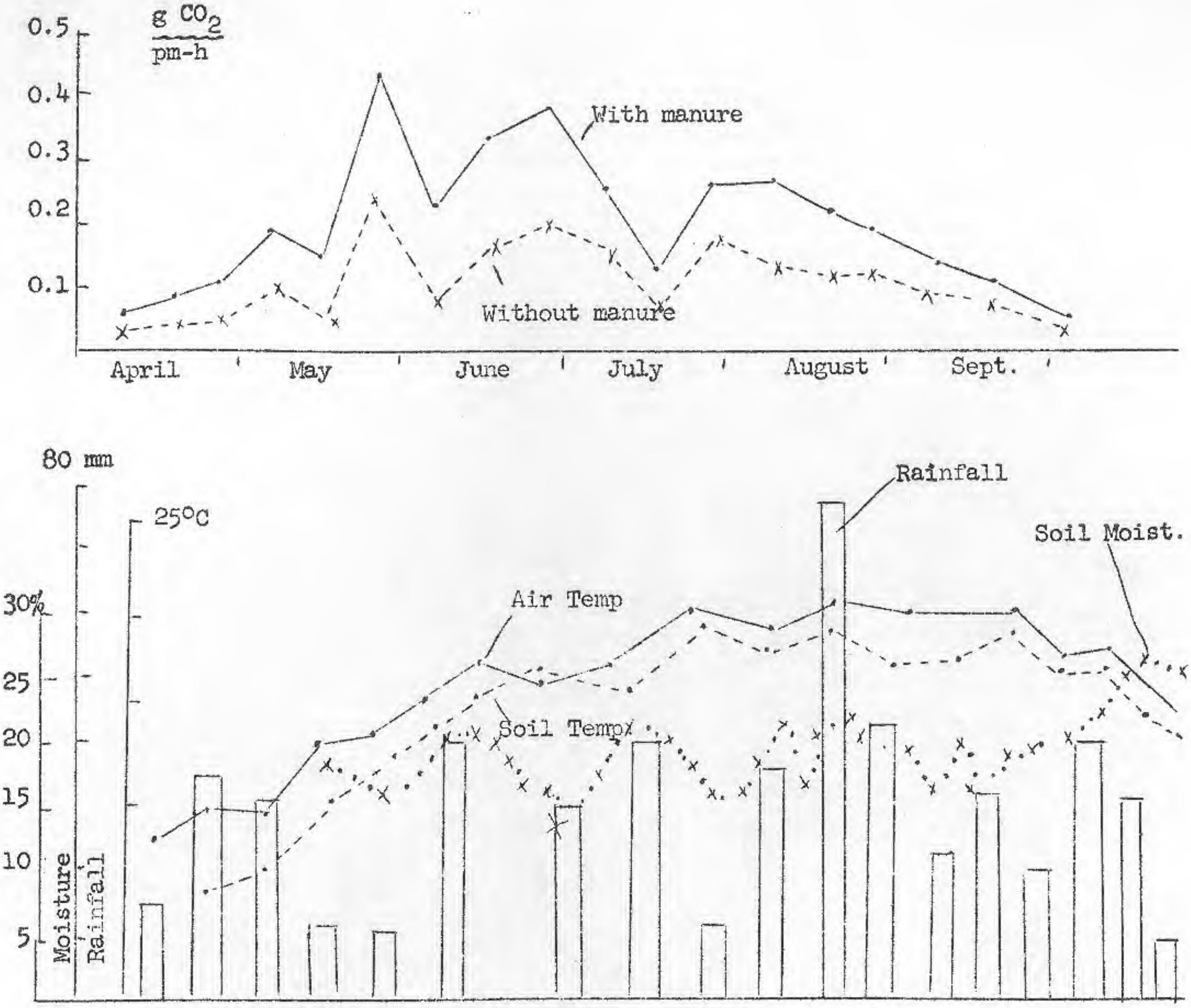
The difference of CO_2 evolution by fertilizing with manure is noticeable.
Table 2.
To show in which way a single factor can be determined, the curves of soil respiration of the fertilized and unfertilized cultivated land without crops is shown. Most significantly the effect of the single factor can be determined if one forms the quotient of the curves of the two plots.

The two plots differ by an amount of mineral fertilizer correspondent to 100 kg N/ha. The curve of the quotient shows the influence of the fertilizing under elimination of the influence of climate. This curve is a good example for the influence of fertilizing on the biological activity which cannot be characterized with one value at any time. Important is the course of the curve.

On this point we must think about the isolation of humic substances. The dynamic measurements show that not at any time the transformation of the organic matter in the soil is the same. It is influenced by climatic conditions and biological activity. Therefore, it may be important for some investigations to determine the time of isolation.

For basic work, I believe that it will be best to isolate humic substances only out of such systems which are influenced by the mentioned conditions as little as possible. Therefore, this kind of investigations have been and should be done in the future with humic substances isolated from chernozem or peat.

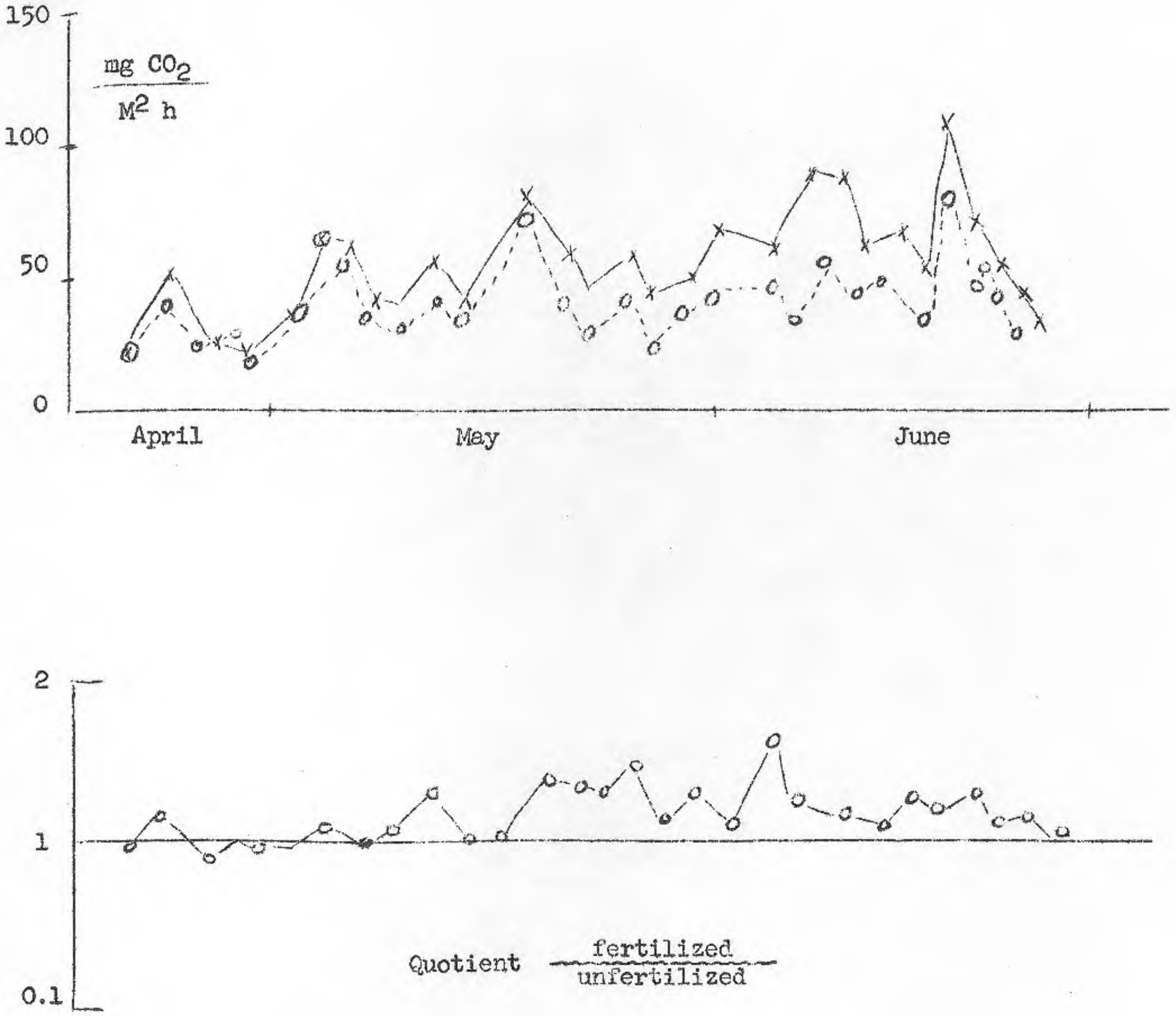
Until now, we have only noted in which way the humus substances decompose independent of climatic conditions, soil types and biological activity. It will be necessary to have more knowledge of ways in which organic matter decomposes. By the determination of the respiration curves of soils with and without organic matter, we get only an idea about the decomposition of the organic matter which has been in the soil before.



Respiration curves of land planted with potatoes.

With and without barnyard manure.

H. Koepf.
Die Biologsiche Aktivität des Bodens und ihre experimentelle Kennzeichnung, Z. Pflern. Dgg. Bdkde. 64 138-146 (1954).



Respiration curves of cultivated land, fertilized and unfertilized (without crops)

M. J. Hallam and W. V. Bartholomew investigated (The influence of rate of plant residue addition in accelerating the decomposition of soil organic matter. Soil Science Society of America Proceedings. Vol. 17, pp. 365, 1953). Ground maize and soybean plants containing radioactive carbon were added at rates of 2.5, 10 and 50 tons per acre to the soil. The mixtures were moistened and incubated during 119 and 247 days. By the decomposition of the organic matter in soil and of the organic substances of the plants, they could measure with the aid of C^{14} the carbon dioxide which is evolved from the organic matter in soil and from the plant residues which have been added. The plant residues increase the decomposition of the organic matter which has been in the soil before. The increase in the evolution of CO_2 varied with the soil type and the nature of plant residues. The greatest increases occurred with 10 and 50 tons of residue but the greatest increase per unit of residue added occurred with 2.5 tons..

Table 3.

Soybean residue decomposes more rapidly than does maize residue. The rate of decomposition of the residues was greater at 2.5 and 10 tons than at 50 tons. The authors could show that a net gain in the organic matter content occurred only when 50 tons of residue were added and that even this gain was very slight.

P. Simonart and J. Mayaudon (A study of the decomposition of organic materials in soil by means of radioactive carbon. Plant and Soil 9, 367-375; 376-380; 381-384, (1958)) labeled ryegrass with C^{14} and divided it in different fractions. They extracted with alcohol of 80% and 20% by cooking, and called this fraction "soluble substances".

Furthermore they extracted the hemicelluloses with sodium hydroxide. This residue they called fraction of cellulose. This fraction contained 80% of cellulose and 20% of substances which can not be hydrolyzed (lignin).

S 12 68

Material	Radioactivity millions counts/minute	Mg C
Soluble substances	42.0	40.0
Hemicelluloses	0.4	8.4
Cellulose + lignin	5.9	20.8

They divided the fraction of soluble substances into other fractions by different solvents. With ether they extracted chlorophyl a and b, carotene, xanthophyl and a residue of waxes. The substances which had been soluble in water but not dialysable has been the fraction which contains the sugars and the amino acids. In the third fraction, there had been the substances which cannot be dialyzed, the proteins.

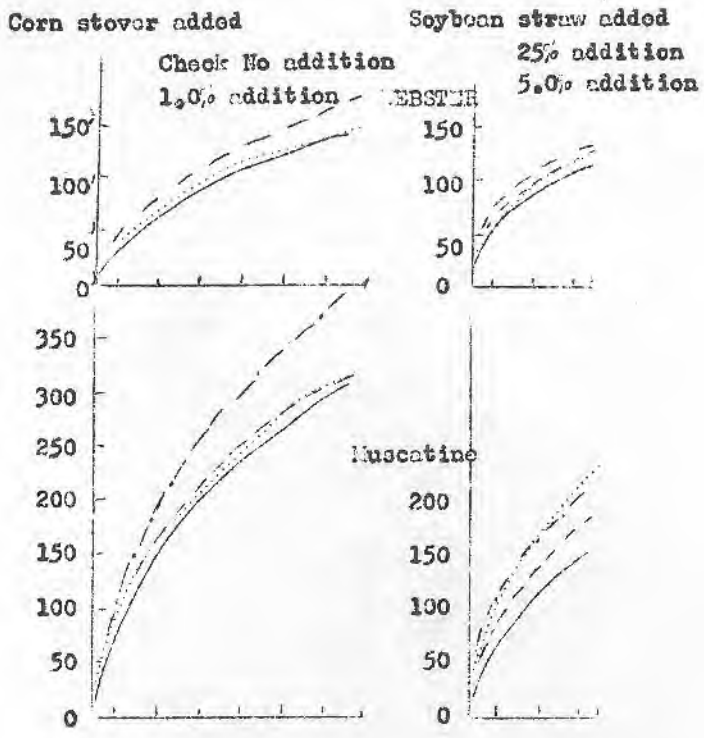


Fig. 1. Influence of the rate of addition of corn and soybean residues on the decomposition of native soil organic matter.

Carbon remaining from residue addition in 100 gms of soil after extended periods of decomposition

Residue rate gm/100 g soil	Carbon addition mg/100 g soil	Carbon remaining from Soybeans after 119 days mg/100 g soil	%	Corn after 247 days mg/100 g soil	%
		Webster Silty Clay Loam			
0.25	63	8	12.7	5	7.9
1.0	250	64	25.6	56	22.4
5.0	1250	592	47.3	426	34.1
		Muscatine Silt Loam			
0.25	63	3	4.8	15	23.8
1.0	250	56	22.4	58	23.2
5.0	1250	471	37.7	419	33.5
		Decomposition apart from soil			
-	1250	436	34.9	598	47.8

The Distribution of the Radioactivity of the Soluble Fraction Establishes itself as follows:

Material	Radioactivity	Mg C
	millions counts/min.	
Substances soluble in ether	1.5	10.0
Dialysable substances soluble in H_2O	36.4	17.4
Non-dialysable substances soluble in H_2O	3.4	12.6

One reveals the percentage of radioactivity, the principal constituents having been separated by chromatography.

Substances soluble in Ether	Chlorophyll a and b: 11% Carotene and xanthrophyll: 31% Residue (Waxes): 58%
Dialysable substances soluble in H_2O	Glucose: 71% Glutamic acid: 10% Alanine: 8% Malic acid: 3.5% Citric acid: 1.0% Phosphoric esters: 1.0%
Hemicellulose fraction	By hydrolysis with N HCl for 6 hours at 100° C, one separates by chromatography galacturonic acid, a hexose, Xylose and arabinose whose radioactivity represents, respectively, 14, 33, 30, and 21% of the total activity of the fraction.
Cellulose and lignin fraction	One digests one part 4 hours in H_2SO_4 to 70% and follows with a hydrolys is of 6 hours in 2 N H_2SO_4. One identifies in this fraction: glucose (78%), xylose (10%), arabinose (7%), amino acids 5% and lignin 7% of total activity.

They determined the activity of these different fractions and of their components. To determine the different rate of decomposition, the fraction had been mixed with a moistened soil and incubated. The evolved carbon dioxide had been measured during the time of decomposition.

Recovery of $C^{14}O_2$ from various substrates

Substrate	Glucose		Cellulose		Hemi-Cellulose		Soluble Extract		Ray-grass	
Initial values	344.097 C/min.		331.600 C/min.		331.150 C/min.		685.150 C/min.		770.675 C/min.	
J	C/min	%	C/min	%	C/min	%	C/min	%	C/min	%
3	25.630*	7.45*	15.200	4.51	16.650	5.03	98.935	14.44	187.576	24.1
10	237.38	69.0	60.601	18.31	166.315	50.25	261.678	38.20	110.760	14.38
14	14.420	4.19	37.207	11.24	22.776	6.88	54.200	7.91	65.858	8.55
21	17.118	4.98	62.650	18.93	22.752	6.87	58.660	8.56	95.174	12.36
33	9.216	2.68	75.154	22.70	20.160	6.09	43.520	6.35	64.640	8.39
42	2.294	0.66	25.42	7.68	7.970	2.40	15.359	2.24	44.894	5.83
51	-	-	8.086	2.44	7.393	2.23	12.378	1.80	31.328	4.05
60	-	-	4.928	1.49	3.520	1.06	5.312	0.77	17.408	2.26
Total	305.058	88.96	289.246	87.38	267.536	80.81	550.042	80.27	617.638	80.0

*The amounts of $C^{14}O_2$ are expressed in counts per minute; the %'s are expressed in proportion to the initial value of the radioactivity of the substrate.

The table shows the evolution of $C^{14}O_2$ due to the different substrates in counts per minute. The percents of evolved carbon dioxide are given in comparison to the initial value of the radioactivity of the substrate. The rate of decomposition varies with the kind of substances.

S 15
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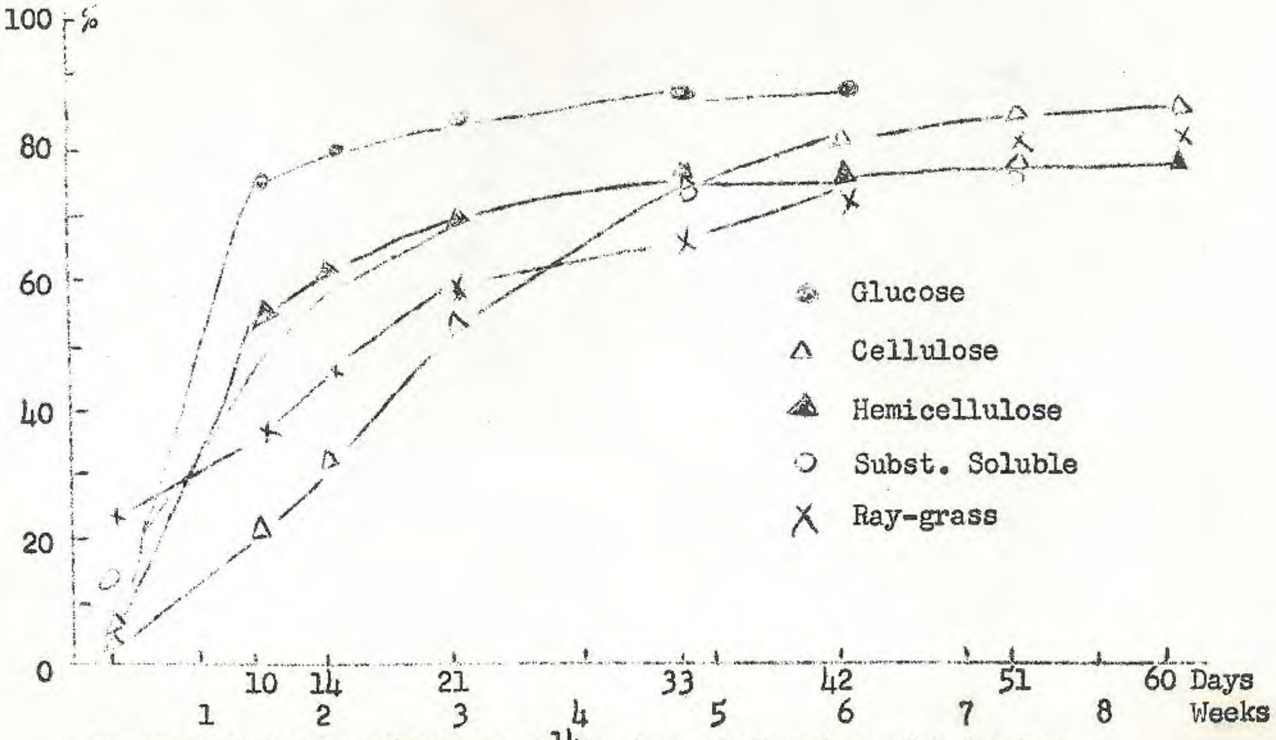


Curves of Decomposition in $C^{14}O_2$ from Radioactive Substrates

The decomposition of glucose is much more rapid than that of hemicellulose and these again more rapid than that of cellulose fraction. 11% of glucose, 50% of hemicellulose and 21% of the cellulose fraction and of ryegrass cannot be found as CO_2 after 2 months when the amount of evolved CO_2 has become negligible.

The decomposition of all these radioactive substrates mixed with soil produces humus-like substances. Therefore, the mixtures have been analyzed. The authors isolated three fractions, 1) soluble substances, 2) substances which are soluble in sodium hydroxide, and can be precipitated in alcohol solution, pH 4.0 up to 4.5. These substances are washed with alcohol of 94%. According to the authors this fraction contains the so-called α- and β-humus. The hymatomelanic acids are partly dissolved by this treatment.

The third fraction are the substances which cannot be solved in sodium hydroxide solution (humin).

S 16 72

Radioactivity of 3 Organic Fractions from the Soil Obtained After 8 weeks at the Expense of Radioactive Substances

Substrate	Glucose		Cellulose		Hemi-Cellulose		Soluble Extract		Ray-grass	
Initial Radio-activity*	344.097 C/min.		331.600 C/min.		331.150 C/min.		685.150 C/min.		770.675 C/min.	
	C/min	%**	C/min	%	C/min.	%	C/min	%	C/min	%
Soluble substances	5.600	1.56	10.300	3.12	7.300	2.33	25.600	3.76	10.300	4.10
α and β Humus	6.034	1.76	11.140	3.15	13.892	4.21	27.799	4.10	11.140	4.54
Humine	14.690	4.33	24.734	7.28	24.442	7.12	57.131	8.39	24.734	11.44
Total		7.65		13.54		13.54		16.25		20.08

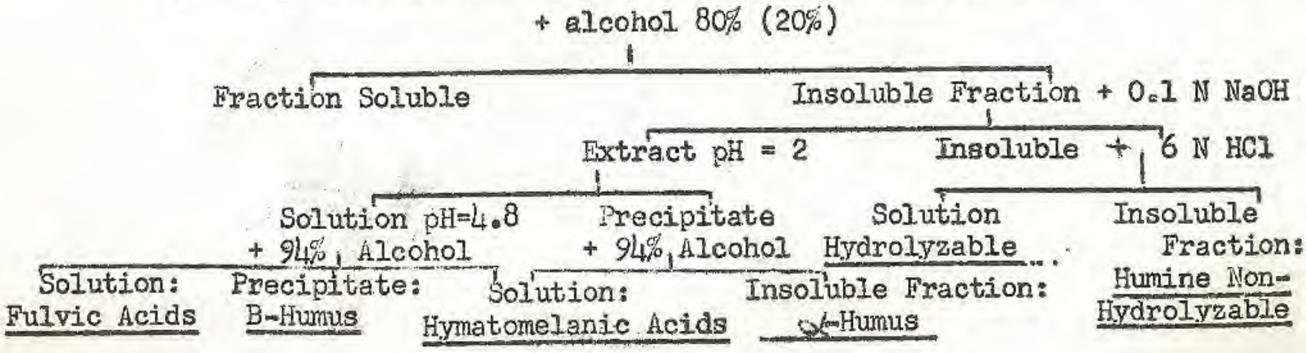
* Expressed in number of counts per minute.
** Expressed in proportion to the initial radioactivity.

The radioactivity of the different fractions formed by the different raw materials shows in every case that the activity of the humins is nearly as high as the two other fractions together. But the amount of humic substances formed out of the raw materials are different.

In the next step of the investigation, the authors mixed glucose which has been uniformly radioactive with soil and incubated 60 days and fractionated the soil organic matter.

Scheme for Fractionating the Organic Matter in the Soil

Quantity of Soil Corresponding to 4 Grams of Dry Material



All these fractions have been brought to a volume of 8 ml. α-humus, β humus and the hymatomelanic acids had been dissolved in 0.1 N sodium hydroxide. 2 ml. of each solution after adding 2 ml. 0.1 N HCl had been evaporated under the reduced pressure to eliminate all traces of carbonate. The content of carbon of the residues of evaporation have been determined. The carbon content of hydrolysable humin is calculated from the total amount of the substances hydrolysable with hydrochloric acid. To this one adds the distilled water which had been used to wash the residue off the hydrolysis. The hydrolysable substance is evaporated in vacuum and by adding water several times during evaporation, the excess of hydrochloric acid is eliminated. The carbon content of the non-hydrolysable humin is determined by the residue of hydrolysis.

S 18 74

Amount in mg. of carbon of various humic fractions from the soil obtained after decomposition of radioactive glucose

J	Total Humic Fractions Mg. C	Fulvic Acids	Percent Carbon		Hymato-melanic Acids	Hydroly-zable Humin	Non-hydroly-zable Humin
			α-Humus	β-Humus			
7	147.4	12.9	19.6	8.5	8.1	12.5	38.4
15	173.6	16.1	21.1	6.2	7.9	13.0	35.7
30	126.2	14.8	22.6	6.3	8.1	16.0	32.2
45	124.4	18.4	23.2	9.8	7.1	11.5	30.0
60	127.4	15.2	23.4	8.5	7.6	15.3	30.0

* The percentages are expressed in proportion to the total sum of carbon contained in the 6 humic fractions.

The radioactivity of 7 organic fractions obtained after decomposition of radioactive glucose

J	Activity of soluble substances 10^3 C/min	Total Activity of the humic fractions 10^3 C/min	% Activity **					
			β Humus	Fulvic acids	α Humus	Hymato-melanic acids	Hydroly-zable Humin	Non-hydroly-zable Humin
7	6.7	472.5	4.7	11.9	23.0	9.9	35.8	14.7
15	0.7	527.5	4.4	15.4	28.3	5.2	28.5	18.2
30	0.4	265.9	5.4	22.0	26.4	5.1	25.4	15.7
45	0.4	248.5	9.2	25.2	29.0	4.5	20.6	11.5
60	0.4	235.7	6.9	17.7	28.4	3.5	28.8	14.7

* Initial radioactivity of substrate: 3.5 x 10^3 C/min.

**The % are expressed in milli counts per minute in proportion to the total radioactivity of the 6 humic fractions.

These tables show the carbon content in ml. of the different humic fractions of soil and the radioactivity of 7 organic fractions after the decomposition of radioactive glucose. The different fractions are scarcely modified in their carbon content between the 7th and 60th day. Only the fraction of the nonhydrolizated humin is decreased in its carbon content from 38.9% to 30% during this time. One must bear in mind that this fraction may contain also the cellulose and the lignin. The microbiological decomposition of them would explain the decrease of the carbon content of this fraction. The different values allow us to classify the substances according to their importance for the humification processes. The fraction of α-humus, the fulvic acids and the hydrolysable humin contain together from 70 up to 75% of the radioactivity of the organic fractions. Therefore the three fractions have been investigated furthermore.

The fraction of α-humus had been hydrolized with three normal hydrochloric acids under nitrogen atmosphere. After hydrolysis the water had been evaporated. The hydrolysate had been divided into three fractions.

1) Soluble fraction (hS) which contains 50% of the total fraction of α-humus and has a yellow color.

2) Fraction flocculating in neutral solution (hA) which contains approximately 50% of the carbon of the α-humus and has a dark brown color.

3) Fraction of the residue (hR) which contains nearly 35% of the carbon of α-humus and has a dark brown color. This fraction is insoluble in acids.

S 19 75

Distribution of the carbon and of the radioactivity in the hydrolysates of α-humus obtained after decomposition of radioactive glucose

J	α-Humus		Fraction hs		Fraction ha		Fraction hr	
	Mg C+	Act. Total 10^3 C/min.	% C+	% Act++	% C	% Act	% C	% Act
7	28.8	108.7	50.5	87.3	13.7	3.7	36.8	9.0
15	30.6	119.3	48.9	76.9	17.7	6.1	33.4	1.0
30	28.5	70.2	52.9	84.7	13.1	2.2	34.0	13.1
45	28.8	72.0	48.1	76.2	13.9	5.4	38.0	18.4
60	29.8	66.9	48.0	76.4	13.9	6.3	38.0	17.3

* The amount of carbon expressed in Mg; the percentage of carbon is expressed in proportion to the total radioactivity of the α-humus.

**The radioactivity is expressed in thousands of counts per minute (C/min), the percentage of radioactivity is expressed in proportion to the total radioactivity of the α-humic fraction.

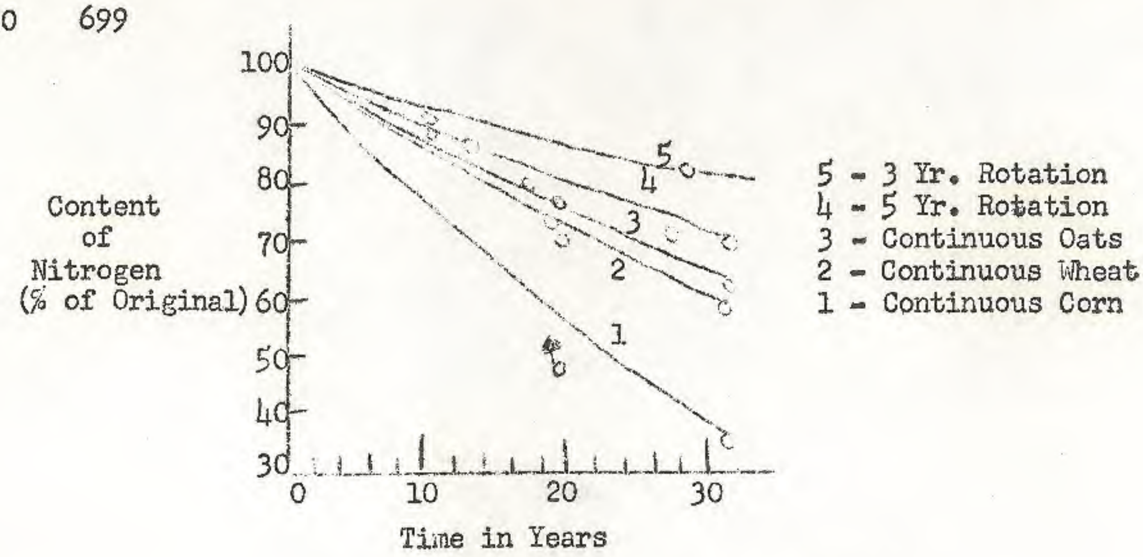
The most part of the radioactivity (72.9 up to 87.3%) is in the soluble fraction hS.

90% of the radioactive substances of the first fraction can be fixed on Dowex 50 and can be dissolved out with 1.5 N ammonium hydroxide. The experience of Bremner with amino acids out of hydrolysates of humus leads us to believe that this fraction consists of radioactive amino acids. This would be one of the proofs that amino acids take part in the formation of humic acids. (Bremner, J. M. Nitrogen distribution and amino-acid composition of fraction of a humic acid from a chernozem soil. Z. Pflanzenernähr. Düng. Bodenk. 71, 63 (1955).

Till now we have only considered the decomposition of plant residues in the soil without thinking about the cycle of the organic substances including the plants. The plant substance consists of inorganic and organic components. Under natural conditions the produced plant substances return to the soil where they are decomposed. With time, balance is accomplished.

In those cases where man cultivates the land, one part of the plant substance disappears. Therefore in the cycle of organic and inorganic substances there are changes. Many authors (Swanson and Latshaw (1919); Lohnes, Yates (1924); Gainey, Sewell, Latshaw (1929); Lyttleton (1929); Burgess (1929); Russel (1929); Salter and Green (1933); etc.) had been occupied with the investigation of the laws on the influence of the cultivation upon synthesis and decomposition of organic matter. I would like to mention one paper of the numerous work which has been done especially in this country, a paper of Jenny in which he summarizes results of Salter and Green.

S 20 699



Decline of Soil Nitrogen as Influenced by Cropping Systems

Amount of organic nitrogen in differently cultivated land.

These results show that with time organic combined nitrogen decreases in a different way with the kind of cultivation. These investigations are interesting in connection with humus research, but they belong more to humus husbandry than to biochemistry. Therefore I do not want to go into details about this kind of research.

I would like only to give some data which concern the inorganic part of organic substances.

S 21 52

Nutrient balance of soil

Kg/ha

Nutrient	N	P_2O_5	K_2O	CaO
Leached from soil by one years rainfall	76	12	102	470
One harvest of sugarbeets	150	60	175	120
Lost per year Kg/ha	226	72	277	590
Amount of nutrients in a depth of 25 cm.	slight	3,000	6,000	10,000
Enough for years	much	42	22	17

Scharrer calculated for Germany the following nutrient balance. Yearly rainfall leaches in kg per hektar the following amounts of nitrogen, P_2O_5, K_2O and CaO. The crop of sugarbeets withdraws from the soil the following amount: In the surface soil the amount of nutrients is enough for different numbers of years. For our consideration is interesting that the amount of nitrogen which is available for the plants without decomposition of organic matter, is relatively low.

In another example, there will be shown the amount of nutrients by the harvested plants and the amount which remains in the soil by rotting of roots.

S 22 680

Amounts of Nitrogen and Phosphorus which are Withdrawn by the Harvest and Remaining Roots

Cultivated Plants	Yield dz/ha	Removed by yield N %	Removed by yield N kg/ha	Removed by yield P_2O_5 %	Removed by yield P_2O_5 kg/ha	Root Residue dz/ha	Amount in roots N %	Amount in roots N kg/ha	Amount in roots P_2O_5 %	Amount in roots P_2O_5 kg/ha
Crops										
Grain	16-20	2.5	40-50	0.6-0.8	10-16	20	0.7-1.0	14-20	0.6-0.8	12-16
Straw	25-30	0.7	15-24	0.5	12-15	-	-	-	-	-
Total	-	-	55-74	-	22-31	-	-	-	-	-
Cotton 1 Rough Harvest 16-20 dz/ha withdrawn			80-100		16-20	20-30	0.5	10-15	-	-
Amounts of Phosphorus and Nitrogen in the Quantity of Harvest and in the Residues of Roots of Leguminous Plants										
Clover after 2 yrs. use	100	2-2.5	200-250	0.5	50	50	2.0-2.5	100-125	0.4-0.9	20-45
Alfalfa after 3 yrs. use	370	-	960	-	200	100-120	2.0-2.5	200-300	-	40-100
Alfalfa after 3 yrs. use	520-660	-	1300-1600	-	260-330	200	2.0-2.5	400-500	-	80-180

The plants are divided into two kinds; those which are not able to fix nitrogen out of the air and leguminous plants. Contrary to the first kind, the leguminous plants may enrich the nitrogen in the soil.

In connection with the considerations about the decomposition of plant substances and the formation of humic substances remarkable differences may exist. We will also exclude this direction of research.

The decrease of organic matter in soil can be inhibited by the incorporation of organic materials. We will not discuss this point in detail. One of the most usual methods is the fertilizing with barnyard manure. In former times, this had been the only method of fertilization. In this connection, I only want to state the composition of the nutrient contents of manure.

S 23 64

Nutrient Content of Stable Manure
Calculated on Dry Weight

Nutrient	Sample from German Federal Republic	from lime rich soil	from lime deficient soil	from new reclaimed ocean soil	from old reclaimed ocean soil
Number of samples	106	56	50	3	10
% Nitrogen	1.90	1.99	1.81	2.23	1.51
% Phosphoric acid	1.24	1.30	1.18	1.91	0.99
% Potassium	2.61	2.73	2.49	2.35	2.39
% Calcium	2.45	2.87	2.09	3.32	1.37
% Magnesium in mg.	0.79	0.89	0.69	0.84	0.48
Boron	1.76	1.89	1.63	1.79	1.12
Cobalt	0.099	0.103	0.095	0.106	0.055
Copper	0.95	1.07	0.83	0.84	0.77
Manganese	21.36	19.24	23.48	20.29	27.69
Zinc	8.07	7.71	8.43	6.92	8.97

In this connection I want to point out that the composition of manure varies with the composition of the soils from which the feed stuff for the animals had been harvested. Especially the contents of calcium, magnesium and phosphoric acids can be different. The same happens also in the content of trace elements.

S 24 63

Nutrient Substances and Restoring of Nutrient
Substances on Account of Stable Manure

Nutrient	Cultivated and Grassland	Average from German Federal Republic	From High Value Soils	From Old Soils from Reclaimed Sea
Nitrogen	110 kg/ha	38 kg/ha	40 kg/ha	30 kg/ha
Phosphorus	45 "	25 "	26 "	20 "
Potassium	160 "	52 "	54 "	48 "
Calcium	50 "	50 "	57 "	27 "
Magnesium	40 "	16 "	18 "	10 "
Boron	100 g/ha	34 g/ha	37 g/ha	23 g/ha
Cobalt	4 "	2 "	3 "	1 "
Sulfur	40 "	20 "	20 "	15 "
Manganese	500 "	420 "	380 "	550 "
Zinc	100 "	160 "	150 "	180 "

Nutrient uptake by plants and amount of nutrients which come back into the soil by manure. (NIESCHLAG: Stallmistuntersuchung - Bodenfruchtbarkeit und Tiergesundheit, Landwirtsschaftsblatt Weser-Ems 103, 551 (1956)). From this table it can be seen the amount of nutrient given by manure is not sufficient to supply the soil with the necessary amount of inorganic nutrient. This occurs particularly in the case of nitrogen. The fact is interesting for us since we have to consider nitrogen not only as a plant nutrient but also as a factor for the transformation of organic substances in the soil.

In the next section we will therefore consider the combination of different factors: Amount of nitrogen; climatic conditions; barnyard manure; inorganic fertilizers; soil properties, such as heavy and light soil, i.e., soils with high and low exchange capacity and the pH value of the soils. 128 field experiments during 6 years with also mentioned variations will be discussed. The locations were scattered all over the Western German Federal Republic in different climatic zones and on different soils.
(See following tables)
If we compare the yield of sugarbeets in dz/ha without nitrogen fertilizer and without manure (I) with the lower amount of manure (II), a significant increase of 20.5 dz/ha is found. Higher amounts of manure do not increase the yield without nitrogen fertilizer. The higher the amount of nitrogen fertilizer, the larger is the effect of manure. The scattering error between preceding truck crops, for instance potatoes (IV) and cereals without manure (V) is too high. The large difference is not significant.

Considering the correlation of mineral nitrogen and manure, it can be concluded: Manure together with increased amounts of nitrogen do not only increase the yields, but also the effective value of nitrogen. The difference of yield between without manure and with manure can partly be explained by the amount of nitrogen, which is given with the manure. The potatoes as preceding crops have also a favorable effect on the yield. The effective value of nitrogen is smaller without manure.

Without manure, there has been an increase in yield of 18% and with manure 29% (table with relative values). These relationships can be observed better if one determines the yielding power per Kg N.

	Yielding power per Kg N			
kg N/ha	I	II	III	IV
80	49.8 kg	58.2 kg	71.7 kg	70.6 kg
120	47.1 "	56.6 "	67.6 "	63.6 "
160	38.8 "	52.8 "	63.8 "	55.9 "

The relative data show that the yield power of nitrogen is much higher with manure than without. The decrease is, without manure - 22% and with manure - 11%. Manure must therefore have an effect on the growth of plants, which cannot be explained by the effect of nitrogen as a nutrient.

With the amount of nitrogen, the sugar content of the sugarbeets decreases. Often it happens that lower yields of sugarbeets increase the yield of sugar. The column I with II to IV can be compared. The manure inhibited in all cases the decreasing of the percentage content of sugar. This result can also be explained as a typical effect of organic matter.

Locations of Experiments on Sugar Beets - 1949-1954 page 253

Average Beet Yields in dz/ha Together with the Years

N-treat. kg/ha	1949 n=4	rel.	1950 n=21	rel.	1951 n=34	rel.	1952 n=18	rel.	1953 n=22	rel.	1954 n=22	rel.	Total n=128	rel.
0	265.3	100	399.2	100	330.2	100	332.9	100	385.5	100	358.2	100	351.1	100
80	293.1	110	450.1	113	378.6	115	381.7	115	410.7	114	419.3	117	402.7	115
120	314.1	118	458.8	115	395.6	120	404.3	121	438.4	122	449.5	125	424.2	121
160	331.0	125	481.1	121	409.5	124	413.9	124	453.9	127	469.5	131	440.7	126
M	300.9	114	447.3	115	378.5	115	383.0	115	415.4	116	424.1	118	404.7	115

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Average Sugar Content in Percent Together with the Years.

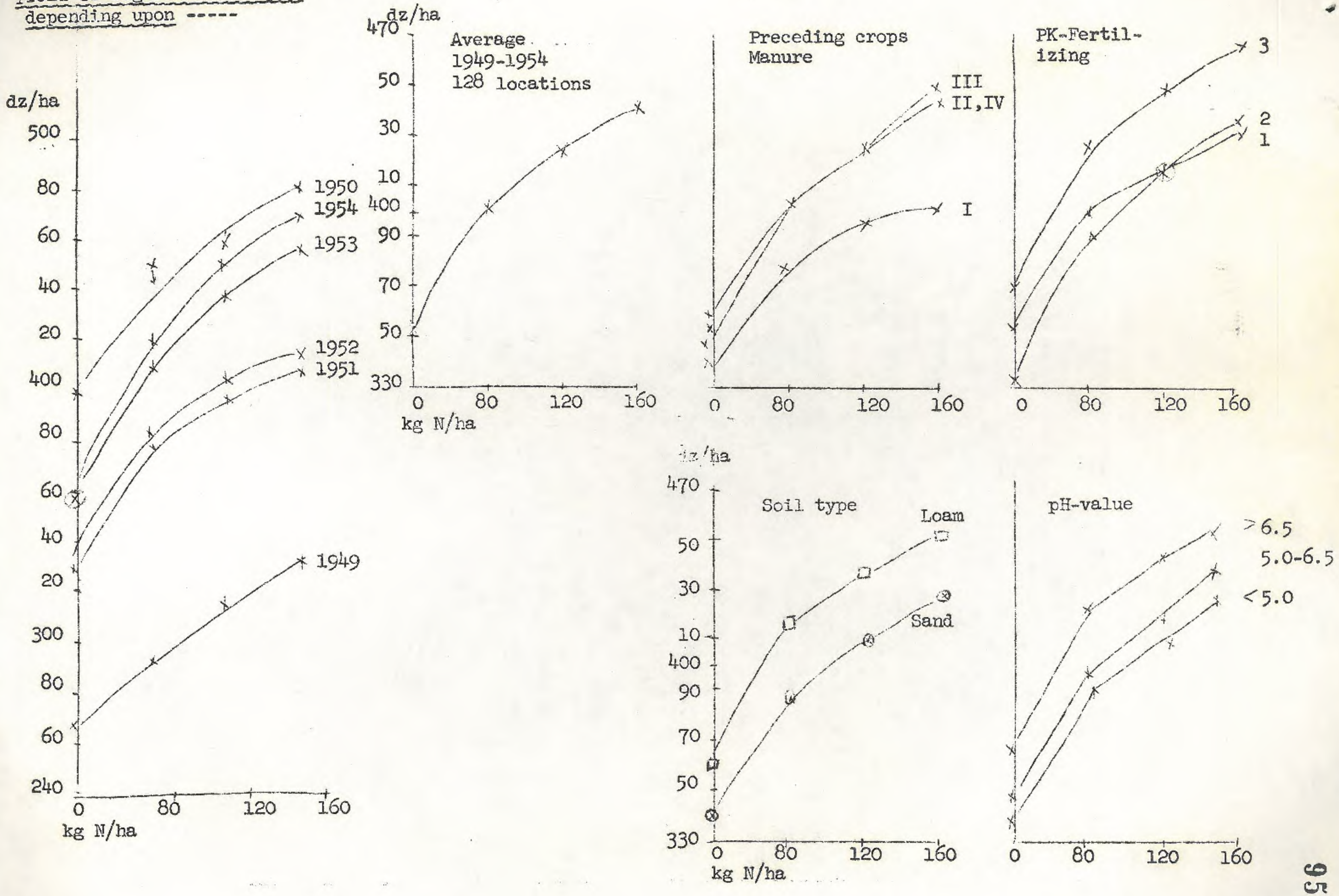
N-treatment: kg/ha	1950 n=11	1952 n= 6	1953 n=17	1954 n=16	Total n= 69
0	16.8	18.0	19.8	18.7	18.5
80	16.8	17.9	19.3	18.7	18.3
120	16.1	17.7	19.3	18.5	18.0
160	15.7	17.4	18.7	18.7	17.8
M	16.4	17.8	19.3	18.7	18.2

page 259

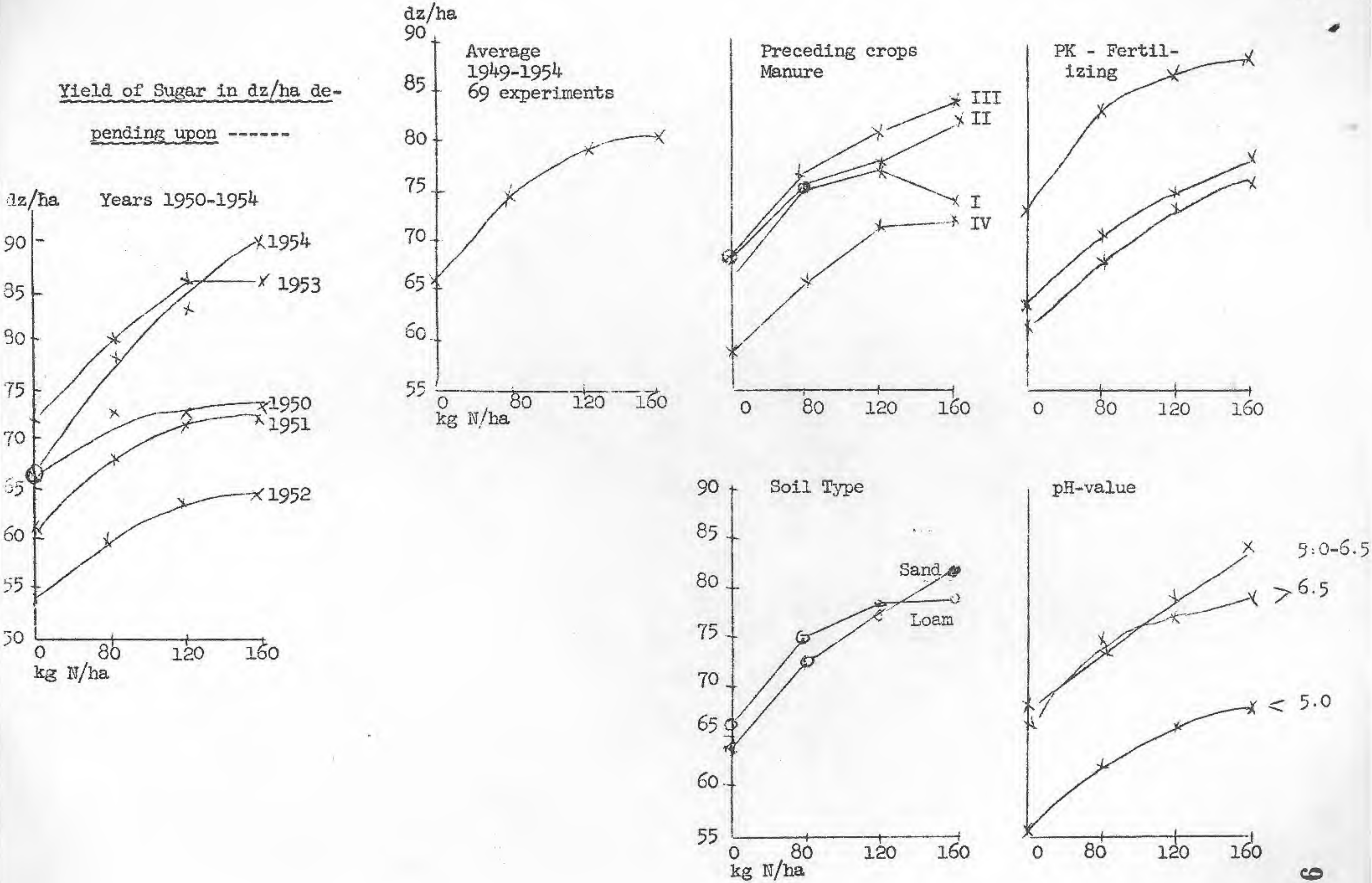
Average Sugar Yield in dz/ha Together with the Years.

N-treatment: kg/ha	1950 n=11	rel.	1951 n=18	rel.	1952 n=6	rel.	1953 n=17	rel.	1954 n=16	rel.	Total n=69	rel.
0	66.3	100	61.0	100	54.2	100	71.2	100	66.0	100	65.2	100
80	72.8	110	68.0	111	59.9	110	79.9	112	78.4	119	74.1	114
120	72.6	110	71.0	116	63.6	117	85.8	121	83.3	126	77.9	120
160	73.2	111	72.3	118	64.5	119	86.0	121	90.0	136	80.0	123
M	71.5		68.3		60.8		80.9		79.7		74.6	

Yield of sugarbeet in dz/ha depending upon -----



Yield of Sugar in dz/ha depending upon ------



Influence of Manure

	Sugar Beets in dz/ha				Yielding power per kg of N				Sugar							
									In % of beet				In dz/ha			
N/ha	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
0	100	100	100	100					18.1	18.7	18.9	17.9	100	100	100	100
80	112	113	116	116	100	100	100	100	18.0	18.5	18.6	17.6	110	114	113	113
120	117	119	123	122	95	96	95	90	17.6	18.2	18.3	17.6	113	117	119	122
160	118	125	129	125	78	89	89	79	17.7	18.0	18.1	17.3	109	123	124	123

Influence of Amount of PK Fertilizer

kg N/ha	Sugar beet in dz			Yielding power per kg N			Sugar					
							In % of beet			In dz/ha		
	I	II	III	I	II	III	I	II	III	I	II	III
0	100	100	100				18.7	18.1	19.0	100	100	100
80	117	113	116	100	100	100	18.2	17.8	18.9	111	111	115
120	125	119	121	97	93	90	18.0	17.6	18.6	120	116	120
160	137	123	126	88	88	82	18.0	17.3	18.2	124	120	123

kg N/ha	Average Yield of			Influence of Soil Type					
		Sugar		Sugarbeet in dz/ha		Sugar			
						In % of beet		In dz/ha	
	Sugar-beet	% of beet	dz/ha	Sand	Loam	Sand	Loam	Sand	Loam
0	100	18.5	100	100	100	19.2	18.1	100	100
80	115	18.3	114	114	115	19.0	17.9	112	113
120	121	18.0	120	120	121	18.7	17.6	119	117
160	126	17.8	123	136	125	18.7	17.3	126	120

Influence of pH Value

kg N/ha	Sugarbeets in dz/ha			Sugar					
				In % of beet			In dz/ha		
	5.0	5.0-6.5	6.5	5.0	5.0-6.5	6.5	5.0	5.0-6.5	6.5
0	100	100	100	18.9	19.0	17.8	100	100	100
80	116	114	115	18.9	18.8	17.4	106	109	113
120	122	121	121	18.5	18.5	17.2	110	114	118
160	127	126	124	17.9	18.4	17.0	116	124	119

Interesting for the farmers is the yield of sugar in dz/ha (curves). Without manure, there is a decrease of yield of sugar with 160 kg N/ha. The yield of sugar with preceding truck crop is much lower than those two with manure, although the relative increase of yield with the increasing amounts of nitrogen are the same (relative values).

At the end of this consideration, it can be presumed another relationship exists. The effect of manure has been that the sugar content is relatively higher than without manure. Therefore, the organic matter has also an effect. This fact may be interesting for us in a later discussion.

As a second factor, the influence of potassium and phosphorus fertilizers has been investigated. Higher amounts of these two fertilizers also increase the absolute and relative yields of sugar beets. The difference between the lowest amount of potassium and phosphorus fertilizers and the middle amount are an average of 11 dz/ha and between the middle and the highest, 26 dz/ha. The most favorable combination is a ratio of nutrients of N:P:K is 1: >0.7: > 1.1.

The yielding power per kilogram nitrogen is of the same magnitude as those of the experiments with manure.

The highest amount of potassium and phosphorus fertilizers also affect the highest yield of sugar.

As a third factor, the increase in yield with nitrogen fertilizer on two soil types, sand and loam have been investigated. The yield of sugarbeets is higher on loam than on sand. The increase affected by the amount of nitrogen fertilizer is in both cases the same.

The sugar content in % is higher in the sugar beets which are grown on sand soil than on loam soil. On the sand, the sugar content decreases at the beginning with the amount of added nitrogen. It doesn't change any from 120 to 160 kg N/ha. On loam the percentage content decreases about 0.3% per 40 kg N unit. The sugar content decreases in total in sand only 0.5%; in loam in total 0.8%.

The yield of sugar in dz/ha increases with the amount of nitrogen. At the end it increases more in sand than in loam. It may be that this effect can be connected with the decomposition of organic matter in soils. Later on we will hear in which manner organic matter influences the sugar production of plants.

In Germany, there has been in the last few years, the question if it is possible to cultivate sugarbeets on acid soils. Therefore, it has been interesting to investigate the influence of pH value on the yield of sugar beets. The yield on the different soils with a pH lower than 5.0 is not as high as on the soils with higher pH values. The tables show that the pH value has an influence on the sugar yield.

Summarizing, it can be said that the different factors - fertilizing with nitrogen, the climate conditions, the soil type, the pH value, the preceeding crops and fertilizing with barnyard manure, the P-K fertilizing - have a different effect on the growth of sugarbeets. There can be given a range of different factors for growth.

The Range of Factors for Growth at Nitrogen-Amount 0

Range No.	Growth factor	Difference dz/ha sugarbeets	Average yield in %	t-value
1	160 kg N/ha	89.6	26	4.2 (significant)
2	120 kg N/ha	73.1	21	3.5 "
3	Favorable climatic conditions	69.0	21	3.2 "
4	80 kg N/ha	51.6	15	2.4 "
5	High P-K fertilizing	37.4	11	1.8 (not signif.)
6	pH value > 6.5	25.5	8	1.3 "
7	Soil type, loam	21.0	6	1.0 "
8	Barnyard manure, without N fertilizing	20.5	6	0.9 "

Range of Factors for Growth at Nitrogen Amount of 160 kg/N/ha

Range No.	Growth factor	Difference dz/ha sugarbeets	Average yield in %	t-value
1	Favorable climatic conditions	71.6	17	3.4 (significant)
2	Barnyard manure with N fertilizing	48.3	12	2.3 "
3	High P-K Fertilizing	30.0	7	1.4 (not signif.)
4	Soil type, loam	25.2	6	1.2 "
5	pH value > 6.5	24.2	6	1.1 "

The last data has given a survey of the different factors which influence plant growth. In the next diagram there shall be shown how factors in the soil have an influence on increasing yield. In this experiment, it has been attempted to maintain the factors such as climate, fertilizing and management as constants.

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Productivity of Various Kinds of Soils in dz/ha

	Rye	Wheat	Potatoes	Sugarbeets
Sand	10.0	-	107	-
Humus sand	12.0	-	125	-
Sand with low loam	13.7	-	140	-
Humus sand - low loam	16.0	18.0	155	-
Light loamy sand	17.3	19.0	160	-
Loamy sand	18.8	21.6	165	290
Heavy loamy sand	20.0	22.2	170	300
Heavy sandy loam	22.0	25.6	175	310
Fine sandy loam	24.0	29.0	180	315
Medium loam	26.4	31.2	185	320
Humus medium loam	28.0	32.5	190	350
Medium slightly heavy loam	25.0	30.2	185	300
Slightly heavy loam	22.0	26.7	170	290
Heavy loam	19.0	22.8	150	280
Very heavy loam	18.7	21.5	140	-
Strong loam	17.8	20.0	135	-
Strong clay loam	16.2	16.8	125	-
Clay	14.0	14.6	105	-

All these experiments have been made under nearly the same climatic conditions. The different crops had in each case the same amount of fertilizer. Obviously, some chemical and physical factors must have influenced the height of yield. Every kind of crop had the highest yield on loam with humus, on a soil type comparable with chernozem.

The physical problems belonging to this effect of growth will only be spoken of in so far as they are interesting in connection with the chemicals. The chemical properties of the organic part of the soil seems to have specific characteristics.