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In this manuscript are some unpublished results and therefore only for friends and not to use for publication.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

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W. Flaig

SOIL ORGANIC MATTER

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Am Pgrafov 11.3.59

THE INFLUENCE OF SOIL ORGANIC MATTER ON PLANT GROWTH

From the viewpoint of chemistry the substances in soil can be divided on the one hand in inorganic and on the other in organic. Both groups consist in each case of compounds of different chemical constitution and variable molecular weights. The same compound can be low as well as high molecular.

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The most important parts of the inorganic component are the hydrates of sesquioxides, the clay minerals, the hydrated silica, the salts and ions. For the problem about which we are talking now, the inorganic components are the incidental interest, except for some physical considerations.

The organic component can be divided in low and high molecular substances, the latter in spherical and in linear colloids.

Salts are necessary for the inorganic nutrition of the plants. They can also be involved for the flocculation of colloids as well as for the solubility of inorganic or organic compounds.

Both kinds of components, the inorganic and the organic can have a physical or chemical effect for plant growth.

The high molecular substances of organic matter in soil have mainly a physical effect on plant growth. This depends again upon size and shape of the particles. They are for the most part responsible for the diameter and the stability of the soil crumbs.

To the organic soil colloids belong proteins, the group of humic acids, polysaccharides and polyuroides. They can be spherical or linear colloids. The behavior of these two kinds of colloids is very different.

As an example for spherical colloids I will show you a fraction of humic acids from chernozem, investigated with the electron microscope.

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The diameter is between 80 and 100 Å (1). The molecular weight is in the most cases between 30000 and 50000 (2). Other physical measurements support the contention that the connections between the particles are hydrogen bonds (3). In acid solution the particles aggregate, in alkaline the aggregates can be dispersed in single particles.

Several properties of the linear colloids are considerably different from those of spherical colloids. In small amounts the linear colloids elevate the viscosity of aqueous solutions. The heteropolar linear colloids show a very different behavior from the heteropolar spherical colloids like humic acids. According to the degree of dissociation there takes place a coiling or stretching of the filiform molecule.

S. 3 Krilium 6/431

After drying during the preparation for electron microscope, the filiform linear colloids aggregate to a branched form (4). In connection with other investigations one makes the observation that linear colloids have a stronger effect for forming soil crumbs than spherical colloids (5). Therefore, one tries to use synthetic linear colloids as soil conditioners such as Krilium (6).

We made some different model experiments for interaction between inorganic soil colloids such as kaolinite and organic colloids such as humic acids and Krilium (1)(4)(7). Both are negative charged heteropolar colloids, and they differ only in their shape.

S. 4 6/407

Until now it has not been possible, for instance, to find an interaction between humic acids and kaolinite both saturated with hydrogenions. The electron microscope picture shows that neither on the edges nor on the surface of the particles can be detected a sorption of the humic acids.

With kaolinite saturated with calcium ions a certain effect can be observed. This can be explained, that the humic acids are finely divided and precipitated on the surface by ion exchange. In the soils the surfaces ofclay minerals are in most cases surrounded with layers of aluminim - or ferric hydroxide. These are formed by weathering. In these cases sorption of humic acids takes place. The action of the linear colloids are completely different.

S. 5 6/849

The results observed with the electron microscope shows an essential difference between the behavior of linear colloids such as Krilium and of spherical colloids such as humic acids. The aggregation of the linear colloids after drying is like a network. The linear colloids surround the clay particles and reach from one to the other.

Of course, these model experiments deviate from the conditions in nature but they give an idea of the behavior of linear colloids in soils.

This problem is a complex one. Comparative investigations with linear colloids isolated from soils or cultures of micro-organisms and those of Krilium had, according to a paper of Rennie, Truogg and Allen (8) the following results.

S. 6 (see top of page 3) 6/410

The diagram shows that substances of this kind are of different efficiency. It depends upon the concentration and the chemical constitution of the substances.

The physical conditions for plant growth are closely connected with a certain size - range of crumbs - in the soils. They influence the supply of plant nutrients, water and air, and are one of the most important factors for soil productivity.

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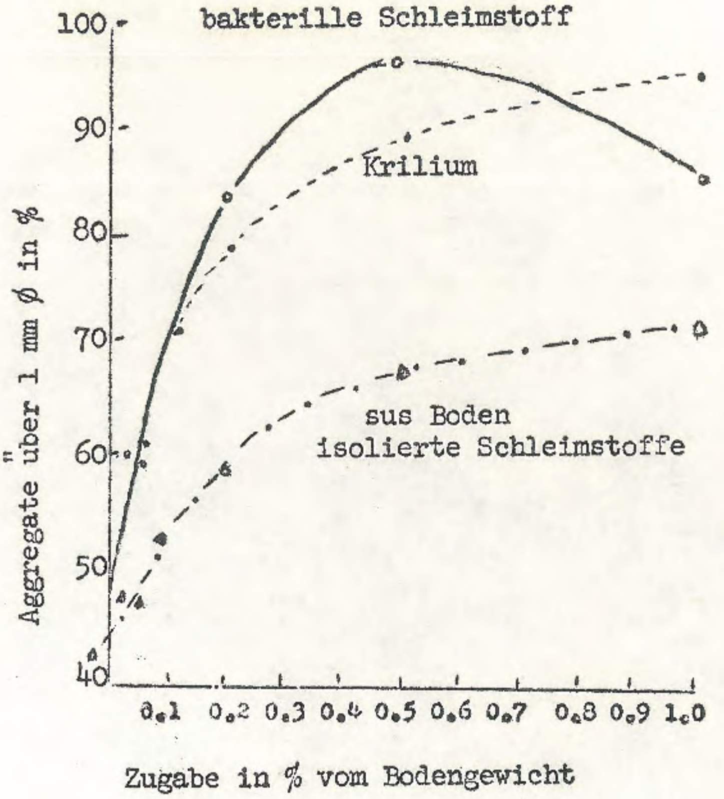
Slide 6



Slide 7

Einfluss der Krümelgrösse auf den Ertrag
nach J. HAGIN

Fraktion	Grösse der Krümel	Trockengewicht d. Pflanze
C	>90% d. Krümel >1,0 mm ∅	20,1 g ± 0,7
M	>60% d. Krümel >0,5 mm ∅	16,5 g ± 0,9
F	>80% d. Krümel <0,5 mm ∅	5,8 g ± 0,7

The next diagram (9) shows the influence of size of crumbs on the yield. Where more than 90% of the crumbs are larger in diameter than 1 mm.20 g dryweight of plants can be harvested. If more than 60% have a diameter larger than 0.5 mm.the dryweight decreases to 16.5 g. If more than 80% are smaller than 0.5 mm. the yield is only 5.8 g.

One of the influences of soil organic matter on plant growth is the effect on the physical properties of the soil. In this case larger amounts of organic matter are necessary, approximately one or one-tenth percent of the weight of the soil.

But there are other effects on plant growth which need a smaller percent. These are the chemical or physiological effects on the metabolism of the plants. It seems to me that these effects are more complicated than the physical. Especially it must be emphasized that the effects of organic substances on plant growth are in the most cases negative, if insufficient amounts of inorganic nutrients are present.

The farmers have the experience especially with soils which are cultivated for a long time, that the best yields can be produced by inorganic and organic fertilizing. In the agricultural literature the pure effect of humus is often spoken of (10). Thereunder is grouped all those effects which neither depend upon the influence of nutrients, nor can be explained by effects on physical properties of the soil. This "pure effect of humus" can only be interpreted by an influence of substances from humus on the metabolism of plants. I give you several examples for this opinion.

G. Barbier and P. Boischot (11) had obtained the following yields during six years.

Influence of Straw on Yield

	Mineral Fertilizer	Without Fertilizer	Straw and Fertilizer
1947/48	100	75	90
1952-53	100	67	108
Ave. of 6 years ..	100	70	101

The first years the supply of straw depressed the yield by nitrogen immobiliaation. With further decomposition of the straw, the nitrogen immobilized by the microorganisms in organic form is mineralized and the yield increases. These effects are not always the same, because they depend upon the climatic conditions.

So H. Kick (12) had not the same success with straw during 8 periods of cropping and got an average of 95.9% in comparison with mineral fertilizers. He used equal amounts of nutrient, but nitrogen in inorganic fertilizers has a different availability than in straw.

A good example for the influence of climate, location and time, when straw was added to the soil is given by P. Boischot and G. Barbier (13). (See top page 5)

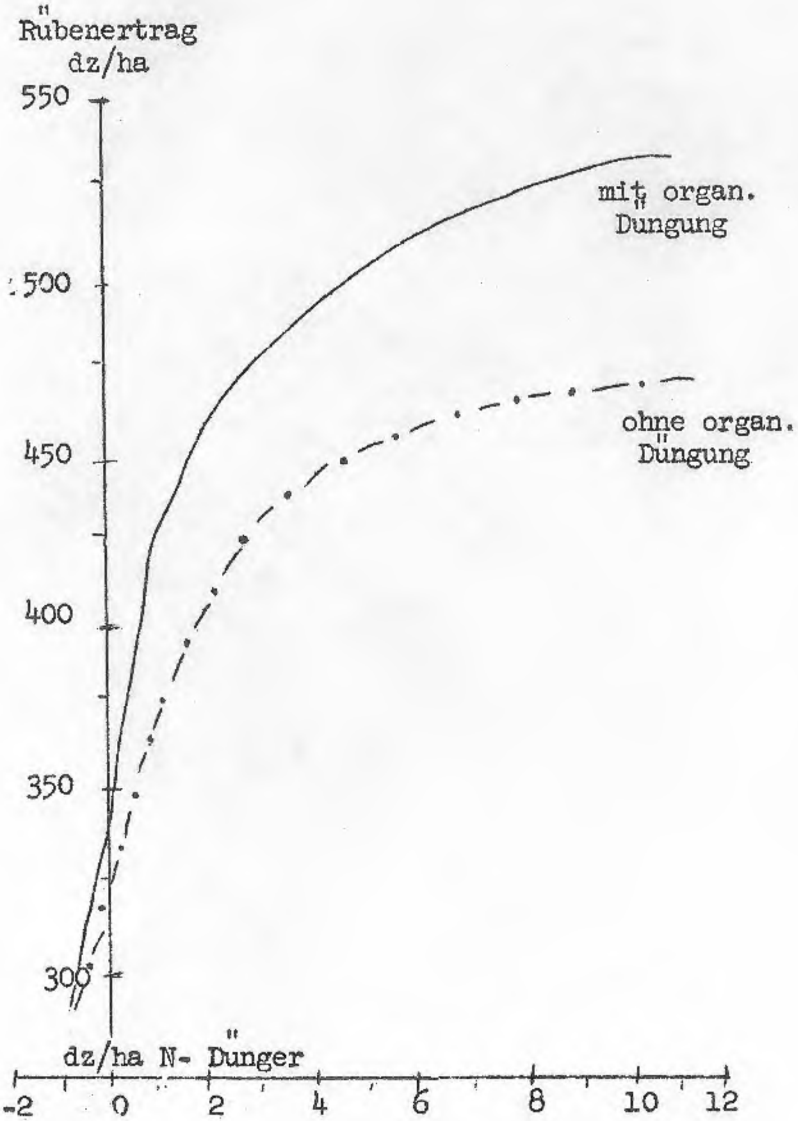
The straw was added in the springtime. The moisture remained longer in the soil. The deficiency of water in final steps of the development of the sugarbeets on the plots without straw caused the different amounts of nitrogen to have no effect, while those with straw resulted in an increased yield.

Kg N per ha	Without Straw Beet*	Leaf*	Kg N per ha	With Straw Beet*	Leaf*
0	262 ± 6	135 ± 4	0	272 ± 11	182 ± 11
20	265 ± 6	154 ± 15	-		
80	289 ± 4	151 ± 5	-		
120	285 ± 9	165 ± 6	120	322 ± 12	194 ± 9
160	277 ± 10	168 ± 4	170	352 ± 15	203 ± 6

*Total wgt. in kg/ha.

Another example of the influence of organic matter is given by P. W. Kürten and M. Wermke (14).

S. 8 7/484



On the basis of 128 field experiments in different parts of the country with all variations of fertilizing, with and without manure, they conclude from their results following the formula of Mitscherlich, that larger quantities of nitrogen together with organic fertilization result in a higher yield of sugar beets.

The order of growth factors between 0 kg N/ha and 160 kg N/ha.

Growth Factors	Difference dz/ha sugarbeets	Increased yield in percent	t-value
1. Favorable weather	71.6	17	3.4 (Highly signif.)
2. Additional fertilizing with manure	48.3	12	2.3 (" ")
3. High PK-fertilization	30.0	7	1.4 (Not signif.)
4. Type of soil	25.2	6	1.2 (" ")
5. ph value of the soil (> 6.5)	24.2	6	1.7 (" ")

In a diagram they give the rank of the different growth factors. Herewith it is interesting to mention that the decrease of sugar content and therefore the yield of sugar per hectare is smaller with the increase of the quantities of nitrogen fertilizers in the presence of manure. Later on we will get an idea about this fact.

Another factor for plant growth is the increase in the content of available potassium for the plants in the soil by organic fertilizing. W. Sauerland and O. Graff (15) have given 25 dz/ha straw during 4 years (1951-1954) and indicated that the available potash for the plants (lactate soluble) had been increased 3.5 mg. per 100 g. soil. This is a larger quantity than was added to the soil with the straw. This was only 30-40 kg/ha. By organic fertilizing the micro-organisms become active and a part of the potassium in the soil is transformed by their metabolism into an available form for the plants. The production of acids by the micro-organisms may play a role. In some cases one can have some question whether the effect is more chemical or physical.

But the next example tends more to a chemical effect on plant growth. R. Chaminade (16) found that in sand cultures only rotted straw has an effect on the uptake of potassium by the plants. This increased also the percentage of potassium on the plants. We made similar observations.

If one will exclude the physical effects of organic matter on plant growth, it is necessary to work in water culture or with such small amounts of organic substances that they can no longer have an effect on the physical properties. For instance Kononowa and Pankowa (17) made experiments with purified humic acid on the growth of roots in water cultures.

S. 9 (see top of page 7) K/686

Generally they used concentrations of humic acids of 0.0005% or 5.10^{-6} gr/ml. This concentration is tenfold higher than the one where β-indole-acetic acid has its

S. 9

Einfluss der Huminsäuren auf das Wachstum des Maises (PANKOWA)

Versuchsanordnung	Zahl der Wurzein von je 2 Pflanzen pro Versuch		Wurzellänge in cm von je 2 Pflanzen pro Versuch	
	Nach 14 Tagen	Nach 24 Tagen	Nach 14 Tagen	Nach 24 Tagen
Kontrolle (dest.Wasser)	29	21	72	90
Huminsäuren aus podsoligem Boden	25	43	178	250
Huminsäuren aus Schwarzerde.......	26	37	168	188
Na-Humat aus Schwarzerde	34	40	262	300

Einfluss der Humusstoffe auf das Wachstum des Weizens (PANKOWA)

Versuchsbedingungen	Wurzelzahl bel 2 Pflanzen		Wurzellänge in cm bel 2 Pflanzen	
	Nach 14 Tagen	Nach 24 Tagen	Nach 14 Tagen	Nach 24 Tagen
Kontrolle (dest. Wasser)	25	25	22	22
Huminsäuren aus Schwarzerden ...	22	28	91	125
Na-Humat aus Schwarzerde	11	15	81	115

most active effect. The figure shows the effect of humic substances on the growth of the length of the roots of maize and wheat. In every case the length of roots is increased.

Many authors observed for a long time a stimulating effect also on the growth of micro-organisms (Remy, 1911; Krzimieniewski, 1908; Prazmoroski, 1912; Söhngen, 1913; Twasaki, 1930; K. S. 148). In old recipes for the preparation of nutrient solutions for the culture of micro-organisms, it is noticed that humic acids or their salts must be added for a better growth.

S. 10 6/687

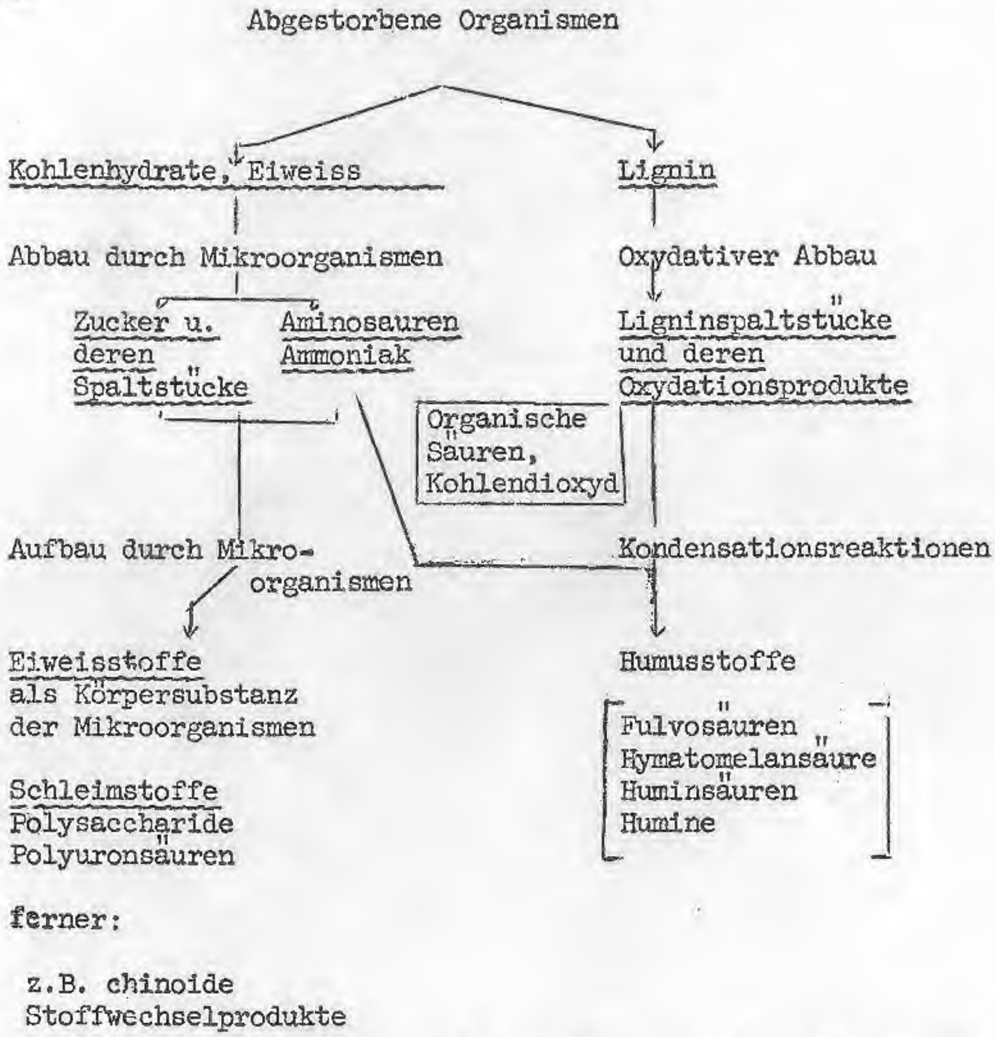
In other experiments Pankowa could show that leaves of Fiscus elastica, gum tree developed many more roots in solutions of the sodium salt of humic acids than in water. Experiments just like these have been made by different other authors. Now it is the question, have these substances an effect outside the cell wall or are they taken up?

S. Prait and F. Pospusil (18) prepared humic substances labeled with ^{14}C and could prove that they are taken up by the plants more or less. Otherwise Winter (19) could also show the uptake with a so-called model substance; i.e., a substance with similar chemical behavior of compounds of the humus, like salicylic acid.

to reflect

In the following we will consider/what kind of substances can have an effect on plant growth during the reaction of the transformation of organic matter in soil.

S. 11 A/12



The scheme demonstrates only the most important reactions of decay and changes of organic compounds in the soil (20). The residues of organisms consist chiefly of proteins, carbohydrates and some special compounds. Most of the residues of the organisms in the soil come from plants. The special substances of plants are lignin, other phenolic compounds, pectins and waxes. The rates of decay of the different substances differ. Proteins and carbohydrates decompose relatively quickly.

They are used by the micro-organisms for their own metabolism. Micro-organisms do not only decompose but also form new proteins for the composition of their own body, furthermore slimy substances, polysaccharides, polyuronides and some special products of their metabolism as, e.g., compounds of quinonic structure.

On the other hand lignin is more resistant towards the degradation by the micro-organisms. With the increasing decay of the cellulose by the micro-organisms the lignin is oxidized. Therefore, fragments of lignin and its oxidation products are formed. Sugars and their fragments are formed by the decomposition of carbohydrates, as well as amino acids and ammonia from proteins. By condensation of these substances together with lignin fragments and its oxidation products the humic substances are synthesized.

The humic substances are usually divided into four groups, according to their solubility -

Fulvic acids
Hymatomelanic acids
Humic acids
Humins

Fulvic acids are soluble in alkaline and acid solutions, while humic acids can be precipitated by mineral acids out of alkaline solutions. Fulvic acids and humic acids are not definite pure chemical compounds.

These two groups of substances chiefly differ in their molecular weight. Fulvic acids are in general compounds of low molecular weight, humic acids of a higher one.

The properties of Hymatomelanic acids range between the two other groups. Humins are soluble in hot alkaline solutions and for this reason they are pointed out as a special group.

The humic acids have a certain similarity in their structure, because they are formed of different lignin fragments. According to our knowledge it is very probable that lignin is the most important component to form humic substances. Let us see what effect on plant growth substances with a relationship to lignin or the products, which are derived from lignin and form humic substances have.

Lignin comes in remarkable amounts into the soil by fertilizing with straw. A. G. Winter and F. Schönbeck (21) leached different kinds of straw with water. These extracts had in relatively high concentration a decreasing effect on the length of seedlings and on the germination percentage of different cereals.

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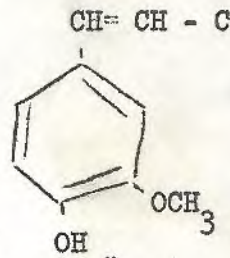
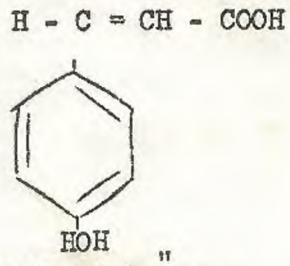
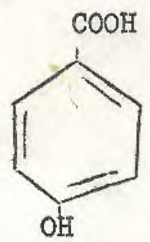


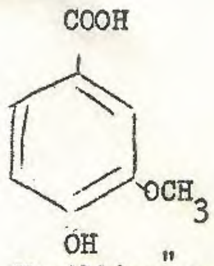
Ferulasäuer



p-Oxyzimtsäure



p-Oxybenzoesäure



Vanillinsäure

H. Börner (22) milled wheat straw, leached with water and identified ferulic-, p-hydroxycinnamic-, p-hydroxybenzoic and vanillinic-acid. These acids are fragments of lignin. We could split up Braun's lignin, so-called natural lignin, in a careful way and find also these substances.

S. 13   8/553

Einfluss von p-Oxyzimtsäure, Vanillinsäure und Ferulasäure auf das Trockengewicht von Roggenkeimpflazen in g

Konzentration in Mol	p-Oxyzimtsäure		Vanillinsäure		Ferulasäure	
	Spross	Wurzel	Spross	Wurzel	Spross	Wurzel
0	0,57	0,30	0,60	0,37	0,92	0,49
10^{-4}	0,66	0,31	0,74	0,58	0,88	0,49
10^{-5}	0,67	0,31	0,70	0,47	0,92	0,48
10^{-6}	0,54	0,30	0,70	0,44	0,93	0,48

These substances had been tested for the effect on the growth of seedlings of rye by us (23) in sand cultures in Neubauer dishes in the presence of nutrient solutions. The concentrations of these acids had been 10^{-4} up to 10^{-6} molar., p-Hydroxycinnamic and vanillinic acid increased the yield of dryweight. C. F. van Sumere and L. Massart (24) investigating the germination of spores of micro-organisms, also found no effect with ferulic acid. We made similar observations with pot experiments. The effect of organic matter on plant growth may occur without a remarkable transformation of the lignin molecule, but only depolymerization.

One of the steps from lignin fragments to humic substances must be an oxidation reaction. I will not talk about all the chemical experiments which gave us the idea that thymoquinone or thymohydroquinone is a model substance for humics compounds (25).

S. 14   8/550

With the same Neubauer technique the substances have an increasing effect on the dryweight of the seedlings of different kinds of cereals. But this effect can only be observed under specific climatic conditions. Later we will speak more about this point. Field experiments, 20 to 30 per year, during 6 years with cereals, potatoes, sugarbeets and other plants, had also the same results.

If we observe an effect on the plant growth, something in the metabolism of the plants must have been changed.

S. 15 (see top of page 11)   8/551

By way of comparison I report on the results of the effect of humic substances. The activities of the enzymes of rye seedlings vary in the presence of humic substances. The activity of aldolase increases, that of amylase decreases in the sprouts. The activity of saccharase increases in the roots (26). These experiments have been made in nutrient solution. The concentration of humic acids has been 10^{-3}%. We had also the same results with the model substance thymohydroquinone. The investigated enzymes are chiefly active in the carbohydrate metabolism (27).

S. 15

Enzymaktivitäten von Roggenkeimpflanzen nach Zusatz von Humusstoffen (H.S.) zur Nährlösung. (Messwerte jeweils in Extinktionen)

	Aldolase	Amylase	Saccharase	Phosphatase
Spross				
ohne H.S.	0,273	0,131	0,209	0,763
mit H.S.	0,329	0,085	0,234	0,724
Wurzel				
ohne H.S.	0,016	geringe	0,097	0,222
mit H.S.	0,013	Aktivität	0,231	0,258

S. 16 A/31

Wirkung von Thymohydrochinon auf den Gehalt der Pflanzensprosse an reduzierenden Zuckern im Neubauerversuch

Thymohydrochinon mg/Schale	Trockensubstanz in %	Reduzierende Frischgew.	Zucker in % des Trockengewichtes
	Roggen (Petkuser	Sommerroggen)	
0	8,8 ± 0,04	0,34	3,85 ± 0,095
1.5 x 10^{-5} mol.	8,9 ± 0,09	0,40	4,44 ± 0,077
1,5 x 10^{-4} mol.	9,2 ± 0,15	0,40	4,32 ± 0,120
1,5 x 10^{-3} mol.	9,5 ± 0,14	0,51	5,38 ± 0,174

Therefore we made different experiments to study the sugar metabolism. The content of reducing sugars is increased depending on the concentration of thymohydroquinone. This means that the physiological behavior is also changed.

S. 17 (see top of page 12) H/760

Pschenitschni (28) studied the influence of infiltrated solution of humic acids on the content of sugars in seedlings of winter wheat. We may only notice two numbers. The content of reducing sugars in seedlings exposed to light is increased by the Na-humate.

S. 18 (see bottom of page 13) H/755

S. 17

Einfluss der Huminsäuren auf den Zuckergehalt bei Keimpflanzen des Winterweizens OD - 3.

(Nach Versuchen von Pschenitschni 1952)

Pflanzen infiltriert mit	ausgesetzt sind	Invertzucker in mg. pro 10 g Blätter		Reduzierbare Zucker in mg pro 10 g Blätter	
		beleuchtet	Dunkelheit	beleuchtet	Dunkelheit
Wasser	Wasser	24,7	7	8,1	8,7
Natriumhumat 0,001%	"	47,5	7,3	9,2	7,0
Wasser	Gemisch nach Hellriegel	22,1	20,3	2,7	6,7
Natriumhumat 0,001%	" "	19.1	3,7	5,0	2,4

Bemerkung: Der Zucker wurde nach Hagedorn-Jensen bestimmt.

S. 18

Einfluss des organischen und anorganischen Anteils der Huminsäuren auf die Sauerstoffaufnahme der Kartoffelblätter.

(Versuch von 1954)

infiltrient	Sauerstoff in mm^3 aufgenommen nach 10 Min. bei einer Einwaage von 0,5%: Weiderholung 1.	2.	3.	mittel	aufgenommener Sauerstoff in %
Na-Humat 0,001%	78,6	112,7	105,5	98,9	140,4
dto. oxydiert mit H_2O_2	47,2	85,2	78,8	70,4	100,0
Na-Humat 0,001%	100,0	115,1	104,2	106,4	147,6
Wasser	70,0	78,2	68,3	72,2	100,0

The oxygen uptake of potato leaves is increased in the presence of Na-humate. The humic acids include always a small content of ash constituents which can contain small amounts of iron. Christewa (29) oxidized the humic acid with hydrogen peroxide and ascertained that the effect on oxygen uptake depends upon the organic part of the humic acids.

When isolating humic acids from different soils or other materials, it can never be guaranteed that the isolated substances are always the same. Therefore, we made experiments with a lot of model substances which have a definite chemical constitution. Furthermore, lower organisms are easier to handle than plants.

S. 19 8/508

O_2-Verbrauch von verarmter Hefe unter dem Einfluss ver schiedener Chinone, gemessen in /ul/h, bezogen auf die gleich 100 gesetzte Kontrolle.

Wirkstoffe	10^{-3}m	10^{-4}m	10^{-5}m	10^{-6}m	10^{-7}m
Benzochinon	17,2 ± 0,3	39,0 ± 4,2	52,0 ± 0,9	-	-
Toluchinon	29,5 ± 1,5	42,5 ± 1,6	66,0 ± 5,0	-	-
o-Xylochinon	42,0 ± 5,2	61,2 ± 6,6	90,7 ± 4,6	99,5 ± 5,5	-
m-Xylochinon	59,7 ± 8,1	81,0 ± 3,1	108,2 ± 3,3	101,5 ± 4,8	-
p-Xylochinon	43,0 ± 3,6 +)	88,5 ± 3,9	99,0 ± 2,3	-	-
Pseudocumochinon	72,2 ± 5,7	90,0 ± 2,8	110,7 ± 2,4	-	-
Thymochinon	-	38,7 ± 2,4	69,5 ± 5,1	98,7 ± 2,2	112,2 ± 4,3
Thymohydrochinon	60,5 ± 3,0 ++)	86,2 ± 2,8	114,0 ± 3,1	-	-
Durochinon	-	-	62,5 ± 2,9	76,2 ± 3,3	96,7 ± 3,2

+) 5×10^{-4}m
++) 8×10^{-4}m

We investigated the consumption of oxygen by yeast in the presence of different quinones (30). The consumption of oxygen depends not only upon the concentration but also on the chemical constitution.

Other investigations concern the change of the acid metabolism in plants. For instance, low concentrations of thymohydroquinone increase the content of pyruvic-, -ketoglutaric and citric acid, and diminish the content of malic- and fumaric acid (31) Generally the content of acids is increased.

S. 20 (see top of page 14) 8/633

At the beginning of my lecture I told you that organic matter increases the availability of potassium. In addition the plants have also a higher percentage content of potassium (32). This figure shows for variation the results with lignin fragments as model substances. Not only the yield is increased by protocatechuic acid and vanillin but also the content of potassium in percent. It may be that one of the reasons is the higher production of acid in the plant metabolism.

Slide 20

Einfluss von Protokatechusäure und Vanillin auf die Erträge von Sommerroggen in Mitscherlichgefässen

Substanz in 10^{-5} Mol	Körnerertrag in g	Körnerertrag rel.	Korn N	Korn P_2O_5	Korn K_2O
unbehandelt	24,4 ± 0,74	100	2,03	0,52	0,49
2 Protokatechusäure	25,5 ± 0,54	105	2,04	0,57	0,58
6 "	27,2 ± 0,48	111	2,03	0,48	0,61
12 "	26,9 ± 0,75	110	2,03	0,60	0,65
2 Vanillin	26,2 ± 0,78	108	2,01	0,53	0,67
6 "	27,5 ± 0,70	113	1,88	0,62	0,71
12 "	27,1 ± 0,46	111	2,00	0,52	0,61

Further experiments, especially with yeast indicated that central processes of the plant metabolism such as phosphorylation reactions are influenced (33). With mitochondria of liver of rats we could prove that, for instance, thymohydroquinone uncouples the oxidative phosphorylation. It may be emphasized again that minute quantities of organic substances influence the metabolism of the plants and that, without sufficient inorganic nutrients, the effects cannot be observed.

But now, after this basic research work we will go back to results also interesting from the practical standpoint.

S. 21 A/33

Einfluss der Luftfeuchtigkeit auf die Wirkung von Thymohydrochinon auf das Anfangswachstum von Sommerroggen

mg/l Thymohydrochinon	Spross: Trockengewicht in g	Spross: Trockengewicht rel.	Spross: Gehalt an red. Zuckern in Frischsubst. in mg %	Spross: Gehalt an red. Zuckern rel.	Spross: Wassergehalt in %	Wurzel: Trockengewicht in g	Wurzel: Trockengewicht rel.	Wurzel: Gehalt an red. Zuckern in der Frischsubst. in mg %	Wurzel: Gehalt an red. Zuckern rel.
100% rel. Luftfeuchtigkeit									
0	0,89±0,04	100	200	100	93,0	0,32±0,012	100	25	100
16,6	0,89±0,03	100	165	82	93,3	0,51±0,023	159	55	220
1,66	0,86±0,02	97	180	90	93,0	0,35±0,025	109	40	160
55-60% rel. Luftfeuchtigkeit									
0	0,75±0,01	100	200	100	91,5	0,38±0,009	100	25	100
16,6	0,87±0,03	116	360	180	91,0	0,59±0,017	155	25	100
1,66	0,94±0,03	125	305	153	90,6	0,50±0,034	132	40	160

I told you that we had only obtained an effect with these different model substances under certain climatic conditions. One of the reasons for the increase of the yield is a higher resistance against wilting (34). Therefore, we investigated the metabolism of the plant with the air at different relative humidities. Even with tests in Neubauer dishes at high relative humidity it can be noticed, that the influence of thymohydroquinone neither raised the weight of dry matter nor the content of soluble sugars in the sprouts when compared with control plants. But this occurs in the roots.

With a low relative humidity on the other hand, the amount of dry matter and the content of soluble sugars are raised in the sprouts as well as in the roots. The water content of the sprouts in treated plants is significantly lowered.

These results together with others such as the influence on transpiration and also the increased respiration of the roots allow us to presume that the treated plants have a higher osmotic value than the untreated ones. Therefore, photosynthesis is less lowered at times of dryness by increased wilting resistance. The plants are able to produce more organic matter.

Application of these ideas to practical conditions would mean that at times when plants need the highest amount of water, dry periods would do less harm to treated plants than to untreated ones. Also the results of our field experiments agree with this application and are confirmed recently by other authors in field experiments and under artificial conditions.

Many of these problems may be important for the future. But they are so complex that they must be begun in time. They are connected with the problem of organo-mineral fertilizers, which will be also of technical interest. Let us remember the difficulties in fertilizing with high amounts of nitrogen fertilizer - 160,200 kg N/ha and more. Perhaps it is not necessary in all cases for organic fertilizing to apply all the inactive materials of the organic manures as we do nowadays. It may be that small amounts of active organic substances are sufficient.

One problem belonging to the influence of organic matter on the metabolism of the plants is the alteration of different compounds in the plant itself. The value for nutrition can be changed by this alteration.

Furthermore, it must be mentioned that the quality of foodstuff is important for mankind as well as livestock. I think we are only beginning to solve all of these problems.

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