Biochemistry of Soil Organic Matter in Relation to Crop Production

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Content

Lecture 7.

Uptake of Organic Compounds By Plant Roots, Transport and Transformation in the Plant.

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Introduction

It is often described, in which way humus improves soil structure by its physical properties, but only few work is done to elucidate the biochemical reactions inside the plant after the uptake of its components.

Physiologically active substances have an effect on metabolism in small traces, and their investigation was therefore difficult in the past. But an elucidation of the action of organic substances of soil organic matter on plant metabolism can be anticipated, because more sensitive experimental techniques have become available.

In the following two lectures some fundamental research work and its consequences is reported, which deals with the soil-plant system concerning soil organic matter.

1. Phenolic compounds as physiologically active substances in soil organic matter.

Investigations of occurence of physiologically active substances in soil organic matter are concerned with two types of substances, such which are usually formed by biological reactions in the soil, and such which get into the soil as pesticides by agricultural use of the soil.

An increase of the last mentioned physiologically active compounds in the soil may possibly happen by accumulation in consequence of the yearly use, when the chemical reactions, which effect the decomposition to inactive components, or the biochemical degradation by soil microorganisms occur to slowly on account of the environmental conditions.

In the following mainly substances from soil organic matter are mentioned, from which one knows or from which one can suppose, that they are formed during plant residue decomposition and that they get into the plant through the roots.

1.1 Fractions from humic substances.

In numerous experiments (CHAMINADE 1956, 1966, CHRISTEWA 1958, 1963, FLAIG 1955, GUMINSKA and SULEJ,1964,Humusdüngemittel 1957, KONONOVA 1956, SCHEFFER and ULRICH 1960, Studies about Humus 1962 and others) a more or less large effect of fulvic acids or humic acids on the growth of plants or their organs is described. The effect of humic acids is next not comprehensible, because these as high molecular weight substances cannot penetrate through the cell membrane into the plants.

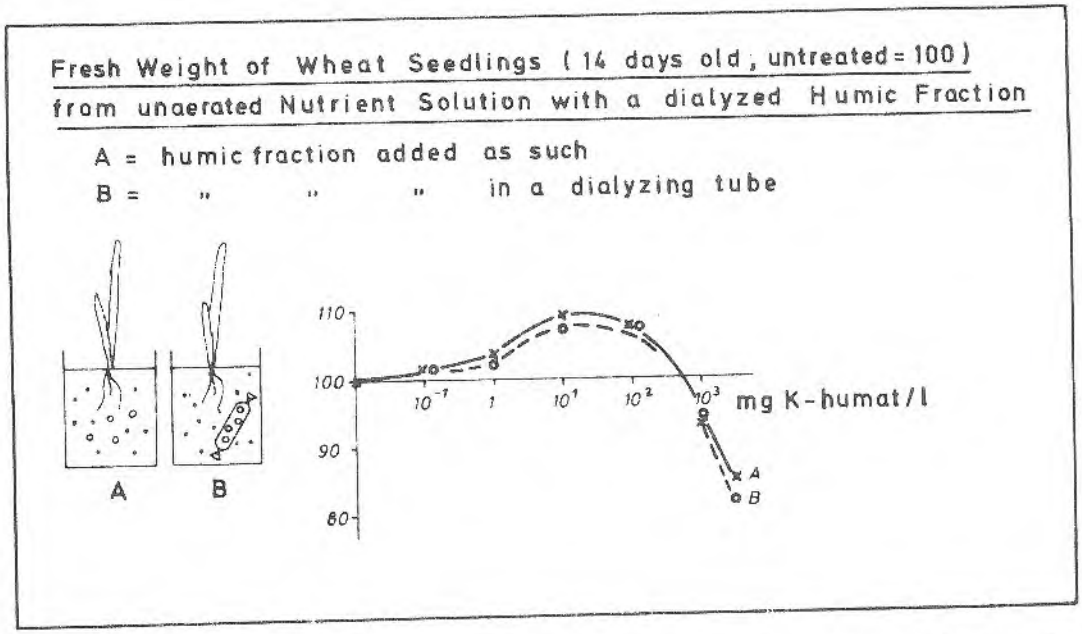


Fig. 1: Scheme of the effect of low and high molecular weight humic substances on plant growth(Söchtig and Harms 1971).

SÖCHTIG and HARMS (1971) could show that potassium salts of humic substances enclosed in a tube for dialysis and added to a nutrient solution had nearly the same effect on growth like such humic substances which have been added to the nutrient solution as a suspension directly. The low molecular weight products diffuse through the membrane of the tube and have an effect on the metabolism of plants.

1.2 Phenols and their oxidation products.

For the elucidation of physiological activity of substances from foil organic matter at first we studied 1,2- or 1,4-diphenols and the corresponding quinones, because larger quantities of polymeric phenols are present in soils in form of lignin as initial material for the formation of low molecular weight phenols during the humification.

Furthermore we found that phenols with hydroxyl groups in 1.3-position are synthesized by microorganisms and are transformed by hydroxylation and by some further reactions in 1,3,5-triphenols or in 1,2,3-triphenols and in hydroxyhydroquinone derivatives. These latter two can be considered as intermediary products for the formation of "microorganism-humic acids".

1.21 By degradation of lignin.

The lignin of the different plant species are polymers of coniferyl alcohol or mixed polymers with sinapyl alcohol and p-coumaryl alcohol as a third building block. The knowledge about the microbial degradation of lignin has been remarkably increased by experiments with labelled monomers of lignin with carbon-14.

From the established reactions only these will be mentioned which seem to be important for the discussion of the uptake of organic compounds from soil organic matter by plants.

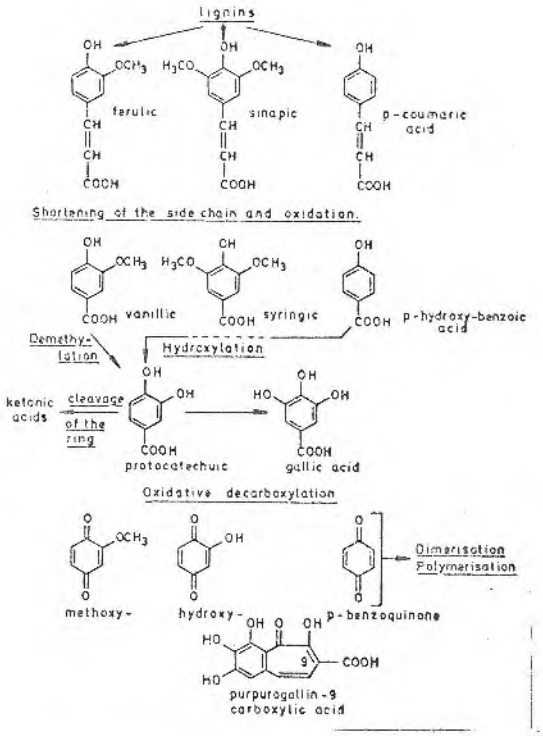


Fig. 2: Transformation of lignin degradation products.

Lignin degradation products are formed by biological reactions; they have an aldehyde- but mostly a carboxyl group and are phenol derivatives with a different number of methoxyl groups in o-position to the hydroxyl group and have side chains with one or three carbon atoms in p-position to the hydroxyl group. The shortening of the side chain of phenolacrylic occurs mainly at the double bound.

Demethylation is a further important reaction, whereby gallic acid is formed from syringic acid and protocatechuic acid from vanillic acid. From protocatechuic acid aliphatic keto-carboxylic acids are formed by the cleavage of the ring.

Hydroxylation is a further reaction, which occurs during transformation of Lignin degradation products. p-Hydroxybenzoic acid is hydroxylated to protocatechuic acid and this to gallic acid.

Quinones are formed in the course of oxidative decarboxylation catalysed by phenoloxidases. After addition of vanillic acid methoxy-p-quinone could be indentified in cultures of microorganisms (FLAIG and HAIDER 1961 a, b) and in plants (HARMS, SÖCHTIG and HAIDER 1971). According to ZENK (1964) hydroquinone is formed by oxidative decarboxylation of p-hydroxybenzoic acid and is present in the plant as the glucoside, arbutin.

All the mentioned compounds are transformed to dimers or polymers of different types by dehydrogenation. The formation of purpurogallin-9-carboxylic acid from the oxidation products of gallic acid is mentioned as a special example of dimerisation reactions (SALFELD 1957, SALFELD and BAUME 1964). Several other transformations of other phenol carboxylic acids are known. There exists a certain dependence of the physiological activity of phenolcarboxylic acids from their chemical constitution.

1.22 By microbial sythesis

HAIDER and MARTIN (1967) made extensive studies about phenols as initial materials during the formation of humic acids in cultures of microorganisms.

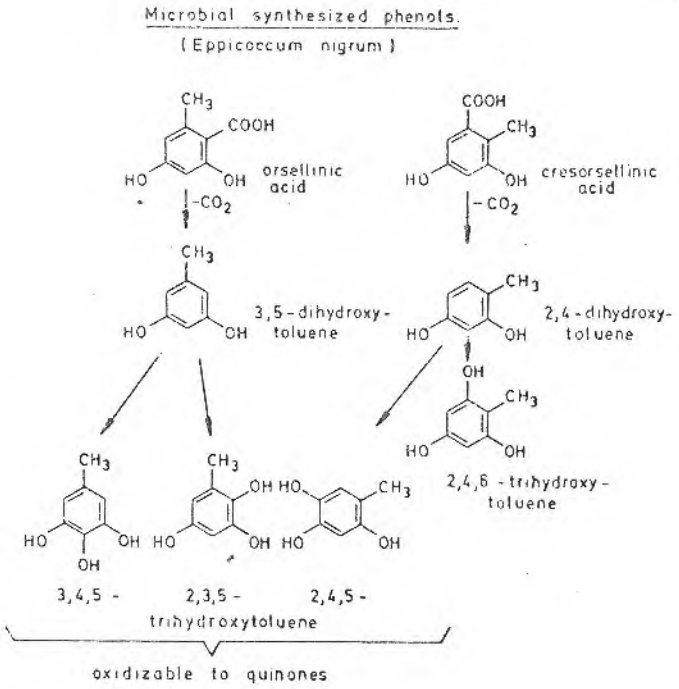


Fig. 3: Synthesis of phenols by microorganisms and their transformations.

Epicoccum nigrum synthesizes orsellinic and cresorsellinic acid. Both are transformed into methyl resorcinols by decarboxylation. Different polyphenols, which have hydroxyl groups in 1,3- or 1,3,5-position as well as in 1,2,3- or 1,2,4-position are formed by oxidation of methyl groups to carboxylic groups, by following decarboxylation and by hydroxylation. Phenolic derivatives with hydroxyl groups in 1,2,3- or 1,2,4-position can be oxidised to quinones and are responsible for the formation of the dark humic acid like substances in the cultures of microorganisms.

By the microbial synthesis also p-hydroxy-benzoic, protocatechuic or gallic acids are formed. As mentioned before these substances occur also during the degradation of lignin and can be oxidised to quinones.

Other species of microorganisms synthesize different other phenolic or quinonoid compounds. From these only spinolusin and fumigatin are mentioned.

1.3 Other physiologically active compounds.

Furthermore indole-3-acetic acid has been found in soil organic matter or in different organic fertilizers (HAMENCE 1948, SEILER - KELBITSCH and RADEMACHER 1964). Finally it is mentioned that antibiotics also occur in soil organic matter which are dominantly of microbial origin. It is not yet known, to which extent this is the case singularly. Further compounds will not be mentioned.

2. Uptake, transport and transformation inside the plant.

At first it shall be reported that only such substances are uptaken without difficulties, which have a molecular weight till to 1000 or 1500. These findings go back to the work of WINTER (1952), who added physiologically active substances such as antibiotics to nutrient solution of plants and identified the added substances again in the guttation drops by means of their effect against microorganisms. In other cases such as phenols the substances have been extracted from upper organs of wheat or bean plants (s.g. WINTER, PREUSS and SCHÖNBECK 1959). By these experiments quantitative statements could not be made in this way.

The labelling of the compounds with isotopes is indispensable for quantitative measurements of uptake of compounds through the roots of plants. Furthermore by labelling also a transformation of compound can be detected which occurs inside the plant. The use of isotopes has the further advantage, that the compounds can be

labelled in different carbon atoms of the molecule and therefore also details can be established during transformation.

2.1 Experimental prerequisite for the proof of uptake.

Experimental prerequisites must be provided for the use of labelled compounds, in order that actually the effect of added compounds and not this of transformation products is observed.

The investigations of labelled fractions of humic substances are connected with some difficulties, because their constituents are not yet chemically identified in detail. By this reason one does not know which transformation of these fractions occurs when they are sterilised.

The added substances can be degraded by activity of microorganisms and may penetrate into the plant faster than the original substances. Therefore it is also possible that degradation products with labelled carbon atoms simulate an uptake of originally added compounds by participation on metabolic processes and therefore by the formation of labelled metabolites. The measured activity of plant organs such as of roots or sprouts etc. is no exact measure of the amount of uptaken compounds.

It seems to us absolutely necessary to work in sterile medium for investigations about uptake of defined compounds, in order that no microbially caused transformation products penetrate into the plants and simulate an uptake of the added compounds by means of measured activity of roots and sprouts or other plant organs. The determination of the released carbon dioxide as in the case of addition of phenol carboxylic acids allows to draw conclusions about the occuring

reactions which transform the added compounds. Therefore in this connection a setup is briefly described which was used for our investigations (HARMS 1967).

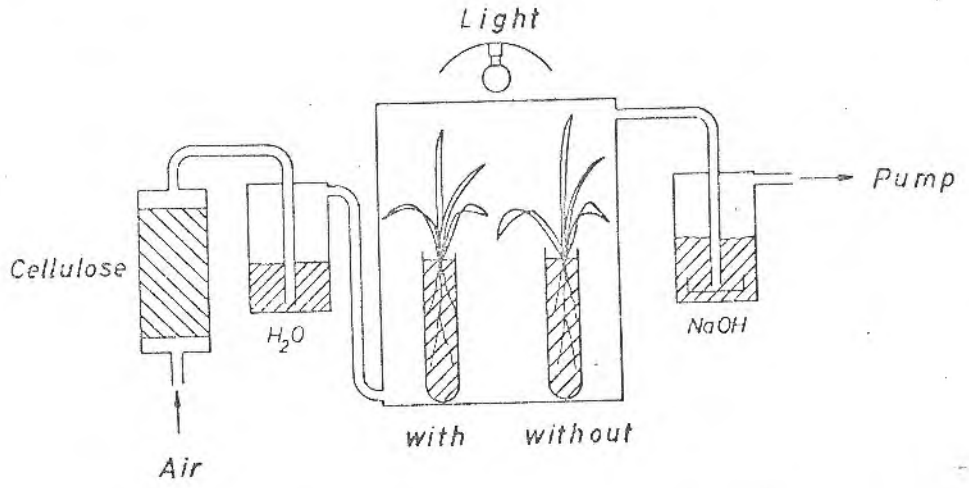


Fig. 4: Scheme of apparatus according to Harms (1967).

An airstream has been sucked by a pump through a cotton-wool strainer and a safety trap, which has been filled with water or differently concentrated sulfuric acid for the regulation of humidity in a vitreous vessel. The vitreous vessel has dimensions that the quantity of air has been as small as possible. In this vessel the singular plants are in smaller test tubes to avoid infections. One part of the plants is in nutrient solution according to Knop, which contains the labelled phenol carboxylic acids, the others were used as check-plants. The sucked air passed then a safety trap with sodium hydroxide in which the liberated carbon dioxide was absorbed. The activity in the sodium hydroxide solution was measured. The rate of the air stream was about 60 liter per hour.

2.2 Investigated substances and compounds.

In the following it will only be recorded about a selection of substances which have been used for the studies of the uptake by plants.

I. Fractions of humic substances.

II. Phenol carboxylic acids as lignin degradation products.

III. Thymohydroquinone as model substance for oxidised lignin-degradation products and oxidised microbial synthesized phenols.

In all these cases the uptaken substance has to be considered as a "biocatalyst" in its function.

2.21 Fractions of humic substances.

FÜHR and SAUERBECK (1966) separated humic substances isolated from labelled and rotted barley straw in different fractions. They established in experiments with a special setup, that sunflowers as experimental plants contained 4 till 10 % of the added carbon. The largest quantity was found in the roots. Only about 0,3-0,4 % of the water soluble part of humic substances or about 0,1 % of humic acids have been transported into the sprout. The authors explained the accumulation of the labelled compounds in the roots by sorption on their surface. They made similar establishments in experiments with radish (Raphanus sativus) (FÜHR and SAUERBECK 1964) and carrots (Daucus carota) (FÜHR and SAUERBECK 1965) by autoradiography of slices.

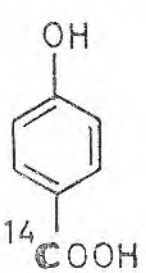
They found also in experiments with sunflowers that the addition of fulvic acids effects a significant increase of the yield of dryweight.

In a further paper they demonstrated that only the low molecular weight parts of humic substances migrate in the sprout and that the high molecular weight substances are sorbed at the surface of roots (FÜHR and SAUERBECK 1967). Therefore only the low molecular weight parts of soil organic matter seem to effect the observed increase of the dryweight of sprouts by their participation in metabolic processes.

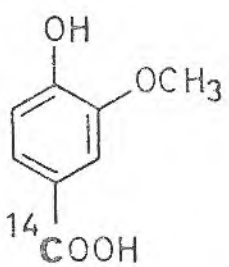
2.22 Phenol carboxylic acids (lignin degradation products)

The use of chemically defined and labelled compounds has the advantage, that their uptake and distribution in the plants can be investigated very exactly. After extraction of plants with corresponding solvents, after separation of the extracted compounds by thinlayer chromatography and by determination of specific activity of the single compounds the uptake cannot only be determined in their order of magnitude, but also the transformations of the added compounds can be followed as long as the group with the labelled atom is not split off.

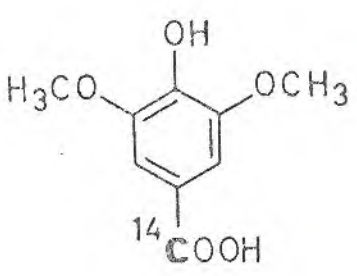
To study the uptake of phenolic lignin degradation products phenol carboxylic acids have been labelled in different carbon atoms. Thereby the transformation of added compounds could not only be determined more exactly, but also their participation in reactions of metabolism could be followed in a better way.



p-hydroxy-benzoic



vanillic



syringic acid

Fig. 5: Labelled phenol carboxylic acids.

Extensive studies were made about the uptake of carboxylic labelled p-hydroxybenzoic, vanillic and syringic acid by the roots of wheat seedlings in sterile nutrient solutions according to Knop (HARMS 1967, HARMS, SÜCHTIG and HAIDER 1969 a, b, HARMS, SÜCHTIG and HAIDER 1971).

The distribution of the activity was determined in roots, in sprouts and in liberated carbon dioxide. The numbers of the activity in percent of the quantity of phenol carboxylic acids added to nutrient solution after an incubation time of 3 and 6 days, are depicted in tab. 1.

Tab. 1: Relative distribution of the activity in the plant and in the released carbondioxide (the total sum of the assimilated activity = 100 %) after incubation with p-hydroxybenzoic, vanillic and syringic acid for 3 or 6 days (HARMS et al. 1969).

		incubated with p-hydroxybenzoic acid	vanillic acid	syringic acid
		percent of the assimilated activity		
incubated for 3 days	roots	69.5	56.4	40.1
	shoots	23.0	9.6	13.3
	released CO_2	7.5	34.0	46.6
incubated for 6 days	roots	67.0	51.5	45.9
	shoots	25.0	10.1	10.6
	released CO_2	8.0	38.4	43.5

It can be concluded that:

1. The largest quantity of activity is in every case in the roots.
2. The quantity of activities increases in the roots, in the shoots and in the liberated carbon dioxide with incubation time.

3. The activity measured in the shoots is about 1 to 3 % of the activity which has been added in form of phenol carboxylic acids or between 10 and 25 % of the assimilated activity. The quantity depends on the substitution of the benzoic acid with hydroxyl or methoxyl groups. The differences of uptaken activity in shoots are not large during the different incubation times.
4. The amount of liberated carbon dioxide differs remarkably; in the case of p-hydroxybenzoic acid it was the smallest (about 0.5 % respectively 0.95 % of the added or 8 % of the assimilated quantity), in the case of vanillic acid it increases largely (about 35 % of the assimilated quantity) and in the case of syringic acid it was the highest (about 45 % of the assimilated quantity).

Therefore the extent of decarboxylation increases with increasing number of methoxyl groups in o-position to the OH-group in 4-position.

After incubation with phenolcarboxylic acids labelled in the methoxyl group or in the ring the roots contain a higher portion of activity than after incubation with carboxyl labelled acids. The ratio in the sprouts is opposite. The amount of released 14C-carbondioxide is much less. (HARMS, SÖCHTIG and HAIDER 1970).

At the end of the experiment it was established by analysis, that besides the added phenol carboxylic acids no other labelled phenolic compounds are present in the nutrient solution. The sum of the remaining activity in the nutrient solution, the uptaken and the respirated activity corresponds nearly to the added.

The measured activity in the plant organs indicated only an accumulation of activity derived from phenol carboxylic acids. Statements about the fixation of the activity by reactions can only be made in further investigations.

Above all the large part of activity in the roots was noticeable. This could not be decreased by rinsing of the roots with diluted sodium hydroxide solution. The investigations made hitherto cannot explain the type of binding. First of all we suppose, that the accumulation is a sorption effect.

The immediately deep-freezed, lyophylized and then pulverised plant organs have been extracted with ether, then with methanol and finally with water for separation of activities which were in roots and sprouts.

The determination of the ratio of activity in the extracts and in the residues of extraction resulted, that there exists a certain differentiation of uptake and distribution of the three acids. In the following only the principal differences are mentioned.

A small amount of free acid is found by thin layer chromatography only in the ether extract of the shoots of plants, which were treated with p-hydroxybenzoic acid.

The sorptively bound and the transformed phenol carboxylic acids are extracted with methanol. These extracts contain by far the largest part of activity.

The sorptively bound acids which were extractable with methanol were found by means of thinlayer chromatography in all cases of added

phenol carboxylic acids. Furthermore it could be demonstrated by hydrolysis with diluted sulfuric acid or by a β-glucosidase, by following thinlayer chromatography as well as by means of UV-spectra and measuring of activity of the single compounds that the phenol carboxylic acids are present in the plant partly as glucose esters, glucosides or as glucose esters of glucosides.

Tab. 2: The relative distribution of the radioactivity in the different fractions of plants, 6 days incubated with labelled phenolic acids (activity of root or sprout = 100) (HARMS et al. 1968).

	incubated with		
	p-hydroxybenzoic acid	vanillic acid	syringic acid
	percent of the assimilated activity		
Ether extract			
roots	1	4	1
shoots	17	14	3
Methanol extract			
roots	86	75	93
shoots	76	62	60
Water extract			
roots	8	10	5
shoots	2	8	11
Extraction residue			
roots	5	11	1
shoots	5	16	26

At the moment only assumptions can be made about the metabolic importance of the reactions between glucose and phenol carboxylic acids to the corresponding glucose derivatives as well as about the cleavage into the initial compounds again. It seems to us not sufficient to explain the formation of glucosides and/or esters only as a reaction to detoxicate the phenolic compounds.

The activity found in the water extracts and in the residues of extraction is explained with the endogenous fixation of carbon dioxide which is split off from the phenol carboxylic acids.

The activity of the residues of extraction of shoots was mostly higher than this of the roots and was mainly fixed in the holocellulose or α-cellulose respectively.

The remaining activity in the residues of extraction after hydrolysis with 6 N hydrochloric (HARMS, SÖCHTIG and HAIDER 1969 b) is fixed in amino acids, soluble proteins and sugars. The main part of activity was in the amino acids, aspartic and glutamic acid, which are formed by amination of oxaloacetic acid and α-ketoglutaric acid from the citric acid cycle.

In further experiments the decarboxylation of phenolcarboxylic acids was studied in the presence of pieces of sprouts or roots with the Warburg technique (HARMS, SÖCHTIG and HAIDER 1969 b). The oxygen absorption was not different in all cases.

The fig. 6 shows that benzoic acid as the fundamental substance of these compounds is not decarboxylated. No cleavage of the ring was observed as it could be proved with ring labelled benzoic acid. It seems to be that the formation of hydroxybenzoic acids did not occur during the time of the experiment, because no active carbon dioxide could be found in the case of benzoic acid. The cleavage of the aromatic ring mainly occurs after hydroxylation.

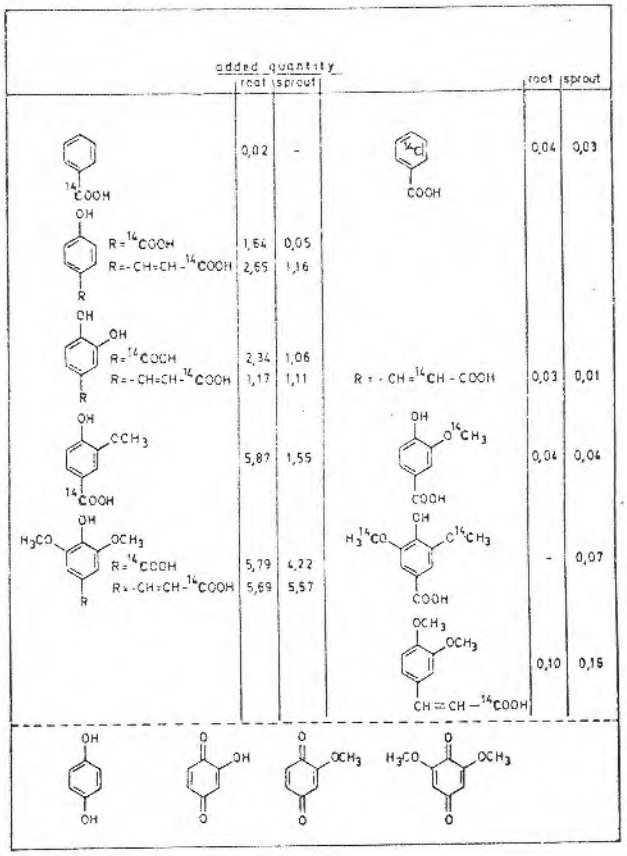


Fig. 6: Formation of 14C-carbondioxide from differently labelled lignin degradation products by pieces of sprouts or roots of wheat seedlings in percent of added quantity.

No remarkable amount of carbon dioxide was formed after addition of caffeic acid labelled in carbon atom 2 of the side chain or after addition of vanillic and syringic acid, both labelled in the methoxyl group, to pieces of roots or shoots.

No decarboxylation is observed after etherification of the hydroxyl group in 4-position , for instance in the case of 3,4-dimethoxy-cinnamic acid. We suggest that the decarboxylation is due to the action of a phenol oxidase, because only compounds with hydroxyl groups in 4-position are decarboxylated. The decarboxylation occurs in a similar way - presumably through semiquinones - as it is also

the case during the decarboxylation of phenol carboxylic acids in the presence of phenol oxidases from white rot fungi. During these reactions phenols or quinones could be identified as decarboxylation products (FLAIG and HAIDER 1961 a,b). The corresponding hydroquinones formed by decarboxylation of vanillic or syringic acid could also be isolated in small amounts from plants after their uptake (HARMS, SÖCHTIG and HAIDER 1971). Furthermore we demonstrated that the effect of of vanillic acid on the increase of dry weight of wheat seedlings is larger than this of p-hydroxybenzoic acid, although the latter is more resistant against chemical oxidation (MORRISON 1963) or against enzymatic oxidation (LIM 1965) than vanillic acid. The effect of protocatechuic acid is somewhat less than this of vanillic acid; the lowest effect is caused by syringic and gallic acid. The reason for this may be, that these two acids are altered oxidatively very easily and decomposed.

Further investigations have shown, that the largest effect of phenol carboxylic acids on the increase of drymatter weight of seedlings of cereales can be observed by an addition of about 10^{-3} mol/liter, whilst the favourable concentrations of phenols or quinones are between 10^{-4} till to 10^{-6} molar.

The experiments of oxidative decarboxylation of carboxylic acids as well as the higher physiological activity of phenols or quinones let assume, that not the phenol carboxylic acids but presumably phenols and quinones as oxidation products may lead to the alterations of the metabolism, whereby an increase of drymatter occurs under certain environmental conditions. This assumption must be proved by further investigations.

According to OXFORD (1942 a,b) and OXFORD and RAISTRICK (1942) the substitution of quinones with methoxyl groups increases the effect against microorganisms. This result may be explained either by physiological activity or by stability of quinones.

Tab. 3: Distribution of the activity in the plant 3 days after adding carboxyl labelled vanillic acid, depending on the pH of the nutrient solution at 55 % rel. air humidity (HARMS et al. 1968).

	pH of nutrient solution		
	3.5	4.5	5.5
	percent of the added activity		
roots	2.43	4.35	3.96
shoots	0.29	0.40	0.26
released CO_2	1.11	2.60	2.37
total	3.83	7.35	6.59

Furthermore we studied the influence of environmental conditions on the uptake of phenol carboxylic acids. The uptake of vanillic acid in the shoots depends upon the pH-value of the nutrient solution and is therefore differently large. The migration of vanillic acid into the shoots is the most when the pH-value of nutrient solution corresponds to the pK-value of vanillic acid, which is 4.4. Similar observations were made in other cases of physiologically active substances.

Another dependence of the uptake of vanillic acid from environmental conditions was observed in experiments with different relative humidity.

The dependence of uptake of vanillic acid from pH-value is larger in the case of a humidity of 50 % than in this of 98 % (HARMS 1967).

An increase of light intensity increases the uptake of vanillic acid by the plants (HARMS, SÖCHTIG,HAIDER 1969 a) .

Light intensity as an environmental factor has also an influence on uptake of vanillic acid and its transformation.

2.23 Model substance of oxidised lignin degradation products and microbial synthesized phenols (thymohydroquinone).

It has been mentioned that phenols or quinones are formed by oxidative decarboxylation of 4-hydrobenzene carbxylic acids. 14C-labelled thymohydroquinone (SCHMID 1962, 1963, 1964) was used as model substance, because we had experiences (summaries: FLAIG and SÖCHTIG 1962, FLAIG 1965) about the effects of this substance on plant metabolism, growth and yield depending on environmental conditions.

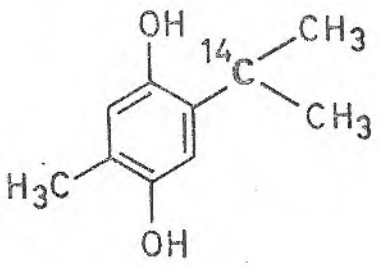


Fig. 7: Thymohydroquinone

Thymohydroquinone was labelled in the secondary carbon atom of the isopropyl group and only small amounts of labelled carbondioxide are split off during experiments with plants.

Tab. 4: Content of thymohydroquinone at different concentrations and times of incubation in root and sprout as well as release of labelled carbondioxide per plant (Kastori et al. 1970)

Concentration in nutrient solution (/ug in 15 ml)	3 days			5 days			7 days		
	root	sprout	$C^{14}O_2$	root	sprout	$C^{14}O_2$	root	sprout	$C^{14}O_2$
1×10^{-3}M (2493/ug)	205	54	1	396	125	3	457	151	4
2×10^{-4}M (499/ug)	138	14	1	279	18	2	293	20	3
5×10^{-5}M (125/ug)	43	2	t	66	3	1	72	72	1

* values in /ug thymohydroquinone, calc. from measured activity; mean values of 10 plants; t = traces.

The uptake of thymohydroquinone by plants during incubation is principally the same as in the case of phenol carboxylic acids (KASTORI, HARMS, SÖCHTIG and HAIDER 1970). But only the inhibition of growth of root or sprout occurs in concentrations, which are lower one or two power of ten.

The concentration of thymohydroquinone increases in the plants with increasing concentration in the nutrient solution. The activity in the roots is also much higher than in the sprouts.

Tab. 5: Distribution of the uptaken thymohydroquinone per plant on the single extracts and the residue after 7 days incubation (Kastori et al. 1970).

concentration in nutrient solution	ether extract		methanol extract		water extract		residue	
	root	sprout	root	sprout	root	sprout	root	sprout
1×10^{-3}M	5,1	6,0	411,8	411,8	12,5	5,0	18,8	17,2
2×10^{-4}M	1,4	0,5	250,7	9,7	9,9	1,5	7,5	3,0
5×10^{-5}M	0,8	0,4	49,4	1,8	6,7	0,3	3,0	0,6

* values in /ug thymohydroquinone, calc. from measured activity; mean values of 10 plants; t = traces.

The extraction of roots or sprouts with ether, methanol and finally with water gave comparable results as in the case of penol carboxylic acids.

The highest amount of activity/g dry weight was also in the methanol extract. Free thymohydroquinone was found only in some cases. The main quantity of the activity was fixed in the glucoside of thymohydroquinone, as it could be ascertained by hydrolysis with sulfuric acid or with a glucosidase, thinlayer chromatography and determination of the activity of the separated substances.

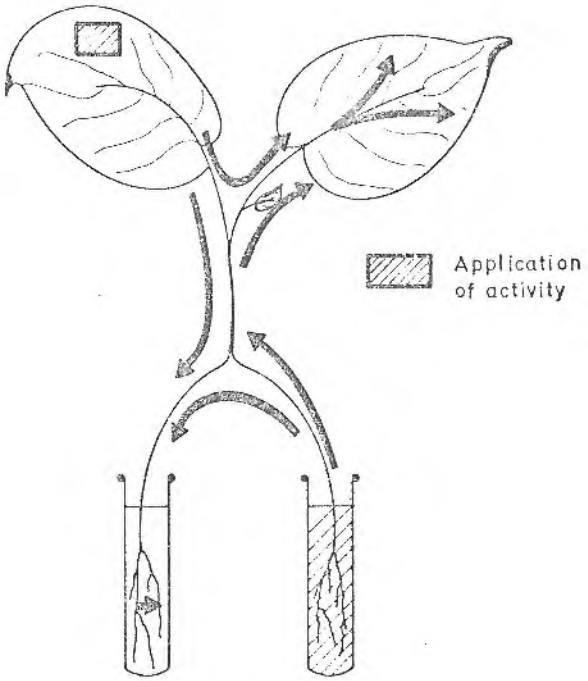


Fig. 8: Distribution of labelled thymohydroquinone in plants.

The transport follows in acropetal, basipetal and transversal direction in the case of monocotyledones (wheat seedlings) or dicotyledones (mustard seedlings). Furthermore it could be demonstrated that thymodydroquinone is secreted in the nutrient solution through the roots as the depicted scheme demonstrates.

Further experiments resulted, that labelled thymohydroquinone is distributed in the whole plant after application of different organs.

In the case of glucosides of thymohydroquinone as well as in the case of glucosides of phenol carboxylic acids no transport could be observed.

References:

ADLER, E.: Über den Stand der Ligninforschung. Z. Papier, 15,604-609 (1961).

AUDUS, L.J.: The transport of growth regulators in plants. Transporto delle molecole organische nelle piante. Atti del VI Simposio Internazionale di Agrochimica Varenna 5-10 Settembre 1966, 273-295.

BADZHOV, K. and E. IKONOMOVA: ^{15}N for studying nitrogen transformations in soil, nitrogen nutrition of plants and in assessing available nitrogen in soil. - Proc. Symp. Vienna 1969. - IAEA, Vienna, 21-32 (1971).

BAILEY, N.T., G.G. BRIGGS, G.J. LAWSON, J.M. SCRUTON and S.G. WARD: Observation on the structure of humic acid. 6. Intern. Kohlenwiss. Tagung, Münster, W., 1.-3.6.1965. Beitrag Nr.3, 1. (1965).

BARTLETT, J.B.: The effect of decomposition of the lignin of plant materials. Iowa State Coll. J. Sci. 14, 11-13 (1939).

BARTLETT, J.B., F.P. SMITH and P.E. BROWN: Lignin decomposition in soils. Proc. Iowa Acad. Sci. 44, 97-101 (1937).

BARTLETT, J.B.,and A.G. NORMAN: Changes in the lignin of some plant material as a result of decomposition. Soil Sci. Soc. Amer., Proc. 3, 210-216 (1938).

BEILER-KELBRITSCH, H. and B. RADEMACHER: Isolierung von Indolderivaten aus Laubkompost und deren Einfluß auf Stellaria media. Beitr. Biol. Pflanzen 40, 237-264 (1964).

BERTHELOT, M. and G. ANDRÊ: Ann. Chim. Phys. 25, Ser. 6, 362 (1892).

BIELAWSKI, J., T.E. THOMPSON and A.L. LEHNINGER: The effect of 2,4-dinitrophenol on the electrical resistance of phospholipid bilayer membranes. Biochem. and Biophys. Res. Comm. 24, 948-954(1966).

BEUTELSPACHER, H.: Physikalisch-chemische Beiträge zur Humusforschung. Z. Pflanzenernähr., Düng., Bodenkunde 57,57-65 (1952).

BEUTELSPACHER, H.: Natürliche Fadenkolloide und Krümelbildung. Landbauforsch. 5, 90-92 (1955).

BJÖRKMAN, A.: Isolation of lignin from finely divided wood with neutral solvents. Nature 174, 1057 (1954).

BJÖRKMAN, A.: Studies on finely divided wood. I. Extraction of lignin with neutral solvents. Svensk papperstidning 59, 477-485(1956).

BJÖRKMAN, A.: Lignin and Lignin-Carbohydrate Complexes. Extraction from wood meal with neutral solvents. Ind. Eng. Chem. 49, 9 1395-1398 (1957).

BLOIS, M.S.: Random polymers as a matrix for chemical evolution. In: The origins of prebiological systems, edit. by Sidney W. Fox, Academic Press New York-London 1965, 19-38.

BONDY, A. and H. MEYER: Lignin in young plants. Biochem. J. 43, 248 (1948).

BLUMER, M.: Benzyprenes in soil. Science 134, 474-475 (1961).

BÖRNER, H.: Untersuchungen über phenolische Verbindungen aus Getreidestroh und Getreiderückständen. Naturwissenschaften 42, 583 (1955).

BÖRNER, H.: Der papierchromatographische Nachweis von Ferulasäure in wässrigen Extrakten von Getreidestroh und Getreiderückständen. Naturwissenschaften 43, 129 (1956).

BÖRNER, H.: Die Abgabe organischer Verbindungen aus den Karyopsen, Wurzeln und Ernterückständen von Roggen (Secale cereale L.), Weizen (Triticum aestivum L.) und Gerste (Hordeum vulgare L.) und ihre Bedeutung bei der gegenseitigen Beeinflussung der höheren Pflanzen. Beitr. Biol. Pfl. 33-38 (1957).

BRAUNS, F.E.: Native Lignin. I. Its isolation and methylation. J. Amer. Chem. Soc. 61, 2120-2127 (1939).

BRAUNS, F.E. and D. A. BRAUNS: The chemistry of lignin; supplement volume: Covering the literature for the years 1949-1958. New York and London, Academic Press 516-518,(1960).

BREMNER, J.M.: "Organic forms of nitrogen". Ch. 85 Methods of Soil Analysis. (Agron. Monographs 9) ASA Madison 1965.

BREMNER, J.M.: The nitrogenous constituents of soil organic matter and their role in soil fertility. Pontificae Academiae Scientiarum Scripta Varia 32, 143-193 (1968).

BREMNER, J.M. and F. FÜHR: Tracer studies of the reaction of soil organic matter with nitrite. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA technical Meeting. - Pergamon Press Ltd. Oxford 1966, 337-348.

BREMNER, J.M., W. FLAIG and E. KÜSTER: Zur Kenntnis der Huminsäuren. IX. Mitteilung. Der Gehalt an Aminosäuren in Streptomyceten-Huminsäuren. Z. Pflanzenernähr., Düng., Bodenkunde 71, 58-63 (1955).

BREMNER, J.M. and T. HARADA: Release of ammonium and organic matter from soil by hydrofluoric acid and effect of hydrofluoric acid treatment on extraction of soil organic matter by neutral and alkaline reagents. J. Agric. Sci. 52, 2 (1959).

BREYHAN, Th.: Eine Mikromethode zur Stickstoffbestimmung. Z. analyt. Chem. 152, 412-417 (1956).

BROADBENT, F.E.: Nitrogen release and carbon loss from soil organic matter during decomposition of added plant residues. Soil Sci. Amer. Proc. 12, 241 (1948).

BROADBENT, F.E.: Modification in chemical properties of straw during decomposition. Soil Sci. Soc. Amer., Proc. 18, 165 - 169 (1954).

BROADBENT, F.E. and A.G. NORMAN: Some factors affecting the availability of organic nitrogen in soil - a preliminary report. Soil Sci. Soc. Amer. Proc. 11, 264 (1947).

BROCKMANN, H. and E. MEYER: Äquivalent- und Molekulargewichtsbestimmungen durch potentiometrische Mikrotitration in nichtwässrigen Lösungsmitteln. Chem. Ber. 86, 1514-1523 (1953).

BRUCKERT, S.F., F. JACQUIN and M. METCHE: Contribution à l'étude des acides phénols présents dans les sols. Bull. de l'École Nationale Supérieure Agronomique de Nancy, IX, 73-92 (1967).

BURGES, A. and P. LATTER: Decomposition of humic acid by fungi. Nature 186, 4722, 404-405 (1960).

BURGES, A., H.M. HURST and S. B. WALKDEN: Nature of humic acids. Nature 199, 696 (1963).

BURGES, N.A., H.M. HURST and B. WALKDEN: The phenolic constituents of humic acid and their relation to the lignin of the plant cover. Geochim. Cosmochim. Acta 28, 1547-1554 (1964).

CHAMINADE, R.: Action de l'acide humique sur le développment et la nutrition minérale des végétaux. VI. Int. Soil Sci. Congr. Vol.D. Paris, 443 (1956).

CHAMINADE, R.: Effet physiologique des constituants de la matière organique des sols, sur le metabolisme des plantes, la croissance et le rendement. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press Ltd. Oxford 1966, 35-47.

CHAMINADE, R.: Rôle specifique de la matière organique sur la nutrition et le rendement des végétaux. Pontificial Academiae Scientiarum Scripta Varia 32, 777-804 (1968).

CHAKRABARTRY, S.K., B.K. MAZUMDAR, S.N. ROY and A. LAHIRI: Structural parameters of coal based on oxidation experiments. Brennstoff-Chem. 41, 5, 138 (1960).

CHENG, H.H. and L.T. KURTZ: Chemical distribution of added nitrogen in soils. Soil Sci. Soc. Amer. Proc. 27, 312 (1963).

CHESHIRE, M.V., P.A. CRANWELL, C.P. FALSHAW, A.J. FLOYD and R.D. HAWORTH: Humic Acid-2. Tetrahedron 23, 1669-1682 (1967).

CHOUDRI, M.B. and F.J. STEVENSON: Chemical and physicochemical properties of soil humic colloids. III. Extraction of organic matter from soils. Soil Sci. Soc. Amer., Proc. 21, 508-513 (1957).

CHRISTEWA, L.A.: Die stimulierende Wirkung der Huminsäuren auf die Lebenstätigkeit höherer Pflanzen und die Effektivität der Humindünger in südlichen Gebieten der Ukraine. SSR. Int. Soil Sci. Congr. Vol. II, Comm. II u. IV. Hamburg 46-55 (1958).

CHRISTEWA, L.A.: Theorie und Praxis der Humindüngeranwendung in der Ukraine. Der Internationale Torfkongress, UdSSR Leningrad (1963)(russ.).

CHRISTEWA, L.A.: Über die Einheitlichkeit des Wirkungsmechanismus physiologische aktiver Stoffe (russ.).
Ministerium für Landwirtschaft der UdSSR, Landwirtschaftliche Hochschule Dnjepropetrowsk, 6-9 (1965).

CHRISTEWA, L.A.: About the nature of physiologically active substances of the soil humus and of organic fertilizers and their agricultural importance. Pontificiae Academiae Scientiarum Scripta Varia 32, 702-721 (1968).

CHRISTEWA, L.A., K.I. SOLOCHA, R.L. DYNKINA, A.I. GOROVAYA and V.E. KOVALENKO: Effect of physiological active substances of soil humus and fertilizers on the transformation of nuclein acids, growth of plants and quality of the seeds. Studies about Humus. Trans. Int. Symp. "Humus et Planta IV" Prague, russ. 212-276 (1967).

CINCEROVA, A.: The effect of humic acid on transamination in winter wheat plants. Biol. Plant 6, 183-188 (1964).

COFFIN, D.E. and W.A. DELONG: Extraction and characterization of organic matter of a podzol B-horizon. 7th. Int. Congr. of Soil Sci. Madison, Wisc. USA Vol. II, 91-97 (1960).

DEUEL, H. and P. DUBACH: Decarboxylierung der organischen Substanz des Bodens. II. Nachweis von Uronsäuren . Z. Pflanzenernähr., Düng., Bodenkunde 82, 97-106 (1958 a).

DEUEL, H. and P. DUBACH: Decarboxylierung der organischen Substanz des Bodens. III. Extraktion und Fraktionierung decarboxylierbarer Humusstoffe. Helv. Chim. Acta 41, 1310-1321 (1958 b).

DEUEL, H., P. DUBACH and R. BACH: Decarboxylierung der organischen Substanz des Bodens. I. Decarboxylierung der gesamten Humusstoffe. Z. Pflanzenernähr., Düng., Bodenkunde 81, 189 (1958).

DIJK, van H.: Die Kationenbildung der Huminsäuren. 4. Torf-Kolloquium DDR - VR Polen, 1-3 (1967) (Rostock).

DINCHEV, D. and K. BADZOV: Bestimmung des pflanzenaufnehmbaren Stickstoffs durch agrochemische Methoden mit Hilfe des stabilen Isotops ^{15}N. - Agrochimica (in press).

DRAGUNOV, S.S., ZHELOKHOVTSEVA and E.I. STRELKOVA: A comparative study of soil and peat humic acids. Pochvovedenie (7), 409 (1948).

DUBACH, P. and N.C. MEHTA: The chemistry of soil humic substances. Soils Fertilizers XXVI, 293-300 (1963).

DUBACH, P., N.C. MEHTA and H. DEUEL: Extraktion von Huminstoffen aus dem B-Horizont eines Podsols mit ÄDTE. Z. Pflanzenernähr., Düng., Bodenkunde 95, 119-123 (1961).

DUBACH, P.,N.C. MEHTA and H. DEUEL: Schonende Extraktion von Huminstoffen und Isolierung der Fulvosäure-Fraktion aus verschiedenen Bodentypen. Z. Pflanzenernähr., Düng., Bodenkunde 102, 1-7 (1963).

ELIAS, H.G.: Ultrazentrifugen-Methoden. Beckman Instruments G.m.b.H., München, 2. Auflage 1961, S. 126.

ERDTMAN, H.G.H. and C.A. WACHTMEISTER: Phenoldehydrogenation as a biosynthetic reaction. Festschrift Prof. Dr. W. Stoll, 8. Jan. 1957, 144-165.

EVANS, L. T.: The use of chelating reagents and alkaline solution in soil organic matter extractions. J. Soil Sci. 10, 110-118 (1959).

EVANS, W.C., B.S.W. SMITH, R.P. LINSTEAD and J.A. ELVIDGE: Chemistry of the oxidative metabolism of certain aromatic compounds by microorganisms. Nature 168, 772-775 (1951).

FARMER, V.C. and R. I. MORRISON: Chemical and infrared studies on phragmites peat and its humic acid. Sci. Proc. Roy, Dublin Soc. Series A 1 , 85-104 (1960).

FARMER, V.C. and R.I. MORRISON: Lignin in Sphagnum and phragmites and in peats derived from these plants. Geochim. Cosmochim. Acta 28, 1537-1546 (1964).

FARMER, V.C., M.E.K, HENDERSON and J.D. RUSSELL: Reduction of certain aromatic acids to aldehydes and alcohols by Polystictus versicolor. Biochim. Biophys. Acta 35, 202-211 (1959).

FLAIG, W.: Zur Bildungsmöglichkeit von Huminsäuren aus Lignin. Holzforschung 9, 1-4 (1955).

FLAIG, W.: Zur Chemie der Huminsäuren und deren Modellsubstanzen. Vle. Congrès Internat. de la Science du Sol. Paris, 2, 471-478 (1956).

FLAIG, W.: Die Chemie organischer Stoffe im Boden und deren physiologische Wirkung. Verhandl. d. II. und IV. Komm. d. Internat. Bodenkundl. Ges., Hamburg, Vol. II (1958).

FLAIG, W.: Chemie der Humusstoffe. Suomen Kemistilehti A 33, 229-251 (1960 a).

FLAIG, W.: Comparative chemical investigations on natural humic compounds and their model substances. Sci. Proc. Roy. Dublin Soc. Ser. A 1, 4, 149 (1960 b).

FLAIG, W.: Zur Umwandlung von Lignin in Humusstoffe. Freiberger Forschungshefte A 254, 39-56 (1962).

FLAIG, W.: Über den Einfluß von Humusstoffen auf den Stoffwechsel der Pflanzen. Der internationale Torfkongress UdSSR Leningrad 1963.

FLAIG, W.: Chemische Untersuchungen an Humusstoffen. Z. Chem. 4, 253-265 (1964 a).

FLAIG, W.: Gedanken zur Nomenklatur der im Boden vorhandenen organischen Stoffe. 8th Internat. Congr. Soil Sci. Transaction, Vol. III, Bucharest-Romania, 389-399 (1964 b). Discussions regarding the terminology in the field of humus, 405-413.

FLAIG, W.: Action des produits de dégradation de la lignine surgle métabolisme végétal mecanisme possible de cette action. C.R. Hebd. des Séances de l'Academie d'Agriculture de France No. 17, 1118-1138 (1965).

FLAIG, W.: c) Humusstoffe.
Handbuch der Pflanzenernährung und Düngung. Bd. II: Boden und Düngemittel 1966, S. 282-458, Springer-Verlag Wien.

FLAIG, W.: Uptake of organic substances from soil organic matter by plant and their influence on metabolism. Pontificiae Academiae Scientiarum Scripta Varia 32, 723-770 (1968).

FLAIG, W.: Contribution à la connaissance de la constitution et de la synthèse des acides humiques. Extrait de "Sciences du Sol", Supplément au Bulletin de l'Association Française pour l'Étude du Sol, No 2,39-72 (1970).

FLAIG, W. and H. BEUTELSPACHER: Zur Kenntnis der Huminsäuren. II. Elekronenmikroskopische Untersuchungen an natürlichen und synthetischen Huminsäuren. Z. Pflanzenernähr., Düng., Bodenkunde 52, 1-21 (1951).

FLAIG, W. and H. BEUTELSPACHER: Physikalische Chemie der Huminsäuren. Landbouwkund.Tijdschr. 66, 306-336 (1954 a).

FLAIG, W. and H. BEUTELSPACHER: Investigations of humic acids with the analytical ultracentrifuge. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968, 23-30.

FLAIG, W. and Th. BREYHAN: Über das Vorkommen von Indolverbindungen in Schwarzerde-Huminsäuren. Z. Pflanzenernähr., Düng., Bodenkunde 75, 132-135 (1956).

FLAIG, W. and K. HAIDER: Reaktionen mit oxydierenden Enzymen aus Mikroorganismen. Planta Medica, Z.f. Arzneipflanzenforsch. 9, 123-139 (1961 a).

FLAIG, W. and K. HAIDER: Die Verwertung phenolischer Verbindungen durch Weißfäulepilze. Arch. Mikrobiol. 40, 212-223 (1961 b).

FLAIG, W. and K. HAIDER: Über die Beteiligung von Phenolen am Aufbau von Huminsäuren. - 9th International Congress of Soil Science Transactions III, 175-182 (1968).

FLAIG, W. and W. de JONG: Untersuchungen über die Wirkung von p-Benzochinonderivaten auf den aeroben und anaeroben Stoffwechsel der Hefe (Saccharomyces aerevisiae).
Arch. f. Mikrobiol. 37, 355-368 (1960 a).

FLAIG, W. and W. de JONG: Vergleich der Wirkung von Thymochinon und Thymohydrochinon mit der von 2,4-Dinitrophenol auf den Stoffwechsel der Hefe (Saccharomyces aerevisiae).
Arch. f. Mikrobiol. 37, 369-378 (1960 b).

FLAIG, W. and S. MOHTADI: Chemische Eigenschaften von Extrakten aus Rottestroh und deren Einwirkung auf den Trockensubstanzertrag von Keimpflanzen. Landbauforsch. Völkenrode 15, 63-64 (1965).

FLAIG, W. and H. RIEMER: Polarographische Untersuchungen zum Verhalten von Trihydroxytoluolen bei der Reaktion mit Glycin unter oxydierenden Bedingungen. Justus Liebigs ANNALEN DER CHEMIE 746, 81-85 (1971).

FLAIG, W. and Chr. SALFELD: UV-Spektren und Konstitution von p-Benzochinonen. Liebigs Ann. Chem. 618, 117-139 (1958).

FLAIG, W. and J.Chr. SALFELD: Zwischenstufen bei der Bildung von Huminsäuren aus Phenolen. Transactions Vol. II, 7th Internat. Congr. of Soil Science, Madison, Wisc. USA, 648-656 (1960 b).

FLAIG, W. and G. SCHMID: Über den Wirkungsmechanismus stoffwechselaktiver Substanzen. In: Eigenschaften und Wirkungen der Gibberelline, Symposium der Oberhessischen Gesellschaft für Natur- und Heilkunde, Naturwissenschaft. Abt. zu Giessen vom 1.-3. Dez. 1960, S. 25-27 (Herausg. R. Knapp). Springer-Verlag Berlin-Göttingen-Heidelberg 1962.

FLAIG, W. and G. SCHMID: Comparison of the effect of chemical compounds and low doses of radiation on plant metabolism. "Effects of low doses of radiation on crop plants". Technical Reports Series No. 64, International Atomic Energy Agency, Vienna 1966, 26-38.

FLAIG, W. and H.L. SCHMIDT: Über die Einwirkung von Huminsäuren auf das Wachstum einiger Penicilliumarten. Arch. Mikrobiol. 27, 1-32 (1957).

FLAIG, W. and G. SCHOLL: Hacia el conocimiento de los acidos huminicos. XVIII. Comunicacion "Influencias de la timohidroquinona sobre la economia del agua en plantas de interes agricola. Anales de Edafologia y Agrobiologia XIX, 251-259 (1960).

FLAIG, W. and H. SÖCHTIG: Einige Grundlagen zur Frage der Krümelbildung.- Landbauforsch. 7, 80-83 (1957).

FLAIG, W. and H. SÖCHTIG: Über die Wechselwirkung von Kaolinit und Polyanionen. -Z. Pflanzenernähr., Düng., Bodenkunde 87, 1 44-57 (1959).

FLAIG, W. and H. SÖCHTIG: Einfluß organischer Stoffe auf die Aufnahme anorganischer Ionen.- Agrochimica 6, 251-264 (1962).

FLAIG, W. and H. SÖCHTIG: Organische Verbindungen als Stickstoffquelle für die Ernährung der Pflanzen. - Anales de Edafologia y Agrobiologia XXVI, 801-828 (1967).

FLAIG, W., H. BEUTELSPACHER and H. SÖCHTIG: Humus als Kationenaustauscher. Kalium-Symposium 1954, 81-107.

FLAIG, W.,H. BEUTELSPACHER and H. SÖCHTIG: Tagungsberichte Nr. 13, Probleme der Krümelstabilitätsmessung und der Krümelbildung.- Deutsche Akad. d. Landbauwiss. zu Berlin, 225-244 (1958).

FLAIG, W., F. SCHEFFER and B. KLAMROTH: Zur Kenntnis der Huminsäuren. VIII. Zur Charakterisierung der Huminsäuren des Bodens. Z. Pflanzenernähr., Düng., Bodenkunde 71, 33-37 (1955).

FLAIG, W., U. SCHOBINGER and H. DEUEL: Umwandlung von Lignin in Huminsäuren bei der Verrottung von Weizenstroh. Chem. Ber. 92, 1973-1982 (1959).

FORSYTH, W.G.C.: The characterization of the humic complexes of soil organic matter. J.Agric. Sci. 37, 132-138 (1947 b).

FREUDENBERG, K.: Forschung am Lignin, Fortschr. Chem. org. Naturstoffe 20, 41 (1962).

FREUDENBERG, K.: Entwurf eines Konstitutionsschemas für das Lignin der Fichte, Holzforsch. 18, 3-9 (1964 a).

FREUDENBERG, K.: Ergänzung des Konstitutionsschemas für das Lignin der Fichte, Holzforschung 18, 166 (1964 b).

FREUDENBERG, K. and J.M. HARKIN: Ergänzung des Konstitutionsschemas für das Lignin der Fichte. - Holzforsch. 18, 166-168 (1964).

FREUDENBERG, K.and A.C. NEISH: Constitution and biosynthesis of lignin. Springer-Verlag Berlin-Heidelberg, New York 1968.

FREUDENBERG, K., J.M. HARKIN, H. NIMZ and H. RENNER: Chem. Commun. 1965, p. 224.

FREYTAG, H.E.: Über die Zersetzung von pflanzlichem Material im Boden und einige Erfahrungen in der Messung von 14 CO_2 mit einer Gas-Zählkammer.- Thaer-Archiv 10, 685-697 (1962).

FREYTAG, H.E. and H. IGEL: Ein Bericht über den Einsatz des ^{14}C bei respirometrischen Messungen in der Humusforschung. Zbl. Bakteriol. Parasitenkunde. Infektionskrankh. Abtl. II, 117, 525-531 (1964).

FRÖMEL, W.: Über Absorptionsspektren von Huminsäuren in Lösungen. Bodenkunde und Pflanzenernähr. 6, 93 -119 (1938 a).

FRÖMEL, W.: Über UV-Absorptionsspektren von Huminsäuren in Lösungen. Bodenkunde und Pflanzenernähr. 11, 129-144 (1938 b).

FRÖMEL, W.: Über Fulvosäuren. Bodenkunde und Pflanzenernähr. 25, 345-358 (1941).

FÜHR, F.: Untersuchungen zur Aufnahme von Kohlendioxid und Strohabbauprodukten durch die Pflanzenwurzel. Dissertation Bonn 1962.

FÜHR, F. and D.SAUERBECK: Über die Aufnahme und Translokation ^{14}C-markierter organischer Rotteprodukte bei Raphanus sativus. Z. Pflanzenernähr., Düng., Bodenkunde 105, 136 (1964).

FÜHR, F. and D. SAUERBECK: Die räumliche und chemische Verteilung durch die Wurzel aufgenommener organischer Rotteprodukte bei Daucus carota. - Z. Landw. Forsch. 19., Sonderheft 153-163 (1965).

FÜHR, F. and D. SAUERBECK: The uptake of straw decomposition products by plant roots. In: "The use of isotopes in soil organic matter studies". Report of the FAO/IAEA Technical Meeting. Oxford Pergamon Press Ltd. 73-83 (1966).

FÜHR, F. and D. SAUERBECK: The uptake of colloidal organic substances by plant roots as shown by experiments with ^{14}C-labelled humus compounds. Isotopes in plant nutrition and physiology. International Atomic Energy Agency, Vienna 1967, 317-328.

FÜHR, F. and D. SAUERBECK: Decomposition of wheat straw in the field as influenced by cropping and rotation. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968, 241-250.

FUKUZUMI, R., K. MINAMI and S. SHIBAMOTO: Metabolic products from aromatic compounds by the wood-rotting fungus "Polystictus sanguineus".II. Acetoacetic acid and a-ketoglutaric acid from the medium containing benzoic acids. J. Japan. Wood. Res. Soc. 5, 76 (1959).

GADET, R. and L. SOUBLES: Le bilan de l'azote dans les sols. - Experimentation de longue durée en cases lysimétriques et utilisation de l'isotope stable de l'azote 15 N.C.R.A. cad. Agric. 1962, 145-153.

GADET, R. and L. SOUBLES: Bilan apparent et bilan réel de l'azote minéral appliqué au sol mesure en cases lysimétriques avec utilisation de l'azote 15. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press Ltd. Oxford 1966, 297-305.

GALE, E. F.: The bacterial amino acid decarboxylases. Advan. Enzymol 6, 1-32 (1946).

GRABBE, K. and K. HAIDER: Z. Pflanzenernähr., Bodenkunde (1971) in press.

GRAHAM-BRUCE, I.J.: Ausorption of disulfoton by soil J. Sci. Fd. Agric. 18, 72-77 (1967).

GROSS, S.R., R.D. GAFFORD and E.L. TATUM: The metabolism of protocatechuic acid by Neurospora. J. Bio. Chem. 210, 781-796 (1956).

GUMIŃSKA, Z. and J. SULEJ: The effect of sodium humate and sodium versenate upon sprouting of seed. Bioletyn Institutu Howowli i Aklimatyzacji. Roslin Nr. 3 29 (1964).

HAIDER, K.: Untersuchungen über den mikrobiellen Abbau von Lignin. Zbl. Bakeriol., Parasitenk., Infektionskrankh. u. Hygiene 198, 308-316 (1966).

HAIDER, K., J.P. MARTIN: The role of microorganisms in the formation of humic acids. - In: Isotopes and radiation in soil organic matter studies. Proceedings of the Symposium on the use of isotopes and radiation in soil organic matter studies. Intern. Atomic Energy Agency, Vienna 1968, 188-195.

HAIDER, K. and J.P. MARTIN: Humic acid-type phenolic polymers from aspergillus sydowi culture medium. Stachybotrys spp. cells and autoxydized phenol mixtures. - Soil Biol. Biochem. 2, 145-156 (1970).

HAIDER, K., L.R. FREDERICK and W. FLAIG: Reactions between amino acid compounds and phenols during oxydation. - Plant and Soil XXII, 49-64 (1965).

HAMENCE, H.: The effects of organic manures on the auxin content of soils and the "auxin balanca" in soils. J. Soc. Chem. Ind. (London) 67, 277-281 (1948).

HANSEN, E.H. and M. SCHNITZER: Zn-dust destillation and fusion of a soil humic and fulvic acid. Soil Sci. Soc. Amer. Proc. 33, 29-36 (1969).

HARMS, H.: Untersuchungen zur Aufnahme von phenolischen Ligninspaltstücken durch die Wurzeln von Weizenkeimpflanzen. Dissert. Justus-Liebig-Universität Giessen (1967).

HARMS, H., H.SÖCHTIG and K. HAIDER: Untersuchungen zur Aufnahme und Umwandlung C^{14}-markierter Phenole durch die Pflanze. I. Aufnahme von C^{14}-carboxylmarkierter p-Hydroxy-benzoe-, Vanillin- und Syringasäure durch die Wurzeln von Weizenkeimpflanzen und Verteilung der Aktivität über die Pflanze. Plant and Soil XXXI, No. 1 129-142 (1969 a).

HARMS, H., H. SÖCHTIG and K. HAIDER: Untersuchungen zur Aufnahme und Umwandlung C 14-markierter Phenole durch die Pflanze. II. Die Umwandlung von p-Hydroxy-benzoesäure, Vanillinsäure sowie Syringasäure nach der Aufnahme durch die Wurzeln von Weizenkeimpflanzen.- Plant and Soil XXXI, No. 2, 257-272 (1969 b).

HARMS, H., H. SÖCHTIG and K. HAIDER: Aufnahme und Umwandlung von unterschiedlichen Stellungen C^{14}-markierter Phenolcarbonsäuren in Weizenkeimpflanzen.-Z. Pflanzenphysiologie 64, Heft 5, S. 437-445 (1971).

HAUCK, R.D.: N-Isotope distribution in nitrogen gas evolved from soil during denitrification. Possible application to N-transformation studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press Oxford 1966 , 447-456.

HAUCK, R.D. and D.R. BOULDIN: Distribution of isotopic nitrogen in nitrogen gas during denitrification. - Nature 191, 871 (1961).

HAUCK, R.D. and S. W. MELSTED: Some aspects of the problem of evaluating denitrification in soils.- Soil Sci. Amer. Proc. 20, 361 (1956).

HAUCK, R.D., S.W. MELSTED and P.E. YANKWICH: Use of N-isotope distribution in nitrogen gas in the study of denitrification. - Soil Sci. 86, 287 (1958).

HAYAISHI, O., M. KATAGIRI and S. ROTHBERG: Mechanism of the pyrocatecase reaction. J. Amer. Chem. Soc. 77, 5450-5451 (1955).

HENDE, A. van den: L'incorporation d'azote dans la matière organique du sol; Possibilités de l'utilisation de l'usage d'azote lourd N-15. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966, 319-327.

HENDERSON, M.E.K.: Release of aromatic compounds from birch and spruce sawdusts during decomposition by white-rot fungi. Nature (London) 175, 634-635 (1955).

HILLMANN, W.S. and A.W. GALSTON: Inductive control of indoleacetic acid oxidase activity by red and near infrared light. - Plant Physiol. 32, 129-135 (1957).

HOBSON, R.P. and H.J. PAGE: Studies on the carbon and nitrogen cycles in the soil. VII. The nature of the organic nitrogen compounds of the soil: "Humic" nitrogen. J. Agric. Sci. 22, 497-515 (1932).

HOCK, A.: Beziehungen zwischen Konzentration und Farbwerten von Huminsäurelösungen. Z. Bodenkunde und Pflanzenernähr., 7, 99-117 (1938 a).

HOCK, A.: Grundsätzliches bei Farbmessungen in Huminlösungen. Z. Bodenkunde und Pflanzenernähr., 7, 279-302 (1938 b).

HOLLECK, L. and D. BECHER: Untersuchungen über den Einfluß der Leitsalzionen auf die polarographische Reduktion aromatischer Nitroverbindungen in Acetonnitril und Dimethylformamid. J. electroanal. Chem. 4, 321-331 (1962).

HOLMBERG, B.: Thioglykolsäure als Ligninreagenz. Ing. Ventenskaps Akad. Handl. No. 131, 5-15 (1934).

HOLMBERG, B.: Hypobromite lignin. - Ber. 75, 1760-1764 (1942).

HORNER, L. and W. DÜRCKHEIMER: Zur Kenntnis der o-Chinone. XII. o-Chinone aus Brenzcatechin-Derivaten. - Z. Naturforsch. 14B, 741 (1959).

HÜSER, R.: Probleme zur biologischen Luftstickstoffbindung in Waldböden. Z. Pflanzenernähr., Düng., Bodenkunde 103, 220-226 (1963).

HÜSER, R.: Experiences with the ^{15}N tracer technique to estimate the microbial fixation of elementary nitrogen in the organic matter of forest soils. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966, 457-469.

ISHIKAWA, H., W.J. SCHUBERT and F.F. NORD: Investigations on lignins and lignification. XXVII. The enzymic degradation of softwood lignin by white-rot fungi. - Arch. Biochem. Biophys. 100, 131-139 (1963 a).

ISHIKAWA, H., W.J. SCHUBERT and F. F. NORD: Investigations on lignins and lignification. XXVIII. The degradation by Polyporus versicolor and fomes fomentarius of aromatic compounds structurally related to softwood lignin.- Arch. Biochem. Biophys. 100, 140-149 (1963 b).

ISHIKAWA, H., W.J. SCHUBERT and F.F. NORD: Investigations on lignins and lignification. XXX. Enzymic degradation of guajacolglycerol and related compounds by white-rot fungi. Biochem. Z. 338, 153-163 (1963 c).

JACQUIN, F.: Chromatographic study of various types of humic acids. C. R. hebd. Séances Acad. Sci. 250, 1892-1893 (1960).

JACQUIN, F.: Contribution à l'étude des processus de formation et d'évolution des divers composés humiques. Thèse Docteur des Sciences. Bull. ENSAN V, 1-156 (1963).

JANSSON, S.L.: Tracer studies on nitrogen transformations in soil.- Ann. Roy. Agr. Coll. Sweden 24, 101 (1958).

JANSSON, S.L.: Balance sheet and residual effects of fertilizer nitrogen in a 6-year study with N 15.- Soil Sci. 95, 31 (1963).

JANSSON, S.L.: Nitrogen transformation in soil organic matter. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting.- Pergamon Press. Ltd. Oxford 1966 a, 283-296.

JANSSON, S.L.: Experimental techniques with isotope-N 15. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting.- Pergamon Press. Ltd. Oxford 1966 b, 415-422.

JANSSON, S.L. and J. PERSON: Co-Ordination of humus chemistry and soil organic matter biology by isotope techniques. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968, 111-123.

JENKINSON, D.S. and J. TINSLEY: A comparison of the ligno-protein isolated from a mineral soil and from a straw compost. Sci. Proc. Roy Dublin Soc. A 1, 141-147. (1960)

JENKINSON, D.S.: The turnover of organic matter in soil. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966 a, 187-197.

JENKINSON, D. S.: The priming action. In: the use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press, Ltd. Oxford 1966 b, 199-208.

JENKINSON, D.S.: Experimental techniques for using carbon-14 in studies of soil organic matter. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966 c, 365-369.

JENKINSON, D.S.: Studies on the decomposition of plant materials in soil I-III. J. Soil Sci. 16, 104-115 (1965; 17, 280-302 (1966 b); 19, 25-39 (1968).

JONES, E.J.jr.: The ultraviolet absorption spectra of complex hydroxyaromatic compounds and derivatives, with particular reference to lignin. Tappi 32, 311-315 (1949).

KAILA, A.: Humification of straw at various temperatures. Acta agral. fenn. Helsinki 78, 3-32 (1952).

KASATOCHKIN, V.I. and O.I. ZILBERBRAND: X-ray and infrared spectroscopy applied to the study of the structure of humic substances. Pochvovedenie No. 5, 80-85 (1956).

KASATOCHKIN, V.I., M.M. KONONOVA and G.I. ZILBERBRAND: Infrarotspektren von Huminsäuren des Bodens. Dokl. Akad. Nauk 119, 785-788 (1958). (russ.).

KASTORI, R., H. HARMS, H. SÖCHTIG and K. HAIDER: Untersuchungen zur Aufnahme und Umwandlung C^{14}-markierter Phenole durch die Pflanze. III. Die Aufnahme, der Transport und die Umwandlung von C^{14}-markiertem Thymohydrochinon durch Weizenkeimpflanzen. Plant and Soil 33, 597-611 (1970).

KAUR-SAWHNEY, R., M. BARA and A. GALSTON: Analysis of labelling patterns in soluble RNA preparations from green pea stem sections supplied with ^{14}C-carboxyl-labelled indoleacetic acid.- Annals of the New York Academy of Sciences 144, Art. I. 63-67 (1967).

KILBY, B.A.: The bacterial oxidation of phenol to ß-ketoadipic acid. Biochem. J. 43, V (1948).

KILBY, B.A.: The formation of ß-ketoadipic acid by bacterial fission of aromatic rings. Biochem. J. 49, 671-674 (1951).

KLEIST, H. and D. MÜCKE: Stabile freie Radikale in Huminsäuren. Experientia 22, 136-137 (1966).

KOLENBRANDER, G.J.: Die Verluste an organischer Substanz im Stalldünger. Z. Pflanzenernähr., Düng., Bodenkunde 69, 125-134 (1955).

KONONOVA, M.M.: Humus der Hauptbodentypen der UdSSR, seine Natur und Bildungsweisen. Rapports VI. Congr. Internat. de la Science du Sol, Chemie du Sol, S. 5, Moskau (1956) (russ.).

KONONOVA, M.M.: Soil organic matter. Its nature, its role in soil formation and in soil fertility. Pergamon Press Oxford, London, New York, Paris (1961).

KONONOVA, M.M.: Gedanken zur Nomenklatur der im Boden vorhandenen organischen Stoffe. 8th Internat. Congr. of Soil Sci. Transaction, Vol. III, Bucharest-Romania, 401-404 (1964). Discussions regarding the terminology in the field of humus, 405-413.

KONONOVA, M.M.: Soil organic matter, its nature, its role in soil formation and in soil fertility. Pergamon Press, Oxford, London, Edinburgh, New York, Toronto, Sydney, Paris, Braunschweig (1966).

KONONOVA, M.M. and N.P. BELCHIKOVA: Rapid methods of determining the humus composition of mineral soils. Pochvovedenie (10), 75 (1961).

KRATZL, K. and P. CLAUS: Zur quantitativen Bestimmung der monomeren Äthanolysenprodukte aus dem Lignin monocotyler und dicotyler Angiospermen. Monatsh. Chem. 93, 219-229 (1962).

KRATZL, K. and E. RISNYOVSZKY: Zum Mechanismus der alkalischen Hydrolyse der Ligninsulfosäure. Chimie et Biochimie de la Lignine de la Cellulose et des Hémicelluloses. Actes du Symposium Internationanl de Grenoble, Juillet (1964),

KRATZL, K., G. BILLEK, E. KLEIN, K. BUTSCHER: Über das Verhalten von markiertem Coniferin in der verholzenden Pflanze. Monatsh. f. Chemie 88, 721-734 (1957).

KRATZL, K., E. RISNYOVSZKY, P. CLAUS and E. WITTMANN: Über den Mechanismus der alkalischen Hydrolyse von Guajacylglyzerin-β-guajacyläther-α-sulfosäure. I. Mitteilung, Modellversuche zur Fragmentierung der Ligninsulfosäure in alkalischem Medium. Holzforschung 20, 21-27 (1966).

KRATZL, K., W. SCHAFER, P. CLAUS J. GRATZL and P. SCHILLING, Zur Oxydation von ^{14}C-markierten Phenolen (Ligninmodellen) Mh. Chemie 98, 891-904 (1967).

KUMADA, K.: Studies on the colour of humic acids. Part. I. On the concepts of humic substances and humification. Soil Sci. and Plant Nutr, 11, 11-16 (1965).

KUMADA, K. and A. AIZAWA: The infra-red spectra of humic acids. Soil and Plant Food 3, 1 2-159 (1958).

KUMADA, K. and K. AIZAWA: The infra-red absorption spectra of soil components. Soil and Plant Food 4, 101-188 (1959).

KUMADA, K. and A. SUZUKI: Isolation of anthraquinone from humus. Nature (London) 191, 415-416 (1961).

KUO, L.H. and A.V. BARTHOLOMEW: On the genesis of organic nitrogen in decomposed plant residue. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press Ltd. Oxford 1966, 329-335.

KÜSTER, E.: Umwandlung von Mikroorganismen-Farbstoffen in Huminstoffe. Z. Pflanzenernähr., Düng., Bodenkunde 57, 51-57 (1952).

KÜSTER, E.: Beiträge zur Physiologie der Streptomyceten. VI. Congrès International de la Sci. du Sol. Paris 3, 67-72 (1956).

KYUMA, K.: A fractional precipitation technique applied to soil humic substances. Soil Sci. Plant Nutr. 10, 33-35 (1964).

LANTZ, R. and H. MICHEL. Action de l'ammoniaque en des amines primaires sur le benzène substitué en 1,3 et par des groupes amino ou hydroxyles, non substitués ou substitués. Bull. Soc. Chim. France 12, 2402-2408 (1961).

LAATSCH, W., L. HOOPS and O. BIENECK: Über Huminsäuren des Pilzes Spicaria elegans. Z. Pflanzenernähr., Düng., Bodenkunde 58, 258-268 (1952).

LAROCHE, J. and R. COMBELLES: Préparation et micro-analyse de composés marqués à l'azote 15. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966, 423-428.

LEMAIRE, F.: Influence of the organic matter on the phosphate nutrition of plants. Vortrag anläßlich des Symposiums Humus et Planta in Prag vom 18.-24. September 1967.

LEVESQUE, M. and M. SCHNITZER: Organo-metallic interactions in soils: 6. Preparation and properties of fulvic acid-metal phosphates. Soil Sci. 103, 183-190 (1967 b).

LIM, S.: Beiträge zur Aufklärung der Zusammenhänge zwischen dem mikrobiellen Abbau des Lignins und der Bildung von Humusstoffen. Dissertation der Rheinischen Friedrich Wilhelms-Universität Bonn (1965).

LITTLE, E.C.S.: An apparatus for the determination of carbon-14 in organic matter. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966, 371-374.

MacDONALDS, D.L., R.Y. STANIER, J.L. INGRAHAM: The enzymatic formation of ß-carboxymucconic acid. J. Biol.Chem. 210, 809-820 (1954).

MAEDER, H.: Chemische und pflanzenphysiologische Untersuchungen mit Rottestroh. Diss. Justus Liebig Universität Giessen (1960).

MARTIN, A.E. and R. REEVE: The extraction of organic matter from podzolic B-horizons with organic reagents. Chem. and Ind. 1955, 356.

MARTIN, A.E. and R. REEVE: Chemical studies on podzolic illuvial horizons. I. The extraction of organic matter by organic chelating agents. J. Soil Sci. 8, 268-270 (1957 a).

MARTIN, A.E. and R. REEVE: Chemical studies on podzolic illuvial horizons. II. The use of acetylacetone as extractant of translocated organic matter. J. Soil Sci. 8, 279-286 (1957 b).

MARTIN, A.E., P. DUBACH, N.C. MEHTA and H. DEUEL: Bestimmung der funktionellen Gruppen von Huminstoffen. - Z. Pflanzenernähr., Düng., Bodenkunde 103, 29-39 (1963).

MARTIN, J.P. and K. HAIDER: Phenolic polymers of Stachybotrys atra, Stachybotrys chartarum und Epicoccum nigrum in relation to humic acid-formation. Soil Sci. 107, 260-270 (1969).

MARTIN, J.P. and K. HAIDER: Microbial activity in relation to soil humus formation. Soil Science 111, No. 1, 54-63 (1971).

MARTIN, J.P., S.J. RICHARDS and K. HAIDER: Properties and decomposition and binding action in soil of humic acid synthesized by Epicoccum nigrum. Soil Sci. Soc. Amer. Proc. 31, 657-662 (1967).

MASON, H.S.: Chemistry of melanin. III. Mechanism of oxidation of 3,4-dihydroxyphenylalanine by tyrosinase. J. Biol. Chem. 172, 83-99 (1948).

MASON, H.S.: Mechanisms of oxygen metabolism. Advan. Enzymol. 19, 79-231 (1957).

MASON, H.S., W.L. FOWLKS and E.W. PETERSON: Oxygen transfer and electron transport by the phenolase complex. J. Amer. Chem. Soc. 77, 2914-2915 (1955).

MUSSO, H., U.V. GIZYCKI, H. KRÄMER and H. DÖPP: Über Orceinfarbstoffe. XXIV. Über den Autoxydationsmechanismus bei Resorcinderivaten. Chem. Ber. 98, 3952-3963 (1965).

MUSSO, H., U. GIZYCKI, U.I. ZAHORSZKY and D. BORMANN: Die Bildung von Hydroxy-Chinonen durch Addition von Phenolen an Chinone. Liebigs Ann. Chem. 676, 10 -20 (1964).

NEHRING, K. and R. SCHIEMANN: Untersuchungen zum Humusproblem. I. Mitt. Beiträge zur Kenntnis der Vorgänge bei der Rotte von Stallmist und Komposten sowie zur Kenntnis der Huminsäuren. Z. Pflanzenernähr., Düng., Bodenkunde 57, 97-113 (1952 a).

NEHRING, K. and R. SCHIEMANN: Untersuchungen zum Humusproblem. I. Mitt. Beiträge zur Kenntnis der Vorgänge bei der Rotte von Stallmist und Komposten sowie zur Kenntnis der Huminsäuren. 2. Teil Beiträge zur Kenntnis der Huminsäuren.-Z. Pflanzenernähr., Düng., Bodenkunde 57, 193-215 (1952 b).

NEHRING, K.: Untersuchungen an aus verschiedenen Bodentypen isolierten Huminsäuren. Z. Pflanzenernähr., Düng., Bodenkunde 69, 71-86 (1955).

NICOLAUS, R.A.: Biogenese der Melanine. Conf. VII Corso chim. Acad. naz. Lincei, Milano (1962).

NITSCH, J.P. and C. NITSCH: Phenolic compounds and plant growth. Ann.Physiol. végét. 4, 211-225 (1962).

NORMAN, A.G. and S.H. JENKINS: The determination of lignin. I. Errors introduced by the presence of certain carbohydrates. Biochem. J. 28, 2147-2159 (1934 a).

NORMAN, A.G. and S.H. JENKINS: The determination of lignin. II. Errors introduced by the presence of proteins. Biochem J. 28, 2160-2168 (1934 b).

NORMAN, A.G. and C.H. WERKMAN: The use of nitrogen isotope N 15 in determining nitrogen recovery from plant material decomposing in soil.- J. Amer. Soc. Agr. 35, 1023 (1943).

OBERLÄNDER, H.E. and K. ROTH: Transformation of ^{14}C-labelled plant material in soils under field condition. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Wien 1968, 251-264.

OGNER, G. and M. SCHNITZER: Chemistry of Fulvic Acid, a Soil Humic Fraction, and its Relation to Lignin. Canad. Journ. of Chem. 49, 1053-1063 (1971).

ORLOV , D.S. and N.M. GRINDEL: Spectrophotometric determination of the humus content in soil. Pochvovedenie Nr. 1, 112-122 (1967)(russ.)

ORLOV, D.S., O.N. ROZANOVA and S.G. MATYUKHINA: Infrared absorption spectra of humic acids. Pochvovedenie Nr. 1, 17-25 (1962) (russ.).

OSTWALD, W.: Kolloid Z. 7, 255 (1928).

OTTEY, L., E.L. TATUM: Protocatechuic acid oxidase of Neurospora. J. Biol. Chem. 223, 307-311 (1956).

OWENS, L.S.: Nitrogen movement and transformations in soils as evaluated by a lysimeter study utilizing isotopic nitrogen.- Soil Sci. Soc. Amer. Proc. 24, 372-376 (1960).

OXFORD, A.E.: Anti-bacterial substances from molds. V. The bateriostatic powers of the methyl ethers of fumigatin and spinulosin and other hydroxy-, methoxy- and hydroxy-methoxy-derivatives of toluquinone and benzoquinone. - J. Soc. Chem. and Ind. 61, 189-192 (1942 a).

OXFORD, A.E.: The chemical reactions occurring between certain substances which inhibit bacterial growth and constituents of bacteriological media. Biochem. J. 36, 438-444 (1942 b).

OXFORD, A.E. and H. RAISTRICK: Antibacterial substances from molds. IV. Spinulosin and Fumigatin, metabolic products of Penicillium spinulosum Thom and Aspergillus fumigatus Fresenius.- J. Soc. Chem. and Ind. 61, 128-129 (1942).

PEOVER, M.E. and J.D. DAVIES: Einfluß der Ionenassoziation auf die Polarographie der Chinone in Dimethylformamid.- J. electroanalyt. Chem. 6, 46-53 (1963).

PHILLIPS, M.: The chemistry of lignin. Chem. Rev. 14, 103 - 170 (1934).

PIRET, E.L., G. WHITE, H.C. WALTHER jr. and A.J. MADDEN jr.: Some physicochemical properties of peat humic acids. Sci. Proc. Roy. Dubl. Soc. A 1, 4, 69-79 (1960).

PLOETZ, Th.: Beiträge zur Ligninbestimmung mit starker Schwefelsäure. Cellulosechemie 18, 49-57 (1940).

PLOETZ, Th.: Polymere Chinone als Huminsäuremodelle. - Z. Pflanzenernähr., Düng., Bodenkunde 69, 50-58 (1955).

PLOTHO, O.v.: Die Humusbildung der Mikroorganismen. Z. Pflanzenernähr., Düng., Bodenkunde 51, 212 (1950).

PLOTHO, O.v.: Weitere Untersuchungen zur Humusbildung der Mikroorganismen. Z. Pflanzenernähr., Düng., Bodenkunde 55, 151-169 (1951).

POLICARD, A. and M. BESSIS: Sur un mode d'incorporation des macromolécules par la cellule, visible en microscope électronique: la rhophéocytose. C.R. Acad. Sci. 246, 3194-3197 (1958).

POSNER, A.M.: The humic acid extracted by various reagents from a soil. Part. I. Yield, inorganic components, and titration curves. J. Soil Sci. 17, 65-78 (1966).

POSNER, A.M., B.K.G. THENG and J.R.H. WAKE: The extraction of soil organic matter in relation to humification. 9th Internat. Congr. Soil Sci., Adelaide, Australia, Transaction III, 153-162 (1968).

PRAT, S. and F. POSPISIL: Humic acids with C^{14}. Biol Plantarum (Praha) 1, 71 (1959).

PRAT, S.: Distribution of the humic substance fractions in plants. Biol. Plantarum (Praha) 2, 308 (1960).

PRAT, S.: On permeability and the effect of humic substances on plant cells. 5th Int. Congr. Biochem. Moskau (1961).

PRAT, S.: Das Problem des Eindringens und der Einwirkung von Humusstoffen auf die Pflanzenzellen.-Intern. Congress of Peat, Leningrad (1963).

PRIDHAM, J.B. and M. SALTMARSH: The biosynthesis of phenolic glucosides in plants. Biochem. J. 87, 218-224 (1963).

RAPER, H.S.: Die Einwirkung von Tyrosinase auf Tyrosin. Fermentforschung 9, 206 (1927).

RAPER, H.S.: The aerobic oxidases.- Physicl.Rev. 8, S. 245-248 (1928).

REINHARDT, G.: Untersuchungen über die Einwirkung von Lignin und dessen Abbauprodukten auf das Wachstum und den Stoffwechsel von Pflanzen. Dissertation Universität Giessen 1961.

RIEMER, H.: Polarographische Untersuchungen über Beziehungen zwischen Struktur und Reaktivität bei Benzochinonen. Dissertation TU Braunschweig 1970 .

RITTER, G.J., R.M. SEBORG and R.L. MITCHELL: Factors affecting quantitative determination of lignin by 72 percent sulfuric acid method. Ind. Eng. Chem. Analyt. Edit. 4, 202 (1932).

ROCHUS, W.: Die unterschiedliche physiologische Wirkung verschiedener Huminstoffqualitäten.- Vortrag anläßlich der Tagung der Deutschen Bodenkundlichen Gesellschaft in Mainz vom 4.-9.9. 1967.

RUHEMANN, H.: Untersuchungen zur Auftrennung physiologisch aktiver Stoffe aus Lignin unter Anwendung von Radiokohlenstoff. Dissertation Th Braunschweig 1964.

RYPACEK, V.: Der Einfluß isolierter Humusstoffe auf einige physiologische Äußerungen der Pflanzenzelle.- Studies about Humus, Symposium Humus and Plant, Praha and Brno. 28. IX. - 6.X.1961, 235-243 (1962).

SAALBACH, E.: Zur Kenntnis der Huminsäuren, XIV. Mitt. Einfluß von Modellsubstanzen von Humusstoffen auf den Stoffwechsel von Getreide. Landw. Forsch. 9. Sonderheft 95-100 (1957).

SAALBACH, E.: Beitrag der Grundlagenforschung zum Problem der Strohdüngung. Landwirtsch. Forsch. 8, 83-84 (1958).

SALFELD, J. Chr.: Zum Reaktionsmechanismus der Purpurogallinbildung. Angew. Chem 69, 723-724 (1957).

SALFELD, J. Chr.: Fraktionierung eines Huminstoffpräparates mit wasserhaltigen Lösungsmitteln. Landbauforsch. Völkenrode 14, 131-136 (1964).

SALFELD, J. Chr.: Die Charakterisierung von Huminstoffen durch Differenzen-Spektrogramme. Mitt. Dtsch. Bodenkundl. Ges. 4, 289-290 (1965).

SALFELD, J. Chr.: Untersuchungen zur Klassifizierung der organischen Bodensubstanz. Mitt. Dtsch. Bodenkundl. Ges. 8, 133-135 (1968).

SALFELD, J. Chr.: Optical measurements on humic systems. Symposium Humus et Planta V, Prag (1971), 257-266).

SALFELD, J. Chr. and E. BAUME: Über die Oxydation von Pyrogallol und Pyrogallolderivaten. IV. Die Konstitution der Purpurogallincarbonsäure -(9). Chem. Ber. 97, 307-311 (1964).

SAUERBECK, D.: Zur Markierung von Pflanzen mit ^{14}C. Atompraxis 6, 221-225 (1960).

SAUERBECK, D.: Stability of recently formed humus compounds in soil. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968 b, 57-66.

SAUERBECK, D.: Die Umsetzung markierter organischer Substanzen im Boden in Abhängigkeit von Art, Menge und Rottegrad. Landwirtsch. Forsch. 21, 91-102 (1968 a).

SAUERBECK, D.: Comparison of plant material and animal manure in relation to their decomposition in soil. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968 c, 219-225.

SAUERBECK, D. and F. FÜHR: Experiences on labelling whole plants with carbon-14. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966, 391-399.

SAUERBECK, D. and F. FÜHR: Alkali extraction and fractionation of labelled plant material before and after decomposition - a contribution to the technical problems in humification studies. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agenca, Vienna 1968, 3-11.

SAUERBECK, D. and F. FÜHR: Die Umsetzung von markiertem Pflanzenmaterial im Boden unter Feldbedingungen. Mitt. Deutsche Bodenkundl. Gesellsch. 10, 174-177 (1970).

SAUERLANDT, W. and O. GRAFF: Die Strohdecke auf dem Ackerboden. - Landbauforsch. Völkenrode 9, 57-60 (1959).

SCHANEL, L.: Laccase activity and decomposition of lignin by white-rot fungi. CSc. Thesis, Fac. Nat. Sci. UJEP Brno, (1962) (Czech.).

SCHARPENSEEL, H.W.: Herstellung und Reinigung von tritiummarkierten Grau- und Braunhuminsäurepräparaten sowie von Tritium-Purpurogallin. - Z. Pflanzenernähr., Düng. und Bodenkunde 91, 131-146 (1960 a).

SCHARPENSEEL, H.W.: Untersuchungen mit radioaktiv markierten Huminsäuren und Vorstufen. 2. Teil.- Z. Pflanzenernähr., Düng. und Bodenkunde 91, 193-202 (1960 b).

SCHARPENSEEL, H.W.: Zur Herstellung von allseitig C-14-markiertem Pflanzen- und Huminsäurematerial.- Landw. Forschung 14, 42-48 (1961).

SCHARPENSEEL, H.W.: Labelling of soil organic matter. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966 a, 351-364.

SCHARPENSEEL, H.W.: Results and problems of radiocolumn chromatographic work with humic acids. In : The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966 b, 375-390.

SCHARPENSEEL, H.W.: Experimental techniques with tritium including the production of labelling materials apparatus required and costs involved. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966 c, 471-481.

SCHARPENSEEL, H.W. and W. ALBERSMEYER: Infrarotspektroskopische Untersuchungen an Huminsäuren, Huminsäureaufschlüssen und phenolisch-chinoiden Vergleichssubstanzen. Z. Pflanzenernähr., Düng., Bodenkunde 88, 3, 203-211 (1960).

SCHARPENSEEL, H.W. and H. BECKMANN: Untersuchung zur Kohlendioxid-Entbindung des Bodens. II. Teil. Spezielle Studien unter Verwendung radioaktiver Tracer.- Z. Pflanzenernähr., Düng., Bodenkunde 104, 110-119 (1964).

SCHARPENSEEL, H.W. and R. KRAUSSE: Aminosäureuntersuchungen an verschiedenen organischen Sedimenten, besonders Grau- und Braunhuminsäurefraktionen verschiedener Bodentypen (einschließlich C^{14}-markierter Huminsäuren). Z. Pflanzenernähr., Düng., Bodenkunde 96, 11-34 (1962).

SCHARPENSEEL, H.W. and K.H. MENKE: Radiochromatographie mit schwachen ß-Strahlen. 1. Mitt. Z. analyt. Chem. 180, 81-92 (1961 a).

SCHARPENSEEL, H.W. and K.H. MENKE: Radiochromatographie mit schwachen ß-Strahlen (^{35}S, ^{14}C, ^{3}H). 2. Mitt. Radiosäulenchromatographie mit Hilfe des Flüssigkeits- und Scintillations-Spektrometers. Z. analyt. Chem. 182, 1-10 (1961 b).

SCHARPENSEEL, H.W., E. KÖNIG and E. MENTHE: Infrarot- und Differential-thermo-Analyse an Huminsäureproben aus verschiedenen Bodentypen, aus Wurmkot und Streptomyceten. Z. Pflanzenernähr., Düng., Bodenkunde 106, 134-150 (1964).

SCHEFFER, F. and R. KICKUTH: Chemische Abbauversuche an einer natürlichen Huminsäure. I. Z. Pflanzenernähr., Düng., Bodenkunde 94, 180-188 (1961 a).

SCHEFFER, F. and R. KICKUTH: Chemische Abbauversuche an einer natürlichen Huminsäure. II. Z. Pflanzenernähr., Düng., Bodenkunde 94, 189-198 (1961 b).

SCHEFFER, F. and B. ULRICH: Lehrbuch der Agrikulturchemie und Bodenkunde. III. Teil. Humus und Humusdüngung 1, Enke Stuttgart, pp. 266 (1960).

SCHEFFER, F., O.v. Plotho and E. WELTE: Untersuchungen über die Bildung von Humusstoffen durch Actinomyceten. - Landwirtsch. Forsch. 1, 81-92 (1950).

SCHEFFER, F., W. ZIECHMANN and H. SCHLÜTER: Über die Sedimentation von Huminsäuren in der Ultrazentrifuge. Kolloid Z. 160, 1-7 (1958).

SCHLICHTING, W.: Die Beeinflussung der Nährstoffaufnahme durch Huminstoffe, Mitt. d. Dtsch. Bodenkundlichen Gesellsch. 8, 165-167 (1968).

SCHMID, G.: Bericht über die Tätigkeit der Forschungsanstalt für Landwirtschaft, Braunschweig-Völkenrode, 12-13, (1962), 13-14 (1963), 15 (1964).

SCHMID, G. and W. FLAIG: Pflanzenstoffwechsel und Wirkstoffe. Landbauforsch. 12, 51-56 (1962).

SCHNITZER, M.: The application of infrared spectroscopy to investigations on soil humic compounds. Canad. Spectroscopy 10, No. 5 121-127 (1965).

SCHNITZER, M. and J.G. DESJARDINS: Molecular and equivalent weights of the organic matter of a podzol. Soil Sci. Soc. Amer., Proc. 26, 362-365 (1962).

SCHNITZER, M. and J.G. DESJARDINS: Carboxyl and phenolic hydroxyl groups in some organic soils and their relation to the degree of humification. Can. J. Soil Sci. 45, 257-264 (1965).

SCHNITZER, M. and I. HOFFMAN: Thermogravimetry of soil humic compounds. Geochim. Cosmochim. Acta 29, 359-370 (1965).

SCHNITZER, M. and S.I.M. SKINNER: Organo-metallic interactions in soils: 1. Reactions between a number of metal ions and the organic matter of a podzol E_h-horizon. Soil Sci. 96, 86-93 (1963 a).

SCHNITZER, M. and S.I.M. SKINNER: Organo-metallic interactions in soils. 2. Reactions between different forms of iron and aluminium and the organic matter of a podzol B_h-horizon. Soil Sci. 96, 181-186 (1963 b).

SCHNITZER, M. and S.I.M. SKINNER: Organo-metallic interactions in soils: 3. Properties of iron- and aluminium-organic matter complexes, prepared in the laboratory and extracted from a soil. Soil Sci. 98, 197-203 (1964).

SCHNITZER, M. and S.I.M. SKINNER: Organo-metallic interactions in soils. 4. Carboxyl and hydroxyl groups in organic matter and metal retention. Soil Sci. 99, 278-284 (1965 a).

SCHNITZER, M. and S.I.M. SKINNER: The carboxyl group in a soil organic matter preparation. Soil Sci. Soc. Amer., Proc. 29, 400-405 (1965 b).

SCHNITZER, M., D.A. SHEARER and J.R. WRIGHT: A study in the infrared of high molecular weight organic matter extracted by various reagents from a podzolic horizon. Soil Sci. 87, 252-257 (1959).

SCHNITZER, M. J.R. WRIGHT and J.G. DESJARDINS: A comparison of the effectiveness of various extractants for organic matter from two horizons of a podzol profile. Can. J. Soil Sci. 38, 49-53 (1958).

SCHOBINGER, U.: Chemische Untersuchungen über die Umwandlung von Weizenstrohlignin im Laufe der Verrottung.- Dissertation, ETH Zürich (1958).

SCHREINER, O. and E. SHOREY: Chemical nature of soil organic matter. U.S. Dept. Agric. Bureau of Soils Bull. 74, 5-48 (1910).

SEIFERT, K.: Die chemische Veränderung der Holzzellwand-Komponenten unter dem Einfluß pflanzlicher und tierischer Schädlinge. II. Abbau von Pinus sylvestris L. durch Coniophora cerebella Pers. Holzforschung 16, 102-113 (1962).

SHMUK, A.A.: The chemistry of soil organic matter. Trudy kuban. s.-kh. Inst. 1, 2 (1924), (russ.).

SHMUK, A.A.: The chemical nature of soil organic matter. Byull. Pochvoveda 5-7 (1930), (russ.).

SHOREY, E.: Some organic soil constituents. U.S. Dept. Agric. Bureau of Soils Bull. 88, 5-41 (1913).

SIMONART, P. and J. MAYAUDON: Étude de la décomposition de la matière organique dans le sol au moyen de carbone radioactif. I. Cinétique de l'oxydation en CO_2 de divers substrats radioactifs. Plant and Soil 9, 367-375 (1958 a).

SIMONART, P. and J. MAYAUDON: Étude de la décomposition de la matière organique dans le sol au moyen de carbone radioactif. II. Décomposition du glucose radioactif dans le sol. B Répartition de la radioactivité dans l'α-humus. - Plant and Soil 9, 381-384 (1958 b).

SIMONART, P. and J. MAYAUDON: Étude des transformations de la matière organique du sol au moyen du carbone-14. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966, 245-258.

SIMONART, P., J. MAYAUDON and L. BATISTIC: Étude de la décomposition de la matière organique dans le sol au moyen de carbone radioactif. IV. Décomposition des pigments foliaires. Plant and Soil 11, 176-180 (1959).

SLYKE, D.D. van, D.A. MacFADYEN and P. HAMILTON: Determination of free amino acids by titration of the carbon dioxide formed in the reaction with ninhydrin. J. Biol. Chem. 141, 671-680 (1941).

SMIDOVA, M.: Über den Einfluß von Na-Humat auf die Oxydations-Reduktions-Prozesse in den Wurzeln von Winterweizenpflanzen.- Studies about Humus. Symp. Humus and Plant, Praha and Brn. 28.9. - 6.10. 1961.

SMITH, J.H.: Some inter-relationships between decomposition of various plant residues and loss of soil organic matter as measured with carbon-14 labelling. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966, 223-233.

SMITH, F.B., W.H. STEVENSON and P. E. BROWN: The production of artificial manures. Agr. Exp. Sta. Res. Bul. 126, (1930).

SNEATH, P.H.A.: The application of computers to taxonomy. J. Gen. Microbiol. 17. 201-226 (1957).

SÖCHTIG, H.: Zur Erfassung der bei der Strohrotte gebildeten Ligninabbauprodukte: Kennzeichnung durch UV-Spektren. Landbauforsch. Völkenrode 11, 13-15 (1961 a).

SÖCHTIG, H.: Inwieweit können Strohrotteprodukte das Pflanzenwachstum beeinflussen? Über Veränderungen von Ligninabbauprodukten. Landbauforsch. Völkenrode 11, 16-18 (1961 b).

SÖCHTIG, H.: Beeinflussung des Stoffwechsels der Pflanzen durch Humus und seine Bestandteile und die Auswirkung auf Wachstum und Ertrag. - Landbauforschung Völkenrode 14, 9-16 (1964).

SÖCHTIG, H.: Auftrennung von Huminstoffen durch Gelfiltration. Mitt. Dt. Bodenk. Ges. 4, 297-300 (1965).

SÖCHTIG, H.: Zur Fraktionierung von Humusstoffen durch Gelfiltration. 1. Mitt. Das Verhalten von anorganischen Ionen aus der Asche und den Lösungen von Humusstoffen auf Sephadex-Gelen. Landbauforsch. Völkenrode 16, 25-30 (1966).

SÖCHTIG, H.: Ein Pflanzentest zur Feststellung der Wirkung stoffwechselaktiver Substanzen, Methodik und Erfahrungen. Deutsch-Polnisches Torf-Kolloquium DDR-Polen in Rostock 1967.

SÖCHTIG, H.: Zur Charakterisierung von Humusstoffen durch Gelfiltration. Dtsch. Bodenkundl. Ges. 8, 137-140 (1968).

SÖCHTIG, H.: Über den Einfluß von N-Lignin auf die Nitrifizierung im Boden sowie den Ertrag und den Nitratgehalt der Pflanzen. - Qual. Plant. Mater. Veg. XX, 1-2, 137-150 (1970).

SÖCHTIG, H. and H. HARMS: Über den Einfluß von Torf auf Keimung und Anfangswachstum von Pflanzen.-Landw. Forsch. 26/II (1971).

SÖCHTIG, H. and J.Chr. SALFELD: Characterization of humic systems in a black earth-Griserde-morphosequence in the area of Hildesheim. Symposium Humus et Planta V, Prag 1971, 247-256.

SÖCHTIG, H., H. HARMS and K. HAIDER: Uptake and transformation of ^{14}C-labelled phenolic acids by wheat seedling. In: Isotopes and radiation in soil organic matter studies. Proceedings of the Symposium on the use of isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968, S. 531-540.

SØRENSEN, H.: Studies on the decomposition of ^{14}C-labelled barley straw in soil. Soil Sci. 95, 45-51 (1963).

SØRENSEN, H.: Formation of soil organic matter during decomposition of plant components. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966, 271-274.

SOWDEN, F.J. and H. DEUEL: Fractionation of fulvic acids from the B-horizon of podzol. Soil Sci. 91, 44-47 (1961).

SPRINGER, U.: 1. Farbtiefe und Farbcharakter von Humusextrakten in ihrer Abhängigkeit von der Alkalikonzentration, zugleich ein Beitrag zur Kenntnis der Humustypen.- Z. Pflanzenernähr., Düng., Bodenkunde 34, 1-14 (1934).

SPRINGER, U.: Der heutige Stand der Humusuntersuchungsmethodik mit besonderer Berücksichtigung der Trennung, Bestimmung und Charakterisierung der Huminsäuretypen und ihre Anwendung auf charakteristische Humusformen. Bodenkunde und Pflanzenernähr. 6, 312-373 (1938).

SPRINGER, U.: Stoffabbau und Humusaufbau untersucht an einem Strohmist und Strohligninmist (Laboratoriumsversuch). Prakt. Blätter f. Pflanzenbau u. Pflanzenschutz 21/22, 1-57 (1944/45).

SPRINGER, U.: Über Komposthuminsäuren aus verschiedenen pflanzlichen Ausgangsstoffen.- Z. Pflanzenernähr., Düng., Bodenkunde 69, 66-71 (1955).

SPRINGER, U., and A. LEHNER: Stoffabbau und Humusaufbau bei der aeroben und anaeroben Zersetzung landwirtschaftlich und forstwirtschaftlich wichtiger organischer Stoffe. I.Z. Pflanzenernähr., Düng., Bodenkunde 58, 193-231 (1952 a).

SPRINGER, U. and A. LEHNER: Stoffabbau und Humusaufbau bei der aeroben und anaeroben Zersetzung landwirtschaftlich und forstwirtschaftlich wichtiger organischer Stoffe. II. Z. Pflanzenernähr., Düng., Bodenkunde 59, 1-27 (1952 b).

SPRINGER, U. and F. SELSCHAB: Zur Kenntnis der bei der Kompostbereitung auftretenden stofflichen Veränderungen. Mit Ergebnissen eines dreijährigen Gefäßversuches. Bayr. Landw. Jahrbuch 38, 250-300 (1961).

STAHLER, R.Y. and J.L. INGRAHAM: Protocatechuic oxidase.- J. Biol. Chem. 210, 799-808 (1954).

STANIER, RIY.: Simultaneous adaption: A new technique for the study of metabolic pathways. J. Bact. 54, 339-48 (1947).

STANIER, R.Y. and J.L. INGRAHAM: Protocatechuic oxidase. J. Biol. Chem. 210, 799-808 (1954).

STEELINK, C.: Free radical studies of lignin, lignin degradation products and soil humic acids. Geochim. Cosmochim. Acta 28, 1615-1622 (1964).

STEELINK, C. and G. TOLLIN: Stable free radicals in soil humic acid. Biochim. Biophys. Acta 59, 25-34 (1962).

STEELINK, C., J.W. BERRY, A.HO and H.E. NORDBY: Alkaline degradation products of soil humic acid. Sci.Proc. Roy. Dublin Soc. Ser. A 1, 59-67 (1960).

STEINMETZ, A.: Modellversuche zur Beteiligung von Polyphenoloxydasen bei der Bildung natürlicher Huminsäuren. Dissertation TH Braunschweig (1956).

STEWART, B.A., L.K. PORTER and D.D. JOHNSON: Immobilization and mineralization of nitrogen in several organic fractions of soil.- Soil Sci. Soc. Amer. Proc. 27, 302 (1963).

STOKES, G.G.: On the theories of internal friction of fluids in motion and the equilibrium and motion of elastic solids.- Trans. Cambridge Phil. Soc. 8, 287 (1849).

STÖCKLI, A.: Über den Abbau von Lignin, Cellulose und Hemicellulose durch Pilze. Versuche mit Streumaterialien, Holz und Ligninsulfonsäure. Promotion ETH Zürich (1952).

SULLIVAN, J.D. and G.T. FELBECK: A study of the interaction of s-triazine herbicides with humic acids from three different soils.- Soil Sci. 106, No. 1, 42-52 (1968).

SUNDMAN, W., K. HARO : On the mechanism by which cyclolignanolyctic agrobacteria might cause humification. Finiska Kemists Med. 75, 11-118 (1966).

SVEDBERG, T.: Die Molekulargewichtsanalyse im Zentrifugalfeld. - Kolloid Z. 67, 2-16 (1934).

SWABY, R.: Soil organic matter.- 8th, 9th, 10th C.S.I.R.O. Annual Reports. Government Printers, Sydney. (1956-1958).

THENG, B.K.G. and A.M. POSNER: Nature of the carbonyl groups in soil humic acids. Soil Sci. 101, 191-201 (1967).

TINSLEY, J. and A. SALAM: Extraction of soil organic matter with aqueous solvents. Soils and Fertilizers 24, 81-84 (1961).

TOKUDOME, S. and I. KANNO: Nature of the humus of some Japanese soils. 9th Internat. Congr. Soil Sci., Adelaide, Australia, Transactions III, 163-173 (1968).

TRAYNARD, Ph. and A. EYMERY: Delignification par les solutions hydrotropiques. II. Etude des lignines hydrotropiques. Holzforschung 10, 6-11 (1956).

TRIPPETT, S., S. DAGLEY and D.A. STOPHER: Bacterial oxidation of protocatechuic acid. Biochem. J. 76, 9p (1960).

TROJANOWSKI, J., A. LEONOWICZ and B. HAMPEL: Exoenzymes in fungi degrading lignin. II. Demethoxylation of lignin and vanillic acid. Acta Microbiol. Polon. 15, 17-22 (1966).

TROJANOWSKI, J., A. LEONOWICZ and M. WOJTAS: Exoenzymes in fungi degrading lignin. III. The effect of peroxidase on veratric acid. Acta Microbiol. Polon. 15, 215-222 (1967).

TYURIN, I.V.: Die organischen Stoffe der Böden. Selchosgis Moskau (1937) (russ.).

WAKSMAN, S.A. and J.W. SMITH: Transformation of methoxyl group in lignin in the process of decomposition or organic residues by microorganisms. J. Amer. Chem. Soc. 56, 1225 (1934).

WAKSMAN, S.A. and F.G. TENNEY: The composition of natural organic materials and their decomposition in the soil. I. Methods of quantitative analysis of plant materials. Soil Sci. 24, 275-283 (1927 a).

WAKSMAN, S.A. and F.G. TENNEY: The composition of natural organic materials and their decomposition in the soil. II. Influence of age of plant upon the rapidity and nature of its decomposition - rye plants. Soil Sci. 24, 317-333 (1927 b).

WAKSMAN, S.A., F.C. TENNEY and R.A. DIEHM: The chemical and microbiological principles underlaying the transformation of organic matter in the preparation of artificial manures. J.A.S.A. 21, 533-545 (1929).

WALTERS, E.H.: The isolation of p-hydroxy-benzoic acid from soils. J. Amer. Chem. Soc. 39, (1917).

WELTE, E.: Zur Konzentrationsmessung von Huminsäuren. Z. Pflanzenernähr., Düng., Bodenkunde 74, 219-227 (1956).

WHITEHEAD, D.C.: Identification of p-hydroxybenzoic, vanillic, p-coumaric and ferulic acids in soils. Nature 202, 417-418 (1964).

WHITEHEAD, D.C. and J. TINSLEY: Extraction of soil organic matter with dimethylformamide. Soil Sci. 97, 34-42 (1964).

WIESEMÜLLER, W.: Untersuchung über die Fraktionierung der organischen Bodensubstanz. Albrecht Thaer Archiv 9, 419-436 (1965).

WILZBACH, K.E.: Tritium-labelleing by exposure of organic compounds to tritium gas.- J. Amer. Chem. Soc. 79, 1013 (1957).

WILZBACH, K.E.: IAEA Tritium Symposium paper TTS/83, Vienna (1961).

WINTER, A.G.: Untersuchungen über die Aufnahme von Penicillin und Streptomycin durch die Wurzeln von Lepidum sativum und ihre Beständigkeit in natürlichen Böden. Z. Bot. 40, 153 (1952).

WINTER, A.G., H. PREUSS and F. SCHÖNBECK: Untersuchungen über die Aufnahme organischer Substanzen durch die Wurzeln höherer Pflanzen. I. Phenolische Verbindungen. Naturwissensch. 46, 536-537 (1959).

WRIGHT, J.R. and M. SCHNITZER: Oxygen containing functional groups in the organic matter of the Ao and Bh-horizon of a podzol. 7th Internat. Congr. Soil Sci. Madison, Wisc. USA 2, 120-127 (1960).

WRIGHT, J.R. and M. SCHNITZER: An estimate of the aromaticity of the organic matter of a podzol soil. Nature 190, 4777, 703-704 (1961).

ZELLER, A., H.E. OBERLÄNDER and F. HIEMER: A growth chamber for raising ^{14}C-labelled plants. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966, 401-413.

ZELLER, A., H.E. OBERLÄNDER, K. ROTH and I. STADLER: The humification of carbon-14 labelled mycelium in soil. In: The use of isotopes in soil organic matter studies. Pergamon Press. Ltd. Oxford 1966, 275-279.

ZELLER, A., H.E. OBERLÄNDER and K. ROTH: A field experiment on the influence of cultivation practices on the transformation of 14C-labelled farmyard manure and 14C-labelled straw into humic substances. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968, 265-274.

ZENK, M.H.: Einbau von p-Hydroxybenzoesäure in die Hydrochinonkomponente des Arbutins in Bergenia crassifolia. - Z. Naturforsch. 19 b, 856-857 (1964).

ZIECHMANN, W.: Spectroscopic investigations of lignin, humic substances and peat. Geochim. Cosmochim. Acta 88, 1555-1566 (1964).

ZIECHMANN, W. and H. SCHOLZ: Spektroskopische Untersuchungen an Huminsäuren. Naturwissenschaften 47, 193-196 (1960).

ZIECHMANN, W.: Infrared spectra of humic acids. Brennstoff-Chem. 39, 353 (1958).

ZIECHMANN, W.: Die Darstellung von Huminsäuren im heterogenen System mit neutraler Reaktion. Z. Pflanzenernähr., Düng., Bodenkunde 84, 155-159 (1959).