Biochemistry of Soil Organic Matter in Relation to Crop Production

W. Flaig

Content

Lecture 5.

Physical Properties of Humic Substances

Optical Properties

W. Flaig

1. Absorption in ultraviolet and visible range of light.
   1.1 Principles of absorption spectroscopy of humic acids
   1.2 Connection between composition and light absorption of humic fractions.
   1.21 Contribution of phenols and their transformation products.
   1.22 Radicals.
   1.23 Heterocyclic ring systems.
2. Electronic spectra of humic acids.
   2.1 Influence of hydrogen ion concentration.
3. Determination of similarity degrees of humic substances by light absorption.
4. An example for the characterization of humic acids and their fractions by infrared absorption.
5. About the efficiency of optical methods for characterization of humic fractions.

From the physical properties of fractions of soil organic matter only some will be mentioned, which are supposed to be important more or less directly in connection with crop production. So for instance contributions to characterization of humic systems or their fractions in dependence of environmental conditions and soil management are very needed and of interest not only for soil chemistry and biochemistry but also for soil genesis and for agriculture.

1. Absorption in ultraviolet and visible range of light

The spectroscopic investigations of soil organic matter and its fractions in the ultraviolet and visible range of light has become more and more important for characterization and determination of genetic differences and also for transitions between the types of humic substances.

1.1 Principles of absorption spectroscopy of humic acids

The concentration used for the analysis was of about o.o1 - o.o5 mg/1ooml. As chemical constitution is unknown the concentration can not be given in Mol/liter as in the case of chemical defined compounds. The absorption of humic substances in solution follows.

The Lambert-Beer law:

(absorbance: $A = E = \log P_o/P = \varepsilon \cdot c \cdot d$)

The extinction coefficient K is $K = \varepsilon \cdot c$ if the length of the light path d in the cell is 1 cm. The extinction coefficient K is therefore

directly proportional to the concentration c (mg/100 ml) whereby the proportionality constant ε is specific for the investigated substance and is named molar extinction coefficient (molar absorptivity). As the value of ε is dependent upon the wavelength, the determination of concentration must be made at a defined wavelength. Owing to the still undetermined molar absorptivity of the humic substances, due to their unknown chemical constitution, the absolute concentration of humic acids in Mol/liter cannot be determined. Therefore the spectroscopic measurements of absorption of soil organic matter or its fractions are used only for the determination of the K-values.

The light absorption of a solution of humic substances of constant concentration is measured in the visible and ultraviolet range and the logarithm of extinction (log K) is plotted against the wavelength ($\log K = (\lambda)_c$). In contrast to many higher molecular weight substances, the electronic spectra of humic fractions show no distinct maxima but only more or less monotonously raising straight lines in the direction of shorter wavelengths with a few deviations from linearity. On account of the applicability of the Lambert-Beer law, whereby $\log \varepsilon$ and log c became additive ($\log K = \log \varepsilon + \log c$), spectra of solutions of the same humic substances measured at different concentrations are shifted parallel. The determination of relative concentrations by alterations of the absorbance are possible.

On the other hand this indicates that the slope of the curves is independent of variation in the concentration leading to the possibility

of characterization of the colour type of humic substances by determination of the slope of the absorption curve. This characterization is based on the differences of the molar absorptivity of these substances.

More recently some other authors such as KUMADA (1955) and SALFELD (1965, 1968) characterized the slope of the colour curve by the difference of logarithmic extinction of at least two different wavelengths ($\triangle \log K = \log K_{400} - \log K_{600}$).

1.2 Connection between composition and light absorption of humic acids.

The classification of humic acids with optical methods is the subject of many investigations. The spectroscopic and physicochemical properties of the humic acids are primarily by the different genetic conditions in soils and are furthermore varied by the methods of extraction and purification.

The multitude of molecular constituents of humic acids, which absorb in the ultraviolet and visible range, such as phenolic compounds and their oxidation products, amino acids and their condensation products with phenols in oxidizing medium, and the formation of heterocyclic components, leads to spectra of mixtures. These show no strongly marked differences in the absorption properties, when different types of humic acids are compared.

1.21 Contribution of phenols and their transformation products.

The absorption of humic acid in the ultraviolet range may be caused by phenolic components and in the visible by chromophoric groups formed by oxidation. It could be demonstrated by oxidative or reductive cleavage of humic acids, that these contain phenolic components (lecture 4).

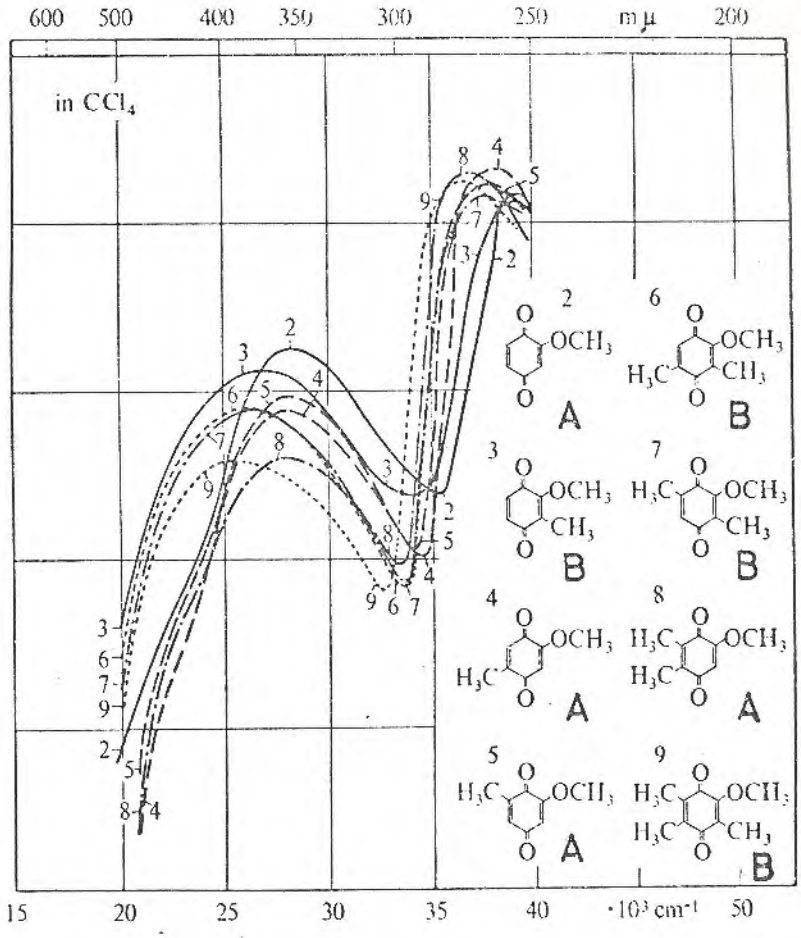


Fig. 1: Absorption curves of methylated 2-methoxy-p-benzoquinone.

A: p-substitution (methoxyl group more effective than methyl group).

B: o-substitution

FLAIG and SALFELD (1958) investigated especially the changes of the optical properties of differently substituted o- and p-benzoquinones as model substances. They demonstrated that the absorption curves of these compounds have two or three significant maxima according to their substitution. An o-substitution causes a stronger shift of the second maximum to longer wavelengths than a substitution in p-position. The kind and the position of the substituents cause changes of the absorption properties or shifts of specific absorption bands.

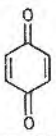
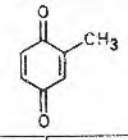
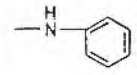
								
	2. maximum in nm	shift in nm	2. maximum m-,p-subst. in nm	shift in nm	2. maximum o-subst. in nm	shift in nm	2. maximum in nm	shift in nm
unsubstituted	282 (CCl_4) 288 ($CHCl_3$)						375 (CCl_4)	
$-CH_3$	309 (CCl_4)	27	310 (CCl_4)	1	332 (CCl_4)	23	328 (CCl_4) in 4-position	7 (CCl_4)
$-OCH_3$	351 (CCl_4)	69	355 (CCl_4)	46	374 (CCl_4)	65	450 (CCl_4) in 3-position	75 (CCl_4)
-OH	369 ($CHCl_3$) 372 (CCl_4)	81 90	381 ($CHCl_3$)	72	396 ($CHCl_3$)	85	505 (CCl_4) in 3-position (3-hydroxy-4,6-di-tert. butyl)	116 (CCl_4)
	369 (CCl_4)	87						
	550 ($CHCl_3$)	262 minus benzene ring - 175						

Fig. 2: Shift of the second maximum of absorption curve of benzoquinones by substitution with different groups.

For instance substitution with an aliphatic group such as a methyl group results in a shift of the second maximum of p-benzoquinone at 282 nm (in carbon tetrachloride) for 27 nm, in the case of a methoxyl group for 69 nm and in the case of a hydroxyl group for 9o nm in direction of longer wavelengths.

Furthermore it could be established, that a shift of the second maximum to longer wavelengths depends less on the chain length of the aliphatic group, but much more on the kind of substitution at the ring with further alkyl-, alkoxyl- or hydroxyl groups. When the second substituent is on o-position to the other the shift is much larger, than by substitution in m- or p-position. It will be remembered that in the case of lignin degradation products and in the case of the transformations of microbial synthesized phenols there was often a substitution in o-position.

o-Benzoquinones absorb light at longer wavelengths than the p-benzoquinones. Substitution in 3-position has a greater effect on the shift than in 4-position. Strongly effective chromophoric groups are also phenyl as well as aromatic or aliphatic (amino acids) amino groups.

It is unlikely that all phenolic units in the molecule of humic acids are present in the form of quinones, because these are not very stable against further oxidation. If quinonoid groups are present to a larger extent, they would presumably effect a broad maximum in the absorption curve in a range between 300 to 500 nm. This is not observed; therefore other effects must exist.

1.22 Radicals

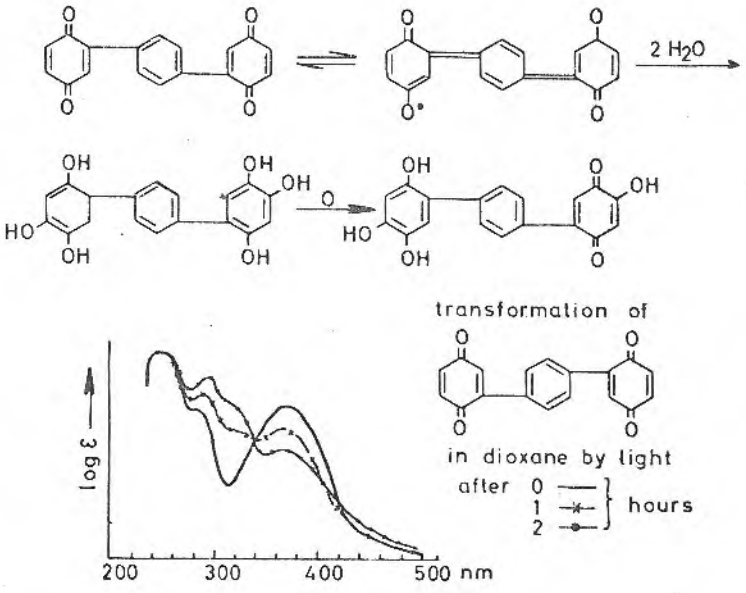


Fig. 3: Polymeric quinones as model substances of humic acids, 1,4-diquinonyl-benzene.

Some model experiments were made to explain the absence of distinct maxima in the absorption curve of humic acids. According to the

UV-spectrum 1,4-diquinonyl-benzene seems to be present in an o- and p-quinonoid configuration in solution (PLOETZ 1955). The o-configuration may be defined asa biradical and is very reactive. A corresponding hydroxylhydroquinone, which can be partially reoxidised to a hydroquinone, is formed by addition of water. A deeply coloured, intramolecular quinhydrone is formed. Diquinonyl-benzene is disproportionated in organic solvents. The formed mixture of substances show similar, nearly monoton increasing spectra as they are known from humic acids isolated from soils (FRÖMEL 1938 a,b, 1941 and later on many others).

STEELINK and TOLLIN (1962), STEELINK (1964) demonstrated by electron spin resonance, that humic acids contain radicals. This result agrees well with the assumption that the humic acids are intramolecular quinhydrones. Measurements by KLEIST and MÜCKE (1966), KLEIST (1967) established that the radicals (semiquinones) are stabilized by mesomery and are responsible for the colour of humic acids. Thereby, the humic acids would have the properties of electron exchanger. BAILEY, BRIGGS, LAWSON, SCRUTON and WARDS (1965) explain absorption in IR-spectra of browncoal humic acids by hydrogen bridge linkages between the hydrogen of phenolic hydroxyl groups and the carbonyl groups of quinones. Hitherto no quinone group could be found by reducing acetylarion (FARMER and MORRISON 1960). Otherwise MARTIN, DUBACH, MEHTA and DEUEL (1963) assume, that the carbonyl group of fulvic acids from podzol, which cannot be reduced by sodium boron hydride ($NaBH_4$), may belong to quinone groups.

1.23 Heterocyclic ring systems.

A bathochromic effect may be caused by the oxygen, nitrogen or sulphur atoms in ring systems, which may occur in humic acids. The extent of a bathochromic effect of these elements is shown in the case of 4 dyestuffs with comparable chemical constitution.

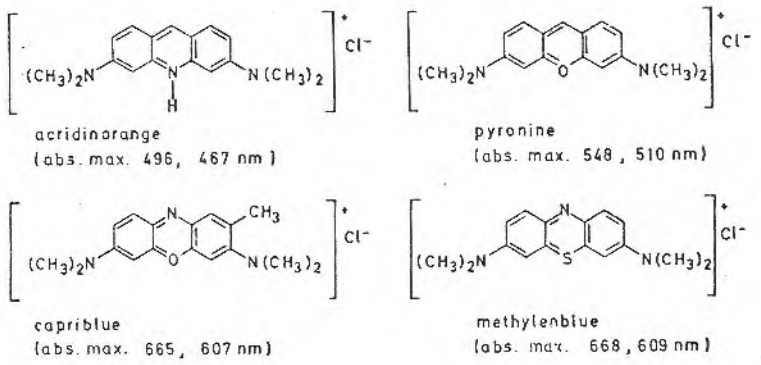


Fig. 4: Bathochromic effects of heteroatoms in dyestuffs with comparable chemical constitution.

The influence of the shift of the absorption maxima increases in order to nitrogen, oxygen, sulphur and corresponding combinations. The range of absorption of these compounds is at longer wavelengths than that of the mentioned benzoquinone compounds.

2. Electronic spectra of humic acids.

In the following figure the absorption spectra of different humic acids and of fulvic acids are depicted schematically. The curves of absorption are not linear, as could be shown by more exact measurements (comp. SALFELD 1965).

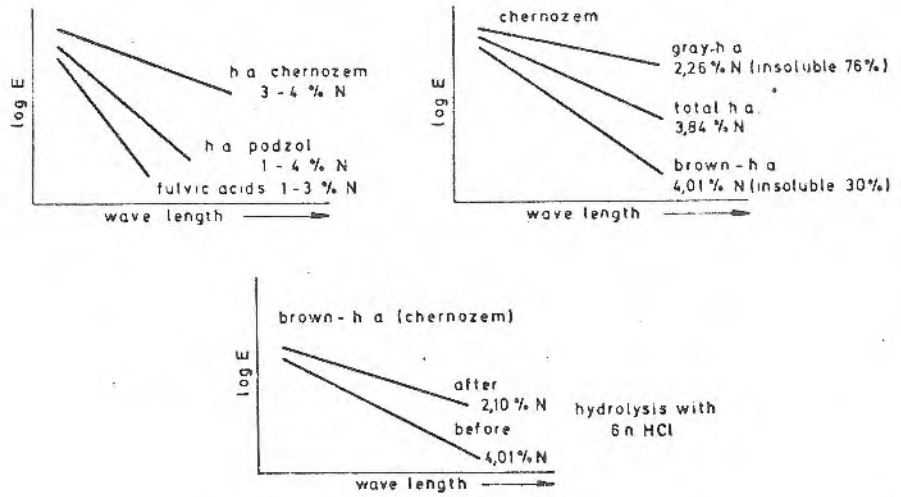


Fig. 5: Absorption spectra of humic acids from chernozem and podzol and fulvic acid (schematic).

As a rule, humic acids from chernozem rich in nitrogen have not only higher absorption, but also stronger absorption at longer wavelengths than the humic acids from podzols poor in nitrogen. The stronger absorption of humic acids from chernozems may be caused by the higher content of non-hydrolysable nitrogen, which may have a higher content of bathochromic heterocyclic compounds, than that in podzol humic acids. The total nitrogen content cannot play an important role in light absorption, since it is found largely in proteins, which do not absorb in the visible range.

The fraction of brown humic acids of chernozems has a higher nitrogen content than the fraction of gray humic acids. However, the absorption of the fraction of gray humic acids is stronger in the total range than that of the fraction of brown humic acids.

Therefore it may be that the residue of hydrolysis of the fraction of gray humic acids contains more heterocyclic, bathochromic components.

The absorption of the residue of hydrolysis of the fraction of brown humic acids is stronger in the total range than that of the fraction of the original brown humic acids, although the nitrogen content of this fraction (4.o1 % N) is higher than that of the residue of hydrolysis (2.o1 % N).

According to KLEIST and MÜCKE (1966) the higher extinction of the fraction of gray humic acids is due to a higher content of radicals, measured by electron spin resonance.

It seems that the absorption of fulvic acids is more due to oxidised phenols than to heterocyclic components with properties of dyestuffs, since these bathochromic components would show stronger absorption at longer wavelengths. The absorption of fulvic acids is less in the range of longer wavelengths. The nitrogen content of fulvic acids is generally lower (KONONOWA 1966) and the carbonyl content higher (SCHNITZER 1965) than that of humic acids.

There is voluminous literature on light absorption of humic substances. KUMADA (1965) and recently ORLOV and GRINDEL (1967) published summaries of work dealing with this problem.

The current theory concerning the colour of humic substances has been developed according to results of chemical investigations, but it must be supplemented by further investigations and isolation of corresponding compounds.

2.1 Influence of hydrogen ion concentration.

Since the investigations of SPRINGER (1934) and HOCK (1938) (a),(b) it is known, that the absorbance of humic substances in solution increases with decreasing hydrogen ion concentration.

SALFELD (1965) studied the influence of pH on the light absorption of humic acids purified by ion exchange from different origin. He found, that the decrease of the hydrogen ion concentration by addition of increasing amounts of 0.1 N NaOH up to pH =10 caused only a parallel shift of the spectra in direction to higher values of absorbance. A further decrease of the hydrogen ion concentration did not effect changes in the light absorption up to 500 nm. Above 500 nm a continuous increase of the absorbance up to 620 nm occurred, which led not only to the formation of a weak shoulder but also to a parallel shifting of the extinction values. A similar effect on the absorption spectrum was observed in the case of humic acids formed by autoxidation of pyrocatechol in sodium hydroxide solution.

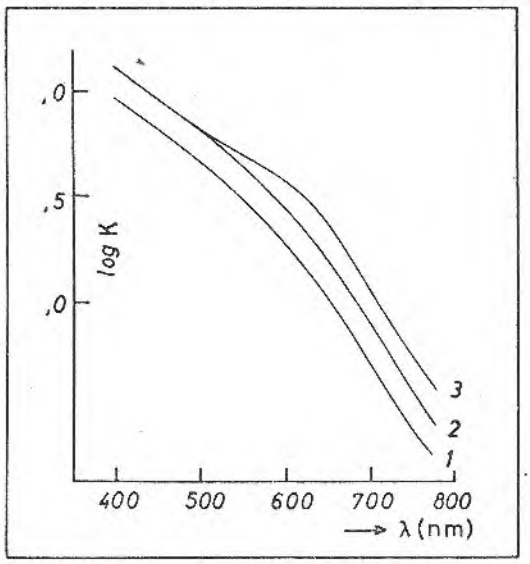


Fig.6: Dependance of absorption of humic acids from podzol at different pH-value(1:pH = 3.75, 2:pH = 9.98, 3:pH = 11.80) (SALFELD 1965).

Therefore it seems improbable that the changes in absorbance in the range of 620 nm are only caused by chlorophyll-like porphyrin systems.

WIESENMÜLLER (1965) investigated "brown" and "gray" humic acids. He compared alkaline solutions of these humic acids with their hydrogen form, which were prepared with strong acid cation exchangers. The slope of the absorption spectra did not change. Therefore he assumed no influence of the hydrogen ion concentration on the absorption properties of these types of humic acids.

3. Determination of similarity degrees of humic substances by light absorption.

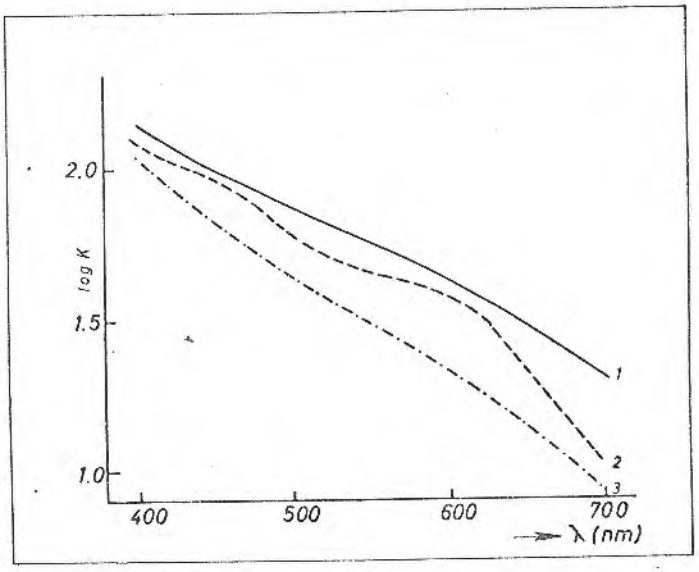


Fig. 7: Spectra of different humic acids. (1) Chernozem, (2) podzol B and (3) black peat in 0.1 N NaOH.

At first it must be established, that the spectra of humic acids are not linear, as the classical chemistry describes them. The spectra of humic acids are curved lines and are different upon the origin of the humic acids. It shall be remembered, that the

ratio of the quantities of phenols found after oxidative cleavage depends on the origin of the humic substances, and that the content and ratio of amino acids differs also after acid hydrolysis.

Therefore the spectra cannot be characterized completely according to classical theory by means of only one quotient of two extinctions at about 400 and 600 nm = $Q_{4/6}$ -value or by the differences of the logarithms of two extinctions e.g. log 400 - 600 nm.

The calculation of the differences of the extinction in smaller ranges of wavelengths $\Delta \log K/\Delta\lambda$: for instance in the range of 20 nm results values, which give a better characterization of humic acids. SALFELD describes different humic acids by these "differential spectrograms".

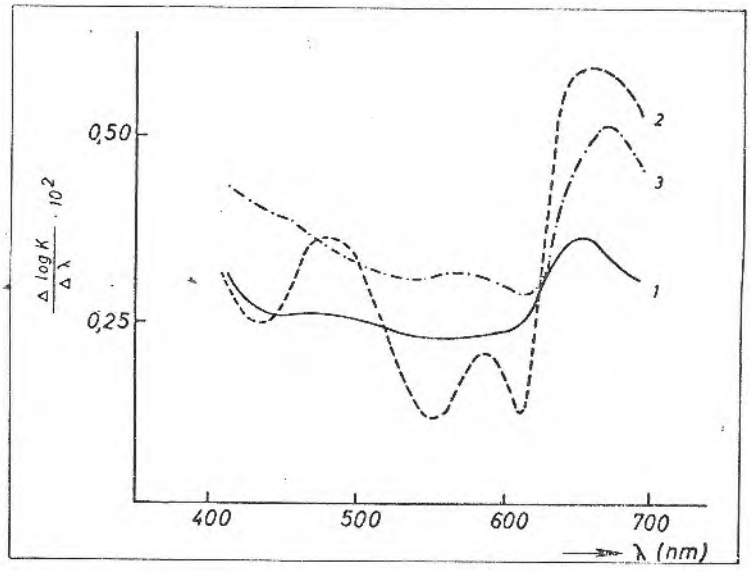


Fig. 8: Differential spectrograms of humic acids in a range of 20 nm in 0.1 N NaOH (SALFELD 1965). (1) Chernozem, (2) podzol B and (3) black peat.

Fig. 8 shows, that the spectra of humic acids are not straight lines with constant gradient, because the gradients change with the range of wavelengths and have minima between 500 and 600 nm for all 3 spectra. This means, that the spectra have a point of inflexion in this range. The changes of the gradient show remarkable quantitative differences. In the case of chernozem humic acids (1), the gradient decreases from lower to higher wavelengths at first only a little and then increases larger. The podzol humic acids (2) show at first a large decrease, a small maximum and then very large increase. In the case of humic acids from black peat (3) a larger decrease is followed by a larger increase.

The differential spectra vary in the different range of wavelength. Therefore it is not possible, that according to the theory at first fulvic acids, then hymatomelanic, then humic acids are formed. If the different acids would be formed in this sequence, the course of the curves should be the same in all 3 cases.

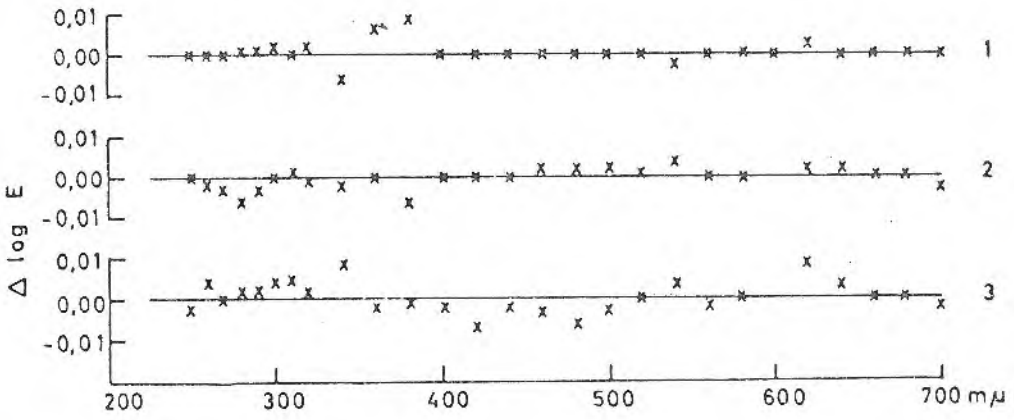


Fig. 9: Reproduceability of differences of logarithms of extinctions of different measurements with the same solution (1 and 2) and with different solutions (3) of the same preparation of chernozem.

To be able to use such measurements for a statistic of the characterization of isolated humic substances and their fractions or of systems of humic substances in soils, in cultures of microorganisms, in humification experiments or in the case of synthesis in vitro with various oxidation of phenols, the limits of reproduceability of the values must be known.

The graph shows the reproduceability of the measurements in the case of spectrum of humic acids from chernozem in 0.1 N NaOH. At first the same solution (1 and 2) has been measured every 3 minutes two times and then a second new prepared solution of the same preparation of humic acids (3) has been measured. The differences of the logarithms of the measured extinctions is plotted against the wavelengths. The differences of the values are here smaller than in the measurements of the differential spectra.

To be able to place in order the humic substances themselves or their alterations during different processes in a common system, the measured values for characterization of differences must be significant. The limits of reproduceability are not in all cases due to the method of isolation, but also due to the properties of the investigated materials. Since a voluminous material is necessary for such investigations, the methods should be automized in regard to the apparatus as much as possible.

Investigations have been made, in which manner larger samples of humic substances or systems could be compared by means of data of light absorption and could be sorted according to groups of similarity. Thus it was tried to compare and to classify groups of preparations of humic substances by means of the data, from spectra according to a method developped by SNEATH (1957).

As a measure for the similarity the ratio of the number of same properties to the number of the total regarded properties is defined. Each object is compared with each other. In this way diagrams of similarity are obtained; one example is demonstrated in the next graph with a group of 12 humic acids.

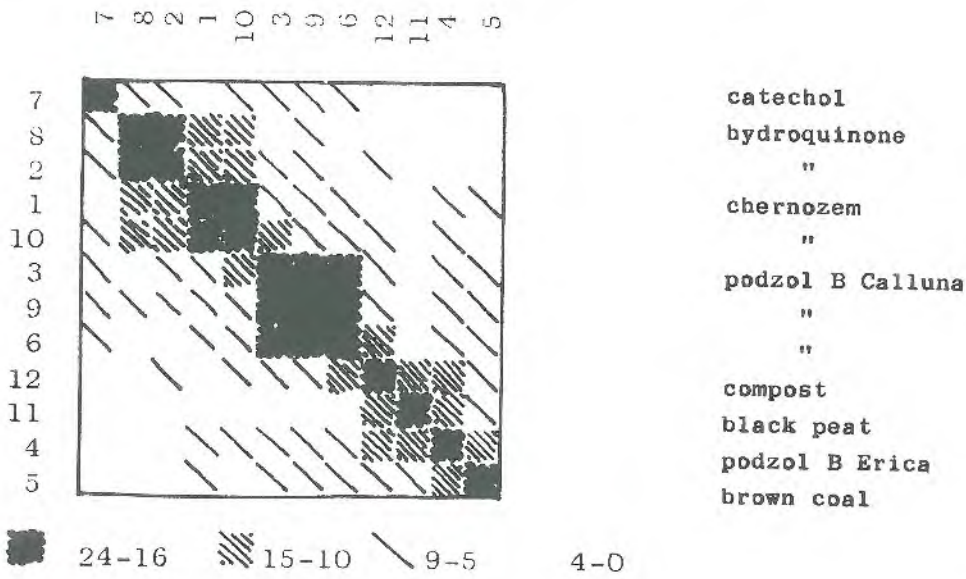


Fig. 10: Classification of humic acids, calculated.

The data can be sorted mechanically or by calculation; a distribution of groups of similarity is obtained. In this example the spectra of 12 humic acids in 8 ranges of wavelengths are subdivided and the gradients as difference of logarithms of extinction are used as measured data. These data are transformed in an index number to simplify the representation. To compare the spectra the same index numbers of two spectra are evaluated with 3 points, a difference between the index numbers of 1 and 2 points and a difference of 2 with 1 point. A number of 24 points for the similarity is obtained, when 2 spectra are identical, because 8 measured values with the same index numbers with an evaluation of 3 points is used. A complete

dissimilarity is zero points.

For further simplification the decrease of similarity are subdivided in 4 groups /24 - 16/, /15 - 10/, /9 - 5/ and /4 - 0/. The more black the quadrats are, the more similar are the spectra of the humic acids. The preparations of humic acids at first marked with any number can be arranged (classified) mechanically or by calculation, so that the hydroquinone-, the chernozem- and the podzol humic acids (Calluna) are in each case in one group.

From the diagram also the similarities between humic acids it can be seen, which are not from the same origin. So No. 10, a humic acid from chernozem is relatively similar (degree of similarity 15 - 10) with hydroquinone humic acids No. 8 and No. 2 or with the podzol B Calluna humic acid No. 3, but very dissimilar (degree of similarity 4 - 0) with the humic acid from black peat No. 11.

This method is used especially in a suitable manner, when the objects are characterized by a larger number of qualitative symptoms. If objects - in our case preparations of humic substances or their systems - are determined exclusively by measured data of properties, the similarity can be defined better as the distance of points in a n-dimensional space, whereby n is the number of the properties of the objects. For a group of objects, which are characterized by these measurable properties, a threedimensional model can be easily realized. So it is possible to represent the humic acids by means of their spectra as points in a threedimensional system of coordinates with the mentioned three extinction quotients as coordinates.

In this model 52 spectra of humic acids are presented as points with the coordinates of the extinction quotients of different ranges

of wavelengths. The position of the points in the space is a measure for the similarity. Three accumulations of points can be determined.

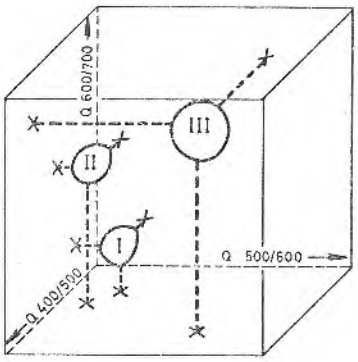


Fig. 11: Strongly schematized model of similarity of 52 humic acids by means of three extinction quotients (Q 400/500; Q 500/600 and Q 600/700) (SALFELD 1968). The three groups of humic acids are marked with the numbers I, II, and III.

The closest accumulation contains the humic acids from chernozem (I), which is clearly separated from the humic acids from the podzol (II). A third accumulation is a group of preparations of humic acids (III) from different origin.

These remarks shall point out, that such possibilities of characterization exist and are worked out to classify systematically the manifold experimental material for humic substances in order to draw more general conclusions. We try to characterize the fractions of humic substances in dependence of soil genetical and ecological symptoms but also to find the correlations between the natural factors and those influenced by men during the formation and the decomposition of soil organic matter (SALFELD 1968,1971, SALFELD and SÖCHTIG 1969, SÖCHTIG and SALFELD 1971).

Further attempts have been made for characterization of humic systems by the use of other data of properties such as carbon and nitrogen content and others.

The data in the literature cannot be used in all cases to complete such investigations, because they do not correspond to the pretentions of the necessary reproduceability.

4. An example for the characterization of humic acids and their fractions by infrared absorption.

The infrared spectroscopy of humic acids preparations and their fractions is used by many authors for the purpose of characterizing humic substances from different soil origin (KASATOCHKIN and ZILBERBRAND 1956, KASATOCHKIN, KONONOVA and ZILBERBRAND 1958, KUMADA and AIZAWA 1958, 1959, ZIECHMANN 1958, 1959, 1964, SCHARPENSEEL and ALBERSMEYER 1960, ZIECHMANN and SCHOLZ 1960, ORLOV, ROZANOVA and MATYUKHINA 1962, SCHARPENSEEL, KÖNIG and MENTHE 1964, KONONOVA 1966, THENG and POSNER 1967, TOKUDOME and KANNO, 1968, POSNER, THENG and WAKE 1968). It gives some information about the modification by chemical treatments (FARMER and MORRISON 1960, ORLOV, ROZANOVA and MATYUKHINA 1962, SCHNITZER 1965), such as methylation, acetylation, esterification, saponification and the formation of other derivatives (SCHNITZER and SKINNER 1965 (1), (2), SCHNITZER and DESJARDINS 1965). On the other hand it is possible by this method to detect changes in the chemical structure of the investigated material during oxidation and pyrolysis (SCHNITZER and HOFFMANN 1964, SCHNITZER 1965). Furthermore metal-humate complexes were investigated, which may occur by organometallic interactions in soils (KASATOCHKIN, KONONOVA and ZILBERBRAND

1958, SCHNITZER, SHEARER and WRIGHT 1959, SCHNITZER and SKINNER 1964 1965, SCHNITZER 1965, LEVESQUE and SCHNITZER 1967 b).

Unfortunately the assignment of the specific absorption bands is limited by the fact that soil organic matter preparations represent in most cases mixtures of more or less complex molecules with different types of linkages and functional groups.

This fact leads to an overlapping of the characteristic absorption bands. The infrared absorption spectra of humic acids therefore show some bands, which are not particularly elucidative for the chemical nature of the molecule. The spectra indicate that some absorption bands do not originate from identical structural features, but probably from similar groups in different molecular surroundings. The infrared absorption properties of these samples are also strongly influenced by the different methods of sample preparation, different methods of soil extraction and the following fractionation. In cases where pellet techniques are used the time of grinding and evacuation is also an influencial factor.

There are some difficulties in the real assignment of the infrared absorption bands of humic acids preparations. Some main absorption regions are found which appear in nearly all soil organic matter preparations with some differences in intensity or specific wavelengths of the absorption.

In order to give a general assignment of the main infrared absorption bands humic acids prepared according to (FLAIG, SCHEFFER and KLAMROTH 1955) from chernozem are chosen for comparison. The soil was prepared by hydrochloric acid (0.5 %) pretreatment and extracted with 0.5 % sodium hydroxide. After centrifugation and several reprecipitations

and dialysis these raw humic acids were subfractionated with 2 N NaCl at neutral conditions. The "gray" humic acids fraction (G-fraction) was precipitated in sodium chloride, while the "brown" humic acids fraction (B-fraction) remained in solution. After dialysis the G-fraction shows an ash content of 10 %, while the B-fractions has only 3,5 % of inorganic constituents.

A comparison of the infrared spectra of the raw humic acids (fig. 12 (1)), the gray humic acids fraction (fig. 12 (2)) and the brown humic acids fraction (fig. 12 (3)) shows that the main differences in intensity of absorption bands are in the region at 9.72 μ (1029 cm^{-1}) which is assigned to the Si-O-Si vibration frequences of a complex silicate mineral component. Specific investigations of the "gray" humic acids fraction by infrared analysis and electron microscopy gave evidence of the occurrence of a smectite mineral of the montmorillonite type, as it is shown by the spectrum of standard montmorillonite (fig. 12 (4)), (RIETZ unpublished).

It shall not be reported about all details of the assignment of the infrared red absorption bands; this can be taken from publications. Only it should be demonstrated, that sometimes it is necessary to do basic research work to get methods for very practical use such as the characterization of humic systems or to explain the properties of different fractions of humic acids, such as "gray" and "brown" humic acids fractions.

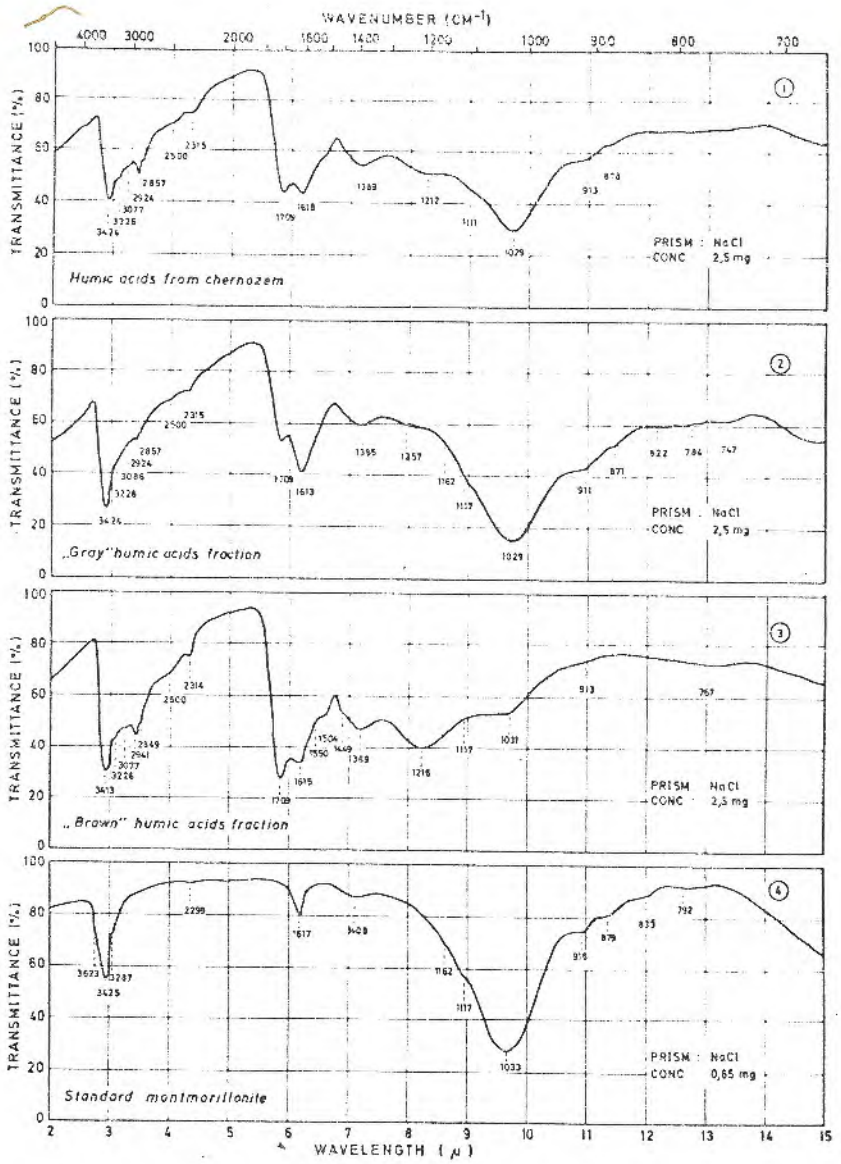


Fig. 12: Infrared spectra of humic acids from chernozem.
(1) Original
(2) "Gray" humic acids fraction
(3) "Brown" humic acids fraction
(4) Standard montmorillonite

5. About the efficiency of optical methods for characterization of humic fractions.

A critical evaluation of the optical methods in the range of ultraviolet, visible and infrared range leadt to the following conclusions:

1) All these methods are not suited for exact determination of chemical structure.

2) It is only possible to show differences when the material is isolated in the same way by a conventional method. Preparations of humic acids for instance, isolated from the same soil but with different methods show differences, which are nearly so large as isolations from different soils.

3) Only some bands of infrared spectra can be assigned to special groups in the molecules of humic acids.

4) The differences in absorption are large enough to determine characteristics of humic systems by statistical methods, which can be used for their classification.

A preposition is the isolation according to a special method which must be used in every case. The needed number for statistical methods requires complete automatized procedures at least of spectroscopy and the calculation.

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).