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399

Biological Parameters to Estimate the Effect of Biogenic Waste Composts on Plant Growth in Pot Trials

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Abstract

About 80 different biogenic waste composts were tested by new or modified conventional microbiological methods (oxygen-consumption, DMSO-reduction, Eh- and pH-drop during anaerobic incubation, reference method: self-heating-capacity) to determine the state of maturity and the effect of composts on plant growth in pot-trials. The progress in ripening of composts could be proved well by oxygen-consumption, pH-drop and self-heating-capacity, while DMSO-reduction and Eh-drop reflected maturity only with restrictions. A satisfactory prediction of plant-growth (dry-matter-production of oats) after compost-application with the help of the biological parameters was scarcely possible, only pH-drop showed a somewhat higher correlation. It was found out, however, that the effect of compost on plants could be estimated well by making use both of the C/N-ratio and of biological parameters.

Introduction

An essential criterion for application of composts in agri- and horticulture is - besides the contents of nutrients and pollutants – the maturity. Conventional methods for determining the ripeness of composts (e.g. self-heating capacity (LAGA 1984)) often do neither reflect the general status of the material nor its effect on plant growth. Moreover some methods demand several days for carrying out. Therefore it was tried to develop and modify biological procedures to evaluate the maturity of composts reliably and in a relativly short time.
The theoretical basis of all biological methods is founded on the presumption that the unriper composts are the higher is the availability of degradable C-compounds and the microbiological activity.

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Material and Methods

1) Composts: The tested composts came both from compost plants in the whole of Bavaria and out of composting experiments. They differed in kind and mixture ratio of raw materials (biogenic household wastes, plant residues), additional substances (mature compost, clayey soil, lime, mineral powder, bacterial preparations), age, pile size, kind and frequency of turning the pile, technical equipment and buildings of the compost plants. Model-composts which are represented graphically to prove maturity progress (Figs. 1 – 4) are characterized in table 1.

Table 1 Raw material, turning intervals and pile size of model composts

Compost designation	0	60	80	I	+N	dly	4wk	lrg
Plant residues %	0	60	80	60	60	60	60	60
Organic house-hold waste %	100	40	20	40	40	40	40	40
Turning interval (d)	3	3	3	3	3	1	28	7
Additional substances	-	-	-	bacteria, clayey soil	$CaCN_2$	-	-	-
Sectional area of pile	triangle	triangle	triangle	triangle	triangle	triangle	triangle	trapeze
Hight of pile (m)	1.5 - 1.8	1.5 - 1.8	1.5 - 1.8	1.5 - 1.8	1.5 - 1.8	1.5 - 1.8	1.5 - 1.8	4
Width of pile (m)	2.5 – 3.0	2.5 – 3.0	2.5 – 3.0	2.5 – 3.0	2.5 – 3.0	2.5 – 3.0	2.5 – 3.0	7 – 8

These model-composts were analyzed for three times during composting (3, 8 and 13 weeks). Together with composts from Bavarian compost-plants there were about 80 different composts being examined by the following methods:

Biological methods for determining maturity:

Oxygen-Consumption:

By advancement of the methods described by Nicolardot (1986), Morel (1986) and Kohmann and Fischer (1993) microbial activity was measured as pressure-drop as a result of absorbing the CO_2 released by the microorganisms with NaOH. For this purpose compost (<10 mm) was brought up to a water-tension of 25 - 35 hPa and was filled in a perforated flower-pot on the basis of 250 g dry matter in a way that the maximum distance between the innermost of the compost and the surrounding gas-atmosphere amounted only to 2.5 cm. Thus advantageous conditions for gas exchange should be created.Then the compost was put in a pressure-tight vessel together with 10 g NaOH and 10 ml H_2SO_4 (30 %) and incubated by 38°C. NaOH was placed at the bottom of the vessel so that the CO_2 (high density, sinking down) produced by the microorganisms could be caught immediatedly. H_2SO_4 was put on the top of the compost to bind ammonia (low density, rising upwards) to avoid pressure changes which are not due to the CO_2/O_2-system. Before incubation started the vessel-atmosphere had been enriched with O_2.

Pressure-decrease was logged continously with a data-logger and calculated as O_2 – consumption in mg per g compost dry-matter and hour.

Dimethylsulfoxide-(DMSO)-Reduction/Dimethylsulfid-(DMS)-Production

To employ this enzyme-activity-method (Alef 1991), which predominantly is used for mineral soils so far, compost had to be sieved (<10 mm), ground (<6 mm) and sieved again (<2 mm). 8 g of compost fresh-matter were filled into flasks (118 ml volume), added with 4 ml DMSO-solution (3,5 %), closed gas-tightly and incubated in a water-bath (40°C). After 3 hours an aliquot of the flask´s gas atmosphere was taken and the DMS produced by microorganisms was analyzed in a gas chromatograph. Furthermore a part of the samples was not added with DMSO-solution but with DMS to determine the DMS-absorption of the composts (Zehner et al. 1992).

Redoxpotential- and pH-drop during anaerobic incubation

This method is founded on the assumption that in compost-suspensions the redox-potential (Eh) and the pH are the more decreasing during anaerobic incubation the higher is the quantity of available C-compounds and the activity/reducing capacity of the present microorganisms (Flessa 1990, Jakob 1970, Jann et al. 1959, Yamane and Sato 1968). For this purpose compost (<10 mm) on the basis of 40 g dry-matter was submerged with distilled, boiled water in a ratio of 1: 6,25. This suspension was incubated in a water-bath by 40°C and Eh, pH and temperature were measured each hour. Between the measurements the flasks were screwed up to avoid O_2 - infiltration.

Pot-trials

The composts were given on the basis of 1,2 g N_t to oat which was cultivated in a silty loam soil of pH 6,1 in Mitscherlich-pots. At the end of the trial dry-matter and N-uptake of the plants were determined. Detailed informations of the pot-trial are given by Ebertseder et al. (1994).

Results

Determination of the progress of maturing:

All methods reflected the process of maturing more or less well as proved in a experiment with modell composts of defined mixture of raw materials and regular turning-intervals. The most evident graduation of increasing maturity depending on the time of composting was given by oxygen-consumption and pH-drop during

anaerobic incubation (Figures 1 and 2). The youngest composts (3 weeks) showed the highest oxygen-uptake and the lowest pH, the oldest composts (13 weeks) behaved exactly in the opposite manner. Composts in the age of 8 weeks were situated between the values of young and old composts, often hardly different from the 13-week-old material. The greatest difference in all cases existed between young and middle-old samples.

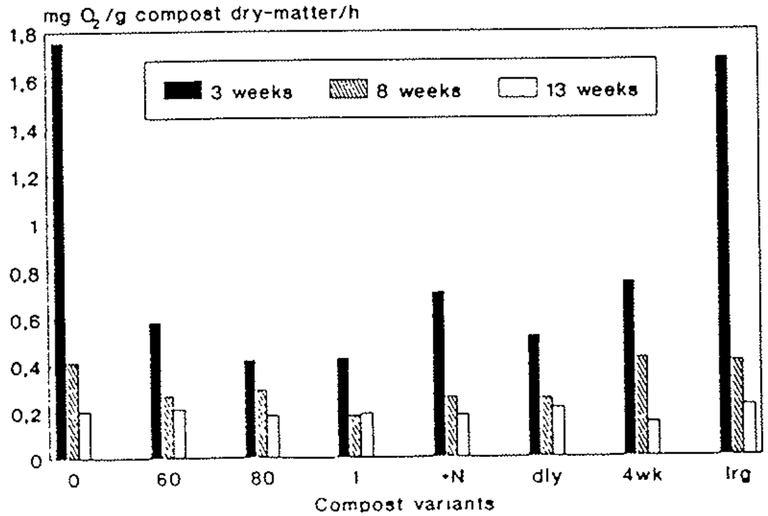

Figure 1 Oxygen-consumption of different composts depending on time of composting (3, 8 and 13 weeks)

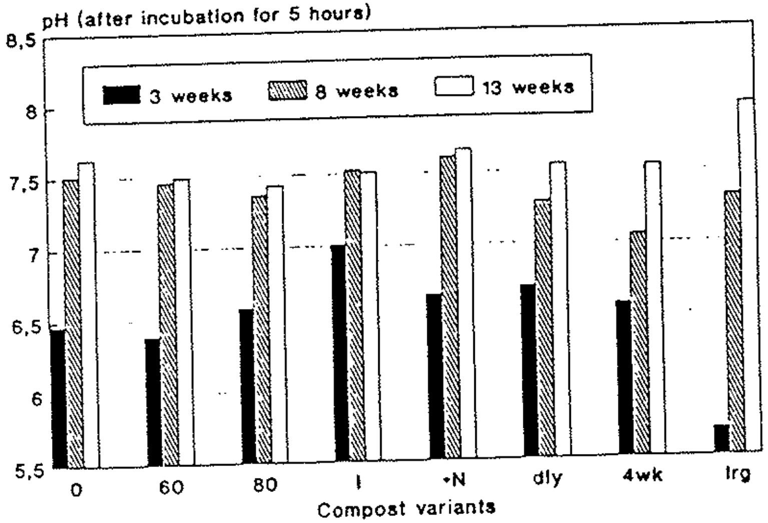

Figure 2 pH after anaerobic incubation (40°C) of different composts depending on time of composting (3, 8, 13 weeks)

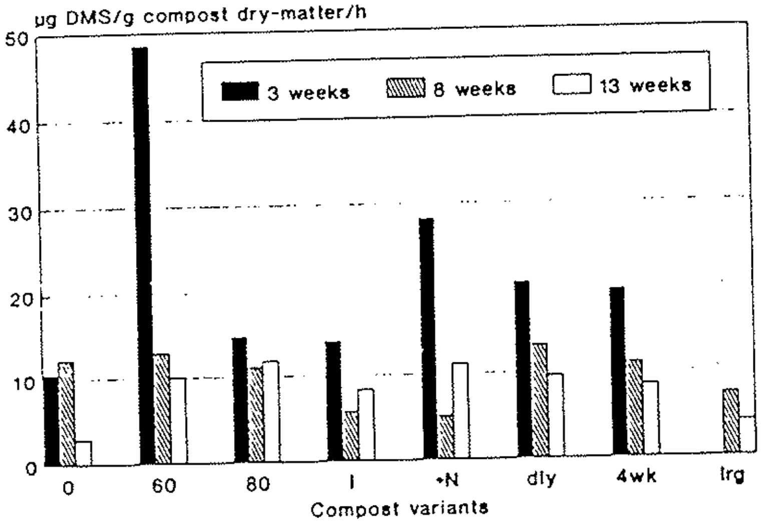

Figure 3 DMS-production of different composts depending on time of composting (3, 8 and 13 weeks)

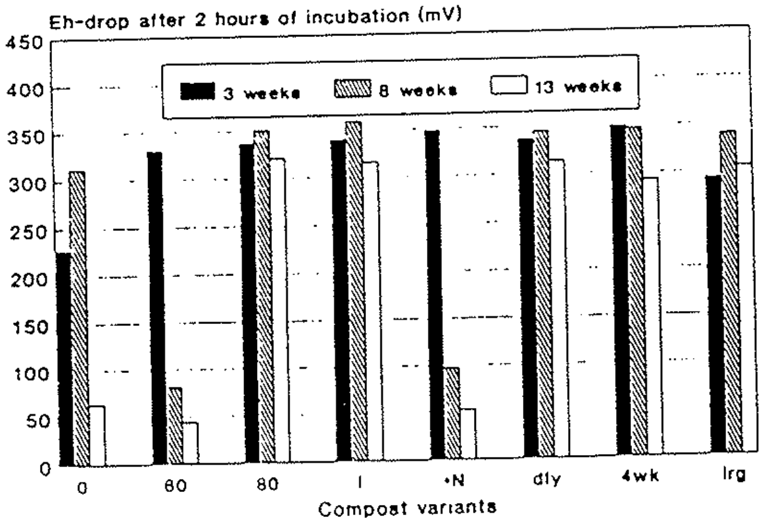

Figure 4 Eh-drop after incubation (40°C) of different composts depending on time of composting (3, 8 and 13 weeks)

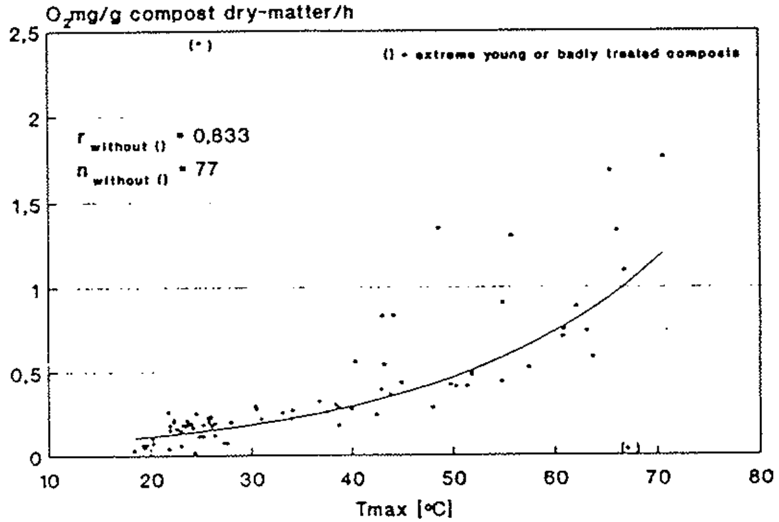

Figure 5 Relationship between self-heating-capacity (Tmax.) and oxygen-consumption of different composts

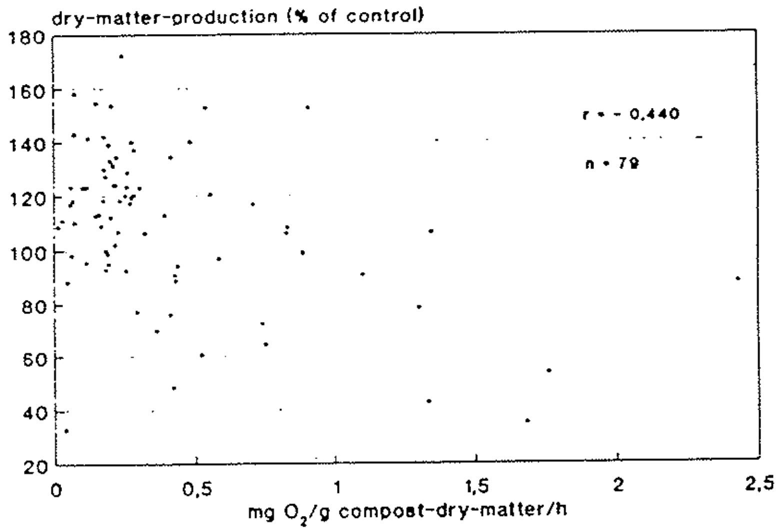

Figure 6 Relationship between oxygen-consumption of composts and their effect on dry-matter-production of oats

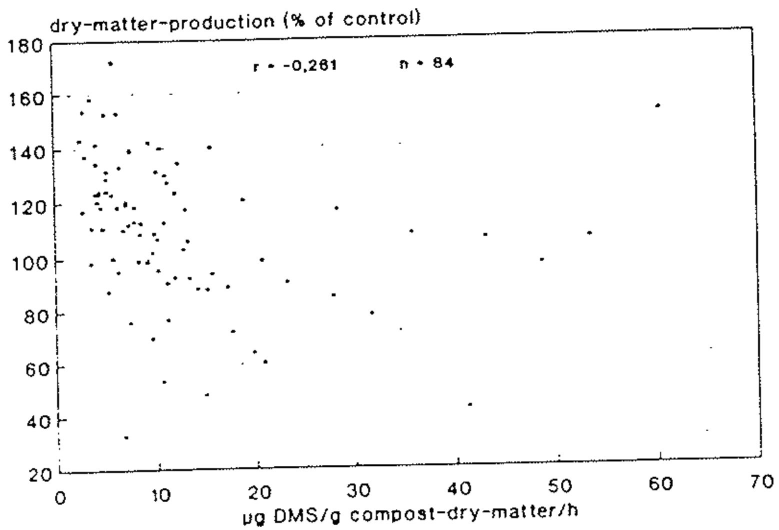

Figure 7 Relationship between DMS-production of composts and their effect on dry-matter-production of oats

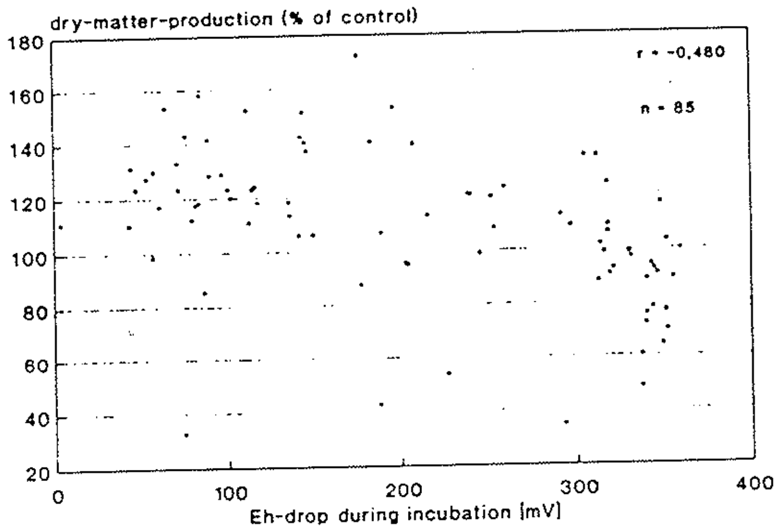

Figure 8 Relationship between Eh-drop of composts and their effect on dry-matter-production of oats

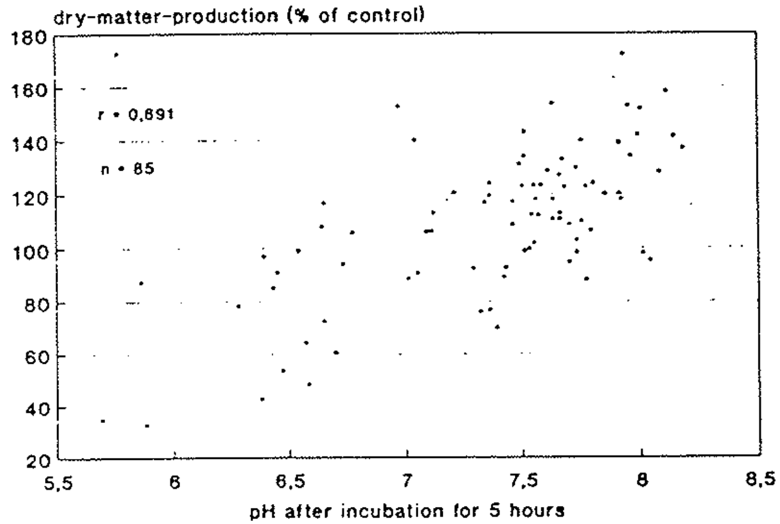

Figure 9 Relationship between ph (after incubation) of composts and their effect on dry-matter-production of oats

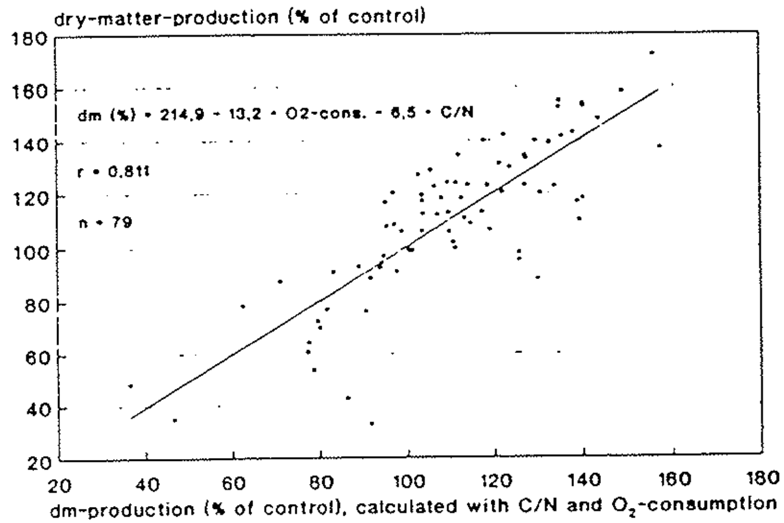

Figure 10 Real and calculated dry-matter-production of oats after compost application in pot trials

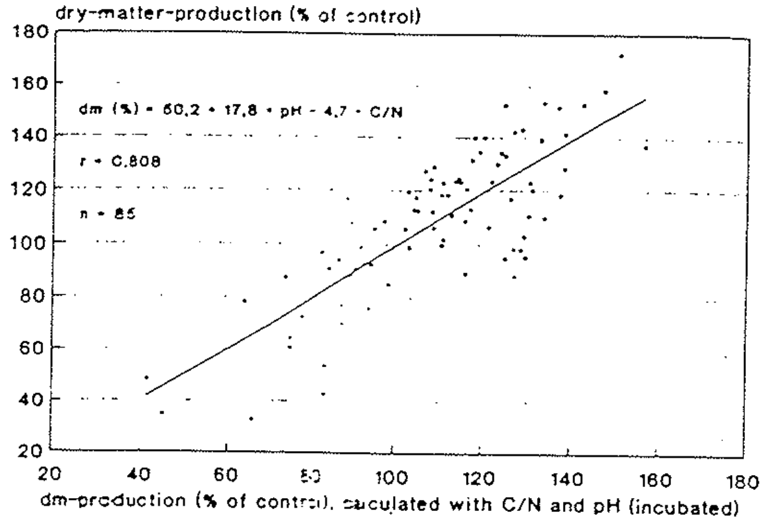

Figure 11 Real and calculated dry-matter-production of oats after compost application in pot trials

Measurements of DMSO-reduction and Eh usually proved that young composts had higher values than old ones, but sometimes the differences between the material of the three sampling times were small or inverse as one would have expected (Figs. 3 and 4). Even with regard to the fact that DMS was partly absorbed by the compost samples (3 - 9 µg DMS/g compost dry-matter during 3 hours) the results were not changed substantially.

DMSO-reduction and Eh-drop showed only weak relation to the three other methods, which correlated among themselves relativly well, for example oxygen-consumption and the self-heating-capacity, the most wide-spread maturity test in Germany (Fig. 5).

Prediction of the effect of composts on plant growth in pot trials:

Contrary to the possibility to determine the process of maturing with biological methods it was almost impossible to predict the effect of composts on plant growth in a satisfactory manner. There was only low correlation between nearly all biological maturity parameters and the dry-matter-production of oats - even oxygen - consumption, which showed a clear relation to the duration of composting couldn't predict the effect on plants (Figs. 6 – 8). Composts with high microbiological activity could both cause high yields (up to 150% of the control) and low yields (ca. 40% of the control). On the other side there were composts with low activity which resulted in serious negative yields compared with the control. Only pH after 5 hours of anaerobic incubation brought about a closer correlation to plant growth (Fig. 9).

One opportunity to improve the estimate of compost behaviour in pot-trials was to use biological parameters and the C/N-ratio of composts supplementarly. Thus one was able to predict the effect of composts with high reliability (Figs. 10 and 11).

Discussion

Though some microbiological methods are more or less able to prove the progress of maturing in dependence on time they evidently cannot produce universally valid results because there is a great influence of raw material and procedure of composting (see figs. 1 – 4). However it would be conceivable to use biological parameters related to single compost plants with relative invariable raw materials and constant technique of composting.

Reasons for partial divergences between the single biological methods probably are the different mechanisms which are tested respectively (Forster et al. 1993). While self-heating-capacity and oxygen-consumption reflect a general ability to dissimilate C-compounds the other methods determine more or less specific properties of composts: DMSO-reduction is a method for measuring the activity of a group of enzymes (Alef 1991). Despite the statement of

Alef (1991) that more than 95 % of soil-microorganisms are capable of reducing DMSO to DMS perhaps it is possible that the microflora in composts reacts somewhat different concerning this enzyme activity. Undoubtedly the conditions in composts vary strongly from soils as DMS produced by biogenic waste compost samples can exceed soil DMS-production by the factor 2000 (own measurements, not yet published).The decrease of pH as a consequence of anaerobic incubation is a combined effect of the presence and availability of C-compounds, the kind of produced organic acids and the puffering capacity of composts. Nearly the same is true for Eh, the puffering capacity presumably being the result of a complex system of redox-effective compounds (e.g. nitrate, Fe- and Mn-oxides and -ions, humic-acids (Ziechmann 1972, Schachtschabel et al. 1982)). Moreover it is to be supposed that the activity of some of the organisms is partly reduced under the extreme conditions being necessary for measuring pH and Eh (anaerobiosis, 40°C).

Therefore it met up to the expectations that self-heating-capacity and oxygen-consumption were closely correlated (only two composts deviated extremely , see Fig. 5) while it was a little bit surprising that pH after 5 hours incubation showed a high correlation with oxygen-consumption, too ($r = -0{,}814$; $n = 78$). Inspite of the different mechanisms being active in both methods they seemed to be very similar ultimately and proved the course of maturing best. DMSO-reduction and Eh however reflected maturity only with restrictions. Latter method apparently detected phenomenons not being directly involved in the ripening process. Moreover in all composts with low pH (< 7,5) at the beginning of the incubation, Eh dropped substantially only after a lag period. Hence in these composts Eh failed in determining maturity while it was possible with the pH-method, which indicated only little progress in composting by low pH-values. DMSO-reduction possibly behaved similar to other enzyme-activity methods, which were on a low level in young or badly treated composts as Abd-el-Malek et al. (1976) and Herrmann and Shann (1993) had ascertained. Therefore low activity found out with the DMSO-method in some cases possibly wasn´t due to increased maturity but to unfavourable conditions in the composting process (e.g. 3 week old compost 0 in Fig.3: no structure material). Generally in young composts enzymic activities can be small though oxygen-consumption may be high (Abd-el-Malek et al. 1976).

Last but not least, one reason for a certain unreliability of biological methods to prove maturity is the fact that during composting there can be sudden changes in microbial activity (Iannotti et al. 1994). This would mean that values measured by biological methods need not reflect the general status of composts and their maturity but indicate only an actual condition perhaps affected by turning, irrigating et cetera.

One essential cause for the relative failure of biological methods to predict the effect of composts on plant growth however, is the fact that these methods give no information about the quantity of usable nutrients, nitrogen in particular, but only determine microbial activity. So it could be that there are concomitantly high activity and a large N-pool. This pool presumably is able to supply both the microorganisms and the plants. This would mean that some composts in spite of 'low maturity' (= high activity) produce good plant growth. This hypothesis is supported by the results brought about by including the C/N-ratio to explain the behaviour of composts in pot-trials (Figs. 10, 11), because the C/N-ratio provides information about both C- and N-contents. A further conformation of this interpretation was given by Ebertseder et al. (1994) who found out that plant growth showed best correlation to C/N-ratio in the K_2SO_4-extract of composts but not to the C- or N-concentration alone.

Conclusions

Measurements of microbiological activity can provide only supplemental information about maturity of composts and their effects on plant growth. For that reason they should not be used as sole methods but only in combination with other chemical parameters, e.g. C/N-ratio of the solid phase of composts. In further investigations, which are not completed yet, is to be examined, wether other methods, for example analysis of the N-status of composts (determination of different N-fractions of compost-samples after drying and extracting under varied conditions) allow better evaluation of composts than the biological methods which are presented in this publication.

References

Abd-el-Malek, Y., Monib, N., Rizk, S.G. and Shehata S.M. (1976): Biological activities during ripening of composts. Zbl.Bakt.Abt.II, 131, 744–750.

Alef, K. (1991): Methodenhandbuch Bodenmikrobiologie. ecomed-Verlag, Landsberg/Lech

Ebertseder, T., Gutser, R. and Claassen, N. (1994): Parameter zur Abschätzung der Wirkung von Bioabfallkomposten auf das Pflanzenwachstum. VDLUFA-Schriftenreihe 38/1994, 325-328.

Flessa, H. (1990): Redoxprozesse in Böden in der Nähe von wachsenden und absterbenden Pflanzenwurzeln. Diss. TU München.

Forster, J.C., Zech, W. and Würdinger, E. (1993): Comparison of chemical and microbiological methods for the characterization of the maturity of composts from contrasting sources. Biol.Fertil.Soils, 16, 93–99.

Herrmann, F.R. and Shann, J.R. (1993): Enzyme activities as indicators of municipal solid waste compost maturity. Compost Science & Utilization, 1 (4), 54–63.

Iannotti, D.A., Grebus, M.E., Toth, B.L., Madden, L.V. and Hoitink, H.A.J. (1994): Oxygen respiro-metry to assess stability and maturity of composted municipal solid waste. J.Environ.Qual., 23, 1177–1183.

Jakob, H.-E. (1970): Redox potential. In: Norris, J.R. and Ribbons, D.W. (eds.): Methods in Microbiology. Academic Press, London, 91–123.

Jann, G.J., Howard, D.H. and Salle, A.J. (1959): Method for the determination of completion of composting. Appl. Microbiol., 7, 271–275.

Kohmann, H. and Fischer, P. (1993): Neue Methode zur Reifegradbestimmung von Kompost. ENTSORGA-Magazin, 6, 72–74.

LAGA (1984): Qualitätskriterien und Anwendungsempfehlungen für Kompost aus Müll und Müllklärschlamm. Merkblatt 10 der Länderarbeitsgemeinschaft Abfall (LAGA). Kumpf, Maas, Straub, Müll- und Abfallbeseitigung, Kennziffer 6856, Erich.Schmidt–Verlag, Berlin.

Morel, J.-L., Guckert, A., Nicolardot, B., Benistant, B., Catroux, G. and Germon, J.-C. (1986): Etude de l´évolution des caractéristiques physicochimiques et de la stabilité biologique des ordures ménagères au cours compostage. Agronomie, 6 (8), 693–701.

Nicolardot, B., Chaussod, R., Morel, J.-L., Guckert, A., Benistant, D., Catroux, G. and Germon, J.-C. (1986): Apprécation simple de la maturité des composts urbains en relation avec leurs effets sur la production végétale. Agronomie, 6 (9), 819.827.

Schachtschabel, P., Blume, H.-P., Hartge, K.-H. and Schwertmann, U. (1982): Lehrbuch der Bodenkunde. Enke, Stuttgart.

Yamane, I. and Sato, K. (1968): Initial rapid drop of oxidation-reduction potential in submerged air.dried soils. Soil Sci. Plant Nutr., 14 (2), 68–72.

Zehner, R., Mentler, A., Pfeffer, M. and Razig, E.A. (1992): Einfluß von Matrixstörungen bei der Bestimmung der mikrobiellen Aktivität in Böden mittels Dimethylsulfoxid-Reduktion. VDLUFA-Schriftenreihe 35/1992, 579–582.

Ziechmann, W. (1972): Über die Elektronen-Donator- und Acceptor-Eigenschaften von Huminstoffen. Geoderma, 8, 111–131.