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Parameters to Estimate the Nitrogen Effect of Biogenic Waste Composts

Th. EBERTSEDER, R. GUTSER and N. CLAASSEN – Institute of plant nutrition, Technical University of Munich, 85350 Freising, Germany

Abstract

Efficient strategies for using composts in agriculture demand for parameters to estimate their nitrogen effect (mineralization, immobilization) in soil. To find such a parameter different extraction methods (water extract, K_2SO_4 extract, hot water extract) were carried out on 81 different biogenic waste composts. Besides this selfheating capacity, total organic carbon and total nitrogen were determined. The results of compost analysis were correlated with nitrogen uptake by oat in two pot trials. Selfheating capacity did not correlate with the nitrogen effect of the composts. The C/N ratio of the solid phase of composts was considerably well related to N uptake by oat and is therefore an important quality criterion of composts. But the correlation was found to depend on the similarity of raw materials and management of composting. All in all the best correlation to N uptake by plants was given by the total organic carbon to total nitrogen ratio of K_2SO_4 extracts (C/N_{K2SO4}). The correlation coefficients were almost the same in both pot trials. C/N_{K2SO4} is therefore proposed to be a good parameter to estimate the nitrogen effect of composts. This is further supported by results from field trials.

Introduction

The use of waste composts on agricultural soils demands high compost qualities. One major aspect of compost quality is its nitrogen effect (mineralization, immobilization) in the year of application which is influenced by the microbial availability of compost nitrogen and carbon. Parameters to estimate the influence of compost on nitrogen turnover in soil are necessary, to avoid yield losses by nitrogen immobilization, to increase the utilization of compost nitrogen and to optimize the nitrogen nutrition of plants through mineral fertilization.
Although many methods to measure compost stability have been proposed

(Jiménez and Garcia, 1989, Senesi, 1989, Gallardo-Lara and Nogales, 1987, Garcia et al., 1992, Forster et al., 1993) the influence of this compost parameters on the nitrogen dynamics in soils fertilized with compost were scarcely investigated. Therefore, the aim of this study was to find parameters that predict the nitrogen effect of composts measured in pot trials. For two reasons the investigations were concentrated on C and N fractions soluble in aqueous extracts: first, the methods should be easily practicable for routine analysis and second, more important, the turnover of organic and inorganic nitrogen compounds by microorganisms occurs in the water soluble phase.

Materials and methods

Pot trials:

Two pot trials (A and B, Mitscherlich pots, 6.0 kg airdried soil) with composts from different sources were carried out in a vegetation hall. Composts were mixed at an amount equivalent to 1.2 g N_t/pot with a silty loam soil (pH 6.1) which was well supplied with other nutrients. Oat was cultivated in the pots (four replicates per treatment). The water content of the soils was kept near 65 % of the maximum water-holding capacity by irrigating daily with destilled water. The oat was harvested at the end of flowering. Dry matter yield and N uptake were measured.

Field trials:

In two field trials running 1992 and 1993 on brownearth soils derived from loess-loam (sandy to silty loam) composts were applied at an amount of 510 kg N_t/ha in spring just before sowing of maize. The aboveground parts of maize plants were harvested in September. Dry matter yield and N uptake were determined.

Composts:

All composts originated in general from organic household and garden waste as well as plant materials from public grounds. The composts were sieved through a 10 mm sieve.

In pot trial A fourty different composts were tested which came from 15 different compost plants all over Bavaria. They differ widely in kind and mixture of the raw material, additional substances (e.g. mature compost, clayey soil, lime), age and management of composting (e.g. pile size, kind and frequency of turning the pile). In pot trial B the tested composts came from a composting experiment. The compost piles in this experiment differed mainly in the mixture ratio of raw materials, frequency of turning, influence of climatic conditions and pile size. Compost samples were taken from each pile 3, 8 and 12.5 weeks after the beginning of composting. On the whole these 41 compost samples were much more similar than the ones of pot trial A mainly because of the same raw materials (only different mixture ratio) and the same sampling dates for all piles.

Compost analysis:

The selfheating capacity (Jourdan, 1988) of compost was measured in Dewar-flasks (1,5 l) at room temperature. The maximum temperature (T_{max}) was determined as a standard criterion on compost maturity (Bundesgütegemeinschaft Kompost, 1994). Total nitrogen content (N_t) was analysed by Kjeldahl method and total organic carbon content (C_t) by $Cr_2O_7^{2-}$–oxidation. The mineral nitrogen content (N_{min}, NH_4-N+NO_3-N) was measured in an 0,01 M $CaCl_2$-Extrakt (w/v=1/10) by steam destillation. Soluble C and N fractions were determined in three different aqueous extracts:

- water extract (40 g fresh weight of compost were shaken in 200 ml dest. water for 1 hour at room temperature),
- K_2SO_4 extract (0,5 M K_2SO_4 instead of dest. water) and
- hot water extract (boiling 40 g fresh weight of compost in 200 ml dest. water for 1 hour under reflux).

All extracts were centrifuged (20 min., 1200 rpm), filtered through 0,45 µm membrane filter and deepfreezed. Ammonium, nitrate and Kjeldahl nitrogen content of the extracts were determined by steam destillation, desolved organic carbon by a TOC analyzer (TCM 480, Carlo Erba Instr.). The total nitrogen content was calculated: $N_{extract}$=Kjeldahl-N+NO_3-N.

Statistics:

Correlation (Pearson correlation coefficients) and regression analysis between the N uptake of oat (means of four replicates) and the parameters from compost analysis were performed by SAS.

Results and discussion

To examine the nitrogen effect of composts the nitrogen uptake by plants is more suitable than their yield. On the one hand the influence of other factors than nitrogen availability is stronger on yield than on nitrogen uptake. On the other hand nitrogen that becomes available at the end of the growing period (only about 8 weeks in this pot trials) may not lead to higher yields but to higher N uptake.

In figure 1 the maximum temperature of selfheating is plotted against the difference in N uptake of compost fertilized and unfertilized plants in pot trial A. Obviously there is no correlation at all. Therefore selfheating capacity is not a suiteable parameter to calculate nitrogen availability of composts for plants. This

is noteworthy because selfheating capacity is the standard method for compost maturity in Germany (Bundesgütegemeinschaft Kompost, 1994).

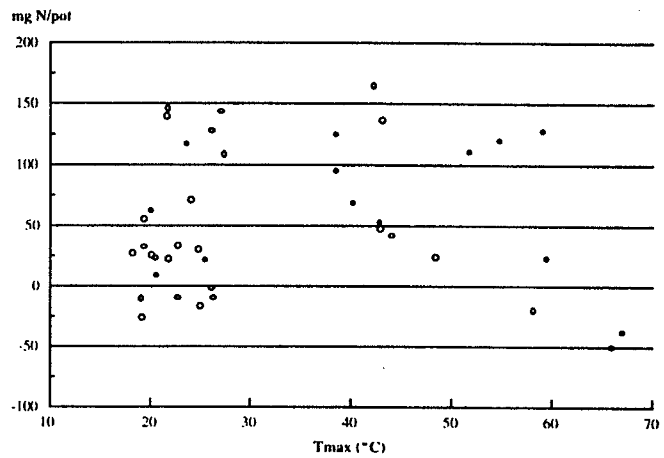

Figure 1 Relation between selfheating capacity of composts and the N uptake by oat calculated as difference between compost fertilized and unfertilized treatments in pot trial A

The different carbon and nitrogen fractions of the composts in pot trial A were closer related to the nitrogen uptake by plants than selfheating capacity (Tab. 1). The soluble nitrogen fractions were higher correlated with the nitrogen effect of these very different composts than the soluble carbon fractions or the total carbon and nitrogen contents. The highest correlation coefficients, however, were found between nitrogen uptake and the diverse carbon to nitrogen ratios. This is due to the fact that carbon availability as well as nitrogen availability plays an important role for nitrogen turnover.

Table 1 Correlations between parameters of compost analysis and the N uptake of oat (pot trial A, n=40)

	N uptake		N uptake		N uptake
T_{max}	−0,00	C_{K2SO4}	−0,16	C/N_{H2O}	−0,61***
C_t	−0,36*	N_{K2SO4}	0,43**	C/N_{K2SO4}	−0,77***
N_t	0,21	$C_{hotwater}$	0,08	$C/N_{hotwater}$	−0,70***
N_{min}	0,61***	$N_{hotwater}$	−0,48**	$\ln C/N_{H2O}$	−0,61***
C_{H2O}	−0,08	C_t/N_t	−0,66***	$\ln C/N_{K2SO4}$	−0,83***
N_{H2O}	0,40*	$\ln C_t/N_t$	−0,67***	$\ln C/N_{hotwater}$	−0,74***

The best prediction of nitrogen availability to plants in this pot trial permitted the C/N ratio of the K_2SO_4 extract (C/N_{K2SO4}). The prediction could be improved by transforming C/N_{K2SO4} to logarithm ($\ln C/N_{K2SO4}$) as shown in figure 2.

It should be noted that for the calculation of the C/N ratios of these aqueous extracts their total nitrogen content was used. Therefore these ratios are different from the carbon to organic nitrogen ratio in water extract which was proposed by

Chanyasak and Kubota (1981) and Saviozzi et al. (1987) as a good parameter for compost maturity. Although the carbon to organic nitrogen ratio of water extract was found to correlate with plant growth too (Hirai et al., 1986), the inorganic nitrogen must be included because it is primary available to plants and microorganisms. The importance of the inorganic nitrogen for the nitrogen effect of composts is clearly shown by the relatively high correlation coefficient between N_{min} and nitrogen uptake of oat in table 1.

Obviously destilled water is to weak a solvent for extracting the readily bioavailable organic and inorganic fractions because of the relatively low correlation coefficient between its C/N ratio (C/N_{H2O}) and the nitrogen utilization by plants. Water extracts contain on the average only 90 % of the nitrogen of the K_2SO_4 extract, especially due to lower ammonium content. Whereas the average carbon content was almost the same in the two extracts. On the other hand boiling water may be to strong a solvent compared with the concentrated K_2SO_4-solution (average N content 180 %, average C content 270 % of K_2SO_4 extract). Therefore the water and the hot water extraction were excluded from the analysis of the compost samples in pot trial B (see lower correlation coefficients, table 1).

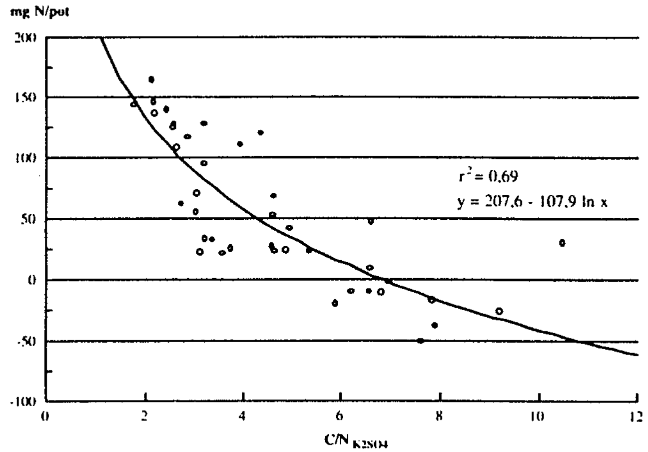

Figure 2 Relation between C/N ratio of K2SO4 extract of composts and the N uptake by oat calculated as difference between compost fertilized and unfertilized treatments in pot trial A

Table 2 Correlations between parameters of compost analysis and the N uptake of oat (pot trial B, n=41)

	N uptake		N uptake		N uptake
T_{max}	- 0,40**	C_{K2SO4}	-0,25	C_t/N_t	- 0,81***
C_t	- 0,10	N_{K2SO4}	0,04	$\ln C_t/N_t$	- 0,80***
N_t	0,67***	C/N_{K2SO4}	- 0,74***		
N_{min}	0,14	$\ln C/N_{K2SO4}$	- 0,76***		

The correlation coefficient between the C/N ratio of the solid phase (C_t/N_t) and the nitrogen uptake by oat in pot trial B was very high (Tab. 2) compared to pot trial A. This is in agreement with findings that only if very similar composts (especially in raw material) were used C_t/N_t can be accepted as an indicator of compost maturity (Hirai et al., 1983, Jiménez and Garcia, 1989). Nevertheless the C/N ratio of the solid phase can be considered as an important quality criterion of composts as has been pointed out by several authors (Watanabe and Kurihara, 1982, Jiménez and Garcia, 1989) since its correlation to N uptake was also rather high in pot trial A. But the only use of the C/N ratio of the solid phase for estimating the nitrogen effect of composts without taking into account other factors may in many cases lead to mistakes in fertilizing strategies with compost application.

Compared to pot trial A, the similarity of the composts in pot trial B also led to an improvement of the correlation coefficient between the selfheating capacity (T_{max}) and the nitrogen uptake by plants. In contrast no soluble nitrogen fraction (N_{min}, N_{K2SO4}) correlated with the nitrogen effect of the composts in this trial neither did the soluble carbon (C_{K2SO4}). The C/N ratio of the K_2SO_4 extract (C/N_{K2SO4}), however, was almost as suitable to predict the nitrogen effect of the composts as in pot trial A (Figure 3).

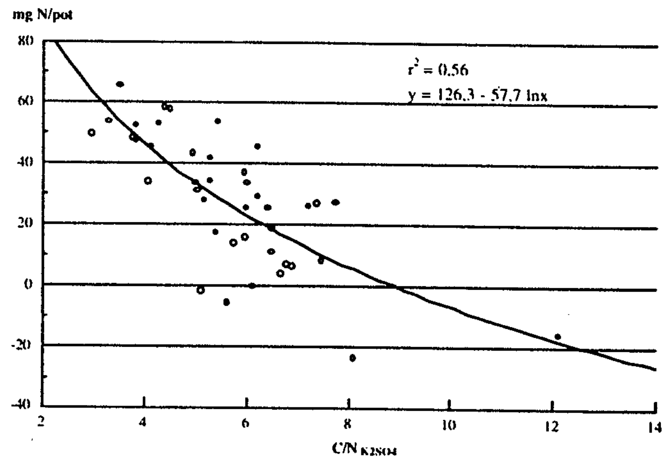

Figure 3 Relation between C/N ratio of K2SO4 extract of composts and the N uptake by oat calculated as difference between compost fertilized and unfertilized treatments in pot trial B

In both trials (Figures 2 and 3) composts with a C/N ratio of the K_2SO_4 extract below 5 - 6 increased the nitrogen uptake of plants due to the supply of inorganic nitrogen or the mineralization of organic nitrogen from compost. On the other hand composts with C/N_{K2SO4} higher than 6 led to the risk of nitrogen immobilization.

All in all the ratio of total organic carbon to total nitrogen of the K_2SO_4 extract seems to be a good parameter to estimate the short-term nitrogen effect of composts in the year of application. Yet it only can be completely accepted if a satisfying correlation consists in field trials too, because most often the standardized conditions of pot trials differ strongly from that in field. Till now only a few data from field trials with maize are available but they seem to support the results of the pot trials (Figure 4).

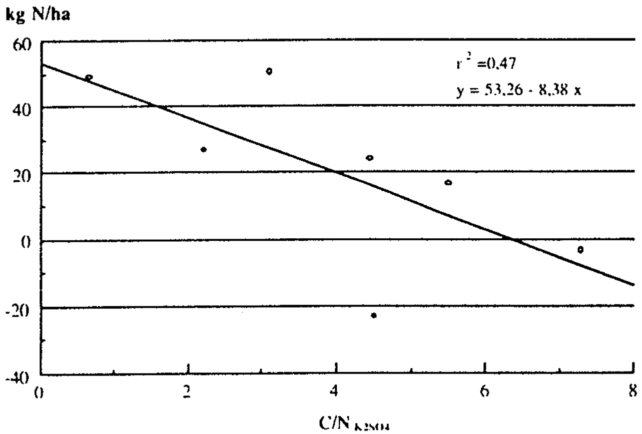

Figure 4 Relation between C/N ratio of K2SO4 extract of composts and the N uptake by maize calculated as difference between compost fertilized and unfertilized treatments in two field trials

Conclusions

1. The selfheating capacity is not related to the short-term nitrogen availability after compost application on agricultural soils. Therefore it is not a suitable parameter to estimate the short-term utilization of compost nitrogen by plants.
2. The ratio of total organic carbon to total nitrogen (C_t/N_t) of composts (solid phase) is relatively well correlated with their nitrogen effect in soil. However, the correlation between C_t/N_t and nitrogen availability in compost fertilized soils depends on their raw materials and management of composting. Therefore it can not be used as the only parameter for calculating the potentially for plants useable compost nitrogen in the year of application.
3. The ratio of total organic carbon to total nitrogen of the K_2SO_4 extract (C/N_{K2SO4}) is proposed to be a good parameter to estimate the nitrogen effect of composts. It correlates well with the nitrogen uptake by plants in the year of application and is widely independent of raw materials and management of composting. Composts with C/N_{K2SO4} lower than 5 - 6 lead to a positiv nitrogen effect whereas with higher C/N_{K2SO4} values the risk of nitrogen immobilization increases.

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