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Compared impact of compost and digestate on priming effect and hydrophobicity of soils depending on textural composition

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Abstract. Anaerobically fermented digestates as well as aerobically composted organic substances (OS) are used as valuable organic fertilizers in agriculture. Besides their benefits for plant nutrition and carbon sequestration potential, these amendments are also suspected to interfere negatively with the soil matrix. To compare the relevance of digestates and compost for priming effects and water repellency of soils, a moderate (40 m^3 ha^{-1}) and a threefold (120 m^3 ha^{-1}) amount of digestate derived from mechanically pre-treated silage from 80% maize and 20% sugar beet or 10 t and 30 t of compost, respectively, was mixed with homogenized samples of a loamy Cambic Luvisol (Ut3) and a sandy Podzol (Ss) in a laboratory experiment. The basal respiration rate (BAS) and the repellency index (RI) of moist (pre-dried to -60 hPa) soil-digestate-mixtures (SDM) or soil-compost-mixtures (SCM) were analyzed to determine the effect of digestate and compost on microbial activity and hydrophobicity of soils. Additionally, the content of organic carbon (C_{org}) was investigated using air-dried and finely milled mixtures. The Ss showed quantitative reduction of C_{org} in the SDM and SCM and an increased BAS, which could be explained by a beginning priming effect through microbial stimulation. As a result of enhanced OS protection in the Ut3, constant amounts of C_{org} and a subsequent declined BAS could be detected. The wettability was reduced in both soils; directly in the Ut3 by the supply of amphiphilic components and indirectly in the Ss by increased incorporation of microbial exsudates and mucilages. The supply of higher contents of available organic compounds with digestate and higher amounts of hydrophobic humic acids applied with the compost could be assumed to be the controlling factors decisive for the impact of this amendment on soil wettability. But also the inherent textural composition of the soil controlled the microbial activity and subsequent decomposition and release processes at high degree, since the Ut3 exhibited higher incorporation of OS in finer pores and contributed to the protection against microbial decay.

Keywords

Anaerobic digestates, compost, priming effect, organic carbon, basal respiration rate (BAS), hydrophobicity, repellency index (RI)

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1 Introduction

The ongoing worldwide discussion on realization and satisfaction of environmental targets requires a strategy for sustainable use of resources (Holm-Nielsen et al., 2009), which are economically viable and particularly compatible for health existence and environment (Alburquerque et al., 2012a). Due to an increased awareness on carbon dioxide release and related climate change, vast amounts of biodegradable organic wastes (e.g. slurries, green wastes and agricultural residues) (Mshandete et al., 2006), being present in most countries, are suitable to generate renewable or thermal energy (e.g. as biogas). The microbial decomposition of these organic residues generates by-products, which are used as high valued fertilizers in agriculture: compost under aerobic conditions or digestate as a result of oxygen deficiency (Tambone et al., 2010; Odlare et al., 2011; García-Bernet et al., 2011; Bustamante et al., 2012). Compost and digestates differ – as a result of their generation process – in their composition and could potentially pose major risks for atmosphere, groundwater and the functionality of soils when spreading on arable land. Interactions between soil matrix and the humic substances of these amendments combined with various amounts of fatty acids especially contained in anaerobically produced substances can modify soil wettability (Bayer and Schaumann, 2007). As a result of the amphiphilic character of such molecules, hydrophobic conditions can be intensified when soil water content falls below a critical level (Woche et al., 2005). It is frequently reported that compost and digestate augment the microbial activity in soils by the incorporation of organic substance into new microbial biomass (Tejada et al., 2006; Hurisso et al., 2013). Odlare et al. (2008) found the activity of microorganisms to be more increased after digestate application compared to compost supply. The subsequent higher production of microbial exsudates may cause enhanced cohesion between soil particles and, hence, soil stability (Chenu et al., 2000; Mataix-Solera and Doerr, 2004; Mylavarapu and Zinati, 2009) but may also contribute to soil hydrophobicity (Hallett and Young, 1999). Since the composition of organic residues differs among compost and digestates, the organic carbon (C_{org}) fraction was either detected to increase (Ros et al., 2006; Fabrizio et al., 2009) or remained unchanged (Quédraogo et al., 2001; Abdel-Rahman, 2009) after compost application. During digestion major part of easily degradable C_{org} is transferred into methane and carbon dioxide (CO_2) and will not serve as carbon source for soil C-stock. Accordingly, the organic residues available in the digestates become stabilized in fermenter, but not that much compared to organic substance present in compost (Odlare et al., 2008).

For their economical as well as ecological value as fertilizer, compost and digestates have to fulfill innocuousness for buffer-, conservation- and transport-capacity of soils. However, the compared effects of compost and digestates on chemical and microbiological soil properties as a function of soil texture remain still incomplete. This information would be essential to understand the interaction with various soil types across the borders and ensure a sustainable way of using those organic

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substances (Rowell et al., 2001). We hypothesized that the application of both amendments implies hydrophobic conditions and promotes microbial activity, inducing a priming effect. We further assumed a higher sensitivity of the loamy compared to the sandy soil as a result of an inherent higher specific surface area of clay particles.

Therefore, the objectives of this laboratory study were:

(1) To determine the effects of differently treated organic wastes (aerobic vs. anaerobic) on hydrophobicity with special focus on soil texture,
(2) to investigate the change of C_{org} content as well as microbiological activity in relationship to the applied amendment in order to
(3) draw a close connection between the detected parameters.

2 Materials and methods

2.1 Experimental sites and soil characteristics

For the laboratory investigations of chemical (C_{org} and repellency index; RI) and biological (Basal Respiration Rate; BAS) parameters, homogenized soil from two arable land sites differing in texture were sampled from the topsoil (A-horizon, 0-10 cm) in June 2014 under warm and dry conditions: an Ae-horizon of a sandy Podzol derived from glacial outwash from the research farm Karkendamm of the University of Kiel, near Kiel and a Cv-horizon of a loamy Cambic Luvisol derived from weichselian glacial till from the research farm Dikopshof of the University of Bonn, near Wesseling. According to the German texture classification (AG Boden, 2005), the soil from Karkendamm was characterized as a sandy sand (Ss), while the soil from Dikopshof was classified as a strong clayey silt (Ut3) (table 1). The topsoil of the sandy sand from Karkendamm was slightly acid, and exhibited two-fold more C_{org} compared to the strong clayey silt from Dikopshof. The A-horizon of the Ut3 possessed alkaline conditions and showed more than twice the level of the electrical conductivity compared to the Ss.

Table1

2.2 Properties of compost and digestate

Converted compost, derived from garden and park wastes, was produced at the composting plant in Bülk, Schleswig-Holstein. According to the RAL Quality Assurance (2014), the applied compost was classified as NPK-fertilizer with a certain amount of trace nutrients. With a rotting degree of five, the used compost exhibits a high degree of ripeness.

The liquid digestates were generated in batch-fermentation under laboratory conditions at the Institute of Agricultural Engineering at the University of Kiel. Twenty to 30 g of fresh input substrate from 80% maize and 20% sugar beet silage (ground and dried at 58°C) have been added to a microbial inoculum, derived from the biogas plant in Bülk, Schleswig-

Holstein, before starting the digestion process. The mixture was digested at a defined temperature of 38°C for 28 days in nine repetitions. A composite sample of the 9 repetitions was applied to soils.

The chemical analysis of the compost based on the description of the test certificate of the RAL Quality Assurance. The chemical investigations of the digestate were conducted at the LUFA GmbH, Kiel. The pH- and base saturation (S-value) were analyzed following standard procedures (Schlichting et al., 1995).

Both amendments, compost as well as digestate were characterized by alkaline conditions (table 2). The compost exhibited about 20-fold higher level of dry substance compared to digestate. The digestate showed higher cation exchange capacity (S-value) and greater amounts of cations than the composted organic substance.

Table 2

2.3 Sample preparation

To compare the impact of compost and digestate on C_{org} content, RI and BAS in laboratory, air-dried and homogenized (sieved to ≤ 2mm) soil was mechanically mixed with two amounts of compost and digestate by stirring. The applied amounts of the amendments were equivalent to the usual annual compost application rate per hectare of 10 t DS ha^{-1}, respectively 30 t DS ha^{-1} for three years and 30-40 m^3 ha^{-1} for digestate (Lfl, 2013). Additionally, the calculation referred to 15 cm soil depth to take into account the supply of the fertilizer into the topsoil. Comparable to the high compost dosis, the digestate was also incorporated into the soil in the three-fold amount. Besides, a reference (R) was established using the equivalent amount of demineralized water instead. During the exposure time of 1 day for the soil-compost-mixtures (SCM), the soil-digestate-mixtures (SDM) and the untreated reference, the mixtures were stored at 10°C. Afterwards, one part of the amendments was again air-dried and sieved to ≤ 2mm. From SCM, SDM and R, four repetitions were finely ground in the ball mill for the analysis of C_{org}. To determine the sorptivity of water and ethanol into the soil, the remaining part of the mixtures was compacted to a bulk density of 1.45 g cm^{-1} for Ss or 1.4 g cm^{-1} for Ut3 in 6 cylinders (100 cm^3) for each amendment and soil texture. For investigations of BAS, cylinders of 19.5 cm^3 were prepared with a bulk density of 1.45 g cm^{-3}, respectively 1.4 g cm^{-3} in three replicates. Afterwards, the cylinders were pre-dried to -60 hPa for 7 days or 10 days, respectively, to achieve an equilibrated matric potential. The amendments and their abbreviations are summed up in table 3.

Table 3

2.4 Soil measurements

2.4.1 Organic carbon (C_{org}) and repellency index (RI)

The organic carbon (C_{org}) content of air-dried, finely milled samples from SCM, SDM and R was determined coulometrically in four-fold replications following standard procedures (Blume et al., 2011).

Wetting properties of the moist (pre-dried to -60 hPa) samples were evaluated in six-fold replication by detecting the repellency index (RI) using a microinfiltrometer developed by Tillman et al. (1989). The RI is defined as the ratio between the intrinsic sorptivity (***S***) of water (non-wetting) and ethanol (wetting) as reference liquid. The sorptivity can be calculated from the time-dependent infiltration rate of soil every 15 seconds (***Q***), the air-filled porosity (***f***), the infiltrometer tip radius (***r*** = 1.4 mm) and the parameter ***b*** (0.55), which depends on the soil-water diffusivity function:

$$S = \sqrt{Qf/4br} \tag{1}$$

The infiltration capacity of soils can be expressed with the RI from the relationship of the intrinsic sorptivity of water ($\boldsymbol{S_{Water}}$) and ethanol ($\boldsymbol{S_{Ethanol}}$) by the formula

$$RI = 1.95 \cdot (S_{ethanol}/S_{water}) \tag{2}$$

where the constant 1.95 represents the differing surface tension and velocity of water and ethanol. Whereas a RI = 1 shows hydrophilic conditions, a RI ≥ 1.95 represents hydrophobicity. Detailed description of the method is given by Hallett and Young (1999).

2.4.2 Basal respiration rate (BAS)

The impact of compost and digestates on microbial activity was evaluated by measuring the release of CO_2 (µg CO_2 g^{-1} h^{-1}) by titration according to Pell et al. (2006) with 3 replicates for each amendment and texture. The determined CO_2 release was normalized to the influence of atmospheric CO_2 using three blank value measurements. For analysis of BAS, moist SCM, SDM and R (pre-dried at -60 hPa) were pre-incubated at 22°C to wait for the initial flush of CO_2. After 6 days, incubation vessels were filled with CO_2-free air. Afterwards, the amended samples were placed at the ground and a cup of 2 ml of 0.1 M sodium hydroxide at a perforated plate above of the sample. A scheme of the experimental design is shown in figure 1.

Figure 1

During an incubation time of 6h at a temperature of 22°C, the microbial released CO_2 molecules were captured and stored in the sodium hydroxide as a result of the following chemical reaction:

$$CO_2 + 2\,NaOH \leftrightarrow Na_2CO_3 + H_2O \tag{3}$$

The amount of hydroxid ions contained in the sodium hydroxide was back-titrated with 0.05 M hydrochloric acid. The amount of remained hydroxid ions enables a direct prediction of the content of released CO_2 and serves as an indirect indicator for microbial activity. The BAS was calculated from the molecular mass (***M_c***) of CO_2 (12.01 g mol^{-1}), the volume of used hydrochloric acid during the back-titration for the blank test sample (***V_b*** [ml]) and the mixtures (***V_s*** [ml]), the dry substance of the sample (***S_{dw}*** [g]) as well as the incubation time (***t*** [h])

$$BAS\left[\frac{\mu g\ CO_2-C}{g\ TM\ h^{-1}}\right]=\frac{M_C\cdot(V_b-V_s)\cdot 0.01}{S_{dw}\cdot t\cdot 2}\cdot 10^3 \qquad (4)$$

Due to the different valence, two hydroxid ions react with one molecule CO_2, which is described in the denominator by the factor ***2***.

2.5 Statistical analysis

For validation of data, the statistic software R (version 2.15.3) was used. After a graphical residue analysis (Shapiro-Wilk-Test) values of C_{org}, RI and BAS were assumed to be normally distributed and heteroscedastic. The statistical model included the soil textures, the unamended reference R and the mixtures (C10, C30, D40, D120) as well as their interaction terms. Analysis of variance (ANOVA) was applied to investigate the statistical significance among texture and amendments (Tukey-Test). The Dunnett-Test was assessed to evaluate the several levels of influence factors.

3 Results

3.1 Organic carbon content (C_{org}) and basal respiration rate (BAS)

The application of compost and digestate to the sandy sand (Ss) resulted in a significant (*$p<0.05$) lowering of C_{org} content compared to the reference (figure 2). Stirring of digestate into the Ss dropped the amount of C_{org} more intensively compared to compost. Further decline occurred with rising intensity of amendments (C30 and D120).

The development of the C_{org} content in the clayey silt (Ut3) showed the opposite trend. Merely the amendments C10 and C30 resulted in a slight increase of C_{org}, the variant D120 exhibited an almost unchanged picture, whereas a weak decline of C_{org} occured applying digestate in moderate amount (D40) (figure 2). Altogether, an increased application volume resulted in a slight enlargement of C_{org}.

Figure 2

The reference of Ss exhibited a lower basal respiration rate (BAS) compared to R of Ut3 (figure 3). After the application of compost and digestate to Ss, the BAS increased clearly above the reference, which was significant for the amendment D120

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(*p<0.05). The higher the added amount of compost and digestate (C30, D120), the more increased the BAS. In general, the BAS expanded at even higher rates after digestate application compared to compost.

An increase of BAS in Ut3 could be just noted in D120, while the amendments C10, C30 and D40 indicated a descent of BAS (figure 3).

Figure 3

3.2 Repellency Index of pre-dried (-60 hPa) soils

The mixture of compost or digestate to the pre-dried (-60 hPa) Ss and Ut3 increased the repellency index (RI) compared to the reference (table 3-1) but higher amounts of compost resulted in lower wettability, the RI of D120 fell beyond the RI of D40.

Table 4

4 Discussion

The impact of compost and digestate on the organic carbon content (C_{org}) and the basal respiration rate (BAS) exhibited amendment – but also texture specific differences.

Priming occurs as a result of incorporating organic substance (OS) into the soil which contains easily available energy and nutrient sources. This OS stimulates the soil inherent microbial activity, resulting in facilitated mineralization process (Kuzyakov et al., 2000). Thus, the transfer of nutrients and microorganisms with the amendments to the coarse soil matrix may trigger the beginning of priming effects in the sandy sand (Ss) while the higher amount of exchange places as well as an altered aeration status in the amended loamy silt Ut3 samples resulted in a nearly constant behaviour. Thus, the elevated mineralization of organic constituents as a result of stimulated microbial activity after application of compost and digestate coincides with an increased BAS and a subsequent decline of C_{org} in the Ss. By virtue of the higher increase of BAS after digestate amendment compared to compost application, even stronger priming effects of D40 and D120 are expected and could be also proofed. These findings correspond also to the assumption of Kirchmann and Bernal (1997), who reported the OS of highly mature compost to be more stabilized than the OS derived from anaerobic fermentation processes. Thus we need to expect such trends, because the application of digestates offers a higher content of easily decomposable residues compared to compost. However, the priming cannot be detected in the Ut3 – with exception of D40. The steady, respectively increasing level of C_{org} after addition of compost and digestate in Ut3 is in line with findings of Fabrizio et al. (2009), who described rising C_{org} contents in a silty loam, which is more pronounced with rising fertilization intensity. Eventhough the texture specific effect is dominant, the amendment specific differences (higher quantities of stabilized organic compounds in compost compared to digestates (Ebertseder, 2007) are still visible, as the increase is more apparent in the compost amendments.

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These amendment specific differences, causes by different compositions of the OS, occur as well in the BAS: In the Ss as well as in the Ut3 SDM show a higher level of BAS compared to SCM, which reflects lower degree of humification of the OS and indicates a greater content of easily available organic compounds in the soil mixed with digestate. If we consider the effects of the digestate application on the soil properties and functions and also include the input of decomposable fatty acids as carbon source for microorganisms we need to consider more interactions in soils concerning their hydraulic or storage functions (Kirchmann and Lundvall, 1992). Combined with a high level of ammonium-N, digestates offer higher supply of precious resources for microbial growth compared to composted OS, consequently provoke priming effects. To conclude, the differences for higher priming in SDM than in SCM are caused by less stabilized organic substances in digestates in combination with higher amounts of available N.

Beside the differences among the compositions of the amendments, the influence on the BAS is strongly affected by the textural composition of soils, in accordance to the texture specific influence on the carbon stock. The increase of BAS in the Ss exceeds the increase of BAS in the Ut3. Differences between the effects of SDM and SCM in the Ss compared to the Ut3 can be explained by:

- **Different accessibilities**: Reasonable for the facilitated decomposition of OS in coarser Ss is the facilitated accessibility for microorganisms. In contrast, the higher clay content in Ut3 offers an extended specific surface area and a subsequent vast adsorption and storage capacity for organic molecules (van Veen and Kuikmann, 1990). The major preferred habitat for microorganisms are middle pores, shown by higher BAS in the unamended reference in the UT3 compared to the Ss. From this point of view, a change of pore size distribution (shift from coarser to finer pores) in the Ss as a result of compost application would additionally be conceivable, as also observed in light soils by Hartmann (2002).The physical accessibility of fine pores (< 2 µm) is, however, impeded in fine textured soils, because they are impenetrable for bacteria. Therefore, the protection of OS against decomposition processes increase with rising clay content.
- **Different pH-conditions**: Higher BAS in the unamended reference in the Ut3 compared to the Ss shows enhanced living conditions as a consequence of an alkaline pH.
- **Different interactions with hydrophobic substances**: The significant decline of BAS of C30 in the Ut3 compared to R could be explained by humic acids, which protect the soil inherent organic substance from decomposting due to their potentially hydrophobic properties (Spaccini et al., 2002). Thus, not only the OS supplied with the compost may directly participate to humus production, but may also protect indirectly the existing soil carbon pool, resulting in equal or slightly increasing C_{org} contents in the Ut3. Decreased mineralization as a result of incorporated hydrophobic compounds after compost application is unforeseeable in the Ss. It can be therefore assumed, that texture dependent differences in the relationship between the BAS and the repellency index (RI) exist, since positive correlations between reduced wettability and increasing microbial activity can be detected in the Ss, but not in Ut3. This positive correlation is also described by Annabi et al. (2007) and Feeney et al. (2006). The enhanced microbial activity may result in an increased production of exsudates and mucilage which may provoke

hydrophobic conditions in the Ss. The increment of microbial biomass may lead to a release of cell wall components during the decay of the OS, which can be characterized as amphiphilic (Achtenhagen et al., 2015), so that we can assume an impact of secondary processes as well.

This above described phenomenon could not be confirmed for the Ut3, since no positive correlations could be found between the increasing hydrophobicity with decreasing microbial activity but a decreasing BAS with rising RI. This relation was confirmed in a silty clay soil by Goebel et al. (2005). The added OS It can be therefore underlined that the supplied organic substance is more protected against microbial degradation in fine pore system of clay and silt fraction of Ut3 compared to Ss. But this may also have negative effects like an increased soil hydrophobicity due to the added composted OS may. More pronounced hydrophobic conditions in the pore spaces can also cause a reduction of microbial activity by a detiorated water and nutrient delivery (Goebel et al., 2005) and may be proofed by the decrease of BAS in the Ut3 in the SCM compared to R. Thus, not only new OS of the amendment is less degradable in the Ut3, but also a protection of the soil inherent OS against microbial decay occurred through adsorption at clay particles or the incorporation of organic compounds into hydrophobic components. Spaccini et al. (2002) showed that a humic acid of compost increases the carbon sequestration through reduced mineralization. Therefore, protection of OS by humic acids against decomposting can be expected only in fine textured (silty and clay) and not in coarse textured soils. This trend is also reflected by the results of the conducted laboratory study: the mineralization (BAS) declined in SCM in the Ut3, but not in the Ss. In a 4-year field experiment, Adani et al. (2007) could confirm a shift of carbon fraction after compost application on silty clay towards a higher proportion of humified carbon compounds compared to non-humic compounds. Using the different relations of RI and BAS in the Ss and Ut3 it can be stated that in both soils the wettability is reduced by digestate and compost, but by varying dominant mechanisms: The supply of the amendment to the Ut3 lead directly to the reduction of wettability, while soil wetting declines indirectly in the Ss due to increased microbial activity. An association between either rising BAS (in the Ss) or declining BAS (in the Ut3) and increasing RI is however only available up to the amendments C30 in Ss and D40 in Ut3. Since the BAS is strongly increased after digestate amendment in the Ss, the RI is not increased more by digestates than by compost application. After the addition of digestates to the soil, further mechanisms appear to influence the RI. This would be underlined by the enhanced wettability of both soil types after application of high amount (D120) of digestate compared to the moderate quantity (D40). In a greenhouse experiment, Franco et al. (2000) could show that the fertilization of nitrogen-phosphate-potassium fertilizer results in a microbial decomposition of hydrophobic waxes and diminishes the wetting restriction of soils. With this approach, in turn, corresponds the highest increase of microbial activity in the amendment D120. The high dosis of digestate appears to exhibit more effective fertilization effect on microbial activity compared to the comparable amount of compost applied. This can be explained by the more rapid fertilization effect of nitrogen of digestates. Finally we also need to include the complex effects of the composition of the microbial biomass concerning the changes in the RI under digestate application. Hallett et al. (2001b) found in studies concerning the role of different microbial species for the development of hydrophobicity that a high fungal growth rate has more impact on

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development of water repellency than huge growth of bacterial biomass. Soil-borne bacteria that are stimulated by nutrient input, can reduce the water repellency, because their high activity competes with fungus growth and causes inhibition of this species. Walsh et al. (2012b) found the growth of bacterial populations to be more promoted by digestate application compared to the development of fungal communities. So the effect of stimulated bacterial population through digestates is similar to fungicide application which leads to a decreased RI in this study. This could be a clear evident for the results: Fungi-bacteria ratio decreases in the soils with rising dosis of digestates applied, thereby the water repellency is less pronounced.

5 Conclusions

The impact of compost and digestate on C_{org} and BAS is highly dependent on amendment-specific differences but also on textural composition of the soils. Whereas the addition of both amendments resulted in priming effects due to enhanced mineralization of OS in the Ss, the application of compost stabilized the amount of C_{org} and reduced the microbial activity (BAS) in the Ut3. Higher supply of easily available energy and nutrient sources of digestate OS caused higher stimulation of microorganisms compared to compost. Despite these evident results, the relevance of a possible interaction and competition between plant roots and microorganisms for present nutrients under field conditions remains unexpected. It can be assumed that especially in sandy regions such as the Geest in Schleswig-Holstein, digestate application may intensify the negative effect on carbon storage, since the establishment of intensively humus-consuming crop rotation already exists in this area.

After compost and digestate amendment, soil wettability is reduced in both soils due to direct and indirect mechanisms, nevertheless, the hydrophobic area was not achieved. In this context, it would be necessary to investigate the effect of these organic amendment in relation to climatic factors, e.g. drying and remoistening.

Competing interests

The authors declare that they have no conflict of interest.

Author contribution

A. Voelkner and C. Diercks designed and conducted the soil sampling and laboratory experiments. A. Voelkner prepared the manuscript with contribution from all co-authors. R. Horn contributed to prepare the manuscript.

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Table 1: Soil characteristics of the investigated arable sites Ss (Karkendamm) and Ut3 (Dikopshof).

	Soil textures	
	Ss	**Ut3**
pH (0.02 m $CaCl_2$) [-]	5.3	7.1
Electrical conductivity [µS cm^{-1}]	86	182
Organic carbon (C_{org}) [%]	2.8	0.3
Texture		
Clay [%]	2.6	14.9
Silt [%]	5.8	77.9
Sand [%]	91.5	7.2

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Table 2: Properties of compost and digestate. OS = original substance, DS = dry substance.

	pH	DS	S-value	N_t	NH_4-N	P	K	Mg	Ca
		% OS	$cmol_c\ kg^{-1}$			% DS			
Compost	8.2	56	22.1	1.3	n.A.	0.2	0.7	0.2	2.4
Digestate	7.7	2.7	94.7	6.7	5.2	11	1.6	1.4	8.5

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Table 3: Description and declaration of the amendments regarding to a topsoil of 15 cm depth. DS = dry substance; OS = original substance.

Amendment	Declaration
Reference (demineralized water)	R
10 t DS compost + 1500 m^{-3} soil	C10
30 t DS compost + 1500 m^{-3} soil	C30
40 m^3 OS digestate + 1500 m^{-3} soil	D40
120 m^3 OS digestate + 1500 m^{-3} soil	D120

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Table 4: Repellency index (RI) (n=6) of the Ss and the Ut3 after application of 10/40 t DS 1500 m^{-3} of compost (C10, C30) and 40/120 m^3 OS 1500 m^{-3} of digestate (D40, D120).

	R	C10	C30	D40	D120
Ss	0.9±0.2	1.2±0.3	1.5±0.4	1.2±0.4	1.0±0.2
Ut3	1.0±0.2	1.3±0.1	1.2±0.2	1.4±0.1	1.3±0.1

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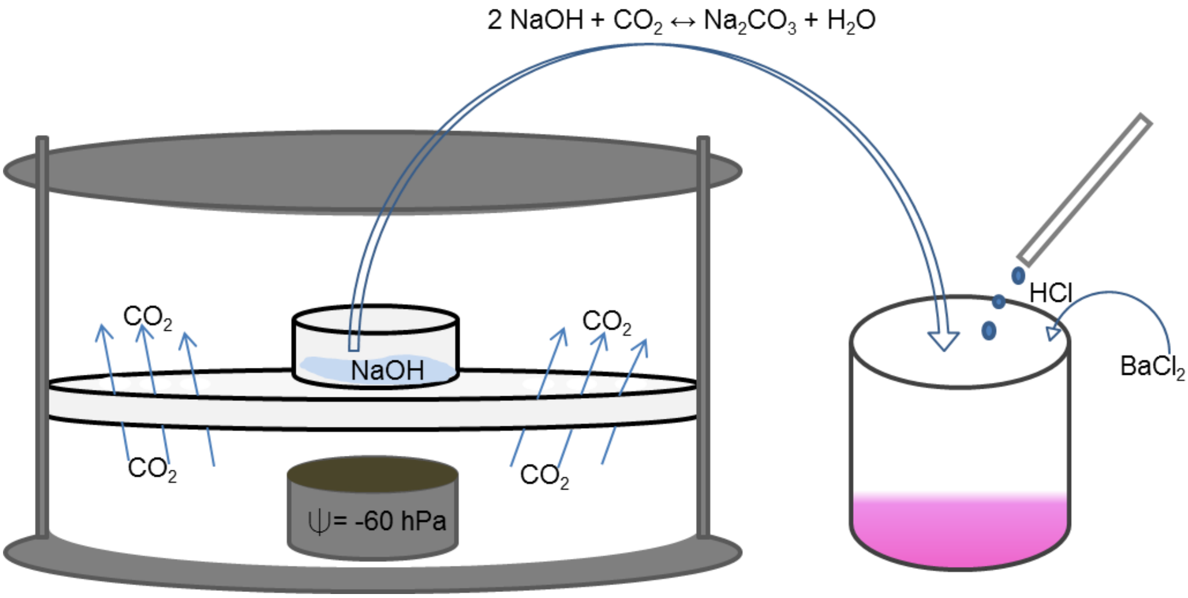

Figure 1: Schematic experimental design of the basal respiration by titration after pre-drying at -60 hPa.

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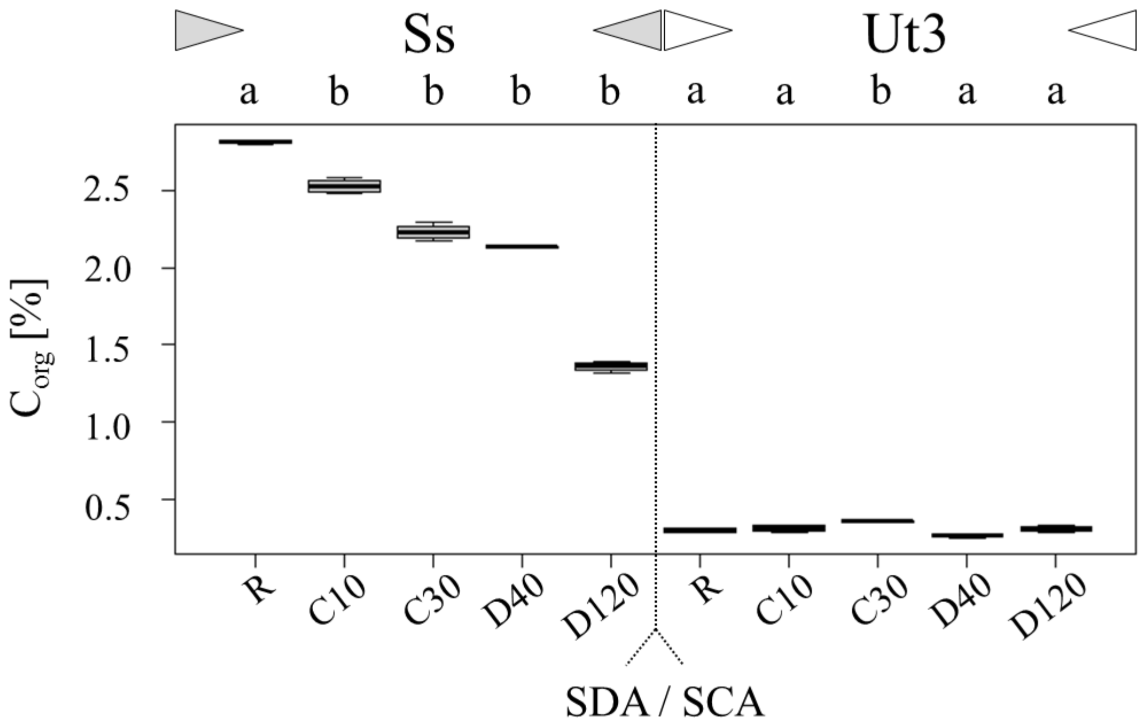

Figure 2: Organic carbon (C_{org}) content (n=4) of the Ss and the Ut3 after application of 10/30 t DS 1500 m^{-3} of compost (C10, C30) and 40/120 m^3 OS 1500 m^{-3} of digestate (D40, D120). Different letters (ab) indicate statistically significant differences (*p<0.05) of the SCM and SDM in comparison to the reference (R). Boxes represent values within the 25th and 75th percentile; the whiskers indicate the range and horizontal bars inside the boxes represent the median values.

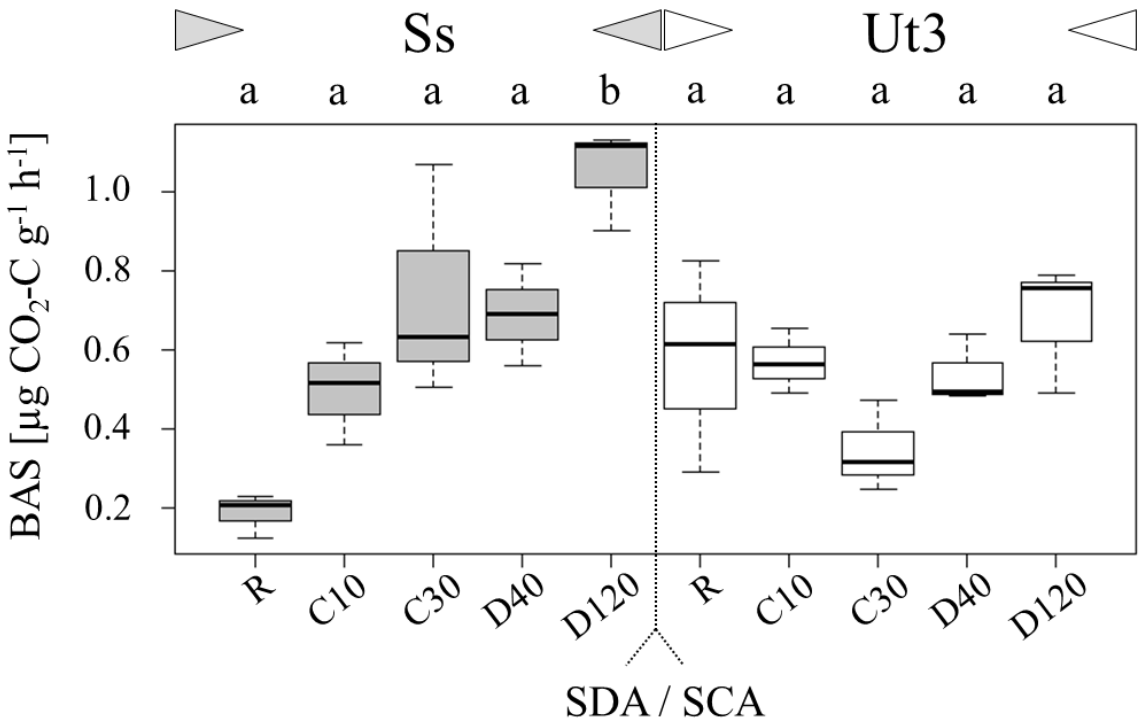

Figure 3: Basal respiration rate (BAS; n=3) of the Ss and the Ut3 after application of 10/30 t DS 1500 m^{-3} of compost (C10, C30) and 40/120 m^3 OS 1500 m^{-3} of digestate (D40, D120). Different letters (ab) indicate statistically significant differences (*p<0.05) of the SCM and SDM in comparison to the reference (R). Boxes represent values within the 25th and 75th percentile; the whiskers indicate the range and horizontal bars inside the boxes represent the median values.