Effects of digestate on the environment and on plant production - results of a research project

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SUMMARY: Composts and digestates can influence soil fertility and plant health. These influences can be positive or negative, depending of the quality of the composts. A currently important question is to know, if digestates differ from composts in these aspects. A Swiss project is concerned with the estimation of the potential of Swiss composts and digestates to influence soil fertility and plant health positively. For this, one hundred composts and digestates representative of the different composting systems and qualities available on the Swiss market were analyzed.

The organic matter and nutrient content of the composts varied greatly between the composts and the digestates; the materials of origin were the major factor influencing these values. The respiration rate and enzyme activities also varied greatly; they are particularly important in digestates. The organic matter of digestates is less stable than that of composts.

The N-mineralization potential from the majority of the digestates added to soil is high, in comparison to young composts. When digestates are not correctly treated or stored, however, they can immobilize nitrogen in the soil. This problem is hardly correlated with the management of the digestate in the first stage after leaving the fermenter. Especially products which have become too dry during this period lost their ammonia-nitrogen, and hence immobilized nitrogen in the soil.

The risk of phytotoxicity is higher in digestates than in composts. This limits the possibility for use of digestate. With a post-treatment of digestate, it is possible to produce high quality compost with a high compatibility with plant growth and with a more stabilized organic matter.

In field experiments, digestates increased the pH-value and the biological activity of soil to the same extent than composts. These effects were observable also one season after compost application. No immobilization of nitrogen was observed.

Introduction

Composts and digestates can influence soil fertility and plant health. These influences can be positive or negative, depending of the quality of the products and on their utilization. A lot is know about the influence of compost on soil fertility and plant growth, but relatively little information is available on the effects of digestates. In order to estimate the potential of Swiss digestates and composts to positively influence soil fertility and plant health, one hundred composts and digestates representative of the different composting and methanization systems were analyzed.

Material and Methods

Samples from one hundred and one composts and digestates were collected from different composting and methanization plants according to the guidelines and recommendations with respect to waste fertilizers (FAC 1995). All plants process only source-separated organic material. The samples were chosen in such a way that they are representative of the composts produced in Switzerland. The samples were either tested immediately after collection, or stored at 3°C until testing.

Chemical and biological characteristics of the composts

Nutrients and heavy metals were analyzed with ICP-AAS according to the official Swiss methods (Schweizerische Referenzmethoden, 2005). The stability of the organic matter in composts was characterized by spectrophotometric measurement at 550 nm. Measurements were made both with aqueous extracts (1:2 water extract (v:v) according to Schweizerische Referenzmethoden, 2005 (2005), and a pyrophosphate extract according to Kaila (1956).
The influence of compost on nitrogen mineralization in soil was determined with the incubation experiment according to the official Swiss methods (Schweizerische Referenzmethoden, 2005). Five to 10 percent of compost was added to a reference soil, placed in PVC boxes (12 x 10 x 5 cm, with aeration holes), wetted and incubated at 25°C. The mineralized nitrogen (NH_4 and NO_3) in the soil was determined after 0, 2, 4, 6 and 8 weeks.
The activity of four enzymes was determined: fluorescein diacetate according to Inbar et al. (1991), dehydrogenase, protease and cellulase according to Alef and Nannipieri (1995). The respirometric activity was determined according to Bockreis et al. (2000).

Biotests

The phytotoxicity tests were performed according to Fuchs and Bieri (2000). In the open phytotoxicity tests, the growth of cress (*Lepidium sativum* L.), salad (*Lactuca sativa* L.) and bean (*Phaseolus vulgaris* L. var. *nanus* L) in pots (Ø 10 cm) filled with compost was compared with the growth in reference substrate BRS-200 (Biophyt Ltd, CH-Mellikon). In the closed phytotoxicity test, PVC boxes (1 liter) were half-filled with compost or reference substrate BRS-200, cress sown onto it, then the boxes were closed hermetically. The growth of the plants in the boxes was then observed.
Two disease suppressivity tests were performed: cucumber (*Cucumis sativus*)-*Pythium ultimum* and basil (*Ocymum basilicum*)-*Rhizoctonia solani*. Both tests were performed in 200-ml plastic pots. Compost (20 % v/v) was added to the soil. In the cucumber-*Pythium* test, the pathogen was grown for 7 days on autoclaved millet, then added to the soil. In the basil-*Rhizoctonia* test, the pathogen was also grown on millet which was placed on the bottom of the pots. Cucumber or basil was then sown. Damping-off of the cucumbers was evaluated 10 to 15 days after sowing. In the basil-*Rhizoctonia* test, the living plants were counted after one, two and three weeks.

Results and discussion

Chemical characteristics of the Swiss composts

The chemical characteristics of the different products are presented in tab. 1. The values for the different composts varied greatly. While the contents of salts, nitrogen, phosphorus, potassium, magnesium and calcium depends predominantly on the materials of origin, the organic matter and the density are more influenced by the maturity of the products. However, high variability was observed for all parameters within a product category. For example, the salt content, which should be low in the composts for covered cultures and private gardening, varied between 328 and 1539 [g KCL equivalent / 100 g fresh matter]. Through a more consistent choice of the materials of origin, the compost producers could obtain a more constant salt content in the final product.

The darkness of the water extract is an important characteristic of composts in view of their practical horticultural utilization. If compost with dark water extract is used for potted plants placed in front of houses, there is a risk of coloration of the house wall by run-off water. The material of origin had some influence on the darkness of the compost extract, but the major influence comes from the maturity of the compost (fig 1A). The humus forms of immature product are water-soluble, and so their water extract is dark. That was the case for the digestates. During compost maturation, the small humus molecules are transformed to larger humus molecules which are not water-soluble, therefore the extract has a lighter colour. This evolution is evident in fig. 1A. The pyrophosphate extraction gives a better indication of stability than the water extract. Very young products such as digestates show a low pyrophosphate index (fig. 1B), because the lignified organic matter is not yet decomposed. The pyrophosphate index then increased significantly and the composts for agricultural use had the highest pyrophosphate index (fig. 1B). The stability of the humus forms, characterized by the decreasing of the index, has a slow evolution, and the variation within a product class is more important than between classes (fig. 1B). The influence of the composting materials seems to play a more important role that the maturation process, in view of the considered composting duration.

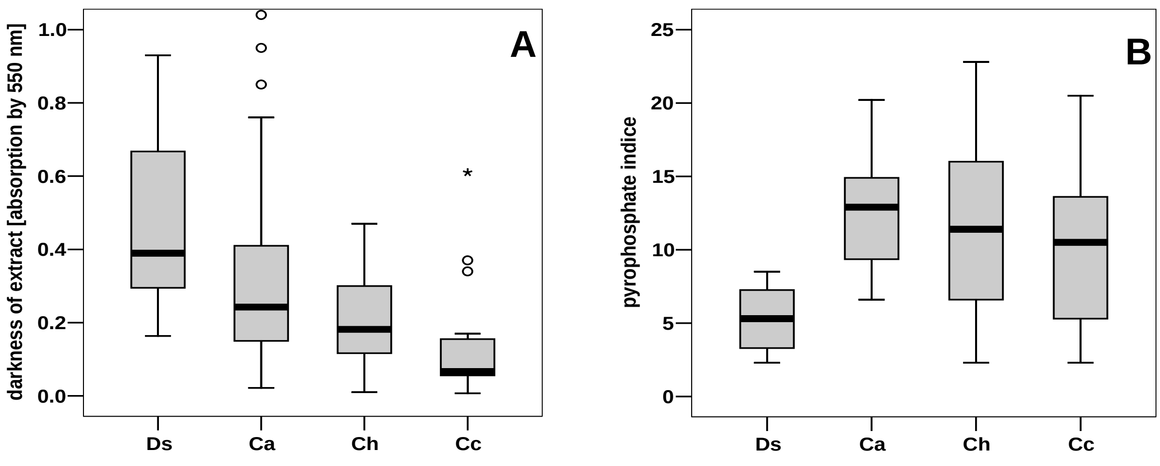


Figure 1 Stability of the organic matter of Swiss digestates and composts. A: darkness of the 1:2 water extracts (extraction according to ….). B: Pyrophosphate indice according to Kaila (1956). Composts were sampled

according to ASCP Guidelines 2001 (Fuchs et al., 2001): Ds=digestate solid, Ca=compost for agriculture, Ch=compost for horticultural used, Cc=compost for covered cultures and private gardening.

Table 1 Chemical characteristics of Swiss digestates acomposts[1]

	Digestate for agricultural use	Compost for agricultural use	Compost for horticultural use	Compost for covered cultures
salt content[2] [mg KCl/100g FM] median (minimum; maximum)	970 (704; 1384)	862 (361; 1580)	787 (173; 2657)	660 (328; 1539)
pH[2] median (minimum; maximum)	8.5 (8.0; 8.8)	8.2 (7.5; 8.7)	8.1 (7.6; 8.7)	7.9 (7.2; 8.5)
density [g/l] median (minimum; maximum)	468 (321; 631)	556 (412; 851)	609 (434; 836)	715 (631; 904)
dry matter [% FM] median (minimum; maximum)	53.1 (45.4; 75.2)	50.8 (28.2; 73.4)	56.7 (40.8; 71.1)	56.3 (32.2; 64.5)
organic matter [% DM] median (minimum; maximum)	50.3 (28.9; 73.4)	47.7 (17.0; 80.1)	38.1 (23.9; 54.7)	30.6 (20.9; 52.8)
total N [g/kg DM] median (minimum; maximum)	15.3 (9.4; 20.3)	16.6 (8.7; 26.0)	14.6 (9.2; 27.6)	15.1 (8.6; 25.2)
total P [g/kg DM] median (minimum; maximum)	3. 6 (2.0; 8.0)	3.0 (1.7; 6.1)	3.0 (1.3; 12.7)	3.3 (2.1; 8.8)
total K [g/kg DM] median (minimum; maximum)	12.5 (6.4; 20.8)	12.0 (5.7; 25.2)	11.6 (2.2; 20.7)	10.7 (5.5; 27.8)
total Mg [g/kg DM] median (minimum; maximum)	6.8 (3.7; 9.7)	4.8 (3.6; 10.3)	6.5 (4.4; 10.7)	6.5 (4.4; 13.3)
total Ca [g/kg DM] median (minimum; maximum)	46.6 (23.0; 57.8)	53.1 (24.0; 83.7)	64.0 (35.0; 91.5)	44.5 (69.4; 29.5)
Fe [mg/kg DM] median (minimum; maximum)	8.9 (3.7; 12.3)	8.8 (2.9; 16.7)	10.1 (5.4; 14.7)	12.0 (6.1; 15.8)
Na [mg/kg DM] median (minimum; maximum)	1.3 (0.5; 2.0)	0.7 (0.3; 4.5)	0.6 (0.2; 1.9)	0.6 (0.3; 1.4)

[1]: according to the “Guidelines and Recommendations of the Research Centre for Agricultural Chemistry and Environmental Science with respect to waste fertilisers” (FAC 1995).
[2]: value determined in 1:2 water extract

Characterisation of the biological activities of the Swiss digestats and composts

The evolution of the activity of four enzymes during composting differed greatly (fig. 2). The FDA (fluorescin diacetate activity) and the protease activity differed significantly between the different product classes (fig. 2). Their higher activities are observed by digestates, and are then decreasing with the advancement of product maturity. A similar evolution, but less evident, is observable in the cellulase activity. By contrast, the dehydrogenase activity was less influenced by the maturity of the products.

Respiration rate decreased with product maturation (fig. 3), as already shown by different authors (Paletski and Young, 1995; Lasaridi and Stentiford, 1998; Popp et al., 1998).

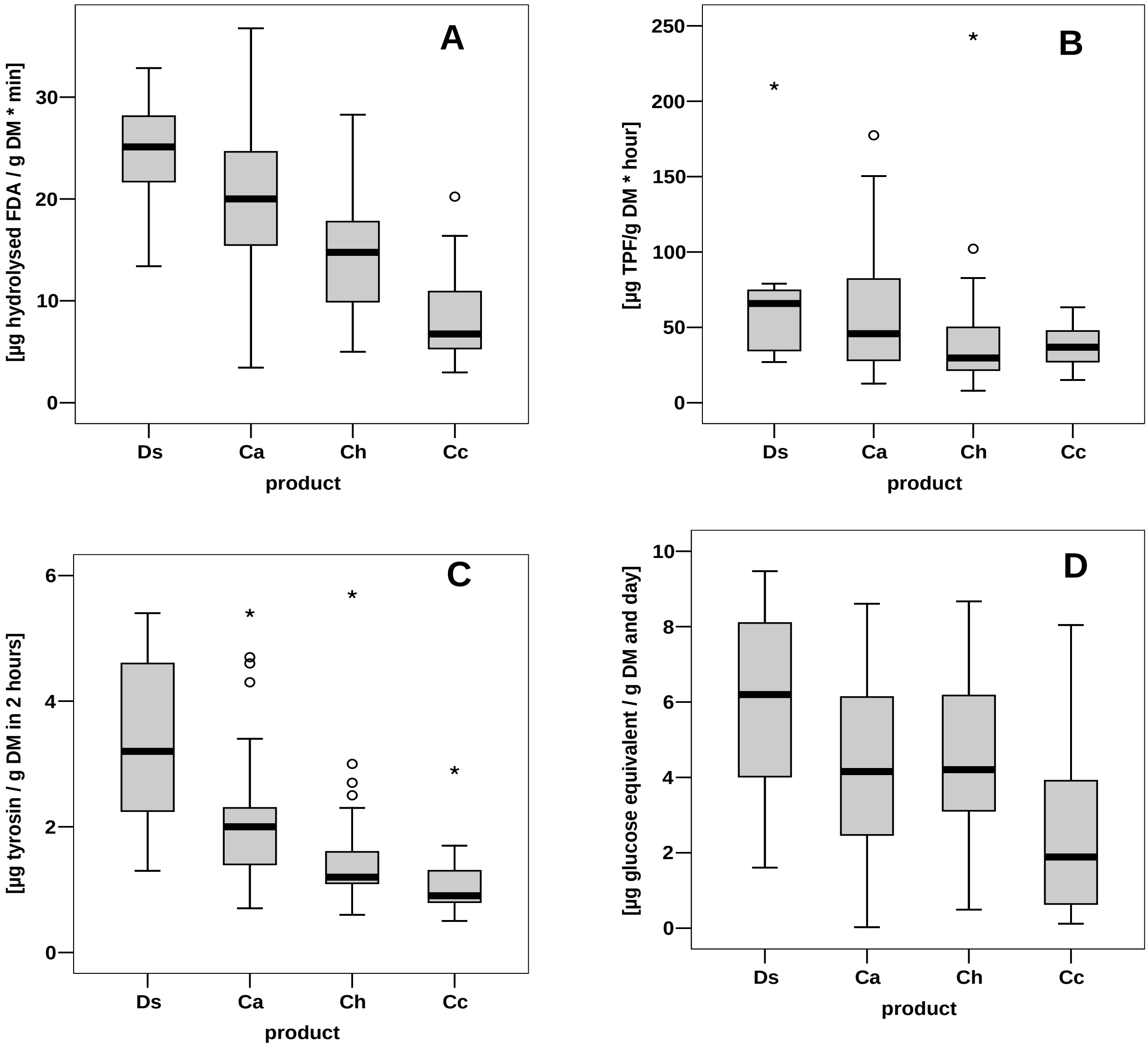
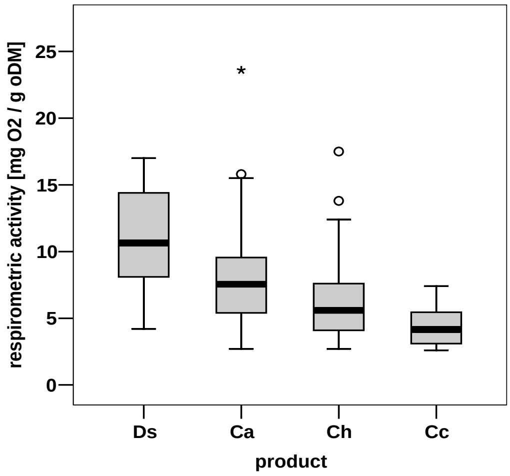


Figure 2 Enzymatic activities of Swiss digestates and composts. A: FDA activity; B: dehydrogenase activity; C: protease activity; D: cellulase activity. Products according to ASCP Guidelines 2001 (Fuchs et al., 2001): Ds=digestate solid, Ca=compost for agriculture, Ch=compost for horticultural used, Cc=compost for covered cultures and private gardening.

Figure 3 Respirometric activity of Swiss digestats and composts. Products according to ASCP Guidelines 2001 (Fuchs et al., 2001): Ds=digestate solid, Ca=compost for agriculture, Ch=compost for horticultural used, Cc=compost for covered cultures and private gardening.



Influence of Swiss digestates and composts on plant growth

Plants react on digestate or compost quality as a whole. Sometimes, all of the above-mentioned chemical parameters of a compost are good, but plants do not develop well in it for unknown reasons. To assess this risk, the phytotoxicity tests were used. The four phytotoxicity tests used react differently to compost quality. The open cress test is the least sensitive, and the plants showed growth depression only in the digestates (fig. 4Co). The salad test is more sensitive in the open system, and only the more mature products allowed a good growth of the plants. In the closed cress test, the plants are not only in contact with the compost, but are also strongly influenced by the gases which evaporate from the compost. This test is therefore very sensitive, and only the composts with high plant compatibility allowed a good growth of the cress.
In all test systems, an evolution in the plant compatibility was obvious, with the plants growing better in more mature composts (fig. 4). Nevertheless, there was considerable variation within a product class. This fact shows that the management of the composting process is at least as important for the biological quality as the maturation advancement.

Capacity of Swiss digestates and composts to protect plants against soil borne diseases

The suppressive potential of the composts against two pathogens was tested: *Pythium ultimum* and *Rhizoctonia solani*. *P. ultimum* is mainly causing damage during germination; once the plant is big enough, this fungus usually causes no more important damage. *R. solani* can attack the plant later and cause important damage also to larger plants.
No differences in the capacity of the products of the different classes to protect cucumber against *P. ultimum* were observed. The great majority of the composts significantly reduced the incidence of the disease caused by this pathogen (fig. 5P). The protection of basil against *R. solani* was clearly less efficient (fig. 5R). It seems that the capacity of the composts to protect basil against *R. solani* reached a maximum at the stage Ch (fig. 5R). In agreement with other authors, we assume a general protection mechanism for *P. ultimum* and a specific mechanism in the case of *R. solani* (Hoitink et *al*., 1997; Fuchs, 2002, Fuchs and Larbi, 2004).

In both cases, there was large variability within the product classes. This indicates that the management of the composting process is a major factor influencing the suppressive capacity of the composts.

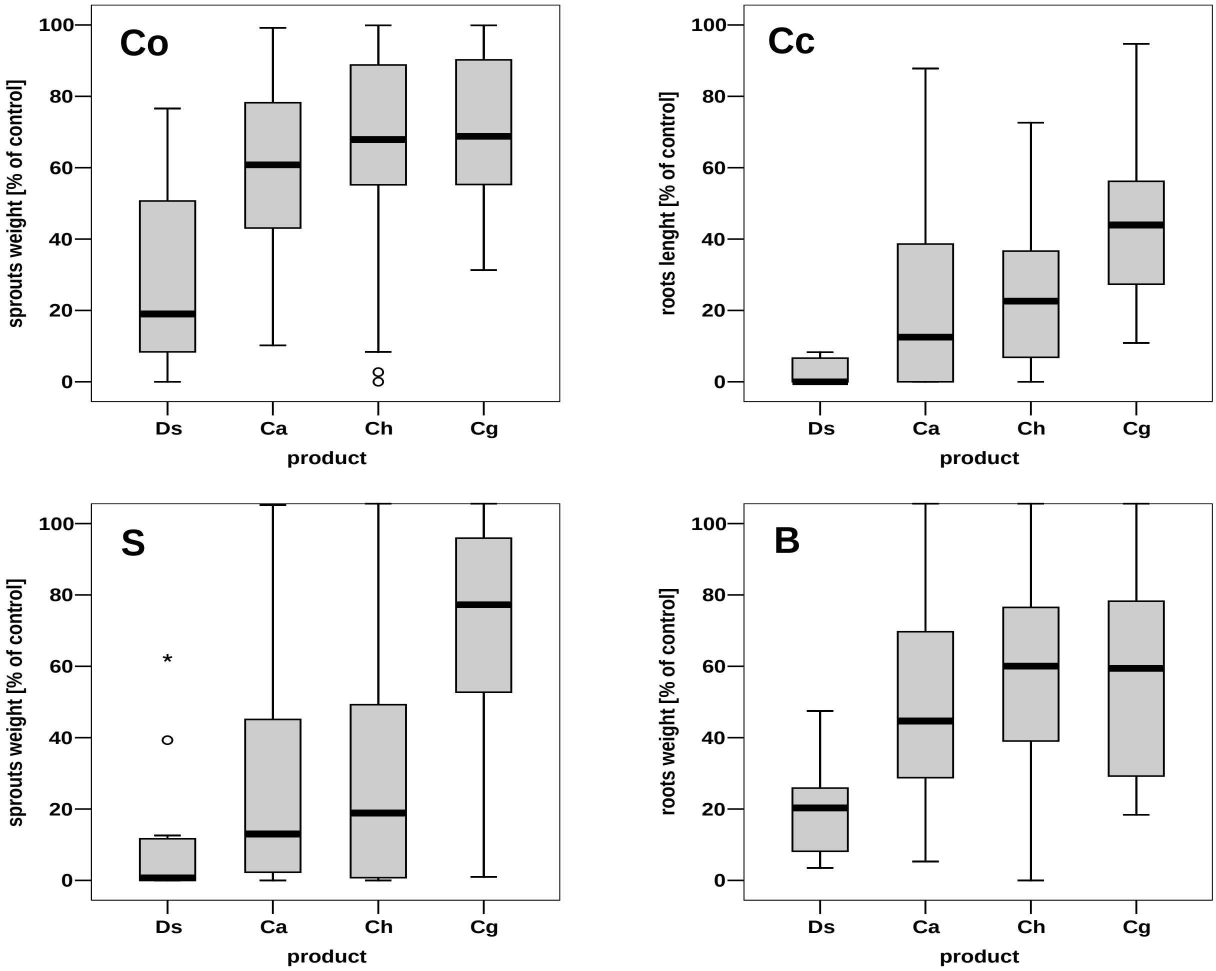


Figure 4 Phytotoxicity of Swiss composts for cress (Co and Cc), salat (S) and beans (B). The growth of the plants in pots filled with compost was compared with the growth of the plants in reference substrate (Co, S and B). Products were sampled according to ASCP Guidelines 2001 (Fuchs et al., 2001): Ds=digestate solid, Ca=compost for agriculture, Ch=compost for horticultural used, Cc=compost for covered cultures and private gardening.

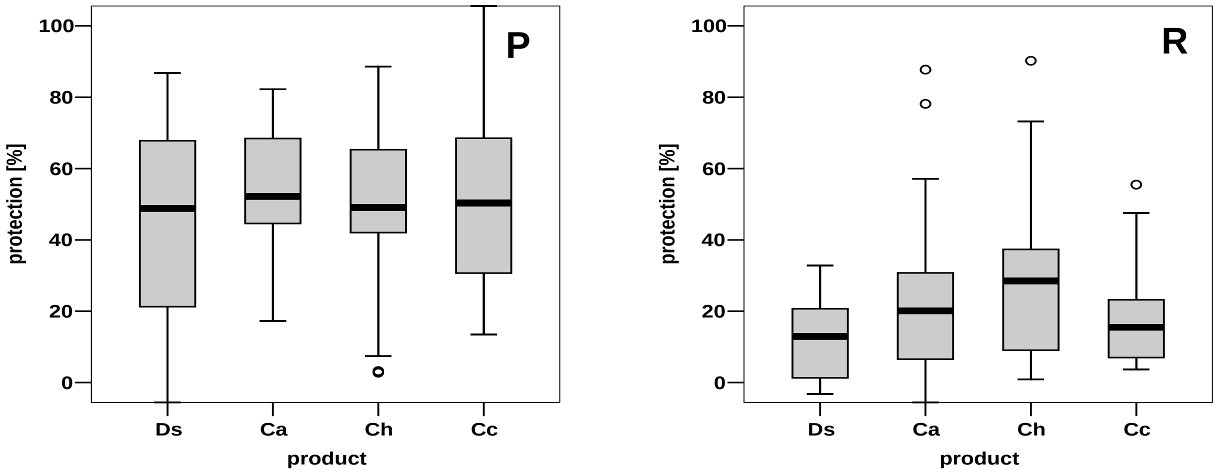


Figure 5 Capacitiy of Swiss composts to protect plants against soilborne diseases. P: protection from cucumber against *Pythium ultimum*; R: protection of basil against *Rhizoctonia solani*. Products sampled according to ASCP Guidelines 2001 (Fuchs et al., 2001): Ds=digestate solid, Ca=compost for agriculture, Ch=compost for horticultural used, Cc=compost for covered cultures and private gardening.

Influence of digestates and composts on the mineralized nitrogen content of soils

The influence of compost on the mineralized nitrogen content in soil depends, beyond the quantity of available nitrogen, also on the microbiological activity of the compost. Normally, digestates contain a high amount of mineralized nitrogen, mainly as ammonia, and they contain relatively low quantities in the form of lignin rich materials. Therefore, nitrogen immobilization is not expected after the utilization of such products. In practice, this is not always the case (fig. 6Ds). The reason for the immobilization of nitrogen in soil by some digestates is that these products are not used fresh, but after an inadequate subsequent treatment, during which the digestate has been dry and has lost all the ammonia.

In the other products, the evolution of the nitrogen immobilization risks can be clearly observed (Fig. 6). The composts for agricultural use are mainly young composts rich in undegraded lignin. The degradation of these woody substances in soil leads to a momentary immobilization of the available nitrogen (Fig 6Ca). When the composts were more mature, this risk decreased (fig. 6Ch and 6Cc).

Post-treatment of digestates

The possibility to make a post-treatment of digestats to enhance its compatibility with plants and to improve the stability of its organic matter was studied. The results obtained were very promising. After few weeks, the digestate showed a good compatibility with plants. Addition of co-product (compost, rests of sieving, soil, …) influenced principally the biological quality of the final product (risk of N-immobilization in soil, phytotoxicity, …). The most important factor during the post-treatement is the humidity management. If the material becomes too dry, the ammonia will be lost.

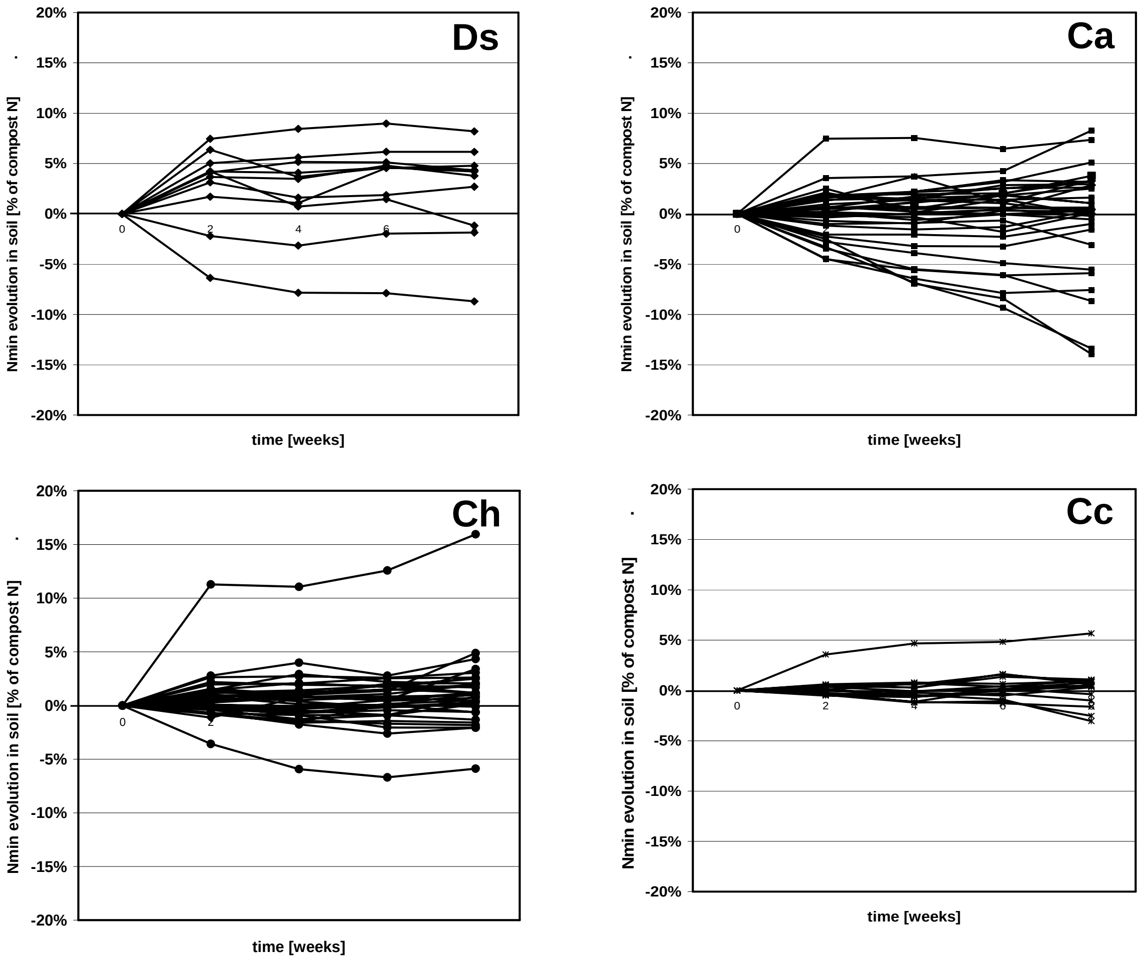


Figure 6 Influence of the addition of different composts to soil on the evolution of its mineralized nitrogen content. For each compost, the mineralized nitrogen after 2, 4, 6 and 8 weeks are compared to the mineralized nitrogen present in the soil immediately after compost addition. Products according to ASCP Guidelines 2001 (Fuchs et al., 2001): Ds=digestate solid, Ca=compost for agriculture, Ch=compost for horticultural used, Cc=compost for covered cultures and private gardening.

Application of Swiss digestates and composts in the field

Two field experiments were performed in 2004 and 2005. Digestates and composts were applied in the spring before a maize crop. After harvest, soil samples were taken and analyzed.
While young composts immobilized nitrogen in soil, no negative effects of digestats were observed (fig. 7).

The digestates and the composts enhanced the soil pH for about ½ unit. This effect is still observable after the harvest of maize. All the products enhanced also the biological activity in the soil. However, no influence could be observed on the disease receptivity of the soil after one maize season. The duration of the experiment could be to short for this, or the basic soil quality (organic field) was already too high to enhanced it more.

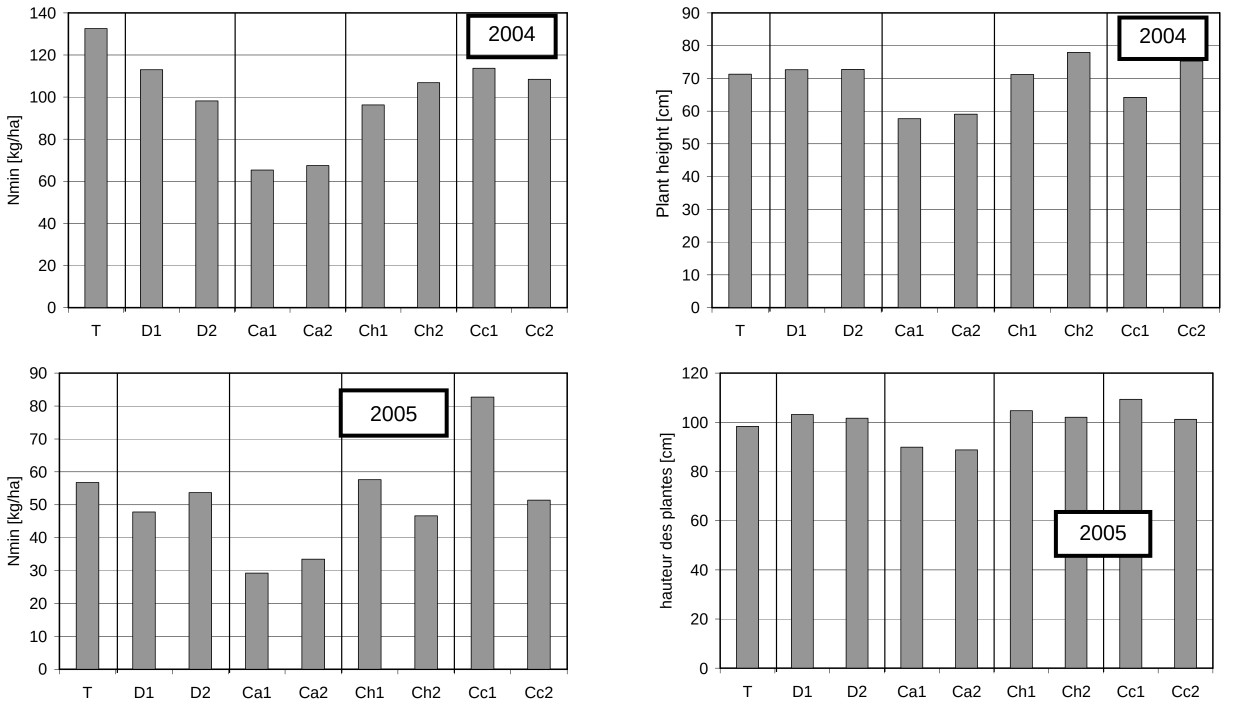


Figure 7 Influence of application of digestates and composts on the mineralized nitrogen content in soil and on the growth of maize. Dose of application of 100m^3/ha before sowing. Measurement 6 weeks after sowing. Products sampled according to ASCP Guidelines 2001 (Fuchs et al., 2001): T: no digestate/compost; D=digestate solid, Ca=compost for agriculture, Ch=compost for horticultural used, Cc=compost for covered cultures and private gardening.

Conclusions

In general, it was observed that the quality of the Swiss digestates and composts is good. No major problems were observed in any sample.

Digestates can be useful for agriculture, They are not as stable as composts, but have more plant-available nutrients. So the digestates have mainly a short-term effect as fertilizer, and less long-term effects on soil structure. Digestates are not as compatible with plants as composts, and so only restricted utilizations of digestates can be considered. Digestates can be stabilized by post-treatment and tranformed into quality composts. During this process, care should be taken to avoid NH_4-losses; for this, the control of the product humidity is very important.

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Acknowledgments

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