EFFECTS OF COMPOST ON SOIL FERTILITY PARAMETERS IN MID- AND LONG-TERM EXPERIMENTS

J.G. Fuchs[1], A. Fliessbach[1], P. Mäder[1], F.P. Weibel[1], L. Tamm[1]

[1]Research Institute of Organic Farming (FiBL), Ackerstrasse, 5070 Frick, Switzerland
jacques.fuchs@fibl.org, andreas.fliessbach@fibl.org, paul.maeder@fibl.org,
franco.weibel@fibl.org, lucius.tamm@fibl.org

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Abstract

To evaluate the influence of compost on soil fertility and plant growth, several medium term and long term field experiments with composts were conducted in different crops.

In two maize experiments, one in a sandy and one in a loamy soil, the influence of different composts and digestates on soil parameters and plant growth were investigated. All products increased pH of the soil and improved the biological soil activity (e.g. enzymatic activities). Immature compost immobilized nitrogen and reduced plant growth. Organic nitrogen fertilizer added during cultivation, could compensate a growth depression.

A full factorial experiment in a 2-years-old organic apple orchard was conducted from 2001-2007. The factors tested in all 9 possible combinations were: i) biowaste compost, ii) commercial organic N-fertilizer, iii) foliar N-fertilizer. In spring, highest values for mineralized N (N_{min}) in the tree strip were found in the treatment with commercial organic N-fertilizer, with addition of compost it was 75%, and biowaste compost alone reached 50 % of this value on average, whereas unfertilized plots had lowest but still sufficient values for the same tree performance and fruit nutrition as fertilized plots. N-Fertlisation plus compost resulted.

In the DOK long-term field trial, three farming systems are compared since 1978: i) mineral and organic fertilisers, synthetic pesticides; ii), organic fertilisers, mechanical weeding and biological disease and pest control; and iii) composted manure and bio-dynamic preparations. A conventional system with mineral fertilisers only and an unfertilized treatment serve as controls. Soil fertility mirrored by soil biological parameters, soil biodiversity and soil organic matter are higher in the organic systems and render these systems less dependent from external inputs.

Introduction

Compost amendments influence various soil fertility parameters, such as nutrient content and availability, soil structure and microbiological activity. They impact plant growth and health directly and indirectly (Fuchs and Larbi, 2005). However, the influence of compost can vary depending on its quality, soil type and target culture.

To evaluate some aspects of the influence of compost on soil fertility and plant growth, medium and long term field experiments with composts were conducted in various crops, soils and climatic conditions. The results of these trials are here presented and discussed.

Materials and Methods

Application of Swiss digestates and composts in maize fields

Two field experiments were carried out in maize: in 2004, the experiment was made in a loamy soil and 2005 in a sandy soil. Digestates and composts (tab. 1) were applied in spring before the maize was sown (100 m^3 per ha). After harvest, soil samples were taken and analysed chemically and biologically.

Nutrient contents, pH value of composts and soils, and the influence of composts on nitrogen mineralization in soil were determined according to the official Swiss methods (Schweizerische Referenzmethoden, 2005). The activity of four enzymes in composts and soils was determined: fluorescein diacetate (FDA) according to Inbar et al. (1991), dehydrogenase, protease and cellulase according to Alef and Nannipieri (1995).

Tab. 1: Calcium contents, pH, nitrogen characteristics, FDA-activities and humic acids content of the digestates and composts used in the fields experiments

Digestates / Compost[1]		Ca [g / kg DM]	NH_4-N [mg / kg DM]	NO_3-N [mg / kg DM]	N-supply or immobilization in soil during 8 weeks[2] [% of Nmin at time 0]	FDA activity [µg hydrolysed FDA / g DM*min]
Field experiment 2004 (loamy soil)						
Digestate	D1	46.6	606.7	260.7	-2.2	23.4
	D2	65.2	1980.1	0.2	16.1	20.3
Compost for agriculture	Ca1	68.4	35.9	0.2	-5.1	17.6
	Ca2	49.7	66.8	0.2	-7.2	20.6
Compost for horticulture	Ch1	81.5	4.4	65.4	-0.3	14.0
	Ch2	64.3	119.8	267.7	2.7	14.1
Compost for covered cultures	Cc1	91.5	4.5	45.3	-1.0	8.8
	Cc2	63.7	10.0	59.0	3.4	15.9
Field experiment 2005 (sandy soil)						
Digestate	D3	38.4	398.4	480.9	0.8	25.1
	D4	152.3	1821.9	0.0	10.5	13.4
Compost for agriculture	Ca3	39.4	19.3	0.0	-17.2	25.2
	Ca4	58.2	132.2	0.0	-10.0	6.5
Compost for horticulture	Ch3	65.7	0	366.1	5.5	10.6
	Ch4	65.5	6.6	215.4	3.4	8.2
Compost for covered cultures	Cc3	65.5	0.0	234.9	2.1	3.0
	Cc4	60.8	9.6	363.8	4.4	6.8

[1] Product description is according to ASCP Guidelines 2001 (Fuchs et al., 2001). [2] Incubation experiment by 25°C

KOB-trial: fertilisation of organic apple orchard with compost and organic fertilizers

This four year full factorial experiment was performed in a commercial organic orchard in Switzerland (KOB trial) with use of compost, commercial N-fertilizer and foliar N-fertilizer in 9 different main combinations and 2 sub-treatments where the same compost was prepared bio-dynamically. The soil is an alluvial para-brown soil of silty clay with signs of pseudo-gley at 40-60 cm (possibly a limiting factor for optimal tree performance in spring); the rooted zone is 70-80 cm deep; ph ($CaCl_2$) is 5.4-6, pH (H_2O) 6.6-6.8; the content of organic matter in the 0-25 cm layer of the plots initially was 3.0 ± 0.06 %. According to the Swiss recommendations and regulations for apple tree nutrition, the fertiliser quantities per ha and year were: 5 m^3 green waste compost, 364 kg Biorga-N (11%N), 68 kg Granophos (18% P_2O_5, 22% Ca, 4.8% Mg), 46 kg Patentkali (30% K_2O, 6% Mg), 97 kg Agrokalk (38% Ca, 0.6% Mg) and/or 135 kg Bittersalz (10% Mg); these amounts were applied concentrated on the regularly tilled tree strips of 1 m width; as foliar spray (14 kg N/y) a molasse product of 5% N was applied.

DOK long-term field trial

Since 1978, the three agricultural farming systems CONFYM (mineral and organic fertilisers, synthetic pesticides), BIOORG (organic fertilisers, mechanical weeding and biological disease and pest control) and BIODYN (composted manure and bio-dynamic preparations) have been compared (Mäder et al., 2002). The fertilization level corresponded to 1.2 livestock units ha^{-1} in the first two crop rotation periods, later 1.4 livestock units ha^{-1} (corresponding to approx. 15-20 m^3 compost ha^{-1} yr^{-1}). An unfertilised treatment and a conventional system with mineral fertilisers only (CONMIN) served as controls. The soil is a haplic luvisol on deep alluvial loess.

Results

Application of Swiss digestates and composts in maize fields

The four composts immobilized N in soil and had a negative influence on maize growth at the beginning of the culture (fig. 1). These results confirm the results obtained in the laboratory: compost with almost no NO_3-N N_{min} immobilized nitrogen also in the field (tab. 2). Notice that this point is relevant only for compost, and not for digestates (tab. 1). N- fertilization after 8 weeks (at the moment corresponding to the observations shown in fig. 1) allows correcting the N deficiency, so that at harvest no significant differences in the yield of the different treatments were observed (data not shown).

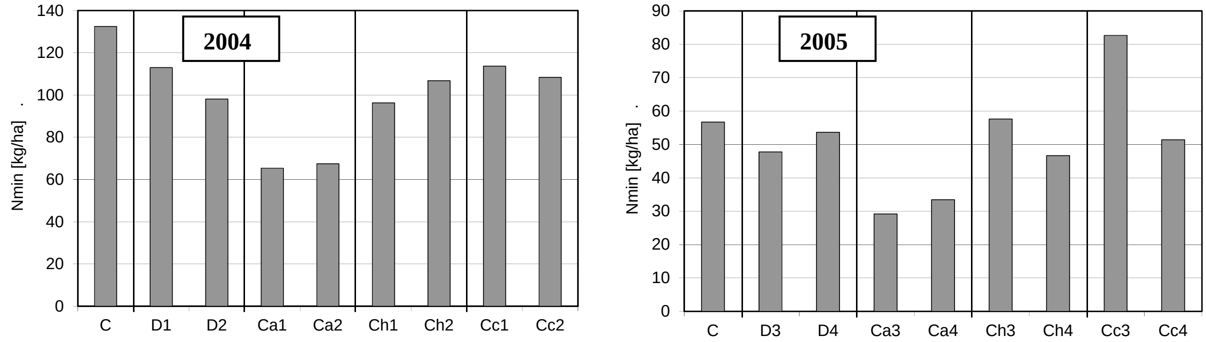


Fig. 1. **Influence of application of digestates and composts on the mineralized nitrogen content in soil and on the growth of maize.**
Application of $100m^3$/ha before sowing. 2004: loamy soil; 2005: sandy soil. Measurement 8 weeks after sowing. Products sampled according to ASCP Guidelines 2001 (Fuchs et al., 2001): C: no digestate/compost; D=digestate solid, Ca=compost for agriculture, Ch=compost for horticultural used, Cc=compost for covered cultures and private gardening.

The digestates and the composts enhanced the soil pH by about 0.5 units (fig. 2). This effect was 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. The enhancement of the pH did not correspond exactly with the Ca content of the composts, although in 2004 the two composts with the greatest quantity of calcium caused the highest rise of the soil pH (tab. 1).

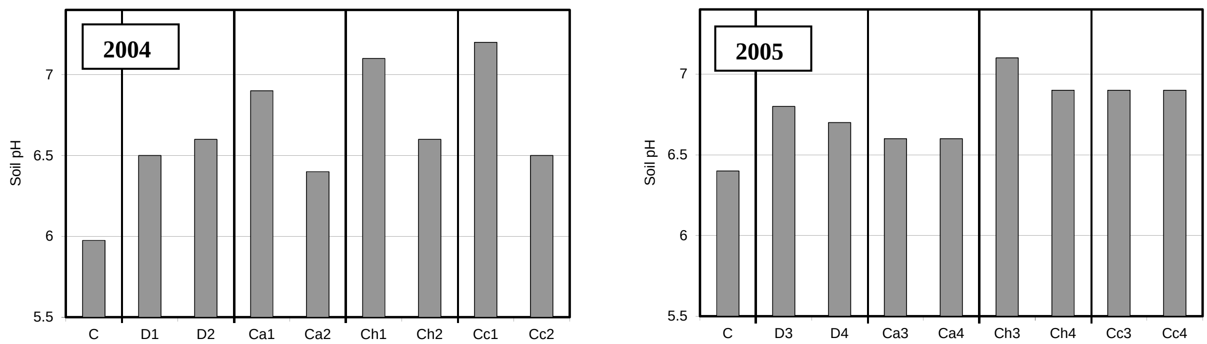


Fig. 2. **Influence of application of digestates and composts on the pH of the soil.**
Application of $100m^3$/ha before sowing. Measurement after maize harvest. Products: see fig.1.

To characterize the biological activity of the soil, its enzymatic FDA activity was investigated after the maize harvest. Almost all digestates and composts increased the FDA activity between 10 and 30% (fig. 3). This shows that compost and digestate have a prolonged effect on the biology of the soil. The biological activity of the soil was not correlated with the biological activity of the compost or digestate applied (tab. 2). So it is probable that activity of the soil microorganisms is enhanced by compost amendment, and that the compost microorganisms are not themselves responsible for the enhanced enzymatic activities in the soil observed after the maize harvest.

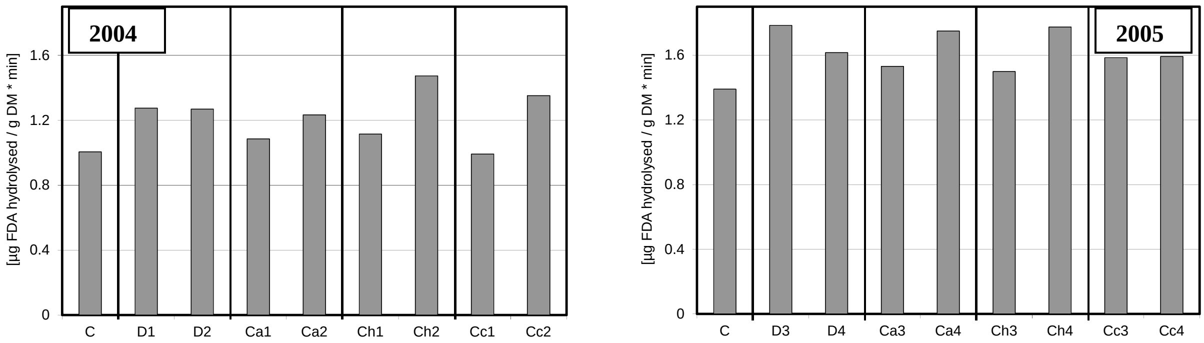


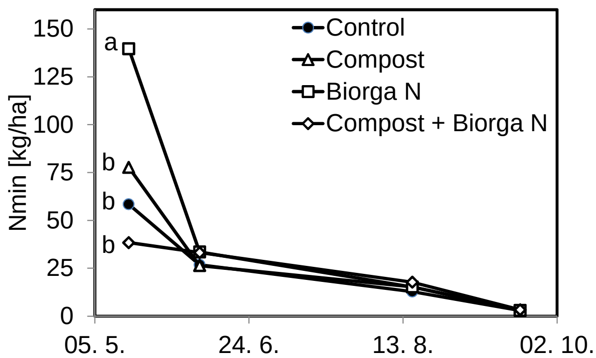
Fig. 3. Influence of application of digestates and composts on the microbiological activity of the soil.
Application of 100m³/ha before sowing. Measurement after maize harvest. Products: see fig.1.

KOB-trial: fertilisation of an organic apple orchard with compost and organic fertilizers

In the year 2001, when starting the experiment with very regularly but almost too weekly growing apple trees (cv. Topaz, grafted on the very weekly growing rootstock M27), a rather distinct response of the different tree nutrition strategies was expected.

In 2006, the highest N_{min} contents could be found in Mai with quantities varying from 39-140 kg/ha between treatments (fig. 4). The by far highest N_{min} content with 139.7 kg/ha was found in the plots with organic N-fertilizer without compost. In all other combinations with compost K+/O- and K+/O+ the N_{min} contents were significantly lower, 77.7 and 38.4 kg/ha, respectively; whereas the untreated control reached in average 58.4 kg/ha. At the sampling date in July, the average N_{min} contents were already much lower, between 24 and 36 kg/ha.

Fig. 4. Mineralized nitrogen (N_{min}) contents in the 0-25 cm top soil layer of the tree strips in 2006
At first analyses date (16.05.2006); mean values per treatment not connect with the same latter are significantly different.



However, the long-term effects of the treatments on tree performance (growth, yield, specific yield), fruit quality, mineral concentration in leaves and fruit, and finally on soil fertility parameters (organic carbon content, enzymatic activities, soil aggregate distribution and stability) were in most cases of minor importance. The bio-dynamically prepared compost revealed a tendency to fix more Nitrogen compared to standard compost (data not shown). The low effect of compost on yield performance and soil fertility can have several reasons: Firstly, as apparent with the N_{min}-content measurements during the season, due to its low

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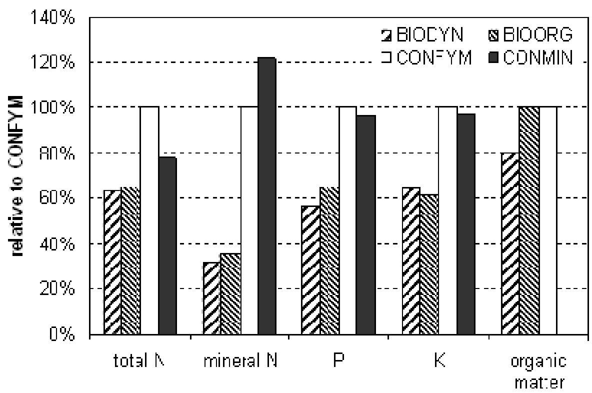
nitrate content the compost apparently fixated some of the N_{min} that was mineralised from the soil reserves or came from the applied N-fertilizer. Secondly, in order to respect the Swiss recommendations and regulations, the applied compost quantities had to be kept at a very low level to prevent P-excess, and contributed only 7-8% of the total C-import of the orchard, the rest coming from grass clippings, leaves, root exudates and cut wood.

Organic fruit growers can or must learn that in an organic orchard system sub-optimal tree performance which is nutrient deficiency induced (mostly by nitrogen) cannot simply be compensated by an increased application of commercial (though organically approved) N-fertilizer. On the other hand, soil improvements with such low doses of bio-waste compost seem to require more than 4 years becoming to improve soil quality and tree performance. If the orchard soil is prone to N-fixation compost applications should be accompanied with a moderate dose of N-fertilizer.

DOK long-term field trial

Over 28 years, the mean yields of all seven crops per rotation in the organic systems were 80% of those in the conventional systems. Fertilizer input (total N, P, K) was reduced by 35 to 40% and nitrogen input in mineral form was even reduced by 65 to 70% in the organic systems (Fig. 5). The organic farming systems used 20 – 56% less energy to produce a crop unit, and per land area this difference was 36 – 53%. The more efficient production of organic systems, based on compost fertilisation, is due to higher soil fertility. Different factors point at this. First, the soil pH remained unchanged or increased slightly with the compost amendment, while it diminished with farmyard manure or mineral fertilisation (fig. 6a). A similar result was observed with the soil organic matter (fig. 6b), which remained at the same level with the utilisation of the mature compost while it decreased with farmyard manure and mineral fertilizers.

Fig. 5. Mean relative input of nutrients to the farming systems in the DOK experiment 1978 to 2005 in percent (CONFYM = 100%).
Absolute values of CONFYM (mineral and organic fertilisers, synthetic pesticides) in kg ha-1 yr-1: total N = 157 kg, mineral N = 101 kg, P = 41 kg, K = 258 kg, organic matter = 2272 kg. CONMIN: conventional system with mineral fertilisers only, synthetic pesticides. BIODYN: composted manure and bio-dynamic preparations. BIOORG: organic fertilisers, mechanical weeding and biological disease and pest control).



Also, the biological activity of the soil was enhanced in the treatments with compost: the microbial biomass and the dehydrogenase activity were higher in the treatment with compost (fig 7), while the metabolic quotient (qCO_2) was lower (fig. 7). This is very interesting, because a high qCO_2 indicates a microbial population with a high energy demand for maintenance. So this confirmed that the soils BIODYN and `BIOORG are biologically more efficient that the soils CONFYM (which is intermediate) and CONMIN. The higher efficiency of the soil BIODYN in comparison with BIOORG is probably due to the compost quality (more mature) or to the bio-dynamic preparation

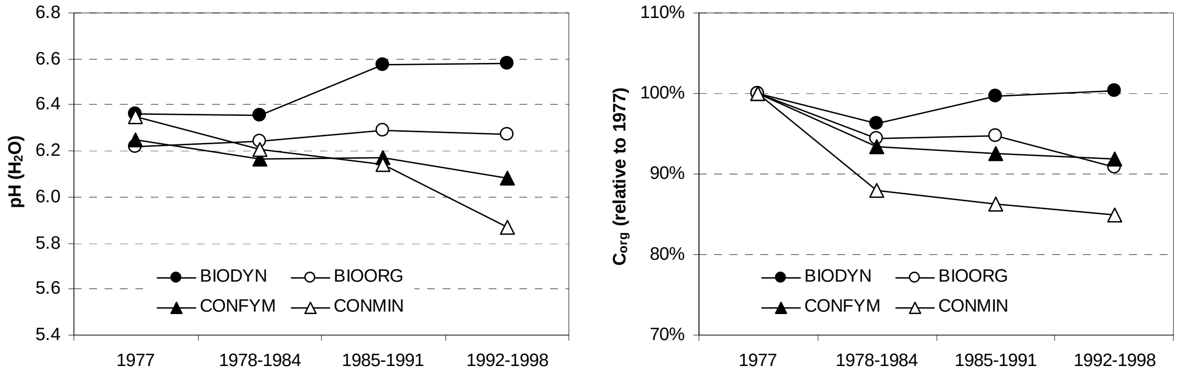
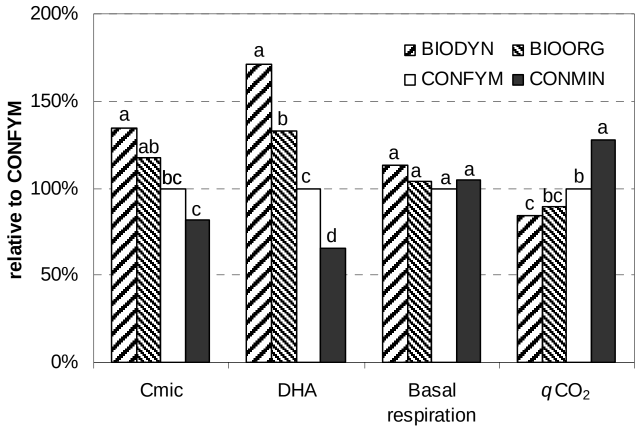


Fig. 6. pH (H_2O) (5a) and soil organic matter (Corg) over 21 years of organic and conventional farming compared to the initial values in 1977 (5b).
BIODYN: composted manure and bio-dynamic preparations; BIOORG: organic fertilisers, mechanical weeding and biological disease and pest control; CONFYM: mineral and organic fertilisers, synthetic pesticides;, CONMIN: conventional system with mineral fertilisers only, synthetic pesticides.

Fig. 7. Soil microbial biomass (Cmic) (267 µg g^{-1})**,** **dehydrogenase activity (DHA)** (132 µg TPF g^{-1} h-1)**,** **basal respiration** (31 µg CO2 g^{-1} d^{-1}) **and** **metabolic quotient (qCO2)** (1.3 mg CO2-C g^{-1} Cmic d^{-1}) **in soils of the DOK experiment relative to the CONFYM system (**values for CONFYM in brackets)**.**



Conclusions

Digestate and compost can considerably improve soil fertility. They can influence physical, chemical and biological soil parameters. However, the influence of compost and digestate can vary depending on their quality, the soil parameters, the utilization strategy and the culture.

Especially in apple growing or grape production, the maximum quantity of compost which can be legally used in Switzerland is very modest. In this situation, particularly attention has to be given to compost quality and activity and to the application strategy.
In agricultural use, the quantity of compost which can be used is higher, and the effect of compost or digestate is much more evident at short and long term. However, the quality of the compost use is also very important here, to avoid phytotoxicity and nitrogen immobilization. The quality compost is consequently a very important production parameter to support soil fertility in organic agriculture, especially on stockless farms.

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