Soil biological quality in short- and long-term field trials with conventional and organic fertility input types

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Abstract

Soils of the DOK trial and three other field trials with manure input were analysed for effects on soil biology. While long-term effects indicate a new steady state at the DOK trial site, differences at the other field trials suggest that fresh manure at the Bonn trial and chicken manure at the UK sites are at least temporarily advantageous, probably due to their relatively fast mineralization.

Introduction

Fertility inputs to soils are an important means to improve plant production in agricultural systems. While conventional or integrated farming systems may utilize mineral fertilizers that are immediately and easily available to the crop, nutrient inputs to organic farming systems may be derived from livestock, from commercial organic fertilizers, and from green manure. Mineralization of these organic inputs by soil microorganisms is crucial for nutrient delivery to the crops. An active and abundant soil flora and fauna is advantageous for a fast mineralisation of organic nutrient sources, which is ruled by soil temperature, moisture and by the chemical composition of the fertility input. The aim of our study was to evaluate long-term and short-term effects of organic fertility inputs. For this we compared chemical, physical and biological properties of soils from the DOK trial in Therwil (CH) and from short-term fertility input experiments with lettuce in Bonn (DE) and with onions in Yorkshire (UK).

Tab. 1. Soil characteristics of the four field sites

	Therwil (CH)	Wiesengut (DE)	Tadcaster (UK)	Stocksbridge (UK)
coordinates	47°30'N;7°33'E	50°47' N;7°17' E		
soil type	haplic luvisol		calcic cambisol	gleysol
sand/silt/clay *1	8/78/14	50/38/12	48/30/22	86/6/8
pH *1	5.63	6.70	7.24	7.01
C_{org} (mg g^{-1}) *1	14.03	11.05	29.90	16.96
Sampling date	-	20.04.2004	05.05.2004	
Sampling date	17.03.2004	06.07.2004	15.10.2004	
Treatments	No fertilizer	Fresh manure	Compost	
	Mineral fertilizer	Comp. manure	Mixed chicken manure and compost	
	Biodynamic 1&2	Mineral fertilizer	Chicken manure	
	Bioorganic 1&2			
	Integrated 1&2			
Intensities	1: 0.7 LSU *2	85 kg N		
	2: 1.4 LSU	170 kg N	170 kg N	170 kg N
Crop	3 crops pooled	Lettuce	Onion	
Samples	8	8 + 24	4 + 12	4 + 12
Replicates	0	4	4	4

*1average values of all treatments; *2LSU: livestock units ha^{-1} yr^{-1}

Materials and methods

Soil samples were taken from 0-20 cm at each site. At the DOK trial a mixed sample from the four replicate plots and the three crops for each treatment (grassclover 2nd yr, catch crops before maize and soybeans) was taken. At the short-term field trials in Tadcaster, Stocksbridge and Bonn a bulk sample from each replicate field plot was taken before application of the fertility input and at the time of harvesting lettuce and onions. Soils were homogenised and divided into subsamples that were sent to the partners for analysis. We analysed soil physical (water release curves, aggregate stability, particle size classes), chemical (CEC, pH, Corg, Nt, nutrients and trace elements) and biological soil parameters (soil microbial biomass, basal respiration, phosphatase-, protease- and dehydrogenase-activities, fluorescein-diacetate-hydrolysis, and calculated ratios).

Results

The DOK-long term study has been included in this program as a reference to document the reliability of our measurements and to produce an estimate of long-term effects of organic and conventional farming practice. Soil analyses of the DOK-trial have been done regularly in the last decades and may be compared to our data (Fließbach and Mäder, 2000; Fließbach et al., in press; Mäder et al., 2002). Microbial biomass values are similar to earlier measurements (Fig. 1). All analyses showed the same trend as earlier estimates, except for phosphatase activity, where differences between organic and conventional have become smaller than in measurements of 1991 (Mäder et al., 1993). In the organic farming systems with 1.4 livestock units, soil microbial biomass and phosphatase activity was 30-80% higher than in the mineral fertilizer treatment. At reduced intensity (0.7 livestock units) the organic systems showed 20-40% higher values.

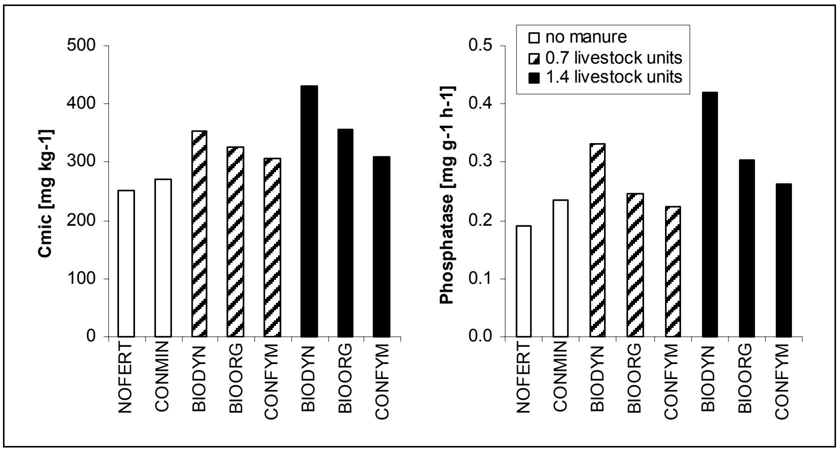

Figure 1: Soil microbial biomass and alkaline phosphatase activity in soils of the DOK-trial

At the other field sites, samples taken before fertility input and at crop harvest were compared. Lettuce was harvested 77 days and onions 163 days after the first sampling. In the lettuce trial, soil microbial biomass declined in all treatments over this time period (Fig. 2). This decline was significant for composted manure and mineral fertilizer at both intensities. Compared to these two treatments, application of fresh manure resulted in a gain in microbial biomass. This was also mirrored in phosphatase activities. Whereas all treatments showed a tendency towards increased phosphatase activities compared to the start, this increase was only significant when fresh fertilizer was applied at a high rate. Among the treatments at harvest time, fresh manure revealed higher phosphatase activity than mineral fertilizer.

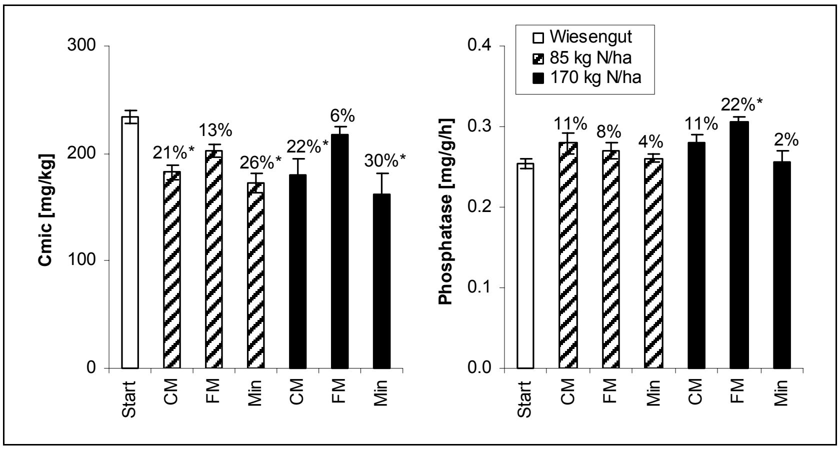

Figure 2: Soil microbial biomass and alkaline phosphatase activity in soils of the lettuce-trial at the Wiesengut of Bonn University (DE) at planting and harvest time. Standard errors of mean are shown and the numbers are % reduction relative to the start. (CM: composted manure, FM: fresh manure, Min: mineral fertilizer, *: significant difference compared to the start)

Sandy soils from Stocksbridge showed a relatively low level of microbial biomass. The Tadcaster site was characterized by higher clay and silt contents and a higher pH. It had 2.5 times higher microbial biomass and almost twice the phosphatase activity than Stocksbridge soil. Unexpectedly, microbial biomass and alkaline phophatase activity in Stocksbridge showed opposite trends. Whereas microbial biomass in Stocksbridge soil was slightly reduced in all treatments at harvest time compared to the start, phosphatase activity increased in all treatments. However, this increase was significant only in the chicken manure treatment (Fig. 3). After application of chicken manure alone microbial biomass was 46% and phosphatase activity was 67% higher than in the chicken manure/compost treatment. Chicken manure at the Tadcaster site enhanced microbial biomass significantly by 22% as compared to the start. Apart from this there were no significant effects of the fertility inputs on microbial biomass and phosphatase activity in Tadcaster soil. No differences were obtained between the treatments at sampling time.

Discussion

While analyses in the DOK trial were showing long-term effects that were not influenced by a growing crop, these values may be interpreted as a new steady state. This is also supported by the continuing monitoring of soil biology in the same soils. The trials at Bonn, Tadcaster and Stocksbridge comprised one single fertilizer application per treatment followed by a crop. Over time, the fertilizer for the crop may have influenced both, the soil and the crop, and interactions on soil biology are likely to occur with a higher crop biomass. Among the treatments, fresh manure at Bonn and chicken manure at the two UK sites showed some advantages, but it cannot be excluded that these effects are reflecting peak situations due to the differences in amount and quality of the fertilizers applied.

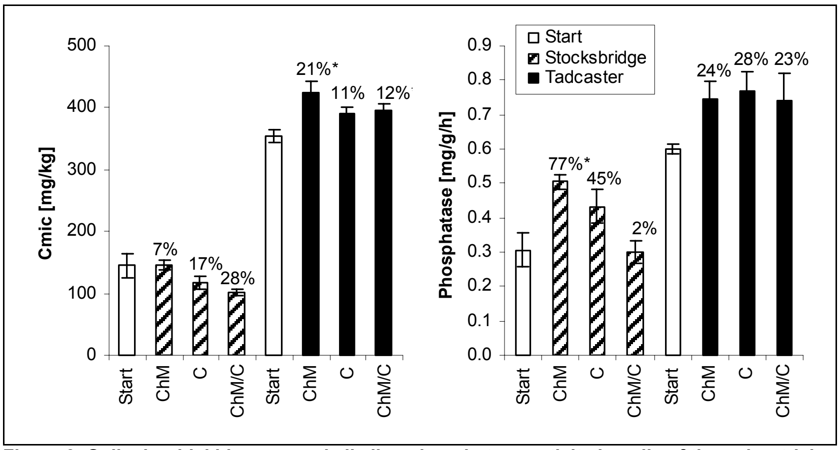

Figure 3: Soil microbial biomass and alkaline phosphatase activity in soils of the onion-trial at Stocksbridge and Tadcaster (UK) at planting and harvest time. Standard errors of mean are shown and the numbers are % reduction relative to the start. (ChM: chicken-manure, C: compost, ChM/C: chicken-manure/compost, *: significant difference compared to the start)

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References

Fließbach, A., Mäder, P. (2000): Microbial biomass and size-density factions differ between soils of organic and conventional agricultural systems. Soil Biol. Biochem. 32, 757-768.

Fließbach, A., Oberholzer, H.-R., Gunst, L., Mäder, P. (in press): Soil organic matter and biological soil quality indicators after 21 years of organic and conventional farming. Agriculture, Ecosystems & Environment.

Mäder, P., Fließbach, A., Dubois, D., Gunst, L., Fried, P., Niggli, U. (2002): Soil Fertility and Biodiversity in Organic Farming. Science 296, 1694-1697.

Mäder, P., Pfiffner, L., Jäggi, W., Wiemken, A., Niggli, U., Besson, J.-M. (1993): DOK-Versuch: Vergleichende Langzeit-Untersuchungen in den drei Anbausystemen biologisch-Dynamisch, Organisch-biologisch und Konventionell III.Boden: Mikrobiologische Untersuchungen. Schweizerische Landwirtschaftliche Forschung 32, 509-545.