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Organic Soil Management: Impacts on Yields, Soil Quality and Economics

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Abstract

Understanding organic management practices is a key in developing sustainable organic farming systems. We report the results of four different organic fertilization strategies in a field trial on yields, soil quality and economic performance. We found highest yields and economic performance in two direct plant feeding strategies. One of these strategies, a newly developed strategy based on biowaste compost (GFT) and an additional fertilizer performed well in terms of yields but looks also very promising in terms of soil quality and biodiversity. The economic perspective of this strategy renders it promising in regions with little animal manures.

Introduction

In recent years a great deal of research has been done in the field of comparing organic and conventional management strategies, mainly in long-term field trials (Mäder, et al., 2002). Little attention, however, has been given to the fertilization strategies that are behind these system comparisons and might explain differences found in economic, ecological and environmental performance. In this study we compare different fertilization strategies. We focus on the question often asked in sustainable and organic farming whether it is better to supply nutrients to crops by building up soil fertility over time or to focus on a fertilization strategy that tunes organic inputs directly to the plant's nutrient demand within a season.

Materials and methods

In 2003 four organic fertilization strategies were set up in an organic crop rotation on a clay-loam at Colijnsplaat, Zeeland (The Netherlands). In the crop rotation of spring wheat, potatoes, grass-clover, onion, brown beans and sugar beet, four fertilization strategies were applied:

- Goat manure (GM): fertilization based on soil improvement within the regulation limit of a maximum of 80 kg P_2O_5 year^{-1} for the whole crop rotation (35 t ha^{-1} 2 years^{-1}).
- Green compost (GC): fertilization based on soil improvement through the use of very clean plant-based green compost (less 80 kg P_2O_5 year^{-1} in the whole rotation (50 t ha^{-1} 2 years^{-1}).
- Biowaste compost (GFT): fertilization focusing on soil and plant fertilization in a combination of compost (30 t ha^{-1} 2 years^{-1}) and vinasse (3 t ha^{-1}) to potato, sugar beet and wheat.
- Cattle slurry (CS): fertilization fully based on plant feeding within the regulation of less than 80 kg P_2O_5 year^{-1} for the whole rotation.

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Results

Wheat yields were lowest in 2003 in the CS strategy as a result of soil compaction due to slurry application in spring (Figure 1). Lowest sugar beet yields were found in the GC strategy in 2004, whereas no significant differences were found in onion yields in 2005. Potato yields were lower in the GM strategy compared to the other strategies in 2003 but in 2004 lowest yields were found in the GC strategy. Differences in grass-clover yields were found to be small.

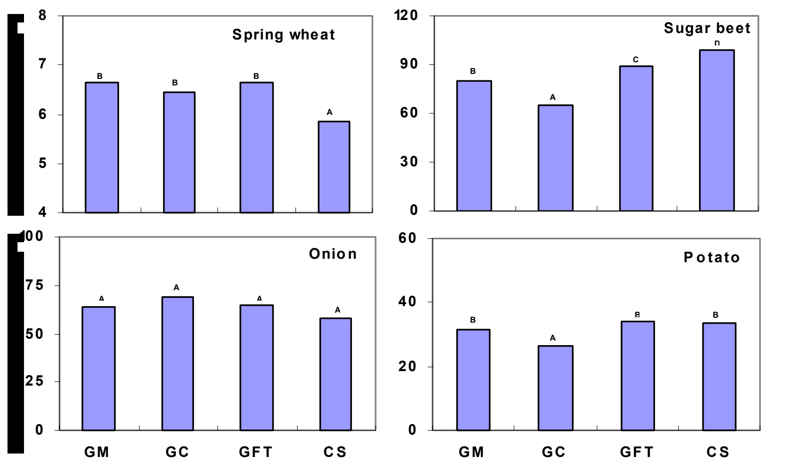

Figure 1: Yields of spring wheat (2003), sugar beet (2004), onion (2005) and potato (2004) in the management practices goat manure (GM), green compost (GC), biowaste compost (GFT) and cattle slurry (CS).

Nutrient balances (tab. 1) for the different fertilization strategies were calculated for the period 2003-2005 using the NDICEA model (van der Burgt et al., 2006). Nitrogen in the crops differed little between the strategies. As a result considerable nitrogen surpluses existed in the strategies receiving the compost additions. With these compost additions nitrogen is applied, which is not directly available to plants.

Tab. 1: Nitrogen balance (in kg N/ha/year) for the period 2003-2005.

Strategy	Application with fertilizers	Product removal	Calculated surplus	Leaching losses[1]	Organic matter[2]
GM	175	151	24	45	38
GC	252	150	102	43	110
GFT	265	164	101	58	79
CS	87	156	-69	34	-28

[1] No full rotation was covered per strategy. Average nitrogen application for these years was higher than for the full rotation of 6 years.
[2] Leaching losses were calculated using the NDICEA model
[3] Organic matter: modelled incorporation of nitrogen into the soil organic matter

Nitrogen efficiencies were highest in both the GM and CS strategies. Using the NDICEA model, it was possible to calculate total losses due to nitrogen denitrification and leaching. Highest nitrogen leaching losses were found in the GFT strategy. Losses differed little between the GC and the GM strategies. In the GC and GFT strategies high amounts of the added nitrogen were incorporated into the organic matter of the soil. In the CS strategy a net loss of nitrogen from organic matter was calculated by the model.

The soil quality assessment (Tab. 2) showed that potential C and N mineralization were higher in the GC and GM strategies as compared to the CS strategy. In the data the low C mineralization in the GFT strategy is striking. Potential N mineralization was lowest in the CS strategy. Neither bacterial nor fungal biomass differed between the strategies. Bacterial feeding nematodes were low in the GFT strategy. Most plant feeding nematodes were found in GC, whereas lowest levels were found in the CS strategy. No differences were found in earthworm counts, soil structure and organic matter levels. Significantly higher levels of P-total and potassium were found in the CS strategy compared to the other strategies. This may be due to the spring application of the slurry as all other fertilizers were mixed into deeper soil layers as a result of ploughing in autumn. The shallow application of cattle slurry in spring did not have a mixing effect.

Tab. 2: Biological, physical and chemical soil properties of the different strategies

Soil property	GM	GC	GFT	CS	P
Microbial biomass	16.0	25.5	28.7	10.9	NS
Fungal Biomass	14.0	15.0	16.6	14.3	NS
Pot. N mineralization	2.0b	1.9 b	1.7 ab	1.3 a	0.05
Pot. C mineralization	18.5 c	15.4 b	5.2 a	5.4 a	<0.001
Bacterial feeding nematodes	781 b	590 b	346 a	527 ab	0.007
Fungal feeding nematodes	142	80	93	96	NS
Plant feeding nematodes	457 b	561 c	452 b	323 a	0.002
Earthworm biomass	88	75	50	57	NS
Soil structure	27	22	23	23	NS
Organic matter	2.3	2.3	2.4	2.3	NS
PH	7.5	7.5	7.5	7.5	NS
N-total	1075	1083	1214	1188	NS
P-total	149 ab	139 a	155 b	174 c	<0.001
Potassium	24 ab	22 a	25 b	32 c	<0.001

In the balance calculations (Tab. 3) use was made of costs and yields per crop in the 3 years of the research. Per crop a balance calculation was made. These balances were averaged per plot (Tab. 3). In the period 2003-2005 the balance was highest in the CS and GFT strategies. The spring application of fertilizers to the sugar beet in the CS and GFT strategies resulted in particularly high yields and earnings if compared to the other two strategies.

Discussion and Conclusions

In the period 2003-2005 the GFT and CS strategies produced the best results in terms of yields and economic performance, especially in high-yielding crops like potatoes and sugar beets.

Tab. 3: Average balance (in € ha^{-1}) for different fields in the period 2003-2005

Strategy	Plot A Bean- Sugar beet Spring wheat	Plot B Potato Grass clover Onion	Plot C Spring wheat Potato Grass clover	Average
GM	2127	2465	1430	2007
GC	1833	2798	1432	2021
GFT	2424	2881	1731	2345
CS	2577	2654	1735	2322

The strategies using green compost and solid goat manure lagged behind in terms of yields but resulted in improved soil properties such as higher potential nitrogen and carbon mineralization due to build-up of organic matter. It might be expected that the soil fertility or production function of the soils improves with these strategies over time. The higher plant-feeding nematodes populations in the composts are likely to result from the high root densities observed in the compost strategies (Koopmans and ter Berg, 2005). The significant differences in bacterial and plant-feeding nematodes are likely to result in higher disease resistance in these strategies.

The calculations using the NDICEA model showed that nitrogen from the compost applications is largely built into the organic matter and does not result in high nitrogen leaching losses, necessarily. A crop rotation which is tuned to available nitrogen from these composts and use of catch crops is important in these strategies, however. In the slurry application, it was possible to tune crop demand and nitrogen availability to each other. In this strategy, the risk consists of a loss of organic matter and an increased soil compaction due to the spring application using heavy equipment.

We conclude that both fundamental strategies focusing on soil improvement and direct crop fertilization within organic farming are realistic and sustainable strategies in the short term. For further research the question remains on the impact of the different fertilization strategies on yields, soil quality and mineral use-efficiency in the long run.

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