Livestock in organic farming – how important is it for soil fertility management?

FRANZ SCHULZ[1], CHRISTOPHER BROCK[2], GÜNTER LEITHOLD[3]

Key words: farming systems, stockless farming, soil fertility, soil organic matter, rotational ley

Abstract

Stockless management is increasing even in organic farming, but it is not known until now, whether organic matter supply is sufficient in such systems. Results from the long-term Organic Arable Farming Experiment Gladbacherhof (OAFEG) show that after two 6 y rotations, only a "mixed farm" treatment (MF) with fodder legumes in the rotation and cattle manure application corresponding to 1 LU ha^{-1} was able to maintain, and in the long term perhaps increase, SOM levels. The "stockless farm" with fodder legumes as green manure ley (SFL) was barely able to maintain the SOM level, while the "stockless cash crop farm" where organic matter supply relied on green manure catch crops and straw alone (SFC) showed considerable SOM decrease. We conclude that the inclusion of fodder legumes is a crucial prerequisite for sustainable soil organic matter management in stockless organic farming, unless new approaches (e.g. farm cooperation concerning fodder-manure exchange) provide a full substitution.

Introduction

The general orientation in organic farming is a system with livestock (usually cattle), perennial fodder legumes in crop rotations, and farmyard manure application. But, as concentration and specialization of farms increase even in organic farming, roughly 25% of organic farms in Germany do not keep livestock today. In order to evaluate the effects of stockless organic farming in comparison with a "classical" system with cattle keeping and farmyard manure application, the two-factorial Organic Arable Farming Experiment Gladbacherhof (OAFEG) on organic crop rotation/fertilization and tillage effects has been set up in 1998 at Villmar in Hesse, Germany (Schulz et al. 2013). With this paper we want to present results on the effects of the three included crop rotation/fertilization treatments (called "farm types" in the experiment) on soil organic matter levels, nitrogen balances, and crop yields in the first two rotations (1998-2009).

Material and methods

The experiment is located at the Gladbacherhof experimental station of Giessen University at 50° 24' N, 8° 15' E. The soil under the experiment is a haplic luvisol with 285/680/35 g kg^{-1} clay/silt/sand. Mean annual precipitation is 649 mm, mean annual temperature is 9.5°C. Table 1 outlines the three crop rotation/fertilization (farm type) treatments that correspond to a mixed farming system with perennial fodder legumes in the rotation and farmyard manure application (MF), a stockless farming system with rotational ley as a green manure crop (SFL), and a stockless farming system with cash crops in all main crop positions (SFC).

[1] Justus Liebig University Giessen, Organic Farming, Germany,
www.uni-giessen.de/cms/orglandbau, eMail: franz.schulz@agrar.uni-giessen.de
[2] Justus Liebig University Giessen, Organic Farming, Germany,
www.uni-giessen.de/cms/orglandbau, eMail: christopher.j.brock@agrar.uni-giessen.de.
[3] Justus Liebig University Giessen, Organic Farming, Germany,
www.uni-giessen.de/cms/orglandbau, eMail: guenter.leithold@agrar.uni-giessen.de

Table 1: Crop rotations and fertilization in the „farm type“ treatments of the OAFEG. Unless indicated differently, stubble crops and underseed are green manure.

Field no. in rotation	Year	MF (Mixed farm)	SFL (Stockless farm with green manure ley)	SFC (Stockless cash crop farm)
1	1998, 2004	*Alfalfa grass* (harvested)	*W. wheat* (1998) / *Oats* (2004) (straw left) +underseed	*W. wheat* (1998) / *Oats* (2004) (straw left) +stubble crop
2	1999, 2005	*Alfalfa grass* (harvested)	*Alfalfa grass* (incorporated)	*Field beans* (straw left) +underseed
3	2000, 2006	*Winter wheat* (straw removed) +stubble crop	*Winter wheat* (straw left) +stubble crop	*Winter wheat* (straw left) +stubble crop
4	2001, 2007	*Potatoes* (450 dt cattle manure ha^{-1})	*Potatoes*	*Potatoes*
5	2002, 2008	*Peas+oats* (2002) / *W. wheat* (2008) +stubble crop	*Peas* (straw left)	*Peas* (straw left)
6	2003, 2009	*Winter rye* (straw removed, 150 dt cattle manure ha^{-1}) +underseed (harvested)	*Winter rye* (straw left) +stubble crop	*Winter rye* (straw left) +stubble crop

Data collection included, inter alia, soil organic carbon (SOC) and soil total nitrogen (STN) contents in topsoils (0-30 cm) on an annual basis, biomass, DM, C, and N contents of all plants (crops and weeds), biomass removal (harvest), and DM, C and N inputs from cattle manure applications. On that basis, we i) analyzed the development of SOC and STN levels under the treatments, ii) calculated soil N balances (i.e. nitrogen balances including quantitative N changes in soil organic matter) and nitrogen use efficiency of the soil-plant system in the treatments, and iii) compared the treatment crop yields.

Results

Table 2 shows the development of SOC levels under the farm type treatments. While an increase is indicated for MF, both SFL and SFC obviously lost SOC over the two rotations. Trends for STN were similar. Even though the trends for MF were not significant, and SOC change was not significant for SFL either, differences in the state of SOC levels in 2009 support the apparent changes (variation of starting values 1998 has been considered). According to our results, the SOC loss in the stockless SFC system corresponds to roughly 0.4 t SOC per ha and year.

Soil nitrogen balances were 41 kg N ha^{-1}a^{-1} for MF, 66 kg N ha^{-1}a^{-1} for SFL, and 79 kg N ha^{-1}a^{-1} for SFC. The potential loss, correspondingly, increased in the same order. At the same time, nitrogen use efficiency in the soil-plant system (data not shown) decreased in the order MF (0.82) > SFL (0.72) > SFC (0.66). This is due to the trends in SOC and STN development indicated above, and to the yield levels in the farming system treatments. The mixed farming system (MF) had a significantly higher yield than the stockless cash crop system (SFC). Total aboveground biomass in SFC was roughly one fourth lower than in MF, the mean non-legume cash crop yield was lower by one fifth, and the sum of all harvested crop biomass was even lower by more than one third. The stockless farming system with rotational ley, however, could keep up with MF, except for the sum of all harvested biomass

Table 2: Aboveground biomass production and yield indicators dependent on the "farm type" in the OAFEG long-term field experiment. Data refer to the second rotation (2004-2009).

	MF (Mixed farm)	SFL (Stockless farm with green manure ley)	SFC (Stockless cash crop farm)
SOC change in 0-30cm (kg C $ha^{-1}a^{-1}$)	233 (n.sig.)	-158 (n.sig.)	-407*
STN change in 0-30 cm (kg N $ha^{-1}a^{-1}$)	7.4 (n.sig.)	-20.2*	-57.0*
SOC state 2009 in 0-30 cm (kg SOC ha^{-1})	54107 a	51273 ab	47881 b
STN state 2009 in 0-30 cm (kg STN ha^{-1})	5962 a	5736 a	5332 b
Aboveground biomass (dt DM ha^{-1})	591	536	440
	a	a	b
Mean non-legume cash crop yields (dt DM ha^{-1} a^{-1})	39,9	38,3	32,9
	a	ab	b
Sum of all harvested biomass (dt CU* ha^{-1})	326	200	208
	a	b	b

Different letters denote significant differences within rows (α = 0,05, Tukey-Test).
Denotations in rows "SOC change" and "STN change" refer to the significance of trends.
DM = Dry Matter. CU = Cereal Units (KTBL 2009).

Discussion

Soil organic matter is of great relevance for crop production in organic farming, and for the production of non-legumes in particular (e.g. Brock et al. 2011). Therefore, losses of soil organic matter are likely to have a negative impact on crop yields in organic arable farming systems. In the OAFEG the slight increase of SOM levels under MF will be an effect of the combined impact of crop rotation and fertilization. Both the cropping of perennial legumes and cattle manure application have been identified as efficient measures in organic matter supply to soils (e.g. Lipavský et al. 2008). Green manure leys cropped with fodder legumes have been identified as key factors of soil fertility management especially in stockless organic farming e.g. by Watson et al. (2002). Our results show, that even this measure could be insufficient for organic matter supply in stockless organic farming systems. Whether it will be possible to maintain SOM levels in organic cash crop rotations, where organic matter supply is based on green manure catch crops and straw alone, cannot sufficiently be assessed until now. Results on green manure catch crops do not indicate a general ability to build up organic matter (Shepherd 1999), and the same is true for straw (van Groenigen et al. 2011).

Conclusions

Sustainable soil organic matter management in organic farming can most easily be achieved by mixed farms with fodder legumes and animal manure. Stockless systems should at least maintain fodder legumes as a green manure ley. Otherwise the sustainability of farming systems may be threatened. Such conditions require the development of new approaches: farm cooperations (fodder-manure exchange), biogas production with recirculation of residues, or intercropping to extend legume shares in rotations.

References

Brock C., Fließbach A., Oberholzer, H.-R., Schulz, F., Wiesinger K., Reinicke F., Koch W., Pallutt B., Dittmann B., Zimmer J., Hülsbergen K.-J., Leithold G. (2011): Relation between soil organic matter and yield levels of nonlegume crops in organic and conventional farming systems. J. Plant Nutr. Soil Sci. 174: 568-575.

van Groenigen K., Hastings A., Forrista. D., Roth B., Jones M., Smith P. (2011): Soil C storage as affected by tillage and straw management: An assessment using field measurements and model predictions. Agric. Ecosys. Environ. 140: 218-225.

KTBL (2009): Faustzahlen für die Landwirtschaft. 14th edn. KTBL, Darmstadt, Germany

Lipavský J., Kubát J., Zobac J. (2008): Long-term effects of straw and farmyard manure on crop yields and soil properties. Arch. Agron. Soil Sci. 54: 369-379.

Schulz F., Brock C., Schmidt H., Franz K.-P., Leithold G. (2013): Development of soil organic matter stocks under different farm types and tillage systems in the Organic Arable Farming Experiment Gladbacherhof. Arch. Agron. Soil Sci., DOI: 10.1080/03650340.2013.794935

Shepherd M. (1999): The effectiveness of cover crops during eight years of a UK sandland rotation. Soil Use Manage. 15: 41-48.

Watson C., Atkinson D., Gosling P., Jackson L., Rayns F. (2002): Managing soil fertility in organic farming systems. Soil Use Manage. 18: 239-247.