Apparent N Balance in Organic and Conventional Low Input Cropping Systems

A. Boldrini[1], P. Benincasa, G. Tosti, F. Tei, M. Guiducci

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Abstract

The determination of nutrient surplus is one of the indicators of potential N losses from the agricultural system to the environment. An experiment was started in 1998 in Central Italy to evaluate the soil surface N balance of an organic and a conventional low input cropping system over a long term crop rotation. Results at the end of a 6-year crop rotation showed an estimated N surplus in organic system 1.3-2 times higher than in conventional system while N content in the top soil was not different in the two systems, so that organic system should have involved a higher N loss from that soil layer.

Introduction

Organic systems are expected to reduce N leaching (Haas et al., 2002), but this is not always confirmed (Kirchmann and Bergström, 2001). Actually, nitrogen release from organic fertilizer and green manuring might not match crop requirement for both N total supply and timing of N release, with consequent inefficient use of supplied N and increase of residual N exposed to leaching (Benincasa et al., 2004; Jenkinson, 2001; Kirchmann and Bergström, 2001). The determination of nutrient surplus (N supply minus N off-take) at a field scale is often used as an indicator of the potential loss of N (Webb et al., 2000; Heathwaite, 1997; Meisinger and Randall, 1991) and can give an indication of the risks that are associated with specific farming practices. This research is aimed to evaluate the apparent N balance of an organic and a conventional low input system over a long term crop rotation.

Materials and methods

An experiment was started in 1998 at Perugia (Italy, 43°N, 165 m a.s.l.) to compare an organic (ORG) and a conventional low input (CONV) system in two contiguous fields, both clay loam and with same organic matter and total N contents. Both fields were divided in six sectors (A1, A2, B1, B2, C1, C2) to reproduce the steady-state running of a 6-year rotation in a farm and test several food crops contemporaneously. In each cropping systems a randomized block design with three or four replicates (depending on year and crop) was adopted. The same sequence of cash crops over the six years was adopted in both systems (Table 1). Nitrogen supply to the system was assured by green manuring (legumes, pure or mixed with non-legumes) and/or poultry manure in ORG and by green manuring (only until 2000) and mineral fertilizers in CONV. Above ground N accumulation of any crop and its partitioning between commercial biomass and crop residues were determined by plant sampling and analysis of organic N d. m. content (Kjeldhal method).

[1]Department of Agricultural and Environmental Sciences, University of Perugia, 06121 Perugia, Italy, Internet www.agr.unipg.it, E-mail corresponding author: arianna.boldrini@agr.unipg.it

Tab. 1: Six-year crop rotations in the six field sectors in organic (ORG) and conventional low input (CONV) cropping systems. Green manure crops (GM) were adopted in ORG and CONV until 2000, only in ORG afterwards. Nitrogen supply (kg ha-1) from fertilizers in ORG/CONV system is reported in brackets.

Field sectors	Years					
	1999	2000	2001	2002	2003	2004
A1	common bean (40/0)	spelt (40/40)	GM1+maize (40/150)	GM4+soybean (0/0)	GM1+pepper (0/200)	wheat (0/80)
A2	common bean (40/0)	wheat (80/80)	GM1+pepper (40/175)	GM4+maize (40/40)	GM1+tomato (0/200)	wheat (0/80)
B1	field bean (0/0)	GM3+pepper (100/100)	pea (40/0)	wheat (80/80)	GM2+maize (0/150)	GM3+tomato (60/160)
B2	field bean (0/0)	GM3+maize (100/100)	field bean (40/0)	wheat (80/80)	pea (0/0)	GM3+pepper (60/200)
C1	GM1+pepper (0/70)	common bean (40/0)	spelt (80/80)	GM1+tomato (60/200)	wheat (40/80)	field bean (0/0)
C2	GM1+millet (20/135)	common bean (40/0)	wheat (80/80)	GM1+pepper (60/200)	wheat (40/80)	GM1+maize (40/150)

GM1: field bean; GM2: field bean+rapesed; GM3: hairy vetch; GM4: barley.

In legumes, N derived from atmosphere (Ndfa) via symbiotic N_2 fixation was assumed to account for 80% of accumulated N, based on data reported by Vance (1988) and by Cazzato et al (2003) for the Italian environment, and on our own data (not yet published) analysed according to Müller and Thorup-Kristensen (2002) on leguminous and grass species grown contemporarily for several years in field experiments carried out in the same location of the present trial. The Ndfa accumulated in legume roots is not considered here. For this reason, due to the different frequency of green manure crops in the two systems (Table 1) the underestimate of N input by legume roots Ndfa is most likely higher in ORG than in CONV. Apparent residual N in the soil (i.e. the soil-crop component of the soil surface budget) (Aarts et al., 2000) was calculated at the end of each crop cycle as: $\Delta N = A + B - C$; where ΔN = apparent residual N in the soil per unit area (kg ha^{-1}); A = N input as mineral and organic fertilizer (kg ha^{-1}); B = estimated legume Ndfa (kg ha^{-1}); C = N off-take with commercial yield removal (kg ha^{-1}). The soil N content (both organic and mineral N) was determined in each sector at the end of the 6-year crop rotation by sampling four 0-0.40 m soil cores per each sector. Data were submitted to analysis of variance according to a hierarchical design (crops within systems).

Results

As an average over the six field sectors, the 6-year cumulated total N input (i.e. N from fertilizers + legume Ndfa) (Table 2) was similar in the two systems (594 kg ha^{-1} in ORG vs 603 kg ha^{-1} in CONV), with estimated Ndfa component in ORG about 3.5 times higher than in CONV, the N off-take was 17% lower in ORG than in CONV, while the ΔN was 34% higher in ORG than in CONV. In particular, except for sector A1, field sectors in ORG showed a cumulated ΔN 1.3-2 times higher than in CONV. Between-sectors variability was observed for all N balance components, with sectors sorted pretty similarly in both systems, except for Ndfa that in CONV was affected by occasional green manuring in some sectors.

Table 2: Cumulated 6-year N input from fertilizers, estimated legume N derived from atmosphere, N off-take and ∆N (i.e. total input minus off-take) in six field sectors of organic (ORG) and conventional low input (CONV) cropping systems.

Field sectors	N from fertilizers (kg ha^{-1})		Legume Ndfa (kg ha^{-1})		N off-take (kg ha^{-1})		∆N (kg ha^{-1})	
	ORG	**CONV**	**ORG**	**CONV**	**ORG**	**CONV**	**ORG**	**CONV**
A1	120	470	335	66	284	300	172	236
A2	200	575	303	38	450	579	53	34
B1	280	490	368	151	341	486	307	155
B2	280	380	373	237	302	341	351	276
C1	220	430	386	110	345	399	261	141
C2	280	645	421	26	369	406	332	264
mean	230	498	364	105	349	419	246	184
Pooled SD	*31*	*74*	*58*	*38*	*45*	*48*	*69*	*71*

Both organic and mineral N contents of the 0-0.40 m top soil at the end of the 6-year rotation were substantially the same in both ORG and CONV (Table 3).

Table 3: Organic, mineral and total N contents in the top soil layer (0-0.40 m) in organic (ORG) and conventional low input (CONV) cropping systems at the end of the 6-year crop rotation.

Systems	Organic N Kg ha^{-1}	Mineral N Kg ha^{-1}	Total N Kg ha^{-1}
ORG	4065	29	4095
CONV	4188	34	4222
Pooled SD	*561*	*8*	*563*

Discussion

The higher 6-year cumulated ∆N in ORG with respect to CONV was determined by both the lower cash crop N off-take and the imprecise N availability from green manuring in ORG. The exception of sector A1, where ∆N was higher in CONV than in ORG, is mainly due to vascular diseases and a heavy nematode attack on sweet pepper in 2003, so that a great part of commercial yield was damaged and therefore left in the field and then incorporated into the soil. The lower cash crop N off-take in ORG resulted from a generally lower commercial yield of many crops as a consequence of lower initial growth (especially in summer crops, due to low early N availability and/or to scrubby organic transplants) and/or of higher weed competition (especially in grain legumes). The imprecise N availability from green manuring concerned both the total N supplied from green manure crops and the timing of N release from incorporated biomass which both showed a high inter-annual variability (Benincasa et al., 2004). Differently from CONV, where mineral fertilizer at low rates generally allowed high N uptake efficiency, in ORG sometimes N supply by green manuring exceeded cash crop total requirements and sometimes N release from incorporated biomass did not cover cash crop early N requirements, with consequent reduction of cash crop N uptake efficiency. Since at the end of the 6-year rotation both organic and mineral N contents in the 0-0.40 m top soil layer were similar in the two systems, it can be argued that the higher ∆N recorded in ORG should have caused a higher loss of N from that soil layer.

Conclusions

In our experiment, organic system involved a higher N surplus (i.e. N input by fertilizers plus estimated legume Ndfa minus N off-take) with respect to the conventional low input system. However, the higher N surplus did not involve an important difference between systems in the top soil N content (both organic and mineral) at the end of the 6-year rotation. For this reason organic system in this experiment was estimated to involve a higher N loss from the top soil.

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