Below ground nitrogen dynamics in the sequence clover-grass maize in the DOK long term experiment

JOCHEN MAYER[1]*, ASTRID OBERSON[2], ANDREAS LÜSCHER[1], EMMANUEL FROSSARD[2], STEFANO M. BERNASCONI[2], PAUL MÄDER[3], ANDREAS HAMMELEHLE[1,2]

Key words: clover-grass, below ground N, rhizodeposition, N transfer, N stabilisation

Abstract

We investigated the effect of organic versus conventional cropping systems on the below ground nitrogen inputs of *Trifolium pratense* L., its transfer to corresponding grass and the fate in the soil organic matter in the clover-grass ley of the DOK long term experiment, Switzerland. BGN tended to be largest in conventional and organic treatments with standard fertilisation and decreased with lower fertilisation intensity. The largest amount of clover N transferred to grass was observed in the minerally fertilised conventional treatment. Clover N derived from rhizodeposition was rapidly stabilised in all treatments to clay rich fractions and thus clover N will have a relatively low direct N contribution to subsequent nonlegumes**.**

Introduction

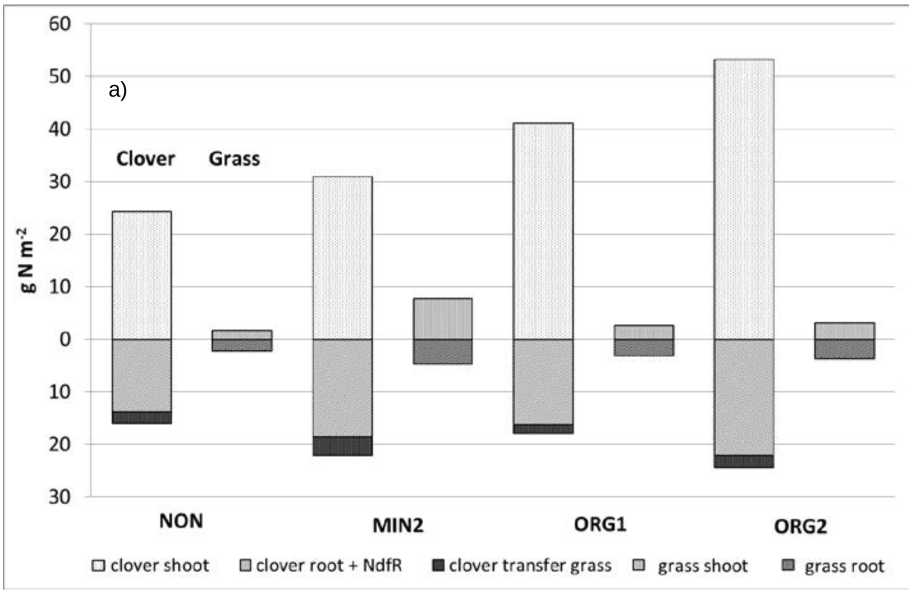
Clover-grass mixtures are important animal feed and the main nitrogen (N) source in organic cropping systems. However, biomass production and related below ground N (BGN) inputs vary in a wide range dependent on site conditions, environmental factors, and management practices and are not well understood (Oberson et al. 2013). The direct contribution of legume N to subsequent nonlegumes is small and often not in synchrony to the demand. Improving organic cropping systems require a deepened knowledge in BGN processes in the sequence legume – nonlegume under field conditions.

Our objectives were therefore to examine the effect of different cropping systems, that is conventional and organic, on i) the amount of N rhizodeposition and total below ground N for red clover, ii) the N transfer from clover to grass within the mixture, and iii) the fate of clover root derived N in functional soil pools and its contribution to subsequent maize.

Material and methods

Investigations were carried out in the DOK experiment, near Basle, Switzerland which compares two organic and two conventional cropping systems at two fertilization levels (1=50% and 2=100% of the systems standard fertilization) since 1978 (Mäder et al., 2002). We included the following cropping systems and fertilization levels: bio-organic (ORG1, ORG2), conventional receiving exclusively mineral fertilizers (MIN2), and an unfertilized control (NON). During the model clover-grass mixture (*Trifolium pratense* L. + *Lolium perenne* L.) 11 red clover plants per micro plot (tubes of Ø 40 cm, 25 cm depth) were ^{15}N multi pulse leaf labelled with 99 atom % ^{15}N urea after each cut in 2011 and 2012. BGN and N derived from rhizodeposition (NdfR) were determined from the soil ^{15}N signal after removal of all visible roots and sequential extraction of the soil. From this procedure the fate of NdfR in functional soil pools as dissolved N (DN) and microbial biomass N (N_{mic}) were determined. Stabilisation of NdfR in soil density fractions and subsequent reuse over a 3-years period (clover-grass; clover-grass, maize) was determined by soil density fractionation and the recovery of clover derived N was determined in the subsequent maize (*Zea maize* L.*)* in 2013.

[1] Agroscope, Institute for Sustainability Sciences INH, Zürich, Switzerland; jochen.mayer@agroscope.admin.ch, www.agroscope.ch
[2] Research Institute of Organic Farming FiBL, Frick, Switzerland
[3] Swiss Federal Institute of Technology ETH, Zürich, Switzerland



Results and discussion

We present the first results from 2011. Cropping systems differed significantly between the above ground N (AGN) uptake by clover and grass N with 24 (NON), 31 (MIN2), 40 (ORG1) and 53 (ORG2) g N m^{-2}. Grass AGN ranged between 2 and 8 g N m^{-2} whereas MIN2 had the highest percentage of grass in the mixture and grass N uptake (Fig. 1a). However, clover BGN did not follow the above ground pattern. The lowest input showed NON and ORG1 with 14 and 16 g N m^{-2}, respectively followed by MIN2 with 19 and ORG2 with 22 g N m^{-2}. In all treatments the largest amount of NdfR (54 – 68%) was found in soil organic nitrogen (SON), with the lowest proportion in MIN2 (54%) (Fig. 1b). Considering the N transfer from clover to grass, the highest amount was transferred in MIN2 (4 g m^{-2}), although this treatment had a comparatively low clover N uptake and the lowest clover percentage in the mixture. This could be explained by a denser root network growing around the clover roots compared to ORG 1 and ORG2. ORG2 with the largest clover N uptake and a low grass N uptake could transfer less N to the grass partner. However, in NON grass benefited strongest from clover (56%). Including transfer, the treatments at 100% standard fertilisation showed in tendency higher NdfR inputs.

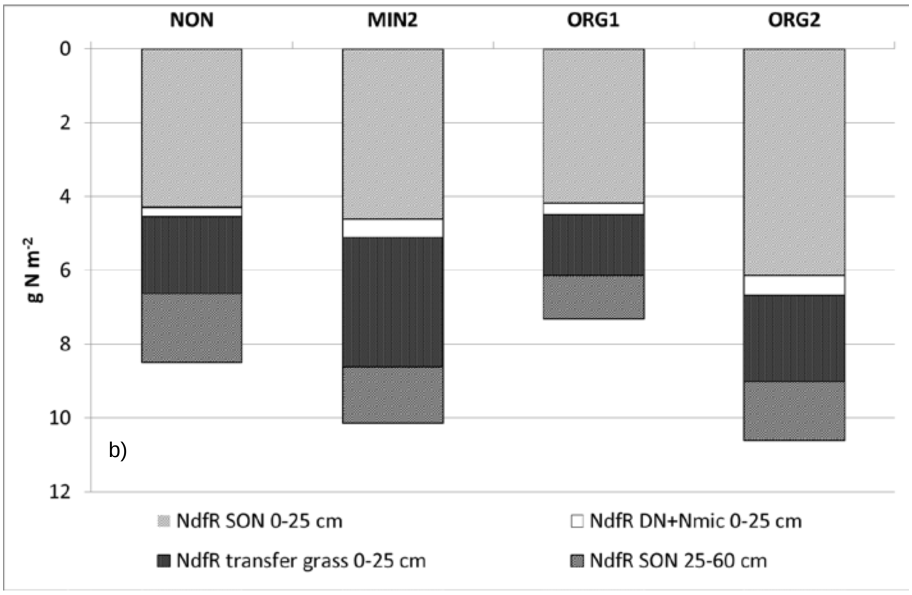


Figure 1: Above and below ground N uptake in treatments of the DOK clover-grass mixture (a), distribution of red clover NdfR in functional soil pools (b)

The ^{15}N enrichment of SON showed the highest value in the fraction <1.65 (particulate organic matter). The following fractions showed decreasing enrichments which are characterized by increasing mineral associations and, thus, increasing stabilization. However, the highest amount of NdfR was found in the clay dominated fraction 2.25 – 2.55 g cm^{-3} indicating a very fast stabilization of the major part of NdfR within 8 months during the first year (Table 1). This fast and strong N stabilization might be one reason of the relatively low direct N contribution from clover-grass to subsequent nonlegumes. We can conclude that it will be difficult to remobilize that stabilized N by management measures to face the N demand for e.g. winter cereals in temperate climate. We will get more evidence by the results from the second year of the clover-grass mixture and the transfer into subsequent maize which are evaluated at present. These data will be available at the conference and presented there.

Table 1: a) Percentage of red clover NdfR in soil density fractions after six months of clover-grass establishment in 2011 in different DOK cropping systems and b) proportion of amounts of NdfR in the respective soil fraction

Soil	a) Percentage of N derived from rhizodeposition[2]					b) Proportion of NdfR[1] in the respective soil fraction (total = 100% of NdfR)[2]			
fraction [g cm^{-3}]	< 1.65	1.65 - 2.25	2.25 - 2.55	> 2.55	bulk soil	< 1.65	1.65 - 2.25	2.25 - 2.55	> 2.55
Treatment									
NON	6%	1.4%	0.7%	0.5%	0.9%	25%	18%	48%	8%
MIN2	4%	1.8%	1.2%	0.8%	1.4%	16%	24%	51%	10%
ORG1	5%	1.8%	1.0%	0.6%	1.2%	20%	23%	48%	10%
ORG2	4%	2.0%	1.2%	0.9%	1.5%	16%	27%	46%	11%

[1] NdfR: N derived from rhizodeposition
[2] Means between DOK treatments differed not significantly

References

Mäder P, Fließbach A, Dubois D, Gunst L, Fried P and Niggli U (2002): Soil fertility and biodiversity in organic farming. Science 296, 1694-1697.

Oberson A, Frossard E, Bühlmann C, Mayer J, Mäder P, Lüscher A (2013): Nitrogen fixation and transfer in grass-clover leys under organic and conventional cropping systems. Plant and Soil 371, 237-255.