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Adaptation and Management of Forage Legumes – Strategies for Improved Reliability in Mixed Swards

20-22 September 2004 Ystad, Sweden

Edited by

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Does N-cycling impair the N_2-fixing activity of mulched legume-grass in the field?

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ABSTRACT

N-balance studies suggest that mulching, as compared to cutting, of legume-grass reduces N_2-fixation and intensifies N-cycling. However, field data of N-cycling are still scarce. Here we present data from a two-year experiment with multi-species mixed legume-grass swards. The importance of N-cycling for (i) growth and N-uptake of the component species, and (ii) N_2-fixation of the legumes in the mixture was quantified by the ^{15}N isotope dilution method. The experiment was carried out in a long-term plot experiment comparing crop rotations for organic farming with and without livestock, which is located in a tertiary hilly landscape in southern Germany. The soil is an eutric cambisol with loess cover. Mulch-N was rapidly recycled. Ten percent of it was already detected in the shoots of the next regrowth. Irrespective of harvest occasion and harvest year, almost 25% of the N taken up by the grass was from mulch-N, proving that recently applied mulch made up a stable and important proportion of the plant available soil-N. The biological nitrogen fixation of mulched as compared to cut legume-grass swards was reduced by *c.* 30% and was mainly the result of a smaller percentage of legumes in the latter.

Keywords: legume-grass, mulching, N-cycling, N_2-fixation

INTRODUCTION

Biological N-fixation (BNF) by legumes is a crucial factor for the sustainability of organic farming systems. It is common that stockless organic farms depend on legumes grown as a green manure crop for their N input, but little is known about the effect of mulching on N_2-fixation of the crop. N-balance studies suggest that mulching, compared to cutting and removing the crop, reduces BNF and intensifies N-cycling (Loges *et al.*, 2000; Beckmann *et al.*, 2002). In this paper we present data from an experiment with multi-species mixed swards, where the ^{15}N-enrichment method (Danso *et al.*, 1993) was applied to determine the effect of N-cycling from applied mulch on N uptake and N_2-fixation of the sward.

MATERIALS AND METHODS

The measurements were done in a long-term experiment carried out at the Bavarian State Research Centre for Agriculture, Freising, Germany, in which crop rotations for organic farming with and without livestock are compared, both with three replicates. The experiment was located at Viehhausen (48°24' N, 11°37' E) in a tertiary hilly landscape (480 m above sea level, 797 mm mean annual precipitation, 7.5°C mean annual temperature). The soil was a eutric cambisol with loess cover. Fields from a stocked (herbage removed) and a stockless (herbage mulched) crop rotation, both with multi-species legume-grass swards, were used to (i) compare N_2-fixation (g N/m²) of cut and mulched legume-grass, (ii) quantify the N-cycling from fresh mulch, and (iii) evaluate the effect of recycled N on the rate of N_2-fixation (pN_{dfA}) of the legume. Mineral ^{15}N ($^{15}NH_4{}^{15}NO_3$, 0.5 g/m², 20 at% ^{15}N) and ^{15}N enriched legume-grass shoots were used to estimate the rate of N_2-fixation using the grass component in the mixture as the reference plant. Fresh ^{15}N mulch was obtained from separate subplots. Mineral ^{15}N and mulch ^{15}N were applied at the beginning of each of the three regrowth periods; each time to a new set of subplots (1 m²). From their centre (0.25 m²) herbage samples were taken, and separated by hand into grass, legume and weed fractions. Subsamples were dried and ground for N and ^{15}N-analysis by EA-IRMS (ANCA SL20-20, Europa, Crewe, GB). The yield of the mixture was determined for the whole plot (128 m²) and dried and ground subsamples were used to estimate legume content by NIRS as described by Locher *et al.* (2005).

RESULTS

Mulch-N, applied at a rate of about 11 g N m^{-2}, was rapidly recycled: about 10% of it was already detected in the shoots of the following regrowth (Table 1). A stable proportion of mulch-N within the N of the grasses was found, while for the legume component mulch- and soil-N were of relevance for N-uptake only during the last regrowth. As a consequence, the rate of N_2-fixation decreased to about 55% in the fourth harvest compared to 85-91% at earlier harvests (Table 2). The legume content of mulched plots was consistently l compared to cut plots after the first mulching event (Table 2). Total BNF was mar reduced (> -30%) by using the crop for mulching compared to removing it from the (Table 2).

Table 1. Amount of ^{15}N-mulch applied to the subplot (1 m²) of the mulched legume-mulch-N use efficiency (MUE), and nitrogen derived from fresh mulch-N (N_{dfM}). All da a mean of three replicates

Harvest	Applied mulch-N		—MUE—		N_{dfM} of grass-N		N_{dfM} of legume-N	
No.	2000	2001	2000	2001	2000	2001	2000	2001
	----- [g/m²] -----		---------- [%] ----------					
1	11.7	11.9	-	-	-	-	-	-
2	14.0	9.2	11.0	8.8	22	31	1.4	2.2
3	13.3	10.7	7.8	9.1	20	24	1.2	2.0
4	-	-	12.1	11.4	28	21	9.4	9.6

Table 2. Legume content and biological nitrogen fixation of mulched and cut legume-All data are a mean of three replicates unless otherwise stated

Harvest	Legume content of DM-yield				Biological nitrogen fixation						
No.	mulching		cutting		mulching		cutting		mulching		cutting
	2000	2001	2000	2001	2000	2001	2000	2001	2000	2001	2000
	------ [%] ------				[% of N in shoots of legumes]				------ [g N/m²] ------		
1	62	58 [a]	71	48 [b]	95	95 [b]	96	98 [a]	6.6 [b]	7.1	9.6 [a]
2	54	57 [b]	66	73 [a]	91 [b]	90 [b]	96 [a]	97 [a]	6.1 [b]	5.0 [b]	9.8 [a]
3	53 [b]	72 [b]	80 [a]	96 [a]	86	85 [b]	90 [$]	96	6.3	8.1 [b]	11.2 [$]
4	41	40 [b]	55	70 [a]	61 [b]	47 [b]	86 [a]	95 [a]	1.8 [b]	1.0 [b]	3.4 [a]

[a, b]: significant differences between treatments at a harvest date (t-Test, α=0.1)   [$] only one replicat

DISCUSSION

Recycling of mulch-N took place immediately and was of similar magnitude irrespecti harvest occasion and harvest year. The fact that the grasses derived similar proportic their N-uptake from mulch-N points in the same direction and suggest that recently aı mulch-N made up a similar proportion of the plant available soil-N. The decrease in BNF of the mulched sward compared to the cut sward can be explained by two effects: (i) the consistently lower proportion of legumes in the mulched sward, and (ii) the reduced rate of N_2-fixation of the legumes. More than 66% of the total effect on BNF was caused by the smaller legume yield. The rate of N_2-fixation, on the other hand, appeared to be much more sensitive to the actual environment, as indicated by the increased soil-N availability recorded during the last regrowth (Kaiser, 2002).

CONCLUSION

Recently applied mulch represented about 25% of the plant available N in the soil. At the two last harvests it can be assumed that the total increase in the plant available N in soil due to the application of mulch was even higher, since only the N-uptake from recent mulch was measured. Legume content determined the total amount of BNF and appeared to be a sensitive indicator for changes in soil-N availability.

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