Effect of green manure management on barley yields and N-recovery

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Implications

Mulching of GM herbage can increase cereal yields compared to its removal. However, the same GM herbage removed for biogas production will provide biogas residue that can be used as spring fertilizer to cereals. This will improve N-recovery and reduce the risk for N pollution. Cooperation with existing biogas plants will be more efficient, as building small biogas plants are costly and challenging.

Background and objectives

In cereal production on stockless organic farms, green manure (GM) is commonly used to improve soil fertility. Because of the short growing season in Norway, it is usual to keep the GM as a whole year crop. Clover-grass swards are commonly used as GM. They are mown frequently as a means to control perennial weeds in the GM-cereal rotations and to keep the sward in a vegetative state. The mown GM herbage is commonly mulched. The nitrogen accumulated in the GM is a potential pollution problem. Some investigations in fertile soils in temperate climate have concluded that mulching of GM herbage did not increase the yields of successive cereal crops, compared to removal of the mown GM herbage. If the GM herbage is removed, the risk of N-pollution from the field is reduced, and the herbage may be used elsewhere. If GM herbage is anaerobically digested for biogas production, the biogas residue can be used to fertilize cereal fields in the spring. This might lead to higher yields as a common constraint to organic cereal cultivation is lack of easy available nitrogen at the start of the growth period.

The objectives of this study were to investigate the effects of removing, mulching or returning green manure herbage as biogas residue, on barley yields and on nitrogen recovery, potential N-leaching and N_2O emissions.

Key results and discussion

On average, the mulched or harvested GM herbage contained 220 kg N per ha. Removing green manure herbage (0M) reduced substantially the grain yield of the subsequent spring barley crop on the sites with light soils (Site 2 and 3, Table 1). When only the last harvest was mulched, the grain yields where intermediate (1M, Table 1).

Table 1. Barley grain yield (Mg DM per ha ± S.E., n= 4) at four sites in 2010. Treatments: 3M – all three harvest of green manure are mulched, 1M – the last harvest is mulched, 0M – all three harvests are removed, B – Biogas residue applied spring 2010, corresponding to 50% of the herbage removed. Within a site, treatments that share a letter are not significantly different (p<0.05, TukeyHSD).

Sites	3M	1M	0M	0M-B
1.Kvithamar	1.4 (.2)ab	1.2 (.1)ab	0.9 (.1)b	1.6 (.2)a
2.Værnes	3.3 (.2)ab	2.6 (.3)bc	2.2 (.2)c	3.6 (.1)a
3.Apelsvoll	3.2 (.1)ab	2.6 (.2)bc	2.5 (.1)c	3.5 (.2)a
4.Ås	2.5 (.2)b	2.5 (.3)b	2.4 (.1)b	3.1 (.2)ab

In spite of evident N-limitations on barley growth, mulching did not increase grain yield on the heavy soil of the Site 1. A positive effect of mulching on plant growth observed at Site 4 was lost due to unfavorable weather after ripening that damaged the most fertile plots.

The nitrogen recovery calculated as *amount of N harvested in percentage of herbage N added (equation),* was very low. The recovery was particularly low when all three harvests were mulched. Low content of inorganic N in soil indicate that only a small part of N from decomposing herbage is plant available during our nearly 2 year measurement period. Shortly before ploughing spring 2010 the highest total content of inorganic N in the soil 0- 80 cm depth (NH_4-N+NO_3-N), was found at Kvithamar (3M) corresponding to 64 kg N per ha. This was only 17 kg N higher than when green manure herbage was removed. Ploughing and spring fertilization increased the content of inorganic N in soil, but there were no differences between 3M and 0M. Most of the inorganic N was in the upper soil layer. The maximum level of NO_3-N in the deeper soil layers (30-80) cm ranged from 13 kg per ha at Site 1 (before ploughing spring 2010) to 24 kg per ha at Site 3 (Spring 2011).

Table 2. Apparent nitrogen recovery (%) of herbage N in barley 2010 (equation below).

Sites	3M	1M	0M-B
1.Kvithamar	4	7	10
2.Værnes	9	1	16
3.Apelsvoll	10	16	24
4.Ås	2	5	15

The mulching of herbage increased N_2O emission only slightly (Nadeem et al. 2012). In the year with green manure it was 0.37 kg N_2O-N per ha higher throughout the whole growing season than when herbage was removed. Sward management or application of biogas residue did not affect N_2O emissions during barley production in 2010.

So where did the nitrogen in green manure herbage go? Probably most of the N was incorporated in soil organic matter as indicated by the high C/N ratio of the herbage (16). We can however not exclude ammonia volatilization or leaching from decomposing herbage, or denitrification events that we did not capture with our measurements.

How work was carried out?

The effect of various GM treatments on spring barley yields and nitrogen dynamics was investigated at four sites differing in soil and climatic conditions. The locations were Central Norway (Site 1: silty clay loam and Site 2: sandy loam), Eastern Norway (Site 3: loam) and South-Eastern Norway (Site 4: clay loam). In 2008 a grass clover mixture was undersown in barley. In 2009 the clover-grass herbage was either harvested or mulched. In spring 2010 the GM sward was ploughed down and barley was sown. Biogas residue from anaerobically digested GM herbage was applied before barley was sown in spring 2010. It contained 110 kg total N and 60 kg NH_4-N per ha (56 % of the total N in the GM herbage). Soil mineral-N was analyzed at 0-0.8 m depth on several occasions from 2008 until spring 2011, and used to judge the potential for N-leaching. N_2O emissions were measured with the chamber method at Site 4 in 2009 and 2010, when the soil was not covered by snow. Apparent N recovery was calculated according to equation below.

Apparent N recovery (%) = $((N\ yield_{3M,1M\ or\ 0M\text{-}B} - N\ yield_{0M})/N\ applied_{3M,1M\ or\ 0M\text{-}B})*100$

Where *N yield*$_{3M,1M\ or\ 0M\text{-}B}$ *is harvested total N (g m*$^{-2}$*) in barley grain and straw 2010 in the treatments* 3M,1M or 0M-B*,* N yield$_{0M}$ *is corresponding barley total N yield (g m*$^{-2}$*) in 0M, and* N applied$_{3M,1M\ or\ 0M\text{-}B}$ is total N *(g m*$^{-2}$*)* applied either as mulch in 2009 (3M,1M) *or as biogas residue spring 2010 (0M-B).*

Reference Nadeem S, Hansen S, Azzaroli Bleken M and Dörsch P 2012. N_2O emission from organic barley cultivation as affected by green manure management. Biogeosciences. 9:2747-2759.