Anaerobic digestion of manure – consequences for plant production

A.-K. Løes[1], A. Johansen[2], R. Pommeresche[1] and H. Riley[3]

[1]Bioforsk Organic Food and Farming, Gunnars veg 6, N-6630 Tingvoll, Norway (anne-kristin.loes@bioforsk.no), [2]Aarhus University, Denmark [3]Bioforsk Arable Crops, Norway

Implications

Organic farming systems are today dependent upon fossil energy. Another challenge are soil nutrient concentrations, which may be depleted with time even in animal husbandry systems (Løes & Øgaard 2001). Anaerobic digestion (AD) of animal manure may produce biogas to replace fossil fuels, and reduce methane (CH_4) emissions during manure storage. Co-digestion of substrates rich in energy increases the economic viability of the biogas plant, and off-farm substrates such as fish silage or household waste may add nutrients to the farming system. AD may also ease manure handling, while reducing the amount of weed seeds and animal pathogens. A reduced proportion of easily degraded C in the AD-manure may however impact the soil fauna/microflora and humus levels. Mineralization of organic N during AD may increase nutrient availability and crop yields. Possibly, the increased levels of root and shoot residues may compensate for the organic C removed via AD.

Background and objectives

A biogas plant was established in 2010 at Tingvoll research farm, NW Norway for AD of the slurry from 25 organically managed dairy cows. A project (SoilEffects, 2010-14) has been established to compare crop yields and soil characteristics after application of untreated versus anaerobically digested slurry. Will AD of animal manure influence crop yields, and impact soil characteristics which are important for soil fertility? Soil physics, chemistry, microbiology and fauna are being studied in a field experiment with slurry application in two cropping systems: 1) arable crops with annual ploughing and no legumes and 2) perennial grass-clover ley established in 2010. The crops in the arable system were oats in 2011 and ryegrass in 2012. Low and high application levels of AD slurry and untreated slurry are compared, with total levels of 85 and 170 kg total N ha^{-1} yr^{-1} applied to arable crops, and 110 and 220 kg to perennial ley.

Key results and discussion

In the perennial ley, the proportion of grass increased with time in both AD treatments (Table 1). The proportion of weeds was lowest in this treatment, especially at the low manure application level.

Table 1. Botanical composition of grass-clover ley over time with different manure application. Values are means (n=4) presented as % DM of Grass, Clover and Weeds. One statistically valid result is highlighted in **bold**.

Treatment	**2011, G/C/W**		**2012, G/C/W**	
	1st cut	2nd cut	1st cut	2nd cut
Control, no manure	40/59/1	49/15/36	58/28/14	55/35/10
Untreated slurry low level	50/48/2	57/12/31	59/26/15	56/34/10
Untreated slurry high level	55/44/1	67/8/25	55/31/14	**77**/15/8
AD slurry low level	41/59/0	55/15/30	77/19/4	70/26/4
AD slurry high level	41/58/1	51/11/38	69/14/17	74/18/8

The botanical composition of the control and the low level untreated slurry treatments was quite similar in 2012, in spite of very different yield levels. Only the proportion of grass in the 2nd cut in 2012 differed significantly between treatments, and was then highest by high application of untreated slurry (Table 1).

In the grass system, the yield levels were strongly increased by slurry application (Table 2). AD slurry gave the same yields as untreated slurry. The yields declined over time in the control treatment, whereas they increased in the fertilized treatments. Hence, the relative differences between the fertilized and unfertilized treatments increased over time.

Table 2. Total and relative yields of ley (sum of two cuttings) in 2011 and 2012, tonnes of dry matter (DM) ha^{-1}. Statistically significant differences within year ($P<0.05$) are suffixed as a, b, c.

Treatment	2011	2011 rel.	2012	2012 rel.	2012/2011*100
Control	6.61a	100	5.42a	100	82
Trad. Low	8.05ab	122	9.03b	167	112
Trad. high	8.78b	133	10.45bc	193	119
AD low	8.19b	124	8.95b	165	109
AD high	8.44b	128	11.56c	213	137

In the arable system, the yield increases by slurry application were not statistically significant (Table 3). In 2011, this was surprising because differences in growth characteristics such as straw length and plant color were clearly visible between treatment plots during the growing season and straw lengths varied significantly (Table 3). Yield levels in 2012 were generally very small due to bad establishment of fodder rape, which had to be replaced by a late-sown ryegrass crop. Emissions of N_2O were measured in this system in 2012, showing remarkably high values as compared to former measurements in ley at Tingvoll. The average proportion of weeds in 2011 was 10.4 % of the total DM and seemed to increase with fertilization since the control averaged 8 %, whereas fertilized treatments had 10-12 % of weeds. In 2012, this pattern was opposite, with more weeds in the control (34 % at 1st cut, 11 % at 2nd) than in the fertilized treatments (15-20 % at 1st cut, 4-5 % at 2nd).

Table 3. Total and relative yields of arable crops in 2011 and 2012, tonnes of dry matter (DM) ha^{-1}, sum of straw + grain in 2011, sum of two cuts of ryegrass 2012. Suffixed letters as in table 2. 2011 cm = average length of oats straw.

Treatment	2011	Rel.	2011 cm	2012	Rel.	2012/2011*100
Control	5.35a	100	65a	2.23a	100	42
Trad. Low	5.80a	108	69a	2.56a	115	44
Trad. high	5.98a	112	72ab	2.75a	123	46
AD low	5.60a	105	71ab	2.57a	115	46
AD high	6.11a	114	78b	2.64a	118	43

References

Løes, A.-K. & Øgaard, A.F. 2001. Long-term changes in extractable soil P in organic dairy farming systems. Plant and Soil 237: 321-332.
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