RAHMANN G & AKSOY U (Eds.) (2014) Proceedings of the 4th ISOFAR Scientific Conference.
'Building Organic Bridges', at the Organic World Congress 2014, 13-15 Oct., Istanbul, Turkey (eprint ID 24008)

Management of biomass resources within the crop rotation for eco-functional intensification on stockless organic farms

TORA RÅBERG[1], GEORG CARLSSON[1], ERIK STEEN JENSEN[1]

Key words: nitrogen, anaerobic digestion, cropping system, biomass, stockless system, multifunctionality

Abstract

The present study investigates if a cropping system can be designed to produce both high-quality food crops and biogas substrates in synergy with strategic recycling of the nutrient-rich digestate within the system, while considering environmental quality and climate change.

The comparison of three different management systems indicated an increase in food crop productivity when the digestate was used to fertilize the nitrogen demanding crops, in comparison to directly supplying the crop with ensiled biomass or incorporation of biomass in situ. The preliminary results show that it is possible to produce high yields of food crops and use the residual biomass to produce biogas as well as strategically recycle the digestate, without excluding the production of any of the three.

Introduction

There is a need to optimize the use of agricultural land, considering the increased competition for food or energy production (Harvey and Pilgrim, 2011). Farmers may use green manure based on N_2 fixing legumes for supplying nitrogen (N) to stockless organic systems. The practise is often problematic, since significant amounts of N can be emitted as the crop is cut and left as mulch (Larsson et al. 1988) or incorporated into the soil (Baggs et al. 2000).

The aim of this study was to determine the effects of strategic application of a biogas digestate from biomass resources (ley, harvest residues and catch crop) derived from the same system. The application of digestate was compared to *in situ* or redistributed placement of the equivalent biomass resources. Our hypothesis was that anaerobic digestion of biomass and recycling of the digestate will lead to improved resource use efficiency in terms of crop yield per land area, compared to incorporating the biomass directly into the soil.

Material and methods

The experiment was established in 2012 on arable land with sandy loam, included in an organic certified cropping system at the Swedish University of Agricultural Sciences in Alnarp, Sweden (55° 39′ 21″N, 13° 3″E). The anaerobic digestion of ley, catch crops and crop residue in the system, was made in collaboration with Lund University using a leach bed reactor. The pre-crop was ley and the field was fertilized with digestate at the start of the establishment. The choice of crops and design of the crop rotation was made with the ambition to yield food products and allow for an additional production of biomass for efficient nutrient recycling (Table 1).

[1] Department of Biosystems and Technology, Faculty of Landscape Architecture, Horticulture and Crop Production Science, Swedish University of Agricultural Sciences, Sweden, www.slu.se/bt,
e-mail: tora.raberg@slu.se

Table 1. Composition of the crop rotation.

No in sequence	Main crop	Catch crop/winter crop
1	6 species ley (*Dactylus glomerata*, *Festuca pratensis, Phleum pratense, Melilotus officinalis, Medicago sativa, Trifolium pratense)*	6 species ley
2	White cabbage (*Brassica oleracea)*	Buckwheat (*Fagopyrum esculentum)* and oil radish (*Raphanus sativus*)
3	Lentil (*Lens culinaris*) (90%) and oat (*Avena sativa*) (10%) undersown with 3 species ley (*Lolium perenne, Trifolium repens* and *T. pratense.*)	3 species ley
4	Beetroot (*Beta vulgaris* var. *conditiva*)	Winter rye
5	Winter rye (*Secale cereale*)	Buckwheat and lacy phacelia (*Phacelia tanacetifolia*)
6	Pea (*Pisum sativum*) (80%) and malt barley (*Hordeum vulgare*) (20%) undersown with 6 species ley	6 species ley

All of the six main crops were represented each year in separate experimental plots, each plot measuring 3 x 6 m. Each main crop was followed by an autumn or winter-growing crop, to reduce nitrogen leaching, reduce weeds and produce biomass during the autumn-winter season. Eighteen individual plots (six main crops x three treatments) within each of four replicate blocks were randomly assigned to one of the following biomass management treatments:

1) IS - Leaving the biomass resources *in situ* in the field.
2) BR - Moving the biomass resources to nitrogen demanding crops.
3) AD - Collecting the biomass resources for anaerobic digestion and using the resulting digestate for the nitrogen demanding crops.

The 6 species ley was harvested at four consecutive occasions: in June, July, August and September. The grain legumes and cereals were harvested at maturity while the harvest of cabbage and beetroot were based on optimal timing for high quantity and quality but also leaving sufficient time for establishment and growth of catch crops before winter. The biomass resources comprised straw from the grain legumes and cereals, leaves from cabbage and beetroots, and total aboveground biomasses of the ley and catch crops. The biomass was ensiled before application to the field in treatment BR and before the anaerobic digestion in treatment AD. The ensiled and digested biomass was applied to cabbage, beetroot and winter rye in equal proportions in the BR and AD treatments. The composition of the digestate from 2012, applied in the AD field plots in 2013, is presented in table 2.

Table 2. Composition of digestate from the anaerobic digestion reactor in 2012.

Liquid, total amount (kg)	2108,5
Solid residue, total amount (kg)	449
NH_4-N concentration (mg/L)	574
Total N concentration (mg/L)	4635
Phosphate concentration (mg/kg)	330
Potassium concentration (mg/kg)	2300
pH	7,4
Dry matter, total amount (kg)	79.4
Volatile substances, total amount (kg)	50.95

The effect of the different biomass management systems was measured in terms of total yield (food fraction + straw/residual leaves) of each crop, using the sum of mixed species in the intercrops (lentil/oat, pea/barley, ley).

Results

Nitrogen demanding main crops (rye, cabbage, beetroot)
The comparison of the three different management systems indicated an increase in yield when the digestate (AD) was used, but the difference was not significant, Fig. 1.

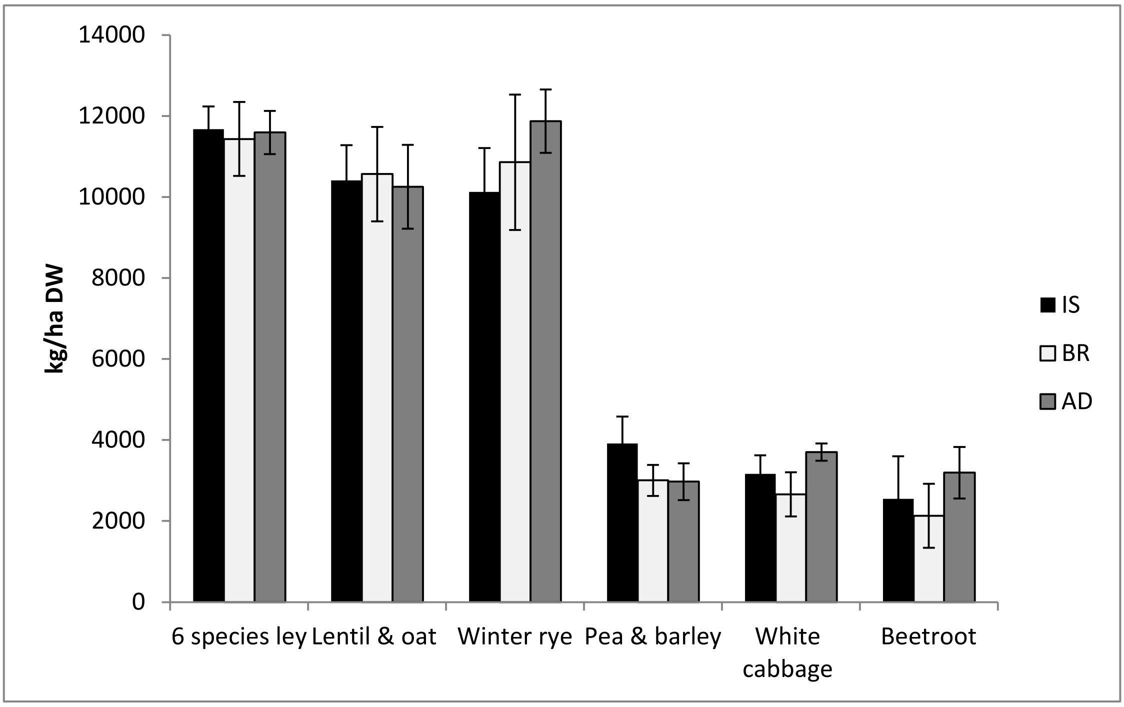

Fig. 1. The total biomass yield (dry weight) of the six main crops indicates an advantage of anaerobically digested biomass resources (AD) as compared to redistribution of the undigested biomasses (BR) to the nitrogen demanding crops (winter rye, white cabbage, beetroot), even though the differences were not statistically significant. The bars represent mean values +\- SEM of 4 replicates.

The cabbage and beetroot crops, which both followed pre-crops containing legumes, showed tendencies of higher yields in the IS treatment than in the BR treatment. Rye, on the other hand, which followed nitrogen demanding beetroot in the crop rotation, had the lowest yield levels in the IS treatment.

Intercrops with legumes (6 species ley, lentil/oat and pea/barley)
The main crops containing legumes did not receive any biomass resources or digestate except from in the IS treatment. The results indicate similar yield levels for these crops in the three treatments, *i.e.* no evidence for negative effects of removing nutrients with biomass resources as compared to the IS treatment, Fig. 1.

Catch crops (3 species ley, buckwheat/oil radish and buckwheat/lacy phacelia)
The yield of the under sown 3 species ley was highest in the AD treatment, both for the legume and the non-legume components (data not shown). The yields of the buckwheat/oil radish catch crop (following cabbage) showed very small differences between the three treatments, while the yields of buckwheat/lacy phacelia (following rye) tended to be considerably higher in the BR and AD treatments than in IS (not shown).

Discussion

The increase in yield of all nitrogen demanding main crops in the AD treatment, although not statistically significant, indicate high nutrient use efficiency after anaerobic digestion of biomass resources. The small yield difference between the three treatments in buckwheat/oil radish, following cabbage, may be explained by the addition of the nitrogen rich harvest residue from the cabbage crop in treatment IS. In contrast, the large yield difference between treatments in buckwheat/ phacelia, following winter rye, may be explained by a low N contribution from winter rye harvest residues in IS. It is possible that the observed tendencies will be enhanced after continuing the treatments during the next year in the crop rotation. Ongoing analyses will show how the studied biomass management scenarios influence the nitrogen use efficiency, food quality and environmental impact of stockless organic production.

In conclusion, the results presented here show that it is possible to produce food crops and use the residual biomass to produce biogas without lowering the food crop yields when using the digested biomasses for strategic nutrient recycling.

References

Baggs E M, Rees R M, Smith K A and Vinten A J A 2000, Nitrous oxide emission from soils after incorporating crop residues *Soil Use and Management*, 16:82–87.

Larsson L, Ferm M, Kasimir-Klemedtsson A, & Klemedtsson L 1998. Ammonia and nitrous oxide emissions from grass and alfalfa mulches. *Nutrient cycling in agroecosystems*, *51*(1), 41-46.

Harvey M and Pilgrim S 2011, The new competition for land: Food, energy, and climate change *Food Policy,* 36:40-51.