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Productivity and N-leaching in organic dairy grass-arable crop rotations

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Abstract
Due to increasing size of Danish organic dairy farms uniform grazing of all cropped land becomes inexpedient due to long distance to the milking facilities. We investigated nutrient dynamics and feed production in two dairy crop rotations with internal differences in proportion of grazing and cutting. One six year crop rotation represents close to the farm buildings (barley [*Hordeum vulgare* L.] undersown with grass-clover [*Lolium perenne* L.– *Trifolium repens* L.] - 4 years of grass-clover - spring barley/catch crop) and another represents further away (barley undersown with grass-clover, 2 years of grass-clover - barley/catch crop - maize [*Zea mays* L.]/catch crop - lupin [*Lupinus angustifolius*]/catch crop). In each of the crop rotations was made five treatments concerning grazing/cutting strategy and manure application. Results from the first experimental year shows that herbage production was high in year 1-4 of grass-clover. Nitrate leaching in the crop rotations were highest in grazed and manured 2-4 years old grasslands, but also following maize and lupin considerable losses occurred despite the presence of catch crops. Following grassland cultivation, a barley silage crop undersown with Italian ryegrass [*Lolium multiflorum* L.] reduced leaching to a minimum.

Keywords: organic farming, nitrate leaching, manure, grazing, cutting, grass-clover productivity

Introduction

Historically, a large part of organic milk has been produced on smaller farms with maximum integration of animal husbandry and plant production through grazing of the entire crop rotation. An increased proportion of grass-clover in combination with an ongoing structural development in the size of dairy farms, conventional as well as organic, lead to high grassland frequencies near the farms as uniform grazing of all cropped land becomes inexpedient due to long distance to the milking facilities. On Danish organic dairy farms we already experience grass-intensive crop rotations located close to farm buildings with grass-clover pastures of longer duration than the 2-3 years that have been common.

This development has got implications. A concentration of grazed grassland near the farm creates loss of fertility furthest from the farm and accumulation of nutrients near the farm, to an extend that may increase losses of e.g. nitrogen if not efficiently utilized. This is especially important in areas with sandy soils and high winter rainfall where a large proportion of organic dairy farms are located in Denmark. However, the longer duration of grasslands may also provide an opportunity to control nutrient losses due to less frequent grassland cultivation. The theme of the presented project is grass-clover leys as an integrated part of organic dairy farms. The focus is on management strategies with the purpose of overcoming the above-stipulated shortcomings by manipulating grassland frequency and grazing intensity (and nutrient load). Results from the first experimental year are presented.

Materials and methods

Two crop rotations were established on loamy sand soil in an existing grass-arable system at Research Centre Foulum: One represents close to the farm buildings (barley/grass-clover, 4 years of grass-clover and barley/catch crop) and another represents further away (Barley/grass-clover, 2 years of grass-clover, barley/catch crop, maize/catch crop and lupin/catch crop). The area of each crop was app. 0.3 ha. In all grass-clover leys five grassland treatments was made varying in nutrient load and grassland management (Table 1). The other crops in the crop rotations were used as indicators of residual effects. Each combination of crop rotation, crop and grassland treatment is present in duplicate each year. Adjacent to the crop rotations, permanent grassland established in 1993 was used as a reference for crop production with the five grassland management treatments established. In the crop rotations (not the permanent grassland) leaching of nitrogen was estimated from nitrate concentrations in soil water sampled by means of ceramic suction cups and the accumulated nitrate leaching was calculated after modelling the water balance. Leaching nitrate was analysed using a general liniar mixed model on log-transformed data, but results are presented as arithmetic means.

Table 1. Grassland management treatments. Grazing plots were grazed continuously by heifers

Management treatments
1 Grazing regime with cattle manure application in spring (100 kg total-N ha^{-1})
2 Grazing regime without manure application
3 One cut followed by a grazing. Cattle manure application in spring (100 kg total-N ha^{-1})
4 Cutting with cattle manure appl. (200 kg total-N ha^{-1}, ½ in spring and ½ after 1st cut)
5 Cutting regime without manure application

Results and discussion

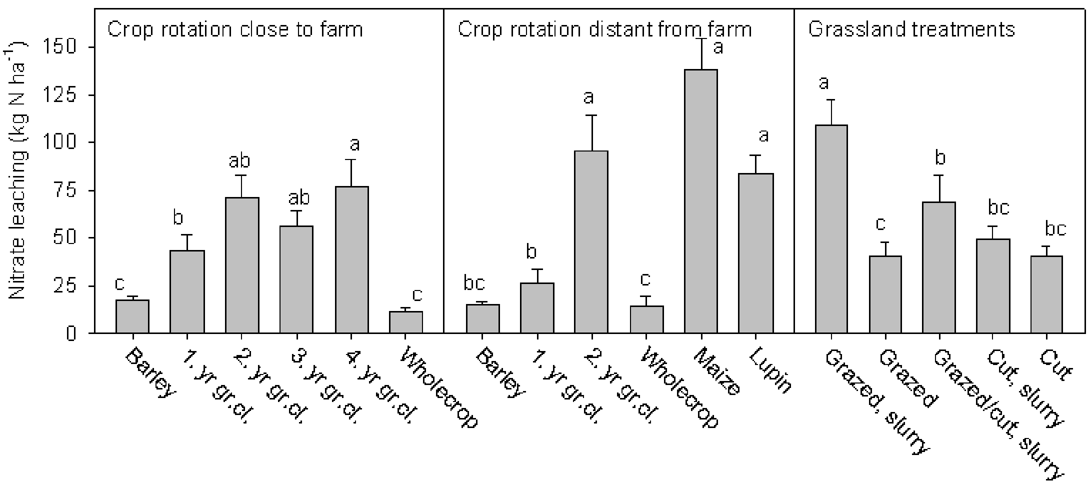
Annual grass-clover production in 2006 is shown for cut grassland in Table 2. Within the 1st to 4th year there was little variation in dry matter (DM) yield and the yield increase caused by manure application was only 5-15%. The explanation for this relatively modest effect of manure was a compensating increase in clover content in unmanured grassland (results not shown). As an effect of the high clover content in especially 2nd and 3rd cut the N yield in manured and unmanured grasslands were almost identical. The effect of manure was higher in the 13-yr-old grassland probably due to a lower proportion of clover.

Table 2. Annual herbage and nitrogen yield for 2006 in cutting regimes (±SE)

Grass-clover prod. year	Herbage yield (Mg DM ha^{-1})			Nitrogen yield (kg N ha^{-1})		
	0 N	200 N	Increase	0 N	200 N	Increase
1st	9.4±0.4	10.8±0.4	15%	268±7	263±8	-2%
2nd	10.0±0.4	10.8±0.2	7%	277±13	285±11	3%
3rd	9.7±0.2	10.1±0.3	5%	269±10	273±8	2%
4th	9.5±0.1	10.6±0.2	11%	260±4	279±18	7%
13th	7.1±1.1	8.4±1.2	18%	175±23	199±25	14%

Nitrate leaching (Fig. 1) in the crop rotation close to the farm was mainly in the grasslands and generally nitrate leaching was lowest in the first production year. In both crop rotations the barley wholecrop undersown with Italian ryegrass was very efficient in accumulating N following spring ploughed grassland and therefore leaching losses at this place in the crop rotations were at a very low level, as earlier demonstrated by Hansen et al. (2007). Distant from the farm leaching losses following maize and lupin were considerable, despite both crops were followed by a catch crop. Maize was undersown with a ryegrass/winter rape mixture and lupin was followed by winter rye. Nitrate losses in grasslands depended on both grazing and manure treatment. Nitrate concentration peaks of random nature were experienced in grazed plots probably caused by urination of grazing cattle. Figure 1 shows the average of all grasslands but the same pattern appeared more or less in all grasslands. Highest nitrate leaching was found following the grazing regime with manure application, but a considerable drop was observed when avoiding the manure application. Also a drop was observed when removing a first cut before start of grazing, although not as efficient as avoiding manure. In cut grassland manure application did not influence nitrate leaching. Previously it has been found that leaching losses were increased in fertilised and grazed grassland on this location (Eriksen et al., 2004).

Figure 1. Annual mean nitrate leaching winter 2006-2007. Left and center: Individual crops in the two crop rotations, average of grassland regimes. Right: Grassland regimes, average of grassland age and crop rotation. Error bars: ±SE. Bars with the same number within each plot are not significantly different (P<0.05).



Conclusions

Results from the first experimental year shows that herbage production was high in year 1-4 of grass-clover and with an N fertiliser response corresponding to 2-7 kg DM kg^{-1} N. Nitrate leaching in the crop rotations were highest in grazed and manured grasslands 2-4 years old, but also following maize and lupin considerable losses occurred despite the presence of catch crops. Following grassland cultivation, a barley whole crop for silage undersown with Italian ryegrass reduced leaching to a minimum.

References

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