Dairy cows back to arable regions? Grazing leys for eco-efficient milk production systems

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Abstract

Recent intensification in European agricultural production has been accompanied by serious environmental trade-offs, thus questioning the sustainability of current specialized production systems for both all-arable cash crops and animal products. Under the temperate conditions of North-West Europe, ruminant-based integrated crop-livestock systems are considered as a strategy towards ecological intensification. The object of the interdisciplinary project: 'Eco-efficient pasture-based milk production', established in 2016, is to provide relevant ecosystem services linked to dairy systems: high quantity and quality of agricultural commodities, low nutrient surpluses, a low carbon footprint and contributions to agro-biodiversity. Four-year data are presented based on a 98 spring-calving Jerseys/crossbred dairy herd on a former all-arable farm as an alternative to traditional specialized systems. Measurements include forage yield and quality, nitrogen fluxes, as well as milk production and quality. The results illustrate the capability of a rotational ley grazing system to provide both a high milk performance per ha combined with low environmental footprints and additionally offer significant yield benefits for the arable crops in the crop rotation.

Keywords: rotational grazing, grass clover, eco-efficiency, integrated crop-livestock systems

Introduction

The recent intensification in European agriculture has raised environmental and sustainability questions, many of which are related to the increasing simplification of agricultural systems. Mixed farming is considered as a strategy to enhance sustainability (Ryschawy *et al.*, 2012). Under the maritime conditions of Northern Germany, ruminant-based mixed farming systems are discussed as an alternative to specialized systems. With respect to ruminant nutrition, pasture is considered a cheap and environmentally friendly forage source (Dillon *et al.*, 2008; Rotz *et al.*, 2009). This is the background for the interdisciplinary project: 'Eco-efficient pasture-based milk production' that started in 2016 at Kiel University's research farm Lindhof in Northern Germany. The project focuses on a whole-farm approach to provide high amounts of energy and protein-rich forages from biodiverse pastures, while simultaneously reducing nutrient surpluses and the carbon footprint. We thus analyse the potential of pasture-based milk production on grass-clover leys to strengthen sustainability of an organic arable crop rotation by comparing the main agronomic and environmental performance indicators of the experimental farm to those of the average performance of almost 1000 dairy farms of the North German state of Schleswig-Holstein (S-H) as reported by the Landwirtschaftskammer S-H (2019).

Materials and methods

At the Lindhof research farm (N 54°27, E 9°57; mean air temperature 8.7 °C; mean annual precipitation 785 mm) a pasture-based dairy herd of 98 spring-calving Jerseys was introduced in 2016 to make use of 7 ha permanent grassland and 55 ha organic grass-clover leys grown in rotation with arable crops. Grass-clover swards at Lindhof are used as two-year leys and are established by under-sowing winter spelt in the preceding year with a seed mixture consisting of 20 kg ha^{-1} *Lolium perenne*, 2 kg ha^{-1} *Trifolium repens* and 6 kg ha^{-1} *Trifolium pratense*. Grasslands and leys in walking-distance to the milking parlour were grazed at least 8 times per year with one cut for baled silage in between. Swards outside of that range were cut 4 times per year for silage. No additional nitrogen was applied to the grass-clover, and all organic manures

produced during winter were used for fertilising 56 ha organic cash crops. Forage yield was determined using a rising plate meter and hand sampling, forage quality was determined using NIRS spectroscopy. Nitrate leaching to groundwater was determined continuously with ceramic suction cups during the winters 2016/17 to 2018/19 and analysed for NO_3 concentrations. The volume of drainage water was calculated by a general climatic water balance model.

Results and discussion

Table 1 relates the performance of forage and milk production achieved at the experimental farm Lindhof to those of the currently dominant milk production systems of Schleswig-Holstein which is characterized by all year indoor-feeding and the use of Holstein-Friesians. Despite of a 37% lower cow live weight and 70% less concentrate feeding, the grazing-based Jersey cows at Lindhof reached 80% of the average annual milk yield of consulted dairy farms at 6,907 kg energy corrected milk (ECM). Using intensive rotational grazing in combination with reduced concentrate feeding at Lindhof lead to 37% higher milk yields produced from forage compared to the S-H average. Compared to the typical forage production based on silage maize and grass silage the intensive grazing system at Lindhof lead to 38% reduced production costs per unit metabolizable energy and 36% lower production costs per kg of ECM. Due to the symbiotic N_2-fixation in the grass-clover swards, Lindhof is independent of external N-fertiliser input, while the average dairy-farm bought in 123 kg ha^{-1} of mineral N fertiliser. On average the 944 considered specialized dairy farms of S-H showed a critical high N-balance per ha forage area with a surplus of 168 kg N.

High rates of grass-clover N_2 fixation in combination with relatively low N-exports via milk and meat are the background for the high surplus of 88 kg N per ha forage area at Lindhof. Exports of manure equivalent to 60 kg N per ha to the 56 ha organic cereal crops improve cereal yields by 15% compared to unfertilised fields. This combination of intensive dairy production and cash crop production leads to a whole-farm N balance of 18 kg N per ha, which is below the threshold values for Germany and still constitutes unavoidable N losses. Figure 1 shows the nitrate-N leaching losses over winter for differently managed grasslands and leys at Lindhof in a range of 4 to 9 kg nitrate-N ha^{-1} as the average over three

Table 1. Production parameters, economic results and nitrogen balance (2017/18) of the experimental farm Lindhof compared to the average of 944 dairy farms consulted by the chamber of agriculture of Schleswig-Holstein.[1]

Parameter	Unit	1. average of consulted dairy farms (n=944)	2. Lind-hof	2. relative to 1.
Annual milk yield	kg ECM cow^{-1}	8,601	6,907	(80%)
Milk solids (fat + protein)	kg cow^{-1} $year^{-1}$	661	539	(82%)
Concentrates fed	kg cow^{-1} $year^{-1}$	2,538	770	(30%)
Live weight[2]	kg cow^{-1}	680	430	(63%)
Performance per kg cow live weight	kg ECM kg^{-1}	12.6	16.1	(127%)
Milk from forage	kg ECM cow^{-1}	3,195	4,386	(137%)
Milk yield per unit forage area[3]	kg ECM ha^{-1}	13,345	11,009	(82%)
Production costs per unit ME	ct MJ^{-1}	1.71	1.06	(62%)
Total feeding costs	ct kg^{-1} ECM	22.22	14.31	(64%)
Forage costs	ct kg^{-1} ECM	13.22	9.15	(69%)
Concentrate costs	ct kg^{-1} ECM	9.00	5.16 [5]	(57%)
Forage area mineral N input	kg N ha^{-1}	123	0	
Forage area N balance[4]	kg N ha^{-1}	168	88	(52%)

[1] ECM = energy corrected milk; ME = metabolizable energy.

[2] Estimated value for black and red Holsteins.

[3] Including imported feed.

[4] Farm-gate nitrogen balance of farm area dedicated to dairy production.

[5] Produced organically.

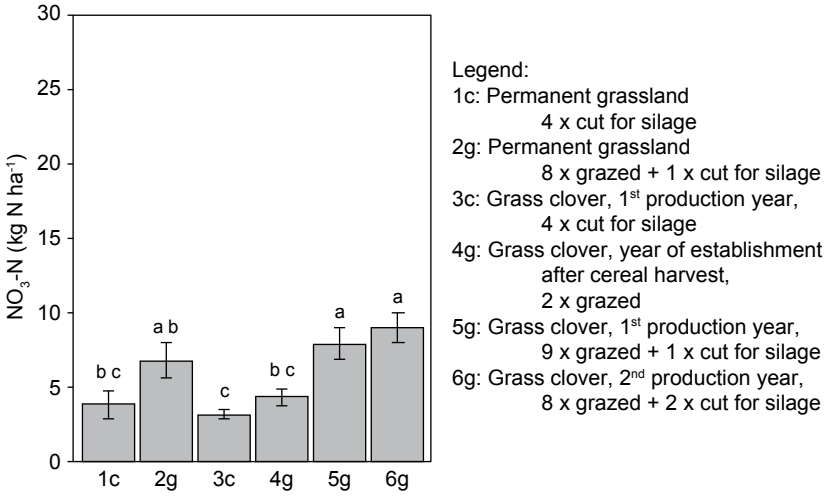

Figure 1. Over-winter NO_3-N leaching losses (kg N ha^{-1}) to groundwater across differently managed grasslands and leys at Lindhof (average over 3 leaching periods 2016/17 to 2018/19). Different lower-case letters indicate significant differences at $P<0.05$.

leaching periods. As expected, grazing experienced higher NO_3-N losses compared to cutting. Within grazed leys, leaching losses increased with the age of the swards. On average there were no significant differences between permanent grasslands and leys. The relatively low nitrogen losses of grazed swards at Lindhof can be explained with (1) lower sward clover contents on grazed than on cut swards and (2) removal of N via at least 1 silage cut taken during summer also from grazed fields. Averaged across the total forage production area, nitrate concentrations in leakage to the groundwater remained at 12 mg NO_3 l^{-1}, far below the EU-threshold value of 50 mg l^{-1} (not shown in the diagram).

Conclusions

The high milk yields at very low costs and almost no nitrate losses show the capability of a rotational ley grazing system to be economically competitive at reduced environmental burdens. The findings underline the strength of ruminant-based crop-livestock systems as a tool towards ecological intensification under the temperate conditions of Northern Germany.

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