Nitrous oxide emissions from urine and dung patches based on grassland diversity

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Introduction

Livestock grazing remains an important source of nitrous oxide (N_2O), contributing up to 80% of N_2O emissions of dairy production (Chadwick et al. 2018). Despite the economic and ecological benefits of intensive rotational grazing, there is a high uncertainty about its greenhouse gas mitigation potential. Although a number of mitigating practices have been suggested, economic and technical constraints limit their adoption, particularly in low-input and organic dairy systems. For example, the use of Dicyandiamide as a nitrification inhibitor has been strongly suggested due to its ability to reduce N_2O emission up to 82% and nitrate leaching up to 69% (Cameron et al., 2014), however, there are uncertainties about its effects across soil types, possible toxicity to plants, rate of degradability and its residues in milk. Moreover, inhibitors are not allowed in organic farming systems. Incorporating alternate forage species into grazing systems have been identified as a potential approach to mitigate N_2O emissions. It is suggested that some forage plant species have the potential to reduce N_2O emissions by producing lower urine nitrogen (N) excretion, ensuring higher soil N uptake due to plant morphology and biology and by influencing soil N-cycling processes through root exudation of plant secondary metabolites that can inhibit nitrification (de Klein et al. 2019). Also, high species richness of pastures is suggested to reduce N_2O emissions due to more efficient use of inorganic N (Niklaus et al. 2016). However, the impact of plants on N_2O emissions and underlying driving mechanisms is inconclusive. The current study therefore tested the hypothesis that a more diversified mixed pasture with high tannin-producing potential will reduce N_2O emissions from cow dung and urine patches.

Materials and methods

The study was located at the organic research farm Lindhof (54°27′N, 9°57′E; elevation 27 m above sea level) of the Christian-Albrechts-University of Kiel in Northern Germany. The long-term mean temperature and annual rainfall of the site are 8.9°C and 768 mm, respectively. The soils consist of 11% clay, 29% silt and 60% sand with a pH and bulk density of 5.7 and 1.5, respectively. The mixed-pastures considered under this study include perennial ryegrass + white clover (GWC); perennial ryegrass + white and red clovers (GWRC); and perennial ryegrass + white and red clovers + forage herbs (GWRCH). The forage herbs consisted of birdsfoot trefoil, chicory, lancelot plantain and caraway. The pastures were established 2 years prior to the start of the experiment. Fresh urine and dung were applied in spring, summer and autumn after collection from dairy cows. N-rates of the applied excreta were 493±43 and 397±47 kg ha^{-1} for urine and dung patches, respectively. The experimental design was a split-split plot design with grasslands as main plots, season of excreta application as split-plot and excreta treatment as split-split plot with replicate subplots for soil sampling all laid out in three replicate blocks.

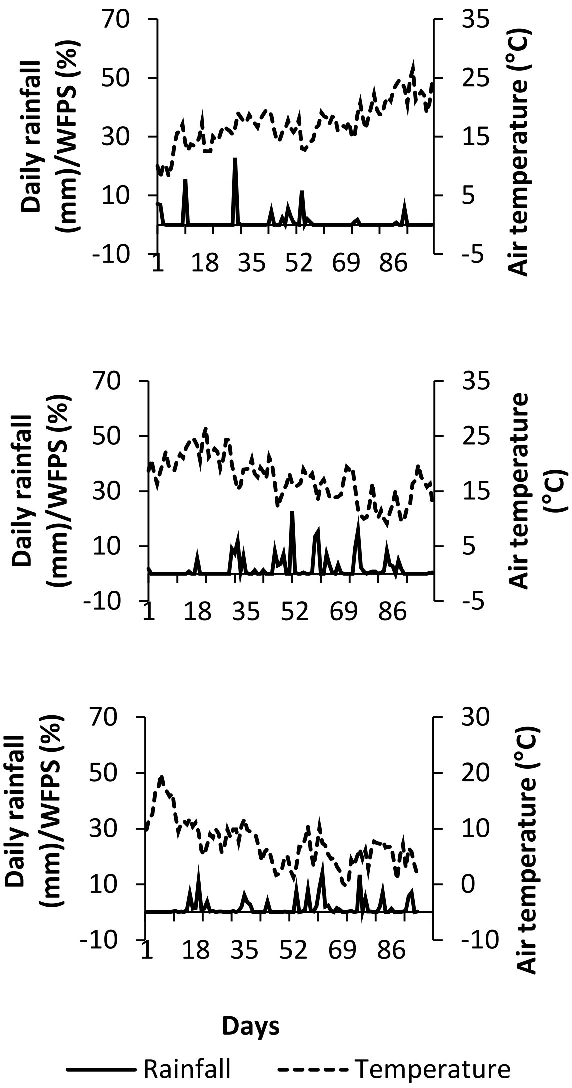

Fig. 1. Temperature, rainfall and WFPS prevailing after excreta application in spring (top), summer (middle) and autumn (bottom)

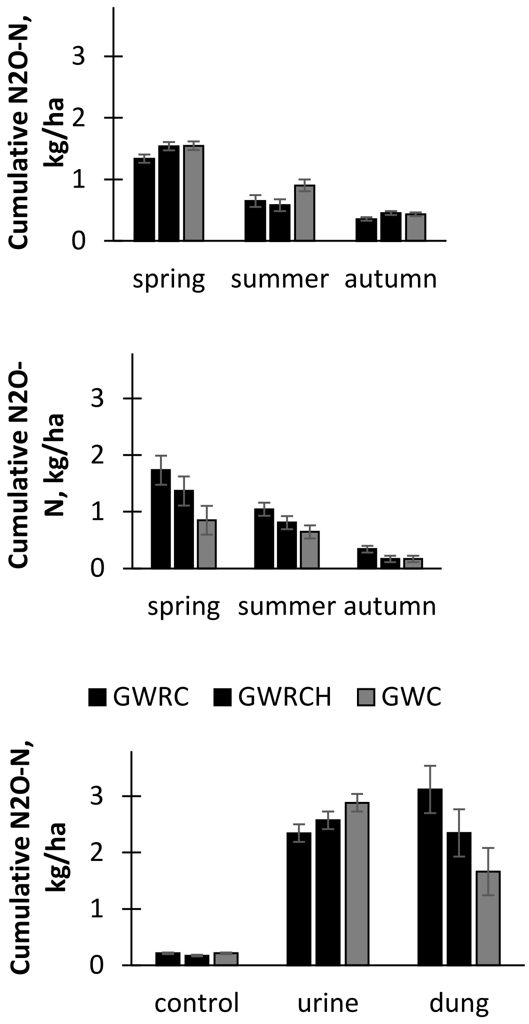

Fig. 2. Cumulative seasonal N_2O-N emission from urine (top) and dung (middle) and sum of all seasons (bottom)

Rainfall, air and soil temperatures were monitored by a weather station on the site. Soil samples were also analyzed for nitrogen fractions and water filled pore space (WFPS). N_2O emissions were measured at least once a week between 10.00 and 13.00 using the static chamber method, with measurements starting immediately after excreta application; the gas samples were measured for their N_2O-concentration using gas chromatography. Hourly N_2O fluxes and emission factors were calculated according to methods by Krol et al. (2018). Cumulative N_2O emissions were determined after linear interpolation of daily fluxes (100 days). Emission factors for each treatment (*EF;* N_2O-N emitted as % of dung or urine N applied) were calculated with the cumulative N_2O emissions using the following Eq. (1):

$$EF = \frac{N_2O(Treatment) - N_2O(Control)}{N\ Applied} X\ 100\% \qquad (1)$$

All variables were analyzed as a split-split plot ANOVA with grassland type as the main plot factor, season as split-plot and excreta treatment as split-split plot. Cumulative N_2O emissions and emission factors were modeled by stepwise multiple regression analysis.

Results and discussion

The cow urine and dung patches experienced different environmental conditions after application (Fig. 1). Generally, N_2O emissions from urine and dung were short-lived after application and occurred within the first 40 days after excreta application (results not shown). Seasonal effect on N_2O fluxes was evident in this study with highest fluxes (0.2 -0.45 kg N/ha/d) in spring and lowest (less than 0.2 kg N/ha/d) in autumn from both urine and dung patches across all grassland types. Accordingly, cumulative N_2O emissions from urine patches differed significantly ($P<0.01$) between seasons. The highest emissions were from spring patches, followed by summer and the lowest from autumn patches across all pasture types (Fig 2A). Similarly, N_2O emissions from dung patches were highest for spring application and lowest for autumn applications (Fig 2B). Krol et al. (2017) reported a similar trend and suggested rainfall, temperature and soil moisture deficit as explanatory factors. Thus, the rainfall and temperature dynamics (Fig 1) that prevailed after excreta application may have been responsible for the N_2O emission patterns observed in this study. The higher fluxes of N_2O observed in spring could be attributed to the relatively higher WFPS and higher temperatures soon after urine application (Fig. 1). Whereas the lower fluxes associated with summer excreta patches could be as a result of low WFPS (<20%). The relatively low N_2O emissions observed for autumn excreta patches, despite the incidence of high WFPS, may be due to limited nitrification by the low temperatures during that time of the year.

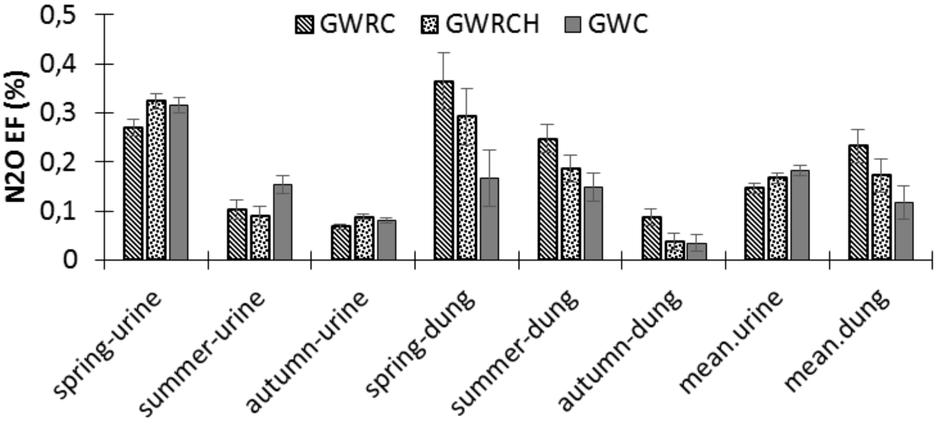

Fig. 3. Emission factors for urine and dung N_2O as affected by season of excreta application and pasture type

The pastures considered in this study did not have a significant ($P>0.05$) impact on N_2O emission from dung and urine patches, however the tendency for lower dung-N_2O emissions was evident in the GWC plots (Fig 2C). de Klein et al. (2019) hypothesized that plants reduce N_2O emissions through the production of root exudates that inhibit nitrification and/or increase availability of C leading to N immobilization. Although GWRCH, which had the highest species richness, was expected to better reduce N_2O emissions, its impact was not significant ($P>0.05$). High efficiency in soil inorganic N uptake due to species richness may be dependent on the number of species, the type and their share in the mixture. A previous study reported reductions in N_2O emissions only when plant species richness increased from 1 to 16 (Niklaus et al. 2016). Moreover, a large proportion of legumes may also hamper the ability of the pasture to reduce N_2O emissions (Niklaus et al. 2016). Thus, the non-significant impact of GWRCH on urine- N_2O emissions may be due to the low share of herbs, and the relatively higher share of clover (30-40% DM) as well as the already low emissions mediated by interfering environmental factors (i.e. the seasonal effect). The EFs for both urine and dung followed a similar trend as the cumulative N_2O emissions (Fig. 3). The N_2O EFs observed for cow excreta in this study were lower than the IPCC (2006) default of 2% and were among the lowest EFs reported in literature (Chadwick et al. 2018), which is presumably the result of the distinct summer drought in 2018. Thus, experiments will be repeated in 2019 to confirm the preliminary results.

Conclusion

Incorporating alternate forage species into grazing systems have been identified as a potential approach to mitigate N_2O-emissions; however, in our study this effect was not significant. Anyway, the observed N_2O-Emissions were low in comparison to the current default emissions factor for dairy excreta on pasture reported by the IPPC, leading to the assumption that emissions from rotational grazing systems under the absence of additional mineral fertilizer inputs are currently overestimated.

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