Estimated nitrous oxide emissions from nitrogen fertilizer use on multispecies grasslands compared to monocultures

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Abstract

Grassland agriculture faces increasing demands in terms of sustainability; economic, social, and environmental. Soils are critical to sustainable agriculture, in terms of maintaining soil fertility and quality, protecting water quality and mitigating greenhouse gas emissions. There is evidence to suggest that greater sward diversity may have benefits in this regard. We report results from SmartGrass; a 3-year field study at two sites in Ireland investigating grass sward diversity along a gradient from perennial ryegrass (*Lolium perenne* L.) monoculture to grass-legume mixes to more complex grass-legume-herb mixes of up to 9 species. Results reported include estimates of N_2O emissions from fertilizer N, soil temperature and moisture conditions, plant-available soil N, and changes in soil organic C and plant-available P. Estimated direct N_2O emissions from N fertilizer (g N_2O-N t DM^{-1} ha^{-1} yr^{-1}) decreased from 146 for the monoculture at 250 kg fertilizer N ha^{-1} yr^{-1} to 35 for the monoculture at 90 kg fertilizer N ha^{-1} yr^{-1}, to approximately 16 for the grass-legume and grass-legume-herb mixes, also at 90 kg fertilizer N ha^{-1} yr^{-1}. This is due to a combination of the grass-clover and mixed swards maintaining high DM yields at low fertilizer N input, and the fact that the fertilizer N for these treatments was applied entirely as urea. These results indicate significant potential for more diverse swards to mitigate greenhouse gas emissions from fertilizer N use in grassland agriculture.

Keywords: Sward diversity, multispecies grassland, clover, nitrogen, nitrous oxide emission, greenhouse gas mitigation.

Introduction

Agriculture faces the challenge of achieving sustainable, profitable production while maintaining environmental quality (Sutton *et al*., 2011). In Ireland, for example, ambitious national growth targets for agricultural output have been set. At the same time, Ireland, like other countries, must meet international environmental obligations in terms of water quality (e.g. Water Framework Directive) and greenhouse gas (GHG) emissions (e.g. EU 2020 targets), for example. Agriculture makes up 65% of Irish land area and 80% of this is grassland. The diversity of swards in Irish managed grassland varies widely, from intensively managed monocultures of selected perennial ryegrass (PRG; *Lolium perenne*) cultivar mixtures, cultivated and re-seeded on a regular basis, to extensively managed permanent semi-natural grasslands with much greater diversity (Sheridan *et al.*, 2011). Perennial ryegrass has become particularly predominant in the more intensively managed grassland systems, such as dairy, and now accounts for 95% of forage grass seed purchased in Ireland (DAFM, 2017).
However, PRG monocultures require relatively high fertilizer N input to support high DM yields and this fertilizer N use is associated with a range of environmental impacts, including

on GHG emissions, water quality and biodiversity. There is evidence to suggest that grass-clover swards and more complex multispecies swards of grass-legume-herb mixes can sustain relatively high yields at considerably lower fertilizer N input, thus minimising associated environmental impacts. The SmartGrass experiment established swards across a range of diversity, from perennial ryegrass monoculture to complex mixes of grasses, legumes and herbs. Here, we report results of estimated direct N_2O emissions from fertilizer N use associated with forage production for five of these experimental treatments to assess their potential for greenhouse gas mitigation.

Materials and methods

Plots (2 × 10 m) were established in September 2013 on UCD Lyons Research Farm in Eastern Ireland on a silty clay loam Gleysol. The area has a temperate maritime climate with mean annual rainfall of 754 mm and mean annual temperatute of 9.7°C. Plots with a range of grass sward diversity were established, from PRG monoculture to complex mixtures of 3 grasses (PRG, timothy *(Phleum pratense),* cocksfoot *(Dactylis glomerata)*), 3 legumes (white clover *(Trifolium repens),* red clover *(Trifolium pratense),* greater birdsfoot trefoil (*Lotus pedunculatus*)), and 3 herbs (ribwort plantain (*Plantago lanceolata*)*,* chicory *(Cichorium intybus*), yarrow *(Achillea millefolium)*) (Grace *et al.*, this volume).We report on results from replicated treatments that were applied to 20 plots within that experiment. These treatments were sown (seed weight %) and managed for annual fertilizer N input as follows; 1. 100% perennial ryegrass at 90 kg N ha^{-1} (PRG90), 2. 100% perennial ryegrass at 250 kg N ha^{-1} (PRG250), 3. 70% perennial ryegrass, 30% white clover at 90 kg N ha^{-1} (PRG+WC90), 4. a simple mix of the 3 grasses (23% each) and 3 legumes (10% each) at 90 kg N ha^{-1} (SIMPLE90), and 5. A complex mix of the 3 grasses (20% each), 3 legumes (7% each) and 3 herbs (3% each) at 90 kg N ha^{-1} (COMPLEX90). Treatments receiving 90 kg N ha^{-1} yr^{-1} received it in the spring/early summer as urea in 4 equal applications. For PRG 250, 165 kg N was applied as urea in 4 equal applications and the remainder as calcium ammonium nitrate (CAN) through the rest of the grass growing year in 4 equal applications.

Recent studies (Harty *et al.*, 2016) have shown that, on average, direct emissions of N_2O from fertilizer N application to Irish soils are lower for urea than CAN, with an emission factor (EF) of 0.25% of applied fertilizer N, compared to 1.49% for CAN. These EFs were used, along with the recorded N fertilizer application rates and forms, and the measured grass DM yields (average over 3 years) from this experiment, to estimate the direct N_2O emissions from fertilizer N associated with growing a tonne of grass DM for each treatment.

Results and discussion

Estimated direct N_2O emissions from nitrogen fertilizer (g N_2O-N t DM^{-1} ha^{-1} yr^{-1}) decreased from 146 for PRG250 to 35 for PRG90, to approximately 16 for PRG+WC90, SIMPLE90 and COMPLEX90, representing a roughly 9-fold decrease from PRG250 to legume-containing mixes (Fig. 1). This is due to a combination of the grass-clover and mixed swards maintaining high DM yields (Grace *et al.*, this volume) at low fertilizer N input, and the fact that the fertilizer N was applied entirely as urea. None of the N in urea is in the nitrate form, thus lowering the risk of N_2O emission. Results indicate that there may be significant potential for grass-clover and multispecies swards to support relatively high yields per ha with much reduced N_2O emissions. It should be noted that nitrous oxide emissions from N fixed by legumes was not estimated and that results could be different under actual grazing conditions. Legumes typically fix N and contribute most to overall DM yield later in the year, and application of N fertilizer at this time can suppress legumes. Also, urea tends to suppress legumes to a lesser degree than CAN. Therefore, N fertilizer was applied to the legume-containing swards early in the year as urea. This has a number of potential advantages: 1. due to typically cooler and damper conditions in the spring, the risk of ammonia volatilization from urea is lower, 2. application of N as CAN during the summer and the associated risk of ammonia volatilization and N_2O emissions, is avoided, 3. urea is a cheaper form of N than CAN. Such changes in fertilizer N practice with the adoption of grass-clover or multispecies swards would have the further advantage that the resultant reductions in GHG emissions could be relatively easily accounted for in a national inventory under “Tier 2” IPCC reporting as the activity data of form-specific fertilizer use (urea vs. CAN) and the appropriate EF.

Conclusion

These results indicate significant potential for more diverse swards to mitigate greenhouse gas emissions from fertilizer N use in grassland agriculture.

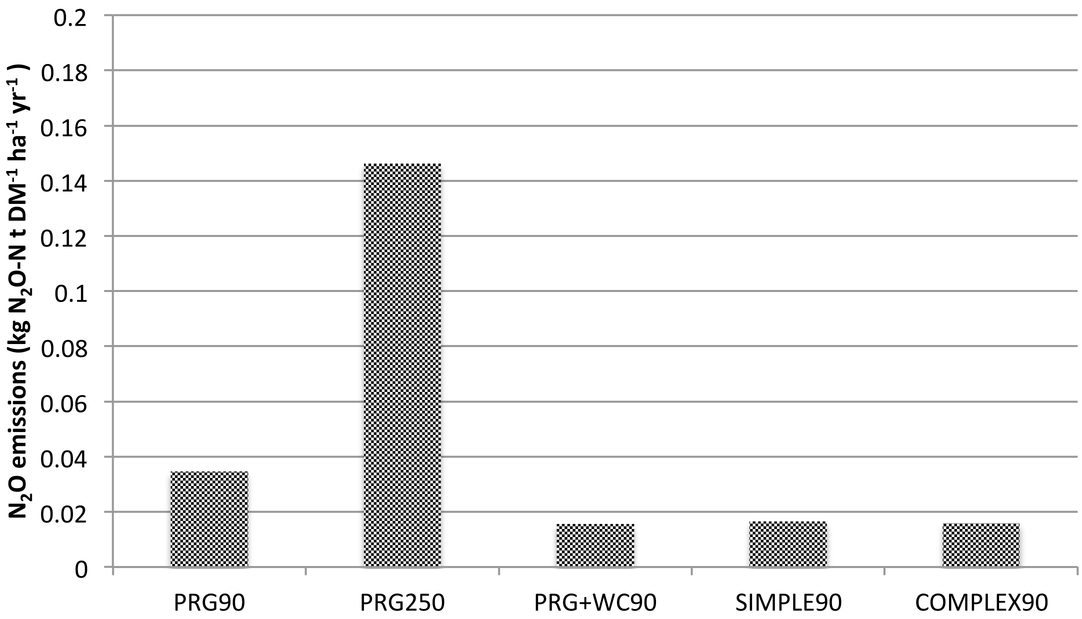

Figure 1. Estimated N_2O emissions associated with a tonne of grass DM production (kg N emitted as N_2O t DM^{-1} ha^{-1} yr^{-1}), using "Tier 2" EFs of 1.49% for CAN and 0.25% for Urea.

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