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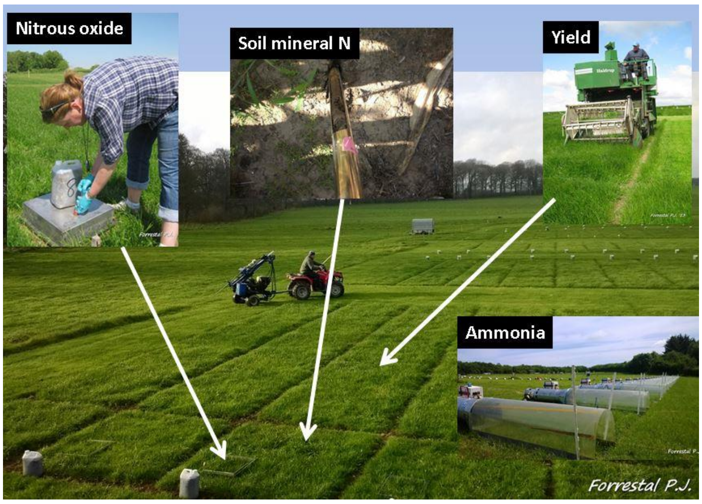
Sustainable nitrogen fertiliser Use and Disaggregated Emissions of Nitrogen (SUDEN)



Key external stakeholders:

Grassland farmers, Agricultural and environmental policy makers, EPA emissions inventory, fertiliser industry

Practical implications for stakeholders:

The outcome/technology or information/recommendation is that switching from calcium ammonium nitrate (CAN) to urea treated with the urease inhibitor NBPT (protected urea) had the same dry matter yields, similar nitrogen uptake and similar ammonia emissions. Switching from CAN and urea to protected urea can maintain yields and reduce nitrogen loss to the environment.

Main results:

The key results were:

- The yields of CAN, urea and protected urea (urea+NBPT) were not significantly different.
- The apparent fertiliser nitrogen recovery was significantly higher for CAN and protected urea compared to urea.
- Ammonia emissions were similar for CAN and protected urea. Protected urea reduced ammonia emissions by 78.5% compared to urea.

Opportunity / Benefit:

Switching from CAN and urea to protected urea can maintain yields and reduce nitrogen loss to the environment.
Farmers can reduce costs and reduce nitrogen loss to the environment by switching from CAN and urea to protected urea.

Collaborating Institutions:

Teagasc Johnstown Castle & Moorepark; Agri-Food and Biosciences Institute; University College Dublin.

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1. Project background:

Ireland's growing agriculture industry is utilising our national soil and climate resources to produce high quality foods. The production of these foodstuffs underpins an export business worth €10.8 billion in 2015 (Bord Bia, 2016). The sustainability of our production systems are an important point for differentiating our exports from competitors through the efforts of the Bord Bia Origin Green programme for example. Fertiliser nitrogen is a cornerstone input of many of our production systems. However, fertiliser nitrogen application is associated with emissions of the greenhouse gas (GHG) nitrous oxide (N2O) and the air pollutant ammonia (NH3). Ireland has committed to making significant reductions in both of these gaseous emissions in the coming years. As agriculture accounts for c. 33% of GHG emissions and c. 98% of ammonia emissions agriculture must play a role in meeting these targets to achieve reductions and to demonstrate contribution to increased sustainability. Fertiliser nitrogen along with dung and urine deposited at pasture are sources of both gases. In the present work ammonia was measured along with yield, N efficiency and nitrate leaching. The greenhouse gas nitrous oxide was measured as part of the sister AGRI-I project, also funded under the Research Stimulus Fund.

2. Questions addressed by the project:

- What is the effect of fertilsier type on yields and apparent nitrogen recovery?
- Can switching fertilizer type reduce ammonia volatilization and nitrate leaching?
- What is the potential impact of intensification on farm profitability and reactive nitrogen loss to the environment?

3. The experimental studies:

To measure the effect of fertiliser N type on grass yield, ammonia volatilisation and soil mineral N, replicated field experiments were conducted at three grassland sites in Ireland (Figure 1) in 2013 and 2014 (six site-years). The locations were Johnstown Castle, Co. Wexford, Moorepark, Co. Cork and Hillsborough, Co. Down. The sites were chosen to represent a range of soil and geo-climatic conditions across intensively managed agricultural areas in Ireland. The experimental design was a randomised complete block with five replicates at each site-year. The CAN, urea and urea+NBPT fertiliser treatments were applied at annual N rates of 100, 200, 300, 400 and 500 kg/ha in five equal split applications between March and September. Urea+DCD and urea+NBPT+DCD were applied at the 200 kg N/ha rate only. In addition there was a zero N control treatment. Plots received a basal application of P, K, and S in line with soil test recommendations. Yield and N uptake was measured by harvesting dedicated agronomic plots (2 m x 10-12 m at the end of each grass growth cycle. Soil mineral N was measured by sampling the dedicated soil sampling area of the plots. Ammonia emissions were measured from each of the fertiliser treatments at the Johnstown Castle and Hillsborough sites during 2014 using a system of wind tunnels (Lockyer, 1984; Meisinger et al., 2001). Leaching was measured using the lysimeter facility at Johnstown Castle. Gross N transformations were measured using a 15N stable isotopes coupled with an isotope tracing model. A new model was created joining the Moorepark dairy simulation model with an environmental model to predict the impacts of FW2025 on Nitrogen emissions.

4. Main results:

Agronomic Yield

- The yield of CAN and urea was not significantly different in these trials.
- Urea treated with the urease inhibitor NBPT consistently yielded as well as CAN.
- The use of the nitrification inhibitor DCD alone decreased grassland yields relative to CAN.
- Addition of NBPT to urea treated with DCD recovered the yield lag caused by the nitrification inhibitor.

Efficiency: apparent fertiliser nitrogen recovery (AFR)

- Urea has the potential for lower (AFR) compared to CAN particularly at higher nitrogen rates.
- Use of the urease inhibitor NBPT ensured that the AFR of urea was consistently at least equal to CAN.
- The nitrification inhibitor DCD used alone had a pronounced negative effect on AFR at the inclusion rate tested in these trials. However, inclusion of NBPT with DCD treated urea increased yields to similar levels to yield from plots fertilised with CAN or urea treated with NBPT alone.

Ammonia

- Inclusion of the urease inhibitor NBPT reduced NH3 losses from urea by 78.5% on average. As a result NH3 loss from urea+NBPT was not significantly different to CAN.
- Variable ammonia loss is a feature of urea usage, however based on comparing the N recovery in plants fertilised with urea, compared to urea+NBPT or CAN, NH3 losses are apparently generally low to moderate in temperate Irish grassland and spring barley production.
- Addition of the nitrification inhibitor DCD to urea fertiliser at the rate tested introduces additional uncertainty to the behaviour of urea fertiliser in terms of NH3 loss.

Nitrate leaching

- There was no significant effect of fertilizer formulation on nitrate leaching under grazing conditions. On average there was 43 kg NO3-N ha^{-1} leached in the conventional urea and CAN systems and 37 kg NO3-N ha^{-1} leached from the urea with NBPT. There were significant differences in N leaching between soils.

Intensification Modelling

- Increasing milk production increased total N loss to the environment from 80 kg N ha^{-1} (baseline scenario) to a maximum of 124 kg N ha^{-1} for the high profit grass based system.
- Incorporation of inhibitors and low emission slurry spreading in the high profit grass system resulted in the lowest reactive N loss of 99 kg N ha^{-1}, a 44% increase in milk production and increased farm net profit of €1,135 ha^{-1} (including the cost of low emission slurry spreading and inhibitors).

The present study found that the fertiliser N form applied along with enhanced efficiency technologies such as urease and nitrification inhibitors are tools which can help to address the key challenge of how to continue to apply fertiliser N to underpin crop yields while curtailing reactive N losses. These trials demonstrate that it is possible to achieve important reductions in nitrous oxide emission, particularly in grassland, without cutting N rates or sacrificing yield or fertiliser efficiency. Options to achieve the N_2O reductions seen in this study by substituting urea+NBPT or urea+NBPT+DCD for CAN in temperate maritime grassland without compromising yield are rare. CAN is generally more expensive than urea as an N source. The resultant price differential provides scope to add urease and/or nitrification inhibitor technologies to urea and remain cost competitive with CAN. As more urease and nitrification inhibitors and formulations enter the market field testing will remain important to evaluate efficacy and to optimise inhibitor rates to meet economic, agronomic and environmental loss mitigation objectives.

Urea holds a significant cost advantage per kg DM produced because urea is considerably less expensive than either CAN or urea + NBPT. Although less tangible to farmers there was an efficiency penalty, particularly at higher rates, when using urea compared with using CAN or Urea + NBPT. The efficiency disadvantage for urea compared to CAN or urea + NBPT ranged from 4 to 7.6%, a difference likely to be primarily associated with ammonia loss from urea. However, as yield and cost rather than ammonia emissions are currently more pertinent to on farm decisions the yield results of the current study and associated implications for cost per tonne DM production will promote additional urea usage amongst farmers. Such additional usage without a urease inhibitor such as NBPT will present a challenge for national governments committed to reducing national ammonia emissions. Urea + NBPT substitution for CAN is likely to create a small cost saving however there will be a net cost when urea + NBPT is substituted for urea.

5. Opportunity/Benefit:

This research has identified that farmers can maintain yields and reduce nitrogen loss to the environment by switching from CAN to urea protected (urea+NBPT). This new technology, widely available on the market, offers farmers a cost effective fertiliser that improves on farm sustainability. For the first time this research

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has generated Irish specific emission factors for dung and urine deposited by grazing cows. The modelling has highlighted that milk production can be increased through the high profit grass system. Nitrogen loss to the environment can be reduced substantially by integrating inhibitors within the high profit grass system but emissions are still above the baseline. This research has added to the international scientific community through the publication of a 10 papers.

6. Dissemination:

Main publications:

1. Hoekstra, N.J., Schulte, R.P.O., Forrestal, P.J., Hennessy, D., Lanigan, G.J., Müller, C., Shalloo, L., Wall, D.P., Richards, K.G. (2020) Modelling the effect of sustainable dairy intensification on farm scale nitrogen flows and economic performance. Science of the Total Environment 707 134606
2. Burchill W.T., Lanigan G.J., Forrestal P.J, Misselbrook T., Richards K.G. (2017) Ammonia emissions from urine patches amended with N stabilized fertilizer formulations. Nutrient Cycling in Agroecosystems 108, 163–175.
3. Burchill, W., Lanigan, G.J., Forrestal, P.J., Reville, F., Misselbrook, T., and Richards, K.G. (2016). A field based comparison of ammonia emissions from six Irish soil types following urea fertiliser application. Irish Journal of Agriculture and Food Research 55: 152-158.
4. Forrestal, P.J., Wall, D.P., Carolan, R., Harty, M.A. Roche, L.M, Krol, D.J. Watson, C.J., Lanigan, G.J. and Richards, K.G. 2016. Effects of urease and nitrification inhibitors on yields and emissions in grassland and spring barley. Proceedings of the International Fertiliser Society, Cambridge, U.K. 9th December, 2016. Proceeding no. 793, ISBN 978-0-85310-430-8.
5. Forrestal P.J., Harty M.A., Carolan R., Watson C.J., Lanigan G.J., Wall D.P., Hennessy D., Richards K.G. (2017) Can the agronomic performance of urea equal calcium ammonium nitrate across nitrogen rates in temperate grassland? Soil Use and Management 33, 243–251 doi: 10.1111/sum.12341
6. Harty, M.A., McGeough, K.L., Carolan, R., Muller, C., Laughlin, R.J., Lanigan, G.J., Richards, K.G. and Watson, C.J. 2017. Gross nitrogen transformations in grassland soil react differently to urea stabilisers under laboratory and field conditions. Soil Biology and Biochemistry 109 23-34.
7. Harty, M.A., Forrestal, P.J., Carolan, R., Watson, C.J., Hennessy, D., Lanigan, G.J., Wall, D.P and Richards, K.G. 2017. Temperate grassland yields and nitrogen uptake are influenced by fertilizer nitrogen source. Agronomy Journal. 109: 1-9. doi:10.2134/agronj2016.06.0362.
8. Forrestal, P.J., Harty, M., Carolan, R., Lanigan, G.J., Watson, C.J., Laughlin, R.J., McNeill, G., Chambers, B. and Richards, K.G. 2016. Ammonia emissions from urea, stabilised urea and calcium ammonium nitrate: insights into loss abatement in temperate grassland. Soil Use and Management. 32: 92-100. doi: 10.1111/sum.12232
9. Fischer, K., Burchill, W., Lanigan, G.J., Kaupenjohann, M., Chambers, B., Richards, K.G. and Forrestal, P.J. 2016. Ammonia emissions from cattle dung, urine and urine with dicyandiamide. Soil Use and Management. 32: 83-91. doi: 10.1111/sum.12203
10. Krol, D.J., P.J. Forrestal, Lanigan, G.J. and Richards, K.G. 2015. In situ N2O emissions are not mitigated by hippuric and benzoic acids under denitrifying conditions. Science of the Total Environment 511:362-368. doi:10.1016/j.scitotenv.2014.12.074

Popular publications:

A joint end of project meeting was held with the AGRI-I project and all the presentations are available on the web https://agri-i.ie/2016/06/agri-i-stakeholder-event/

The project led to a large range of technical and popular articles. These all can be found on the web

- https://agri-i.ie/resources/
- https://www.teagasc.ie/crops/soil--soil-fertility/protected-urea/

Some relevant project presentations can be found on the link below

- https://agri-i.ie/2016/06/agri-i-stakeholder-event/
- http://agri-i.ie/2017/06/agri-i-stakeholder-workshop/overview-of-recent-fertiliser-nitrogen-research-under-suden-agri-i-projects-dr-patrick-forrestal-teagasc/
- https://www.teagasc.ie/media/website/publications/2016/No.-3-LRoche.pdf

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