



# Farming for a Better Climate: Practical and Emerging Solutions



**Dr Patrick Forrestal**



**Reducing greenhouse gas emissions from  
nitrogen fertiliser on farm**



## **Reducing greenhouse gas emissions from nitrogen fertiliser on farm**

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### **Summary**

- Greenhouse gases (GHG) are emitted during the production of and following the spreading of nitrogen (N) fertilisers to soil.
- The use of low emission slurry spreading to retain slurry N, incorporation of clover into swards to fix N on farm, liming, optimising phosphorus, potassium and sulphur nutrition are avenues to reduce farm and national fertiliser N emissions through reduced N fertiliser need to grow the same amount of grass.
- Urea based formulations protected with NBPT, NBPT+NPPT or 2-NPT reduce emissions and sustain yield with low ammonia loss.

- Reduced nitrate-N proportion N fertilisers including solid 10:10:20, 18:6:12, liquid acidified amide N and liquid urea ammonium nitrate (UAN) reduce nitrous oxide emissions while having lower ammonia emissions than standard solid urea.
- The inclusion of nitrification inhibitors with N fertilisers shows promise to further reduce emissions

## **Introduction**

Nitrogen is an important driver of plant growth and N fertilisers are a widely used tool for delivering targeted plant available N on farms over the growing season. However, N fertilisers are also an important source of GHG emissions globally during their production and transport. Nationally N fertilisers contribute to national GHG emissions primarily through emissions of the potent greenhouse gas nitrous oxide ( $\text{N}_2\text{O}$ ) when they are applied to soil. Fortunately, options have emerging to reduce these emissions. A multi-pronged approach to reducing emissions from N fertiliser can be taken on-farm through reducing fertiliser N reliance, even moderately, and choosing N fertilisers with a lower GHG emissions profile when applied under Irish conditions.

To reduce fertiliser N reliance increasing the retention of the N that is already present on farm in manure is an important step forward. The use of low emissions slurry spreading is a key practice farmers undertake to retain existing on-farm manure N for growth. Work is underway to develop solutions to reduce N losses during manure storage which can further increase the retained N value of manure. The liming of acidic agricultural soils is a key practice that will increase soil N mineralisation and unlock soil phosphorus (P) for plant growth. Additionally, optimisation of soil P and potassium (K) levels for your system and the use of targeted in-season applications of a sulphur (S) containing fertiliser are all practices that when combined will ensure that yields are maintained even where fertiliser N rates are reduced. The biological fixation of N on-farm by clover on grassland farms or by leguminous crops on arable farms is

an on-farm rural bioeconomy opportunity that has potential to off-set imported fertiliser N requirements at least in part on most farms. Thus fertiliser N emissions on farm can be reduced through reduced usage but with sustained output.

In parallel to the implementation of the practices above which can each contribute to reducing fertiliser N emissions through reduced reliance while sustaining production the other major avenue for reduced emissions from N fertilisers is the selection of N fertilisers with a lower emissions profile. The results of research in the area of identifying low emission N fertilisers under Irish conditions is discussed in this paper.

### **Reducing nitrous oxide emissions following fertiliser spreading by choosing fertiliser nitrogen source**

#### ***Calcium ammonium nitrate compared to solid urea***

Field trial work by Harty et al. (2016) under Irish conditions found that using solid urea based fertiliser N sources reduces emissions of the potent greenhouse gas nitrous oxide (Figure 1a) in Irish grassland compared to the use of calcium ammonium nitrate (CAN) while maintaining annual grass dry matter yield (Figure 1b). The work was conducted at three sites over two years (6 site years). However, to retain the maximum amount of the solid urea fertiliser N for grass growth and to reduce indirect nitrous oxide loss protection of urea from ammonia loss using an NBPT, NBPT+NPPT or 2-NPT based urease inhibitor was needed (Forrestal et al., 2016; Krol et al., 2020; Matse et al., 2024). Grazing trials conducted at two sites in three years and two sites in two years (ten site years) by Murray et al. (2023) confirmed that urea protected with NBPT delivers grass growth consistent with CAN under grazing conditions and also produces significantly higher yields than standard unprotected urea, by 455 kg DM/ha on average over the ten site years of the study.

A choice of protected urea products supplying N, N-S and N-K-S have been available to farmers for several years. However, the availability of phosphorus (P) containing blends has been limited by degradation of the inhibitor in P blends. However, the NBPT based technology has been developing and the preliminary results of testing at Teagasc, Johnstown Castle in 2025 indicate that protected N-P-K-S blends with low ammonia loss can be produced, offering the potential for a greater choice of products for farmers.

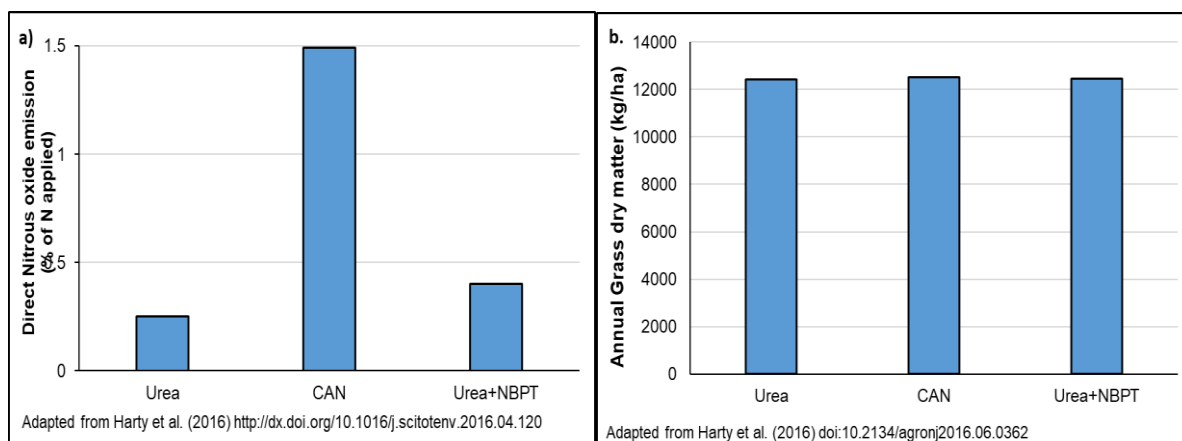


Figure 1a. Direct emissions of the greenhouse gas nitrous oxide and b. annual grass dry matter production as affected by solid nitrogen fertiliser source.

### ***The role of the Ammonium-N component vs the nitrate-N component of fertiliser in nitrous oxide emissions***

The research is clear that urea based formulations have lower nitrous oxide emissions following soil application compared to ammonium nitrate fertilisers under Ireland's moist grassland conditions. However, the relative role of the ammonium-N component of fertiliser compared to the nitrate-N component is also relevant particularly as many conventional compound or blended products contain both nitrate and ammonium. Some products such as 10:10:20 and 18:6:12 have a greater proportion of ammonium vs nitrate compared to CAN (Gebremichael et al., 2021). Research by Rahman and Forrestal (2021) found that the nitrous oxide emission factor for ammonium-N on its own was 66% lower than from nitrate-N on its own (Figure 2a) while the grassland yield was the same for both forms of N (Figure 2b). These findings and those of Gebremichael et al. (2021) indicate that fertilisers with a lower proportion of nitrate will tend to have reduced nitrous oxide emissions when used in Irish grassland.

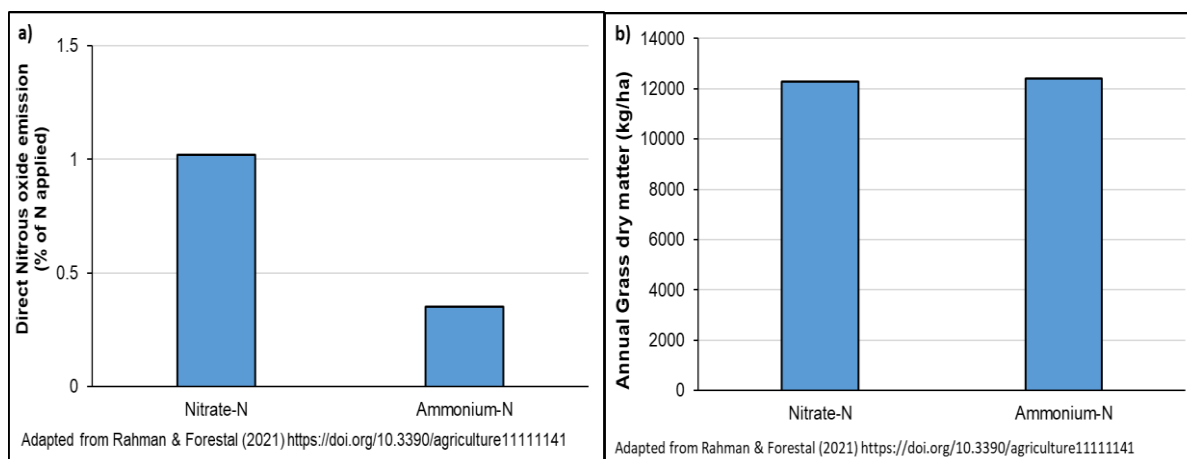


Figure 2a. The effect of nitrate-N only application compared to ammonium-N only application on direct emissions of the greenhouse gas nitrous oxide and on b. annual grass dry matter production.

### ***Liquid Nitrogen***

Over recent years there has been increasing interest and questions relating to liquid forms of nitrogen. Liquid urea ammonium nitrate (UAN) is available through a number of agricultural supply outlets around the country. UAN products typically deliver circa half of their N as urea-N with the remainder roughly split half and half between ammonium-N and nitrate-N depending on the product. As a result while nitrate-N is provided in UAN the proportion present as nitrate-N is less than for CAN. Another liquid N product available to farmers is an acidified amide N product e.g. FLEX and N-xt. Recently published trial work conducted under conditions favouring denitrification by Matse et al. (2025) has shown that the nitrous oxide emission from the acidified amide N product FLEX are as low as from solid urea and significantly lower than from CAN (Figure 3a). In this same trial work the nitrous oxide emissions from UAN were also significantly lower compared to CAN (Figure 3a). The yield performance of the liquid fertilisers was better than from solid standard urea (Figure 3b). Promisingly, preliminary results from ammonia loss testing at Teagasc, Johnstown Castle indicate that the FLEX liquid N had very low ammonia loss, indicating that it is protected

through its formulation. Liquid UAN also had much lower levels of ammonia loss compared to solid standard urea. These results indicate that liquid fertilisers have potential to provide another option to reduce nitrous oxide emissions on farms while sustaining yields with low levels of ammonia loss.

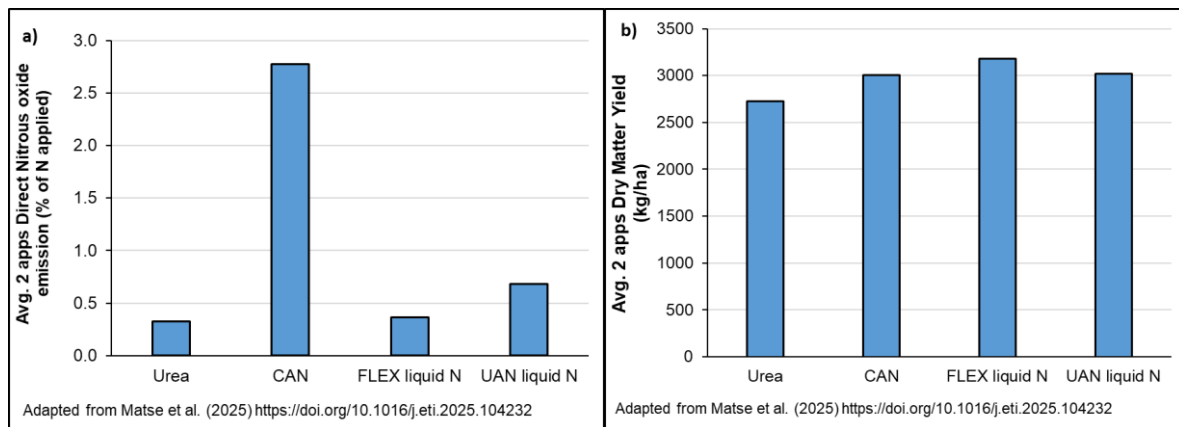


Figure 3a. The effect of liquid N formulations on nitrous oxide emissions and b. grass yield compared to urea and CAN.

### ***Nitrification inhibitors***

The selection of protected urea products and solid or liquid fertilisers with reduced proportions of nitrate-N offers potential to reduce farm nitrous oxide emissions substantially without reducing yield. However, some nitrous oxide emissions will still occur, albeit at a reduced level. Ongoing research is exploring the potential of another class of inhibitor, the nitrification inhibitor to further reduce the emissions from fertiliser N. For example across 6 site years Harty et al. (2016) reported that inclusion of the nitrification inhibitor DCD reduced the NBPT protected urea direct emission factor by 72.5%, down from 0.4 to 0.11, bringing the fertiliser emissions close to zero (Figure 4a). More recently Matse et al. (2025) tested the use of four nitrification inhibitors, DCD, DMPP, MMP and NP in combination with urea and reported average nitrous oxide emission factor reductions over two applications of 40, 71, 70 and 12%,

respectively compared to standard urea (Figure 4b). From a yield perspective Harty et al. (2017) found no benefit to the addition of DCD to NBPT protected urea in season long application. However, Matse et al. (2025) targeted nitrification inhibitor use to spring and early autumn and the trend was for grass yield and apparent fertiliser N recovery to be higher with the inclusion of a nitrification inhibitor. This outcome may have been due to reduced N leaching losses allowing the fertiliser N to be retained for growth. The results suggest that nitrification inhibitors have a role to play in achieving the lowest possible nitrous oxide emissions from fertiliser N but targeted use and or cost sharing is likely to be needed to recover the extra cost of their inclusion.

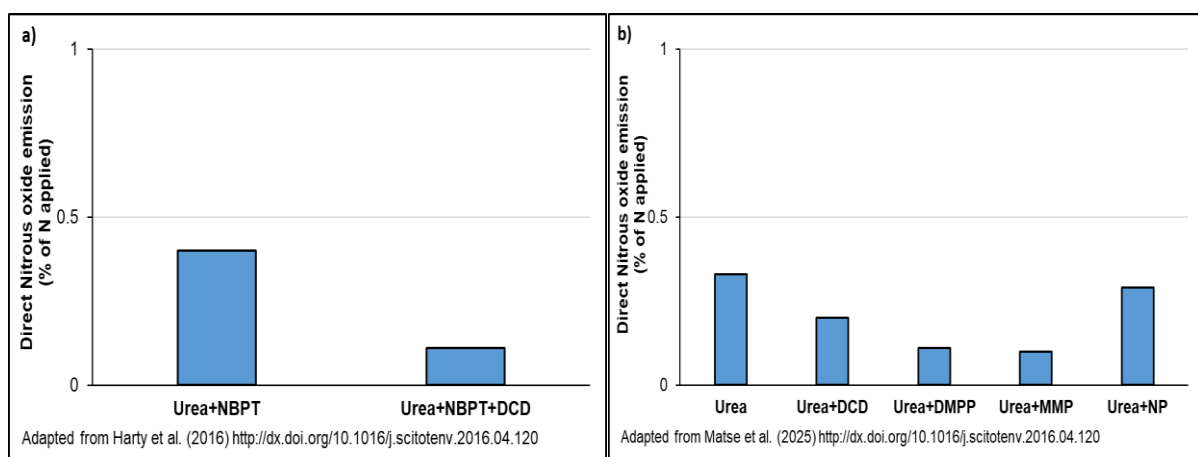


Figure 4a. The effect of the nitrification inhibitor DCD on reducing the nitrous oxide emissions from NBPT protected urea. b. The effect of the nitrification inhibitors DCD, DMPP, MMP and NP on reducing nitrous oxide emissions from urea applied in spring and early autumn.

## Conclusions

Solid urea based N fertilisers protected with NBPT, NBPT+NPPT or 2-NPT have shown a high level of protection from ammonia-N loss while also having reduced emissions of the GHG nitrous oxide when applied to Irish grassland soils compared to nitrate fertilisers. Recent research has also shown that the nitrate-N content of fertilisers is a strong driver of nitrous



oxide emissions in moist grassland. Liquid N formulations are showing promise with lower ammonia loss than solid urea and reduced nitrous oxide emissions. Nitrification inhibitors can further suppress emissions to close to background levels. The results presented indicate the potential for a broad range of individual fertiliser N products with a low or reduced emissions profile.

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