The potential role of inhibitors to increase nitrogen use efficiency with liquid nitrogen and sulphur

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Summary

Nitrogen (N) is an essential nutrient for crop growth and nitrogen fertiliser provides a very cost-effective return on investment, making it a vital input in most farming systems and helping to ensure that the cost of all other inputs is optimised. Nitrogen undergoes a number of transformations in the soil and nitrogen fertiliser is associated with potential environmental impacts, often as a result of these transformations. In this summary position paper we consider the potential impact of gaseous emissions following the use of liquid nitrogen fertiliser (UAN; urea plus ammonium nitrate and ammonium sulphate solution) and review mitigation strategies to minimise the risk of unwanted side effects following use.

Introduction

Liquid nitrogen fertilisers offer advantages in terms of accuracy, ease of application and storage plus flexibility of formulation, with a wide range of nitrogen:sulphur ratios available. They are generally based on a solution of ammonium nitrate, ammonium sulphate, ammonium thiosulphate and urea and offer a range of nitrogen release characteristics to crops. A recent review of work [10] suggests that, when both urea and nitrate sources of nitrogen are available to plants, the induction of the uptake systems of each N source is restricted, while plant growth and N utilisation is promoted. According to the review, based on physiological and molecular evidence, plants might increase N metabolism, promoting more efficient assimilation of N with this approach and the beneficial effect of urea and nitrate nutrition may contribute to develop new agronomical approaches to increase the NFUE (Nitrogen Fertiliser Use Efficiency) by crops. However, the urea content of liquid nitrogen has the potential for losses as it is hydrolysed in the soil via the soil enzyme urease, to form ammonium hydroxide (a solution of ammonia in soil water) and in high pH conditions, the ammonium hydroxide can destabilise, leading to a loss of ammonia gas.

Ammonia

Ammonia (NH_3) emissions are regarded as pollutants as the ammonia combines with moisture in the atmosphere to form ammonium compounds, which can lead to acidification of land and water and can potential degrade the biochemistry of natural ecosystems by depositing nitrogen on areas of low fertility, amending the fertility of the ecosystem. They can also result in the production of particulates (eg PM_{10}) when the ammonia combines with other air pollutants such as sulfuric acid and nitric acid. Particulates contribute to respiratory diseases.

Nitrous oxide

Nitrous oxide (N_2O) is a powerful greenhouse gas and can also break down to nitrogen oxides that trigger ozone depleting reactions. It has a global warming potential around 300 times greater than CO_2 but unlike CO_2, there is no sink for N_2O and it has a half life of 114 years in the atmosphere.

Mitigation additives

Nitrification and urease inhibitors have been widely researched and offer potential to reduce losses of nitrogen to the environment and increase nitrogen use efficiency.

Dicyandiamide plus ammonium thiosulphate plus ammonium phosphate

Didin is a commercial fluid formulation containing dicyandiamide (DCD), ammonium thiosulphate (ATS) and ammonium phosphate (AP). DCD has been shown to inhibit the action of the nitrifying bacteria in the first step of nitrification (NH_4 to NO_2) and ATS has been shown to inhibit the action of the bacteria involved in the second step (NO_2 to NO_3) [1]. Incubation experiments have shown that ATS retards the catalytic degradation of DCD in soils, thus improving the effectiveness of DCD as a nitrification inhibitor[4]. The breakdown of DCD in the soil is known to be catalysed by metal oxides (predominantly iron oxides) [2,3] and AP is thought to buffer the localised availability of iron oxide, further delaying the decomposition of DCD. DCD is a low toxicity material and breaks down in soils to produce urea, which converts to ammonium N, which is nitrified, leaving no residues in the soil [11].

ATS is also an acknowledged urease inhibitor by some workers [6,7] and in work by Goos, examining ammonia losses from a range of droplet sizes of UAN applied to bare soil and soil including straw cover, the average percentage reduction of ammonia loss after 14 days, compared to unamended UAN, was 40% for UAN+ATS and 51% for UAN+Agrotain, a commercial formulation of NBPT, the predominant urease inhibitor in commercial use.

DCD has been shown to be highly effective at reducing nitrate leaching and nitrous oxide emissions and has been shown to have a highly specific effect on nitrifying bacteria, with no effect on the general soil microbial communities [5]. The application of DCD reduced nitrous oxide emissions from ammonium-based fertilisers by up to 64% [8] in controlled field experiments in Scotland and an average of 57-75% in a summary of work looking at various nitrification inhibitors reported to the International Fertiliser Society [9].

UAN compared to urea and calcium ammonium nitrate

A relatively small amount of work has been carried out examining the potential ammonia losses from UAN fertilisers, compared to urea and current guidance is that in the UK, Defra is seeking to define urea-based fertilisers as those containing predominantly urea, rather than including UAN in the definition. There are farm scale surveys in the UK (via the Yield Enhancement Network [12]) that suggest UAN treated crops yield slightly less than crops treated with AN in the UK. Although there is no causal link, there is an association on farms with different nitrogen practices and it is suggested that this may reflect a different management approach, rather than a direct effect of the N source. Indeed, a subsequent survey by ADAS [13] directly comparing UAN and AN revealed no yield difference between the two nitrogen sources and previous studies by UK trials organisations have shown no yield penalty to urea-based nitrogen fertilisers.

Whilst commercial experience suggests yields with UAN compared to AN and urea are similar, further trial work comparing nitrogen sources, with and without inhibitors, may be required to establish the most effective N fertiliser source that is able to provide the best practical solution in the face of economics, emissions, product restrictions and the environment. Liquid UAN plus sulphur may offer one of the best options in terms of accuracy of application, prevention of pollution of field margins and flexibility to include inhibitors while exploring the agronomic advantages of a combined delivery of urea and nitrate N sources.

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