Ammonium nitrate solution

Technology description

Ammonium (NH_4^+) and ammonia (NH_3) are both the same basic compound, yet the first constitutes the water soluble form, whereas the second is the volatile gaseous form. Both these forms are in dynamic equilibrium; increasing pH and/or temperature will convert more water soluble ammonium into the gaseous ammonia and visa versa. In manure or digestate treatment systems, this basic chemical principle can be used to extract ammonium nitrogen from manure via a system that is called 'stripping' (which converts it into volatile ammonia via pH and/or temperature increase) followed by 'scrubbing' to re-capture the extracted ammonia back into soluble ammonium through a low pH 'scrubber' solution. If a nitric acid solution is used, ammonium nitrate will be formed. Ammonium nitrate is currently not obtained for NH_3 recovery from animal housing via air washing with nitric acid because this is more expensive than the most commonly used sulphuric acid which produces ammonium sulphate.

Product characteristics

Similarly to synthetic produced mineral N fertilisers, ammonium nitrate contains total N entirely in mineral form, as NH_4-N and NO_3-N. Usually, higher N concentrations (2x) are measured in ammonium nitrate as compared to ammonium sulphate. Depending on the amount of added acid, the pH and electric conductivity (EC) can vary. Higher pH values can often be observed when compared to ammonium sulphate, which reduces the risk of machinery corrosion, but also results in higher risk of ammonia volatilisation.

Photo 1. Ammonium nitrate solution (© VCM)

Parameter	Ammonium nitrate
Dry matter (%)	19 - 48
pH	5.70 - 7.85
EC* (mS cm^{-1})	234 - 342
N total (g kg^{-1})	34 - 198
NH_4-N (g kg^{-1})	33 - 109
NO_3-N (g kg^{-1})	67 – 89
N mineral/N total (%)	100

*EC: electrical conductivity

Table 1. Product characteristics of ammonium nitrate after N–stripping/scrubbing of liquid fraction of digestate from animal origin in ranges based on average values reported in Digesmart (2016a), Sigurnjak et al. (2019) and other unpublished results from UGhent.

Agronomic aspects

Plants (and by extension crops) take up nitrogen in a mineral form. For example, a common synthetic nitrogen fertiliser of which full plant availability is assumed is CAN (Calcium Ammonium Nitrate). In essence, an ammonium nitrate-rich solution will present the same crop availability as CAN. Up to now, results from three individually published agronomical trials with ammonium nitrate have been identified. Their main focus was to assess the effect of the ammonium nitrate on crop yield and to determine its N fertiliser value (Figure 1 below).

Horizon 2020
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Determination of the N fertiliser values (N Replacement Use Efficiency; NRUE and N Fertiliser Replacement Value; NFRV) depends on the presence or the absence of a control (=unfertilised) treatment in an experimental design, and hence can be determined as follows:

$$\text{NRUE (\%)} = \frac{\text{(crop N uptake AMM. NITRATE / total N applied AMM. NITRATE) *100}}{\text{(crop N uptake REFERENCE / total N applied REFERENCE)}}$$

$$\text{NFRV (\%)} = \frac{\text{((crop N uptake AMM. NITRATE – crop N uptake CONTROL) / total N applied AMM. NITRATE) * 100}}{\text{((crop N uptake REFERENCE – crop N uptake CONTROL) / total N applied REFERENCE)}}$$

The identified studies reported slightly higher crop yields when ammonium nitrate was applied as an N source in lettuce cultivation. In maize cultivation, no significant differences were observed on crop fresh weight yield when ammonium nitrate was used as a N fertiliser compared to the conventional fertilisation regime (=reference).

As a consequence of higher lettuce yield in pot experiments, treatments with ammonium nitrate also resulted in higher NRUE/NFRV values as compared to conventional fertilisation regime where synthetic N fertiliser is used as a sole source of N. In maize cultivation, no differences were observed in regard to NRUE or NFRV when ammonium nitrate was used as a N fertiliser compared to the conventional fertilisation regime of using synthetic N on top of animal manure. This means that ammonium nitrate exhibits a similar effect on crop yield as synthetic N fertiliser, and as such can be used as a valuable N source and used as a replacement for synthetic fertilisers.

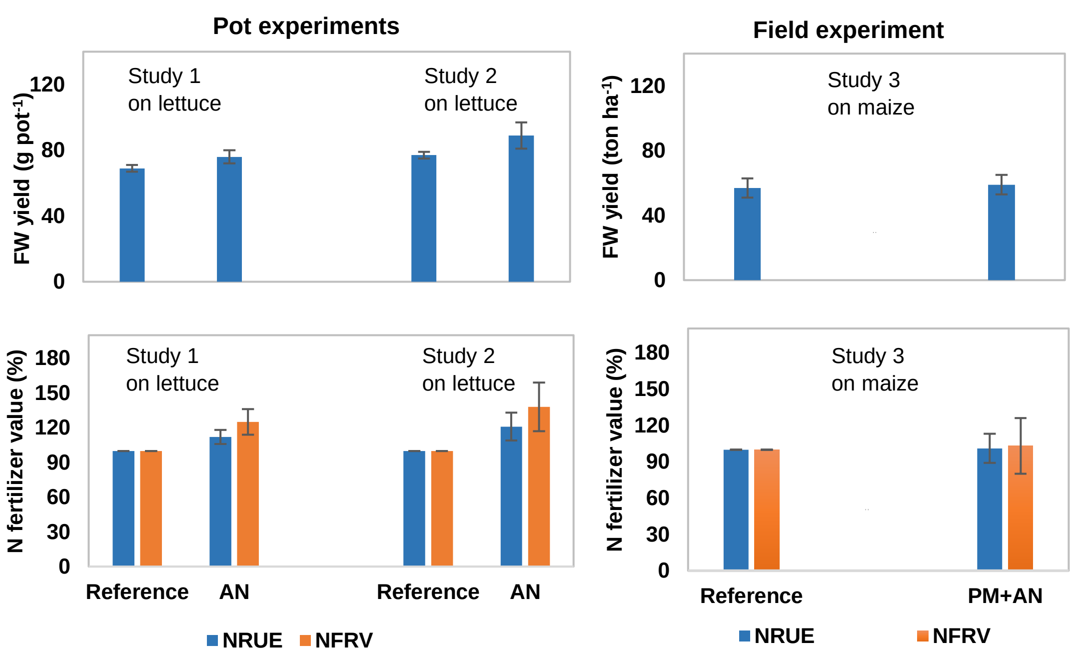

Figure 1. Effect of ammonium nitrate (AN) on fresh weight (FW) yield and its nitrogen (N) fertiliser value compared to conventional fertilisation regime in lettuce (Reference = calcium ammonium nitrate (CAN; 27%N) as synthetic N) and maize (Reference = pig manure (PM) + CAN). N replacement use efficiency (NRUE) does not account for the effect of unfertilised treatment, whereas N fertiliser replacement value (NFRV) takes into account the effect of unfertilised treatment. To determine NRUE and NFRV of ammonium nitrate, the reference treatment is considered to be 100% effective.

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Environmental aspects

Environmental aspects have been assessed in field experiments by measuring post-harvest nitrate residue in soil/water. The measured nitrate residue gives an estimate of the nitrate amount that can potentially leach to ground and surface water. This instrument is used in Flanders (Belgium) since 2004 and in Bretagne (France) since 2014.

Since the nitrate residue is measured on field scale, only results found from field experiment with ammonium nitrate are reported (Figure 2). In maize trials, no significant differences were observed between the reference treatment and the treatment where ammonium nitrate was used as an N source (Figure 2). Both the reference treatment and PM+AN treatment were below the maximum allowable level of 90 kg NO_3-N ha^{-1} in 0-90cm soil.

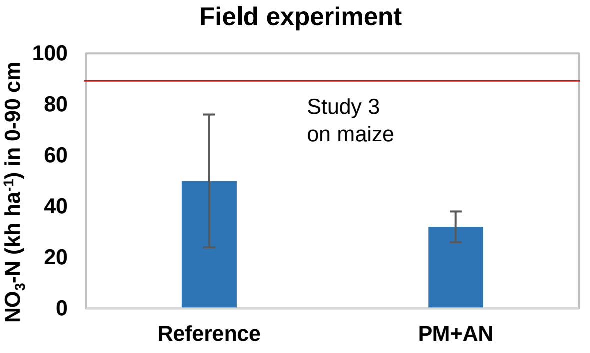

Figure 2. Effect of ammonium nitrate (applied in combination with pig manure) and conventional fertilisation (Reference = pig manure (PM) + synthetic N) on post-harvest nitrate residue (kg ha^{-1}) in 0-90 cm soil layer. The red line indicates the maximum allowable level of nitrate residue in soil (90 kg NO_3-N ha^{-1}) between October 1 and November 15 according to current Flemish environmental standards for maize cultivation in zones where measured NO_3 concentrations in ground water do not exceed 50 mg NO_3 l^{-1}.

Current legal view on ammonium nitrate

By stripping/scrubbing ammonia directly from manure with nitric acid, an end product (ammonium nitrate) is obtained that has a higher N-concentration (13-20%) than the ammonium sulphate produced when using sulphuric acid, since nitric acid also contains nitrogen. According to the current fertiliser Regulation EU2003/2003 ammonium nitrate is recognised as an 'EC fertiliser' (category C1 n°1) if the N-concentration is at least 15%. A concentration of 15% is within the means of current strippers and certainly will fulfil the criteria of the new European regulation on fertilising products (EC 2019/1009) for 'inorganic liquid straight macronutrient fertiliser' (5%). However, it is not clear if an inclusion of ammonium nitrate from manure in CMC 10 (designated animal by-products for fertiliser production) in the new European fertiliser Regulation is required. Finally, the Nitrates Directive defines this product as animal manure and not as mineral N fertiliser. Therefore the product has to fulfil requirements of animal manure and gets into competition with animal manure (which has no financial value).

Main references

Digesmart, 2016, 'Report on the analysis, regulations and field performance of the mineral fertilisers produced: https://bit.ly/2CebQQP

Sigurnjak, I., et al., 2019, 'Production and performance of bio-based mineral fertilisers from agricultural waste using ammonia (stripping-)scrubbing technology' Waste Management 89, 265-274: https://bit.ly/2pI7IWs

Saju, A., et al., 2021. Report on mineral nutrient composition of analysed recycling-derived fertilisers. ReNu2Farm project : https://www.biorefine.eu/publications/d3-1-renu2farm_-report-on-mineral-nutrient-composition-of-analysed-recycling-derived-fertilisers/