SYSTEMIC
Circular solutions for biowaste

Ammonium sulphate

Technology description

Ammonium (NH_4^+) and ammonia (NH_3) are both the same basic compound, yet the first is water soluble form whereas the second is the volatile gaseous form. Both these forms are in dynamic equilibrium in which increasing pH and/or temperature will convert more water soluble ammonium into the gaseous ammonia. In animal housing and manure or digestate processing facilities this principle is very important considering that in stables ammonia will be emitted from the manure into the ambient air. In animal housing the N-rich air is washed: via fans the air is drawn into an air scrubber where the ammonia is captured into water dissolved ammonium by a low pH 'scrubber' solution. For air washing a sulphuric acid solution is used (favourable price). 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 recapture the extracted ammonia back into soluble ammonium through a low pH 'scrubber' solution. Ammonium sulphate can thus be obtained by removing ammonia (NH_3) from nitrogen (N-) rich air or from N-rich biomass streams.

Photo 1: air scrubber (left) and ammonia stripping / scrubbing installation (right) (© VCM)

Product characteristics

Similar to synthetic produced mineral N fertilisers, ammonium sulphate contains Total N entirely in mineral form, as NH_4-N. Since the product is obtained by means of sulphuric acid, ammonium sulphate is also an important source of sulphur (S). Depending on the amount of added acid, it is not only S concentration that will vary, but also the pH and EC. Low pH and high EC values should be taken into account during the product application process since it can cause the corrosion of machinery.

Table 1. Product characteristics of ammonium sulphate (air washing) in ranges based on average values reported in scientific studies

Parameter	Ammonium sulphate
Dry matter (%)	14 - 33
pH	2.40 - 6.43
EC* (mS cm^{-1})	157 - 262
N total (g kg^{-1})	30 - 86
NH_4-N (g kg^{-1})	30 - 86
N mineral/N total (%)	100
S (g kg^{-1})	30 - 114

*EC: electrical conductivity

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Agronomic aspects

Plants (and by extension crops) require nitrogen in mineral form in order to take it up. For example, a common synthetic nitrogen fertilizer of which full plant availability is assumed is CAN (Calcium ammonium nitrate). In essence, an ammonium sulphate rich solution will enjoy the same characteristics as CAN with regard to nitrogen availability to crops. Ammonium sulphate solutions will differ from ammonium nitrate solutions (see corresponding fact sheet) by its lower overall nitrogen concentration and obviously by the fact that also sulphate will be present in the ammonium sulphate solution. Considering that sulphate is also a required plant nutrient this on its own is not a problem. However, ammonium sulphate as a source of nitrogen may need to be examined from a sulphate crop requirement as well in order to avoid adding excessive doses of sulphate beyond the crop's requirement.

So far, seven individual agronomic trials on ammonium sulphate have been identified. Their main focus was to assess the effect of the ammonium sulphate on crop yields and to determine N fertiliser value (Figure 1).

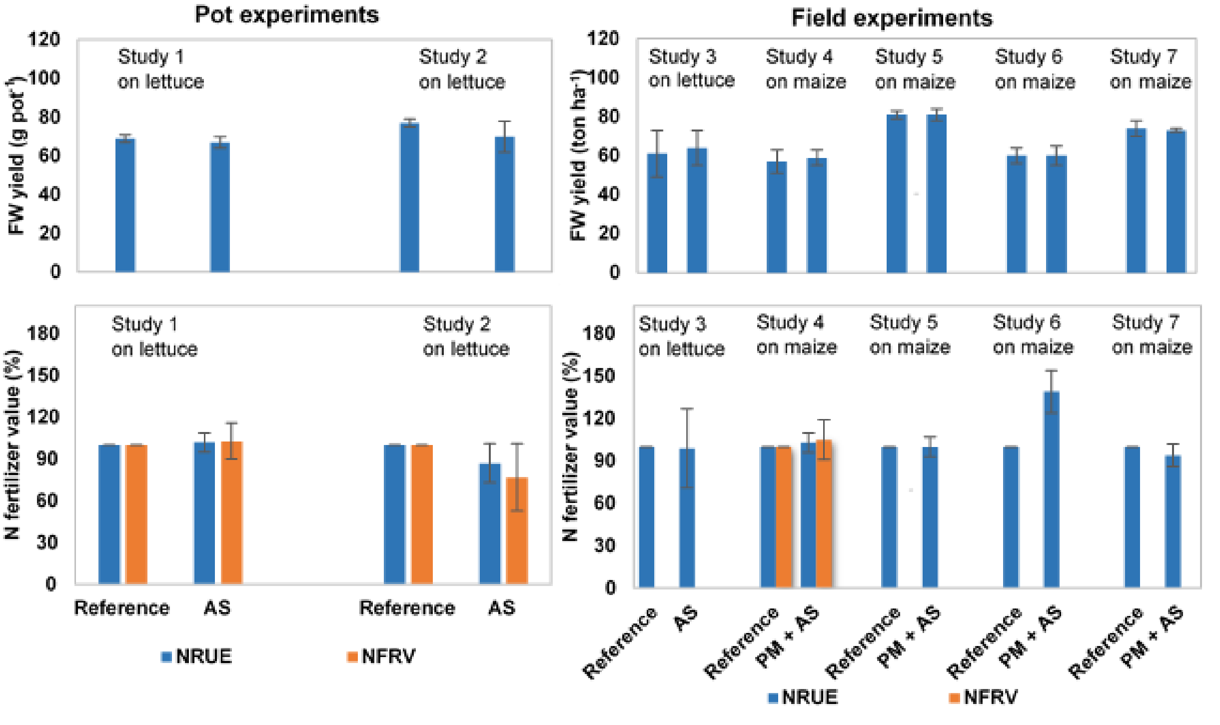

Figure 1. Effect of ammonium sulphate (AS) on fresh weight (FW) yield and its nitrogen (N) fertiliser value compared to conventional fertilization regime in lettuce (Reference = calcium ammonium nitrate (CAN; 27% N) as synthetic N) and maize (Reference = pig manure (PM) + CAN). N replacement use efficiency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

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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 (=unfertilized) treatment in an experimental design, and hence can be determined as follows:

NRUE (%) = (N uptake AMM. SULPHATE / total N applied AMM. SULPHATE) *100
(N uptake REFERENCE / total N applied REFERENCE)

NFRV (%) = ((N uptake AMM. SULPHATE – N uptake CONTROL) / total N applied AMM. SULPHATE) * 100
((N uptake REFERENCE – N uptake CONTROL) / total N applied REFERENCE)

Current results indicate that compared with chemical ammonium sulphate there is no positive nor negative effect on crop fresh weight yield if recovered ammonium sulphate is used as a N fertiliser in the cultivation of lettuce and maize, i.e. a similar effectivity is found. In all seven studies, similar yields were obtained as in the reference treatment that represented the conventional practice of using only synthetic N or synthetic N in addition to animal manure.

Although the EC of ammonium sulphate is high and the pH is low, both parameters did not reduce crop yield. The main reason is that due to the high N concentration in ammonium sulphate (27 – 86 g kg^{-1}), compared to animal manure (c. 3-5 g N kg^{-1}), only low amounts are applied. Furthermore, the soil also has a buffer capacity to neutralize the potentially low pH of ammonium sulphate. Of course, attention should be taken when applying ammonium sulphate to salt sensitive crops. On the other hand there are crops that can handle high EC values of ammonium sulphate and also benefit from sulphur application (e.g. cabbages).

In six out of seven studies, researchers have reported that NRUE and/or NFRV of ammonium sulphate is similar to the conventional fertilization regime where synthetic N fertiliser is used as a sole source of N (lettuce cultivation) or on top of pig manure (maize cultivation). Only in study 6 (Figure 1) was a significant positive effect reported on NRUE of the manure plus ammonium sulphate treatment (PM+AS) compared to the reference regime, which was a result of higher N uptake by the crop in PM+AS treatment. In general, studies on NRUE and NRFV tend to show a notable variation across different experiments . This variation stems from the effects of variable weather conditions on the performance of both bio-based materials and the used references.

Environmental aspects

Environmental aspects have been assessed in the field experiments by measuring post-harvest nitrate residue. The measured nitrate residue gives an estimation of the nitrate amount that can potentially leach to ground and surface water. This procedure has been used in Flanders (Belgium) since 2004, and in Bretagne (France) since 2014. In studies that measured the post-harvest nitrate residue, no significant differences were observed between the reference treatment and the treatment where ammonium sulphate was used as a N source (Figure 2). The measured residues were below the maximum allowable level of 90 kg NO_3-N ha^{-1} in 0-90cm soil layer, with an exception of study 5 where exceedance was observed for the both reference and ammonium sulphate treatment.

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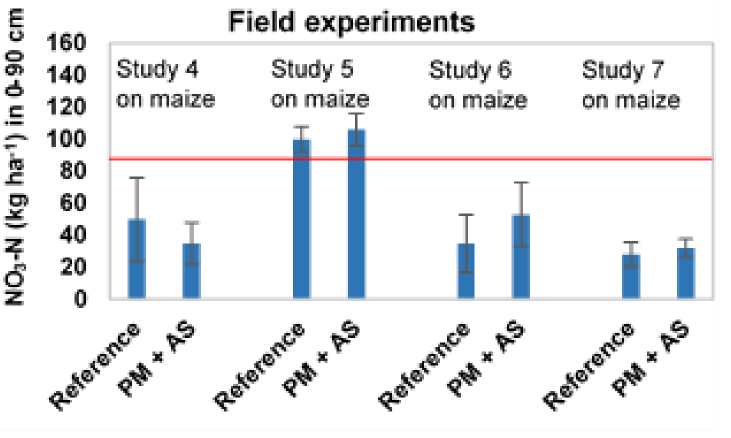

Figure 2. Effect of ammonium sulphate (applied in combination with pig manure) and conventional fertilization (Reference = pig manure (PM) + CAN) on post-harvest nitrate residue (kg ha^{-1}) in 0-90 cm soil layer. The red line indicates the maximum allowable level of nitrate residue in soil (90 kg NO_3-N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

Due to the high mobility of nitrate, the measured nitrate residue is highly influenced by weather conditions. Therefore, the observed exceedance in study 5 was attributed to unfavorable weather conditions – a warm and dry growing season, which has led to the exceedance of maximum allowable nitrate level in 40% of all taken measurements in West Flanders (Belgium).

Current legal view on ammonium sulphate

In livestock farming, air washing was developed to reduce the ammonia from the N-rich air of the stable. In some EU regions, air washing is used frequently, yet the end product (ammonia sulphate) is a recognized fertiliser and can locally be used under the same conditions as a chemical fertiliser. By N-stripping/scrubbing ammonia directly from manure, the end product (ammonia sulphate) has a relative high N-concentration (3-9%; table 1). To date, N-stripping/scrubbing from manure is not used frequently in practice, but more initiatives are arising. According to the current fertiliser regulation EU2003/2003 ammonium sulphate is a nitrogen fertiliser solution and recognized 'EC fertiliser' (category C1 n°1) if the N-concentration is at least 15%. This threshold is higher than the N-concentrations obtained from the current N-stripping/scrubbing installations using sulphuric acid. In the proposal for the new European fertiliser regulation for 'inorganic liquid compound macronutrient fertiliser', lower criteria (1.5 or 3%), which can be met as fertiliser product which is technically feasible. However, it is not clear if an inclusion of ammonium sulphate from manure in CMC 11 (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 therefor has to compete with animal manure (which has no financial value).

Some relevant references

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