Project *brief*

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Influence of urease and nitrification inhibitors on N-use efficiency and NH_3 and N_2O emissions when fertilizing with ammonium sulphate urea

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- **Use of urease and nitrification inhibitors makes a substantial contribution to reducing ammonia and nitrous oxide emissions.**
- **Emission factors determined for ammonia and nitrous oxide emissions were mostly far below the standard values according to the IPCC and EMEP.**
- **No evidence of increased nitrate leaching risk or ecotoxicological effects in drainage water and soil.**
- **Only marginal effects on N-use efficiency and yields, but savings in effort and time due to a double-inhibited fertilizer variant.**

In order to achieve the goal of the Paris Agreement and become climate neutral by 2045, greenhouse gas (GHG) emissions in agriculture must be reduced by 36 % by 2023 compared to 1990. One possible measure here is the reduction of nitrous oxide (N_2O) and ammonia (NH_3) emissions through the use of urease and nitrification inhibitors, which was investigated as part of the WIN-N project, including possible undesirable side effects.

Background and objective

According to the Federal Environment Agency, GHG emissions in agriculture have fallen from 88 to 66 million tons of CO_2 equivalents in 2020 since 1990, but the current trend is not sufficient to achieve the reduction target for 2030. The 2030 climate protection program foresees various measures to reduce GHG emissions. One of the focal points is N_2O, which has 265 times the GHG potential of CO_2, and NH_3, which is an indirect source of N_2O on the one hand and contributes significantly to soil acidification and eutrophication of ecosystems on the other. In 2019, around 81 % of N_2O emissions came from agriculture. These account for around 46 % of agricultural GHG emissions. A large proportion of this is directly or indirectly related to the application of mineral fertilizers containing nitrogen (N). With urease and nitrification inhibitors, up to 75 % of NH_3 and 35 % of N_2O emissions can be avoided. The overall aim of the project is therefore to reduce N_2O and NH_3 emissions and to achieve a significant increase in N-fertilizer efficiency through the use of inhibitors in mineral nitrogen fertilization.

Approach

As part of crop rotation trials, the N_2O and NH_3 emission reductions and the effects on yields when using inhibitors were quantified at four locations with a three-year crop rotation of silage maize (SM), winter wheat (WW) and winter barley (WG). Four fertilizer variants were tested in the crop rotation: 1) unfertilized control (CON), 2) ammonium sulphate-urea (AS-HS), 3) AS-HS with urease inhibitor (UI), 4) AS-HS with UI and nitrification inhibitor (NI). In addition, lysimeter tests were carried out to investigate possible undesirable side effects of the use of inhibitors. These are, on the one hand, an increased risk of nitrate (NO_3^-) leaching and, on the other hand, toxicological contamination of the drainage water and soil by the inhibitors. The latter aspect was supplemented by modeling the mobility and degradation of the inhibitors in the soil using the PELMO (Pesticide Leaching Model) in order to be able to shed light on the ecotoxicological pollution risk under a number of scenarios. Supplementary simulations with the CANDY (Carbon and Nitrogen Dynamics) model at the Thünen Institute shed light on the N leaching risk under a variety of weather scenarios. Laboratory incubation experiments were also carried out to determine actual emissions of atmospheric nitrogen (N_2). The latter is essential for the deduction of N fertilizer quantities. Finally, the measure was evaluated by calculating area-related N-loss rates and three-year N-balances as well as by means of eco-efficiency analyses.

Results

The results were developed in close cooperation with the project partners. The underlying database was harmonized and compiled in a Microsoft Access-based database. The harmonized and compiled data can thus be used to derive national emission factors (EF) for NH_3 and N_2O.

No differences in N-use efficiency, N-removals or yields between the fertilized variants were found at any of the trial sites during the use of the inhibitors. The use of the double-inhibited variant (AS-HS+UI+NI) results in a saving of time and effort in the fertilization process, as in contrast to the non-inhibited and single-inhibited fertilizer (AS-HS+UI), one fertilization date is omitted.

N2O emissions were highest on average across all trial locations and trial years in the non-inhibited variant. The double-inhibited variant showed the highest N2O savings potential, whereby the EFs determined were in some cases far below (< 0.25 %) the IPCC standard value of 1 % of the applied fertilizer N. By using the inhibitors, up to 58 % of emissions could be saved overall compared to the non-inhibited variant.

The NH_3 losses after fertilization were in some cases already very low in the non-inhibited variant (in some cases not quantifiable or < 1 % of the applied N). The EF determined were therefore also far below the EMEP factors for AS (approx. 13 %) and HS (approx. 7.5 %). Despite these low basic losses, further reductions of up to 57 % were achieved.

At the sites where N_2O and NH_3 were measured, UI always led to a lower overall environmental impact across the crop rotation. UI+NI also leads to an improvement, albeit not as strong as UI. From an economic-ecological perspective, UI+NI always achieves eco-efficiency in Cunnersdorf, Dedelow and Ihinger Hof. On the other hand, UI+NI is not suitable for Cunnersdorf or Dedelow on a crop rotation basis, and in Ihinger Hof it is not possible to make a clear statement due to the standard deviation. At the low-emission location Merbitz, on the other hand, neither UI nor UI+NI are worthwhile.

No increased nitrate loads and none of the inhibitors were detected in the leachate samples from the lysimeter test. A degradation product of the inhibitors (2-nitroaniline) was qualitatively detected in only two of 45 samples, albeit below the quantification limit. These results are also reflected in the simulations by PELMO, according to which, due to short half-lives and rapid degradation of the inhibitors, there are no detectable concentrations at groundwater level at any time or at any of the test sites. The simulations with CANDY confirmed a largely negligible leaching risk due to high summer drought during the test years, especially on fine-grained sites.

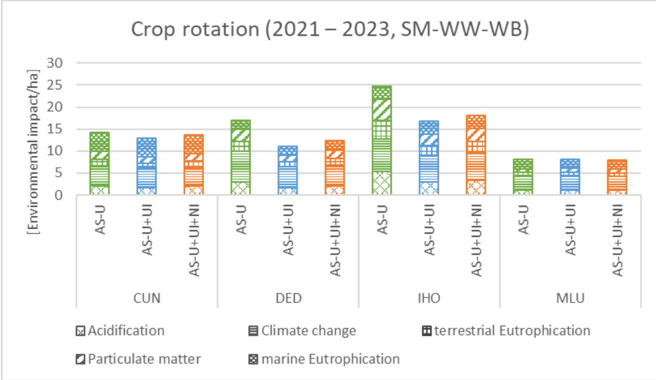

Figure: Illustration of the aggregated environmental impact per hectare for the entire crop rotation for the years 2021 to 2023 at the Cunnersdorf, Dedelow, Ihinger Hof and Merbitz sites (Source: final project report).

In the end, no statistically significant toxic effects of the inhibitors could be detected either in the leachate or in the soil with the biotests used (algal growth inhibition test, Daphnia test, bacterial contact test, nematode biocoenosis test).

Conclusion

- the inhibitors have a marginal effect on yields
- substantial reductions in NH_3 and N_2O emissions were achieved through the use of inhibitors
- at all sites, NH_3 emissions were significantly lower than those calculated in the national emissions report
- on average, approx. 50 % of N_2O emissions were reduced
- the concentrations of inhibitors in the leachate water of the lysimeters were always below the detection limit
- no trade-off in the form of an increased NO_3^- leaching risk or ecotoxicological effects could be adequately demonstrated.

Further information

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Partners

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[3] Stickstoffwerke Piesteritz GmbH
[4] ZALF
[5] Universität Hohenheim
[6] Universität Halle-Wittenberg
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Publications

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