Do nitrification inhibitors increase the N-fertilizer use efficiency and the residual effect in cropping systems?

The application of nitrification inhibitors (NI) is a strategy to increase the efficiency of nitrogen (N) in farming systems. These chemical compounds delay the conversion of ammonium to nitrate in soil by depressing the activity of nitrifiers bacteria. Consequently, when fertilizers pre-blended with NI are supplied the aim is to improve the synchronization between the N supply and crop demand, enhancing N use efficiency (NUE) and decreasing nitrate losses. Evidence for the mitigation of nitrous oxides emissions has being reported in various studies but for the increase of NUE is controversial. Without underestimating the enormous importance of the environmental benefits, it is also crucial to consider the economic costs and profits of NI use. The opportunity of saving N-fertilizer, reducing the number of applications, or increasing the productivity are advantages that would justify the higher price of NI to farmers as a viable alternative over conventional fertilizers. Therefore, identification of cropping systems or environmental conditions in which NI enhances NUE and crop yield may contribute to the best practice of this fertilizer technology.

We begun working in projects funded by EuroChem Agro in 2013 and we eill continue until 2018 at the least. The initial hypothesis was that the application of DMPP as a nitrification inhibitor (NI) could increase the soil N supply capacity over time and contribute to an enhancement of crop recovery in some cropping systems. During two seasons, a field experiment with maize (*Zea mays* L.) was fertilized with ammonium sulfate nitrate (ASN) and DMPP blended ASN (ENTEC) at two levels (130 and 170 kg N ha^{-1}) in Aranjuez (Madrid, Central Spain). A control treatment with no added N fertilizer was included. Maize yield, grain quality, nutritional state and fertilizer use efficiency were evaluated. Due to the observation of a soil residual effect, a non-fertilized sunflower (*Helianthus annuus* L.) was planted in the same plots to study the cumulative effect during a third experimental season. Laboratory determinations were performed in order to elucidate the possible sources of residual N.

In the first year, the irrigated maize crop that showed response to N-fertilizer application with respect to the control (no fertilizer application) did not showed differences between traditional fertilizers and fertilizers with nitrification inhibitors (ENTEC®). The second year of application, ENTEC application allowed a 23% reduction of the fertilizer rate without decreasing crop yield or grain quality. In addition, the non-fertilized sunflower planted after the maize in the third experimental season scavenge more N in treatments previously treated with ENTEC than with traditional fertilizers, increasing N use efficiency in the cropping system. A reasonable explanation was that after DMPP application, N was conserved in non-ready soil available forms during at least 1 year and subsequently released to meet crop demand.

Laboratory determinations confirm this hypothesis. The potential N mineralization obtained from aerobic incubation under controlled conditions was higher

for soils from the ENTEC than from the ASN or control treatments, proving that application of DMPP enhanced retention of NH_4^+ in the microbial biomass. A higher $\delta^{15}N$ in the soil, indicator of partial nitrification, indicated larger non-exchangeable NH_4^+ fixation in soils from the plots treated with ENTEC or ASN-170 than from the ASN-130 or the control. However, differences in fixed NH_4^+ were not detected due to the low concentration in samples.

In this experiment, sunflower was used to scavenge N because of its powerful rooting system. However, in other cropping systems these results open the opportunity to increase N use efficiency by designing crop rotations able to profit from the effect of NI on the soil residual N. Multi-year studies of the cumulative effect of fertilizers blended with NI in different soils and cropping systems may contribute to the best practice of this fertilizer technology.

These results open the opportunity to increase N use efficiency by designing crop rotations able to profit from the effect of NI on the soil residual N. In this experiment, sunflower was used to scavenge N because of its powerful rooting system. The soil had medium-high organic matter content (~3%) and the NH_4^+ fixation capacity (~120 mg N kg^{-1}) was in the 60-270 mg kg^{-1} range reported in the literature for medium texture soils. Future research should be oriented toward comparison of the cumulative effect of fertilizers blended with NI in different soils and cropping systems.

Actual and future research

We are conducting two-years field studies in different locations with different soils and climatic conditions. We are focus on the crop rotation maize/wheat as ideal for studying the residual effect, as it is wide spread and involves two crops of economic relevance in the world. Further laboratory determinations on soil samples from these studies might explain the reason for the different responses. These laboratory determinations are focused on the mineralization potential, NH_4^+ fixation capacity and microbial molecular characterization. Finally, the analysis of this information might contribute to define recommendations for practical purposes that allow establishing the best practice of this fertilizer technology that lead to increase N use efficiency in different soils and cropping systems.

More detail in:

Alonso-Ayuso M, Gabriel JL, Quemada M*. 2016. Nitrogen use efficiency and residual effect of fertilizers with nitrification inhibitors. European Journal of Agronomy, 80: 1-8. DOI: 10.1016/j.eja.2016.06.008.