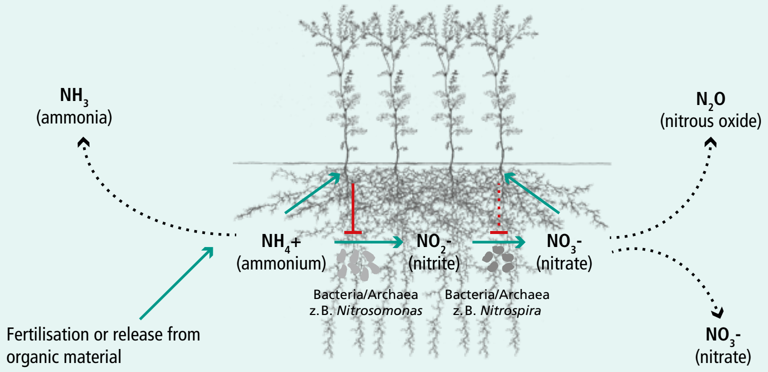
BIOLOGICAL AMMONIUM STABILISATION THROUGH CATCH CROPS

Nitrogen losses are a major problem in agricultural crop production. Around 20 % of the nitrogen fertiliser used get lost in the form of nitrate leaching and causes enormous environmental damage. Stabilising nitrogen in the soil is an efficient way to minimise nitrate losses. Some plant species can even do this on their own. Whether catch crops are also able to stabilise nitrogen and to what extent this can increase the nitrogen efficiency of the subsequent crop is the subject of research in the Catch-BNI project.

Nitrification is the microbial conversion of ammonium to nitrate. In well-aerated arable soils, this process takes place very quickly. Therefore, arable soils usually have 10 to 100 times more nitrate than ammonium, although plants generally prefer a mixed diet of both. As a result, more nitrate is often produced than the crops can absorb, increasing the risk of nitrate leaching during rainfall. Since the middle of the 20th century, it has been observed that various plant species (including grasses such as sorghum, wheat and maize, crucifers, amaryllis and plantain) can slow down the nitrification process in the soil by releasing very potent inhibitors, so-called bionitrification inhibitors (BNI). As a result, more nitrogen remains in the form of ammonium, which binds well to negatively charged soil particles due to its positive charge and is thus less susceptible to washing than nitrate (Fig. 1). This principle is known from the use of stabilised nitrogen fertiliser. Artificial nitrification inhibitors are used there with very good results. For several years, active scientific research has been conducted to improve the nitrogen balance through the targeted use of crop varieties with natural release of nitrification inhibitors.

In the current Catch-BNI research project, work is now being carried out throughout Europe to identify catch crops with BNI effects and to use them to improve the nitrogen efficiency of spring wheat as a subsequent crop.

FIG. 1: THE NITRIFICATION PROCESS IN THE SOIL



Shown is the microbial conversion of ammonium to nitrate (bold print), possible nitrogen loss pathways (dashed arrows), nitrogen uptake by plants (green arrows) and the inhibition of nitrification reactions (red inhibition symbols). Source: Plant pictures from „Wurzelatlas der Kulturpflanzen gemäßigter Gebiete mit Arten des Feldgemüsebaues“ L. Kutschera, E. Lichtenegger, M. Sobotik, DLG-Verlag, Frankfurt/Main, 2009.

Since 2021, the European research project Catch-BNI has linked five institutions under the SUSCROP funding framework with the aim of developing innovative intercropping approaches to develop methods that enable the slow and controlled conversion of ammonium to nitrate in soils for optimal nutrition of the main crops.

Cruciferous superior

In a screening of more than 30 catch crops in a field trial at IPK Gatersleben and in a nutrient solution trial at the University of Liège (Belgium), it was unanimously found that yellow mustard in particular shows a very high capacity for nitrification inhibition. However, there are differences between the varieties. Sorghum was also able to efficiently inhibit the conversion of ammonium to nitrate.

Long-term effects depending on decomposition properties

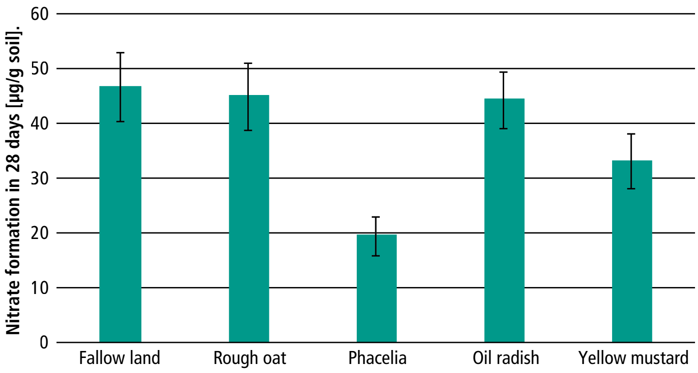
A follow-up trial at IPK Gatersleben and at the Deutsche Saatveredelung AG (DSV) trial station in Asendorf now shows in parallel that although the species mentioned have BNI effects during their active growth period in autumn, these effects decrease after winter. This is possibly due to the early death of sorghum in autumn and the rapid decomposition of a large part of the yellow mustard biomass in winter. In contrast, the slower decomposing phacelia leads to > 50 % less nitrate production than other catch crops in early spring (Fig. 2). This may be due to BNI-active substances released from the biomass during decomposition.

Identification of biological Nitrification inhibitors

Currently, there is considerable knowledge about BNI-active substances. These are structurally very different, many are formed plant- or even variety-specifically, often several active substances occur in one species and their mode of action ranges from the very selective inhibition of an important step in the nitrification process to the broad inhibition of microbial growth. Nevertheless, certain plant species have not yet been tested for their BNI effect. The first results of the Catch-BNI project now provide valuable indications of new plant species with a tremendous effect on nitrification, e.g. phacelia. Attempts are currently being made to identify previously unknown BNIs using various isolations and test methods.

In the long term it will become clear to what extent such substances, plant extracts or admixed plant material can be used for nitrogen stabilisation in fertilisers.

FIG. 2: NITRATE FORMATION IN THE FIELD SOIL UNDER DIFFERENT CATCH CROPS AFTER 28-DAY DARK INCUBATION AT 25 °C*



*Nitrate concentration was measured at the beginning and end of the incubation phase and the difference was calculated. The data were recorded in March 2023 at the Gatersleben (Saxony-Anhalt) and Asendorf (Lower Saxony) sites and show the mean +/- standard error for a sample size of 48.

Conclusion

Nitrogen enrichment in the biomass of catch crops is a well-known advantage for avoiding nitrogen losses in crop rotations. The project presented here opens up a further possibility of nitrogen conservation via the stabilisation of ammonium in the soil, which has received little attention so far. The results already show that some catch crops, such as yellow mustard, phacelia and sorghum, are able to release nitrification inhibitors and, depending on their growth and decomposition properties, to inhibit the nitrification process in the soil at different time points in the crop rotation.

Initial results show that some catch crops can conserve nitrogen by stabilising ammonium in the soil. The extent to which this can influence the nitrogen efficiency of the subsequent crop is currently being investigated in field trials. The first results are expected at the end of 2023.

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Diana Heuermann
Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) Gatersleben
Phone +49 394 825 514