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15N-Urea Release Evaluation From Two Types of Mesoporous Silica Nanoparticles: Perspectives For Future Application As Slow Release Nanofertilizer

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Introduction

Given the current population growth, food demand and increase rate of yields, the development of more efficient fertilization to sustain higher productivities without detrimental effects is crucial. A considerable amount of fertilizers is released in the environment annually, threatening the environmental resources, the public health and the economic investments. Nanotechnologies may play an important role for the ecological transition of the entire food system towards a more sustainable crop production. A new alternative is represented by the nanomaterial enhanced fertilizers that are potentially able to improve the nutrient delivery. The study here presented aimed at evaluating the release of N from two types of ^{15}N-urea loaded nanoparticles: the Periodic Mesoporous Organosilica nanoparticles (PMO) and the Mesoporous Silica Nanoparticles produced from rice husks (rhMSN).

Materials and Methods

Soil from the experimental farm of the University of Udine (pH=7.8±0.1; clay=13%; silt=22%; sand=69%), was used to perform a leaching column test (figure 1); each column received an equal amount of urea (0,22g in 400g of soil), corresponding to 290kg N ha^{-1}, provided as pure ^{15}N-urea and as ^{15}N-urea-loaded-nanoparticles (PMO and rhMSN) for a total of 4 treatments (control included; n=3)). The amount of nanoparticles varied according to the loading capacities that were 26% and 33% for PMO and rhMSN, respectively. Every 3 days, the columns were leached with 45mL of deionized water that corresponds to the local average weekly rainfall; the ^{15}N quantification of leachates was done via NMR. The leaching test lasted 12 days. On top of the columns, NH_3 traps were placed and changed at regular intervals, according to (Grant et al., 1996). This was done to measure the ^{15}N-urea losses due to microbial activity (ammonification).

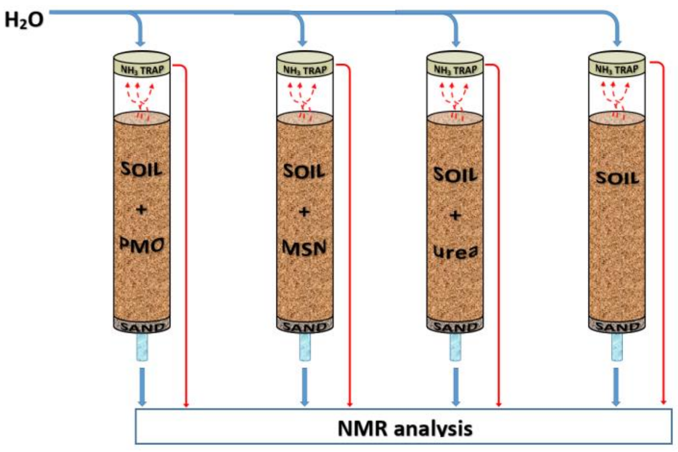

Fig. 1 Scheme of the experimental design. Each column was replicated 3 times for a total of 12 columns and received 400g of soil and 0,22g of ^{15}N-Urea in form of nanoparticles (PMO and rhMSN) or as salt (urea). (No addition=CTRL treatment).

Results

Despite the wide variability of the data, figure 2 shows that the ^{15}N-Urea in the form of powder is promptly leached at the very first leaching (72% of the total amount of urea). On the contrary, both types of nanoparticles (PMO and RMN) release a much lower ammount of urea (respectively, 0,4% and 0,1%). On the second leaching, another 4% of urea was found on the Urea treatment leachate, while the corresponding leachates for the two other treatments were not detectable. As for the third and forth leaching, ^{15}N-Urea was negligible for the salt treatment on the third leaching and not detectable in all the other cases.

Data from the NH_3 traps indicated that no ammonification took place.

Figure 3 shows an example of an NMR spectra that was recorded with a Bruker apparatus at 400 MHz in 5 mm tubes.

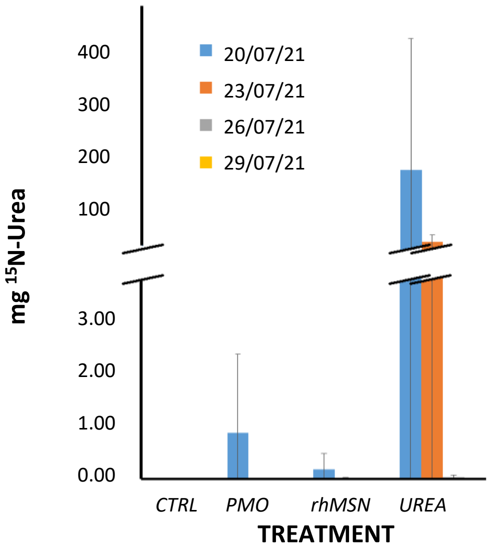

Fig. 2 Mean (n=3) of the ^{15}N-Urea leached in *g* for the four leachings (see dates) of the columns for the four treatments (CTRL, PMO, rhMSN and PMO).

Conclusions

This experiment shows promising results in terms of fertilizer retention as a result of its encapsulation within mesoporous nanostructure (PMO and rhMSN). More investigations are required in order to better define the N balance and the interaction between the fertilizer and the plant-soil system.

Grant, C. A., Jia, S., Brown, K. R., and Bailey, L. D. 1996. Volatile losses of NH3 from surface applied urea and urea ammonium nitrate with and without the urease inhibitor NBPT. Can. J. Soil Sci. 76:417-419.

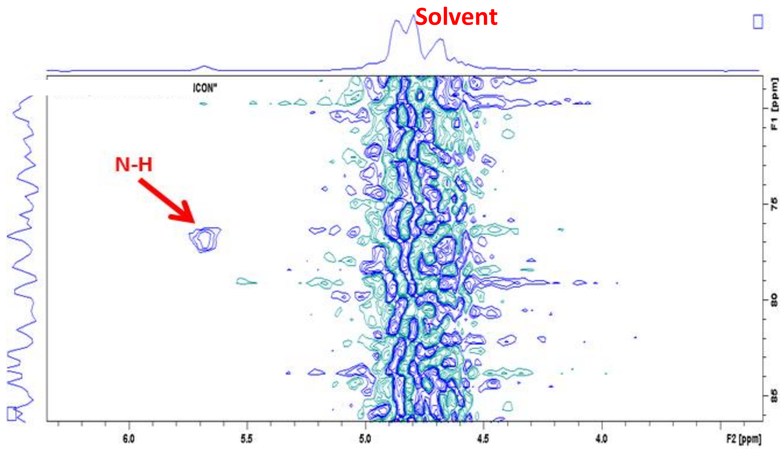

Fig. 3 Experiment used is 15N via HSQC parset HSQCGPPH. Measurements conducted at 298K in H_2O 99%/1% D_2O as a solvent. Standard solution: ^{15}-UREA 0.1 x 10^{-3} M. The red arrow in the spectrum indicates the correlation ^{15}N and H.