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FIRST REACTIONS

Slow Release Nanofertilizers for Bumper Crops

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Nanotechnology could improve fertilizer delivery and help with global pollution (from *ACS Nano*).

The Haber–Bosch process for the commercial production of ammonia demonstrated in 1913 was a watershed event in the mass production of urea, the principal nitrogen fertilizer for modern agriculture. Today, thanks to the so-called "green revolution" starting in in the 1960s, nearly half of the world population relies on increased crop yields, through the use of nitrogen fertilizers, to access affordable food. Urea, $CO(NH_2)_2$, is the principal nitrogen fertilizer (46% N by weight). Sadly, urea's chief strengths—water solubility and ready plant availability—also provide its Achilles' heel. About three-quarters of urea is lost during fertilization due to volatilization and leaching.[1] This not only increases the cost but also has severe negative environmental implications. Specifically, the inefficiency of fertilizer delivery is associated with contaminated groundwater and water bodies suffused with nitrates, expanding coastal water dead zones, and nitrous oxide getting into the atmosphere. Nitrous oxide is the third most abundant greenhouse gas, with a higher Global Warming Potential than either carbon dioxide or methane.[2] Our dependence on synthetic nitrogen fertilizer has dramatically increased anthropogenic interference with the nitrogen cycle, key for protein production for all life forms. Modern food production releases nearly as much nitrogen (150 Mt/year) as is generated by bio fixation and lightning.

Urea leaching exacerbates these problems; thus solutions to improve the plant availability of urea while reducing its adverse effects to the environment will be crucial in the coming decades. This will be true particularly as we work to maintain global food security in a world with an increasing population.

Some recent attempts at addressing this problem draw on the use of nanoparticle based fertilizers to allow slow release of the nutrient on demand and thus preventing premature loss.[2,3] However, compared to controlled drug release for pharmaceutics, there has been a paucity of research on the agriculture applications of nanotechnology to improve release behavior of fertilizer formulations. Previous work has reported that carbon nanotubes can enter tomato seeds, and zinc oxide nanoparticles pass into rye grass root tissues. These results suggest that nanofertilizer delivery systems could be fabricated to take advantage of nanoscale porous zones on plant surfaces.[4] In addition, although different aspects of nanotechnology in agriculture such as plant delivery systems have been investigated by many research groups, no specific strategies for addressing the problem of loss of urea during fertilization have been reported to date.[5−8]

Researchers at the Sri Lankan Institute of Nanotechnology (SLINTEC) have developed a nanofertilizer using urea coated hydroxyapatite nanoparticles for targeted delivery via slow release using nanohybrids that have so far been primarily used in medicine to realize the nanofertilizer (Figure 1).[9] Their method significantly reduces the amount of urea required for fertilization since it can be applied locally. Perhaps more impressively, the authors demonstrate that, with their approach, the rice crop yields are significantly enhanced even when 50% less urea is used.

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The authors' simple and scalable one step method for realizing urea coated hydroxyapatite nanoparticles (HA NPs) is achieved by controlled addition of phosphoric acid into a suspension of $Ca(OH)_2$ and urea, followed by fast drying using spray-drying. Laboratory data for the release of urea from the nanohybrids with a 1:6 HA to urea ratio released urea 12 times more slowly compared to pure urea.

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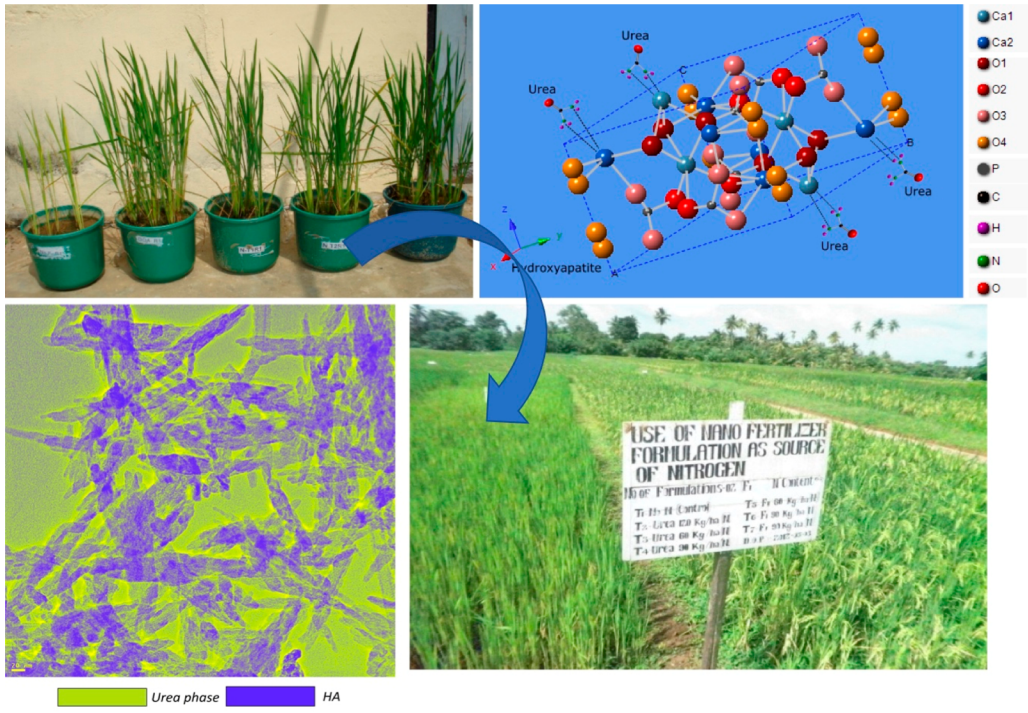

Figure 1. Rod shaped urea–HA nanohybrids maintained efficacy from pot trials to the rice fields. Part of the figure is reproduced with permission from ref 9. Copyright 2017 American Chemical Society.

Furthermore, the nanohybrid contained very nearly the same amount of available nitrogen as pure urea. Farmer field level trials in rice revealed that by using half as much nitrogen from the urea–HA nanohybrids they could achieve the same fertilization as under alluvial soil conditions.

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Through this "less is more" approach using nanotechnology, one can envision additional environmental benefits. Over time, the phosphorus content from the particles will also be released to the soil. The best results are obtained in sandy loam soil, where native fertilizer retention is poor and the slow release nature of urea from the nanohybrid evidently is an advantage. Furthermore, cost advantages realized through the availability of P from the NC are yet to be determined.

It is probable that modeling studies could provide better quantitative data regarding the environmental remediation aspect of this technology. The important goal and challenge for this technology going forward is to fine-tune the urea–HA nanohybrid to maximize its potential in a variety of soil types, while making this simple approach to the global nitrogen issue commercially viable.

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