Efficacy of Hydroxyapatite Nanoparticles as a P Fertilizer in Andisols and Oxisols

Nanotechnology has been proposed as an emerging technology with the potential to improve fertilizer formulations. Nanomaterials are defined as materials that have at least one dimension smaller than 100 nm. Due to the very small size and high surface-to-volume ratio, nanoparticles behave differently from bulk materials. For example, nanoparticles are expected to dissolve faster and be more mobile in porous media than their bulk counterparts. These distinctive properties of the nanoparticles could be used to design more efficient P fertilizers.

Synthetic hydroxyapatite nanoparticles have been mainly used for biomedical applications and remediation of metal-contaminated soil and groundwater. In a new study published in the March–April 2015 issue of the Soil Science Society of America Journal, scientists from the Fertiliser Technology Research Centre, University of Adelaide, Australia, evaluated hydroxyapatite nanoparticles as a potential P fertilizer with improved efficiency for strongly P-sorbing soils. This study was based on the hypothesis that the nano-sized particles can potentially move in the soil and reach the roots of the plants through the mass flow produced by transpiration. Once close to the roots, P depletion would promote the dissolution of hydroxyapatite nanoparticles. That way, there would be less contact of the free orthophosphate-P with the soil compared with conventional water-soluble fertilizers, thus minimizing opportunities for P fixation.

Two experiments were conducted to test this hypothesis. In the first experiment, the transport of commercially available nano-hydroxyapatite (20 nm) and bulk hydroxyapatite (600 nm) in acidic strongly P-sorbing soils was investigated in saturated soil column experiments. For the second experiment, a pot trial using the 33P isotopic dilution technique was conducted to quantify the uptake by wheat (Triticum aestivum) of P derived from nano-hydroxyapatite, bulk-hydroxyapatite, and triple superphosphate applied to two Andisols from Chile and New Zealand (North) and two Oxisols from Australia (Greenwood and Redvale).

Results from the column experiment showed that the mobility of hydroxyapatite nanoparticles in the soils was limited. Over the whole leaching period (48 h), about 5% of added P was recovered in the leachates for the Andisol and only 0.4% for the Oxisol. The limited transport of the nanoparticles in both soils might have been due to aggregation of the nanoparticles in the soil. The greater mobility of nano-hydroxyapatite in the Andisol could be related to the higher organic carbon content that may have acted as an electrostatic barrier hindering the attachment of the negatively charged hydroxyapatite nanoparticles to the soil. Alternatively, the greater mobility of nano-hydroxyapatite in the Andisol could also be due to that soil’s higher porosity. In contrast to the nano-hydroxyapatite treatment, there was no recovery of P from bulk hydroxyapatite in the leachates for either soil, suggesting no movement of the bulk material, which can be related to the larger particle size.

Results from the pot experiment showed that across all soils, plant P uptake and the percentage of P in the plant that derived from the fertilizer followed the order: triple superphosphate > nano-hydroxyapatite > bulk-hydroxyapatite (Fig. 1). The better performance of nano-hydroxyapatite over bulk hydroxyapatite was most likely due to faster dissolution of the nanoparticles, as the rate of dissolution increases with decreasing the particle size. Nevertheless, the fertilizer with readily soluble P was still a more effective P fertilizer.

Even though nano-hydroxyapatite was not a more effective P source than conventional soluble fertilizer in this study, the authors believe that nanotechnology should still be further explored as a fertilizer strategy to enhance P efficiency. The idea of applying nanoparticulate P instead of free orthophosphate in strongly P-sorbing soils still merits further investigation.


![Fig. 1. Distribution of total P taken up by the plant shoot derived from fertilizer, soil, and seed. TSP, triple superphosphate; n-HAP, nano-hydroxyapatite; bulk HAP, bulk hydroxyapatite; control, no P fertilizer.](http://dx.doi.org/10.2134/sssaj2014.09.0373)