Slow Release Characteristics of Crystal Green Struvite Quantified *in Situ* Using X-Ray Computed Tomography

Sharif Ahmed[1], Trudy Naugler Klassen[2], Mike Daly[3], Dan Froehlich[2] and Tiina Roose[1]
(1)Bioengineering Sciences Research Group, Faculty of Engineering and Environment, University of Southampton, University Road, Southampton SO17 1BJ, United Kingdom, (2)Ostara Nutrient Recovery Technologies, Vancouver, BC, Canada, (3)The Agrology House, United Kingdom

BACKGROUND

- Struvite (magnesium ammonium phosphate hexahydrate) can be used as a slow release fertilizer containing plant-available phosphorus, magnesium and nitrogen.
- The unique slow release properties of struvite are due to inherent solubility characteristics - very low water solubility while still being soluble in neutral ammonium citrate.
- Given these properties, it can be challenging to assess the nutrient release characteristics using standard methods.

In this study, time resolved, non-destructive, 3D micro-focus X-ray computer tomography (CT) imaging was used to visualize and quantify the interactions of Crystal Green (CG) struvite granules with plant roots in situ.

A SUSTAINABLE P SOURCE

Crystal Green® is the trade name for a granular struvite fertilizer produced using the patented Pearl® process for nutrient recovery. The recovered Crystal Green (CG) granules are high purity and naturally slow release with no coating or additives.

Figure 1: Crystal Green (CG) granules.

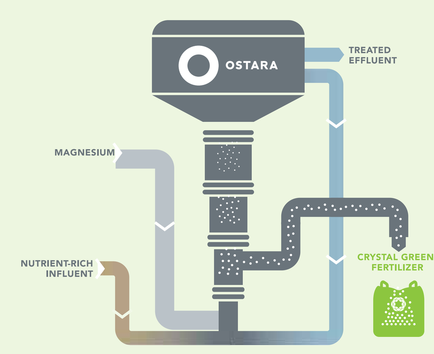

Figure 2: Pearl® Nutrient Recovery Process

- Chemical composition: Magnesium ammonium phosphate hexa-hydrate ($MgNH_4PO_4 \cdot 6H_2O$)
- Guaranteed analysis: 5-28-0 + 10% Mg

METHODS

- Crystal Green (CG) and triple superphosphate (TSP) were used in 3 treatments to apply the equivalent of 80 kg P_2O_5 /ha (Table 1).
- The fertilizer granules were placed in large soil filled tubes (500mm height, 110mm diameter), which were seeded with spring wheat (Figure 3). Nitrogen, potassium, and micronutrients were supplied at recommended rates.
- The soil was an "Index 1" for phosphorus (12.6 mg /L, Olsen P) and had a pH of 5.9.

Table 1: Application Rates of TSP and CG for each

	Application Rate (kg P_2O_5 /ha)	
Treatment	TSP	CG
Zero P Control	0	0
TSP	80	0
CG	0	80
50:50	40	40

- Over 14 weeks, 12 CT scans of the roots were taken at a spatial resolution of 60 µm.
- Scan time was optimized to 56 minutes so that all 12 samples could be scanned in 1 day.

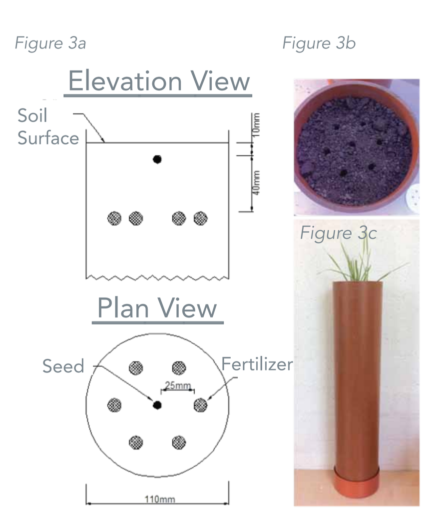

Figure 3:(a) Schematic of seed and fertilizer placement within tubes, (b) the soil surface after placement of fertilizer and seeds, (c) side view of tube with growing spring wheat plant.

Figure 4: Plants ready for scanning.

CONCLUSIONS

- CT scanning was an effective tool to non-destructively look at fertilizer dissolution (volume change) *in situ* and over time.
- Quantification of CG granule volume and root growth confirmed the importance of root interactions for Crystal Green release.
- The slow release mechanism of Crystal Green could have positive implications for nutrient use efficiency and for environmental risks associated with phosphorus fertilizers.

RESULTS & DISCUSSION

To examine the interaction of Crystal Green granules and roots, cuboids of 1 cm^3 around the granules were extracted from the 3D data set (Figure 6). Within these cuboids, the CG granule volume and the cumulative root length was quantified over time.

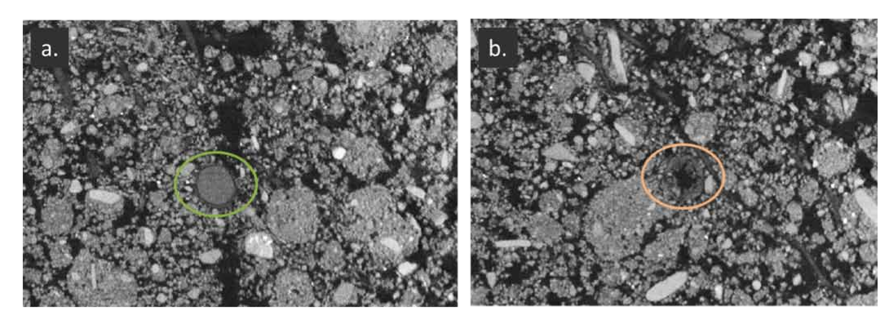

Figure 5: Internal slices from scans showing roots with, (a) a CG granule, and (b) a TSP granule at week 14. Segmentation of the roots was challenging because roots and the components of agricultural soil tend to have a similar density.

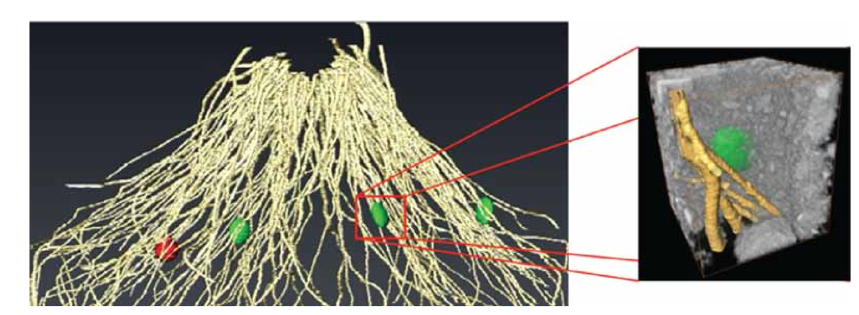

Figure 6: Segmented root structure and fertilizer granules from a 50:50 treatment pot and a $1cm^3$ cuboid extracted from the 3D dataset for analysis of root interactions with CG granules. CG and TSP granules have been shaded green and red, respectively.

- Roots came within several millimeters of the fertilizer granules, close enough for root hairs to access diffused P from the fertilizer.
- CG granules showed negligible volume change until week 8, after roots began to grow within the cuboids around the granules (see Figure 7). This confirms that the low water solubility of CG leads to minimal release in the absence of growing roots, which could have positive environmental implications.
- Volume loss of the CG granules is correlated to root growth, confirming root presence as an important element of struvite release.
- The mechanism of root influence was not visualized, but could be a combination of root exudates and creation of a nutrient gradient.
- This type of "plant-activated" slow release mechanism could have positive implications for phosphorus use efficiency and challenges related to reactions of P in the soil.

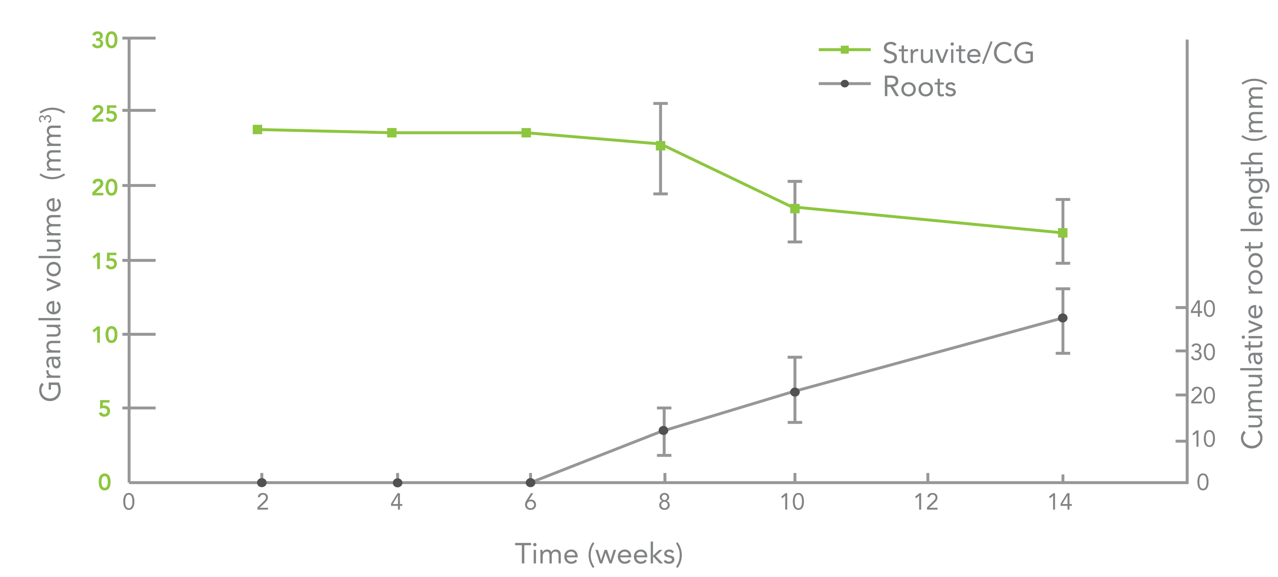

Figure 7: Average volume change of CG granules and average cumulative root length over time. Values are the mean of all 50:50 treatment pots (error bars = ±1 standard deviation).

Ongoing field trials support the performance of Crystal Green as a P source. Combining CG with a more water soluble P fertilizer can provide season-long P release with benefits for crop yield and quality.

Presented in partnership with:

Scan for more information: