



Investigation and Modeling of a Nanoparticle Delivery System for Micronutrients in Corn

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Background

Pheroid Nanoparticle Delivery System¹

- Cost effective for plant applications
- Safe – multi-lamellar lipid system derived mostly from soybeans
- Versatile – payloads delivered range from micronutrients to antibiotics

Micronutrient Deficiency

- Caused by the immobility of micronutrients through the plant
- Leads to low crop yield and malnutrition²
- As fertilizers deliver nutrients, only small percentage obtained by plant.

Purpose of Nanoparticle Delivery System

- Increase plant micronutrient content and yield
- Reduces the effects of run-of, overuse and pollution

Other Nano-Fertilizer Trials

- Desert plant results – in a foliar application versus irrigation application, the foliar nano-fertilizer was 40% more effective.³
- Cucumber plant results – demonstrated increased yield and length.⁴

Transport Mathematical Model

- Mathematical model for the Pheroid delivery system has not been developed, which could help with chemical concentrations.

The different functions of the Pheroid warrant the need for a testing method similar to preclinical trials for medicine. An investigation of the nanoparticle delivery system for micronutrients in corn will lead to a better design of the delivery system, offer deeper insight and eventually produce more nutritious food.

Materials & Methods

Mathematical Model

Through transport principles and based on a drug delivery model, the following model was derived and solved for concentrations for nutrient transport in the phloem:

Absorption and transport of nanoparticles in phloem:

$$P_0(t) = A \begin{cases} (1 - e^{-\alpha t}) / (1 - e^{-\alpha t_P}), & t \leq t_P \\ e^{-\beta(t-t_P)}, & t > t_P \end{cases}$$

Transport of nanoparticle between cells and phloem:

$$\frac{\partial P}{\partial t} + V \frac{\partial P}{\partial x} = -k_P \alpha_P P + k_P \alpha_P F - k_{DP} P$$

$$\frac{\partial F}{\partial t} = k_P \alpha_P P - k_P \alpha_P F - k_{DF} F$$

P- Concentration in the phloem

F- Concentration in the cellular phase

Nutrient transport between cells and phloem:

$$\frac{\partial R_P}{\partial t} + V \frac{\partial R_P}{\partial t} = -q_P \alpha_P R_P + q_M \alpha_P R_M - k_{MP} R_P + k_{DP} \sigma P$$

$$\frac{\partial R_M}{\partial t} = q_P \alpha_P R_P - q_M \alpha_P R_M - k_{MM} R_M + k_{DF} \sigma F$$

Rp- Concentration in the phloem

Rm- Concentration in the cells

Materials & Methods

Micronutrient Experiment

- Hydroponic System (Fig.1)
- Apply treatments at stage 5V-6V
- Harvest at stage 9V-10V

Zinc and Iron Foliar Treatments

- 1: Control (no foliar trt applied, full Hoagland's Sol'n)
- 2: Control (no foliar trt applied, 0 Fe in Hoagland's Sol'n)
- 3: Only Pheroid (full Hoagland's Sol'n)
- 4: Pheroid-Fe (rate 1) (full Hoagland's Sol'n)
- 5: Pheroid-Fe (rate 2) (full Hoagland's Sol'n)
- 6: Fe Chelate (rate 1) (full Hoagland's Sol'n)
- 7: Fe Chelate (rate 2) (full Hoagland's Sol'n)
- 8: Fe Sulfate (rate 1) (full Hoagland's Sol'n)
- 9: Fe Sulfate (rate 2) (full Hoagland's Sol'n)



Figure 1. Hydroponic System

Results & Discussion

$$P(x, t) = e^{-(k_P \alpha_P + k_{DP})t} \left[C \left(t - \frac{x}{V} \right) + C \left(t - \frac{x}{V} \right) * a \sqrt{\frac{x/V}{t - x/V}} e^{-b(t - x/V)} I_1 \left(2a \sqrt{\frac{x}{V} \left(t - \frac{x}{V} \right)} \right) \right]$$

$$F(x, t) = k_P \alpha_P e^{-bt} \int_0^t e^{b\tau} P(x, \tau) d\tau$$

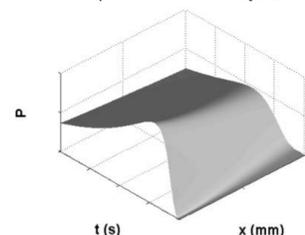


Figure 2. Nanoparticle Concentration Solution

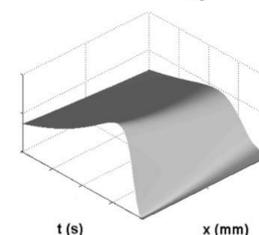


Figure 3. Nutrient Concentration Solution

Model Concentration Preliminary Results

- Both the concentration of the nanoparticle and nutrient increases and decreases exponentially with time and length.

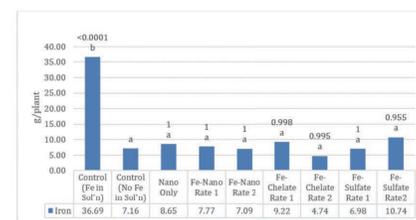


Figure 4. Change in Dry Weight of Iron Deficient Plants

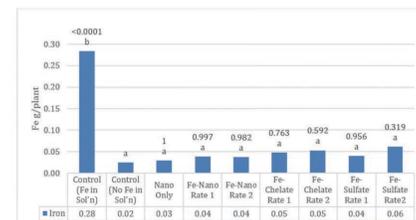


Figure 6. Change in Iron Grams

Micronutrient Results

- Treatments did not give a significant statistical increase in dry weight
- Pheroid and chelate rate 2 treatments did show a significant increase for zinc

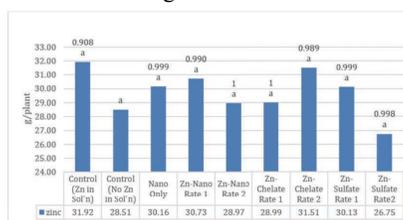


Figure 5. Change in Dry Weight of Zinc Deficient Plants

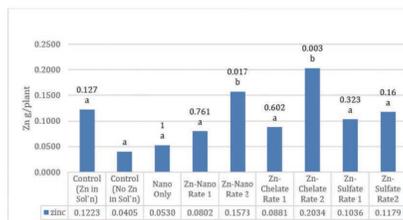


Figure 7. Change in Zinc Grams

Results & Discussion

Visible Results

- Pictures also show how iron was not mobilized as zinc from treatments.

Reaction of Leaves to Foliar Treatment

- All treatments showed some degree of burn on the leaves.



Figure 8. Zinc-Pheroid (left) and Iron-Pheroid(right) Corn Plants



Figure 9. Zinc Treatment Burns Zinc-Pheroid (top);Zinc-Sulfate (bottom)

Conclusions & Future Work

- Since corn plants require a smaller amount of zinc than iron, one reason the treatments in general did not deliver enough iron could be that the rates of the one-time spray were not enough to deliver the needed iron.
- Another reason the Pheroid treatment did not appear to deliver the most iron could be that it was not prepared with additional saccharides, which help the liquid droplets to stick to the leaf.
- For future work, an experiment could be conducted where the Pheroid contains a tracer to trace its transport in the plant and therefore aid in deriving a more complete model. Another experiment with increased rates and more sprays could also be conducted.

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