4-2016

# Investigation of a Nanoparticle Delivery System for Micronutrients in Corn

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# Investigation of a Nanoparticle Delivery System for Micronutrients in Corn

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## Background

**Pheroid Nanoparticle Delivery System**[1]
- 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 malnutrition children in poor countries[2]
- 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.
- Cucumber plant results – demonstrated increased yield and length.

**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, officer 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

$$P_0(t) = A\left[\begin{matrix}(1-e^{-\alpha t})/(1-e^{-\alpha t_P}), & t \le t_P \\ e^{-\beta(t-t_P)}, & t > t_P\end{matrix}\right.$$

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

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

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

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

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

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

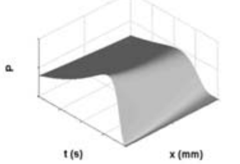


Figure 2. Nanoparticle Concentration Solution

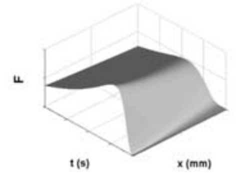


Figure 3. Nutrient Concentration Solution

**Model Concentration Preliminary Results**
- Both the concentration of the nanoparticle and nutrient increases and decreases exponentially with time and length.

**Micronutrient Results**
- All treatments are compared to the control with no zinc in solution.
- Pheroid contributed more to the increase of zinc than increase in iron

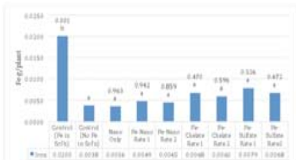

Figure 4. Final Top Iron Grams

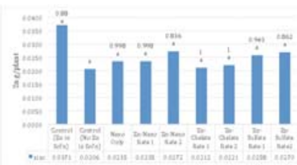

Figure 5. Final Top Zinc Grams

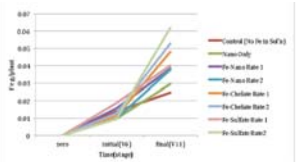

Figure 6. Total Grams of Iron at Final and Initial Stage

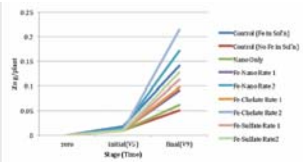

Figure 7. Total Grams of Zinc at Final and Initial Stage

## 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 only require 30 ppm of zinc and 200 ppm of iron, one reason for the all of the treatments in general to not have delivered enough iron was the rates or the one-time spray was not enough to deliver the 200 ppm of iron.
- Another reason the Pheroid treatment did not appear to deliver the most iron could be that it was not prepared with additional surfactants, which help the liquid droplets to stick to the leaf.
- For future work, an experiment where the Pheroid contains a tracer could be done to trace its transport in the plant to aid in derive a more complete model. Another experiment with increase rates and more sprays could also be done.

## Acknowledgements

- Dr. Hendrik Viljoen, UNL Faculty Mentor
- Zachary Stewart, UNL Ph.D Graduate Research Assistant
- McNair Scholars Program

## References

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