Competitive Uptake of Plutonium and Iron in Corn (Zea mays)

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Introduction

- Interested in the plant mechanisms that influence iron uptake, and subsequently plutonium uptake
- Two applications
  - Phytoremediation
  - Nuclear forensics/monitoring
Introduction

• Iron is an essential nutrient for plants
• Pu is of concern due to the long-term environmental and health concerns
• Is plutonium taken up through the same plant pathway as iron?
Introduction

• Corn species of interest
  - Trucker’s Favorite
  - Yellow Stripe 1 (YS1)

• If YS1 uptakes Pu, then the Pu/Fe pathway is different.
Introduction

- Initial experiments compare Pu(DFOB) and $^{59}$Fe(DFOB) corn uptake
- Conducted two experiments: One compared plant uptake of ~37kBq Pu(DFOB) and ~37kBq of Fe(DFOB). The other compared plant uptake of ~37kBq Pu(DFOB) and either 0 or 10x Fe concentration found in nutrient solution
- Experiment 1:
  More $^{59}$Fe activity was found in the shoots than Pu
  More Pu was found in the roots than Fe
- Experiment 2:
  Differences in iron concentrations had no effect on Pu uptake
Hydroponic Solution and Foliar Fertilization

- Hydroponic nutrient (HP) solution
  - Allows nutrient control

- Foliar Fertilization
  - Two different types of foliar fertilization (FF) techniques were attempted
    - Type 1: Hydroponic nutrient solution containing FeCl$_3$
    - Type 2: FeCl$_3$ with DDI
Overall Experimental Setup
Analysis Methods

Harvest

• Roots and shoots
• Cut, separate, and weigh

Dry

• Dry in oven at 50°C for 72 hours
• Reweigh
• Determine moisture content

Ash

• Ash at 450°C for 4 hours

Digest

• Microwave digestion using nitric acid

Analyze

• ICP-MS
Trial Experiments

• Four trial experiments
  - Trucker’s Favorite corn strain
  - Two different types of HP solution: one with FeCl\(_3\) and one without FeCl\(_3\)
  - Observe corn growth in presence and absence of iron
  - Establish foliar fertilization techniques

• The control group and FF spray group should produce similar results
Trial Experiments
Trial Experiments

- Corn was grown for 7 days once placed in HP solutions
- Roots and shoots were measured every day
- After 7 days, roots and shoots were cut, separated, and dried
- Plant tissues will be digested
- Will be analyzed via Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) for magnesium, potassium, calcium, iron, and molybdenum
Trial Experiments - Results

- FF type 1: FeCl$_3$ Hydroponic spray
- FF type 2: 2x FeCl$_3$ + DDI
Trial Experiments - Results
Planned Experiments

- Each experiment conducted twice: once with DFOB in solution and once with citric acid in solution
  - Comparison of two ligands
- Two citrate experiments were conducted based on modeling
- 40 Bq/mL Pu-239
Citrate Experiments

First round results:

$10^6$ [Pu]  

$10^4$ [Pu]
Citrate Experiments

Second round results:

**Median Root Growth**

- Control
- 10[Pu]
- 100[Pu]
- 1000[Pu]

**Median Shoot Growth**

- Control
- 10[Pu]
- 100[Pu]
- 1000[Pu]
Planned Experiments

- Each experiment conducted twice: once with DFOB in solution and once with citric acid in solution
  - Comparison of two ligands

- 4 rounds per experiment:
  
  Round 1 → No plutonium
  Round 2 → High Pu/Low Fe ratio
  Round 3 → High Pu/High Fe ratio
  Round 4 → Low Pu/High Fe ratio
Planned Experiments

Round 1 ➔
No plutonium

Round 2 ➔ High Pu/Low Fe ratio
Future Work

- $^{238}\text{U}$, $^{237}\text{Np}$, $^{232}\text{Th}$ experiments
- Continue to digest and analyze Trial Experiment corn
- Continue primary experiment rounds
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