# UBIQUITOUS SOIL SAMPLING ROBOTS FOR CONFLUENT SOIL MONITORING

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**AIM I**: Design and develop soil swimming robots for soil sensing of the maize plant root and its rhizosphere with an above-ground carrier mobile robot to support large-scale field campaigns.

**AIM II**: Develop the use of the soil robot collective to identify interactions between maize roots and soil water relations at critical plant development time points

**AIM III**: The project will share the impact and scientific findings of this project with the greater scientific community and the public by implementing a coordinated set of activities that engage students, scientists, growers, and the public.

**Scientific Impact:**

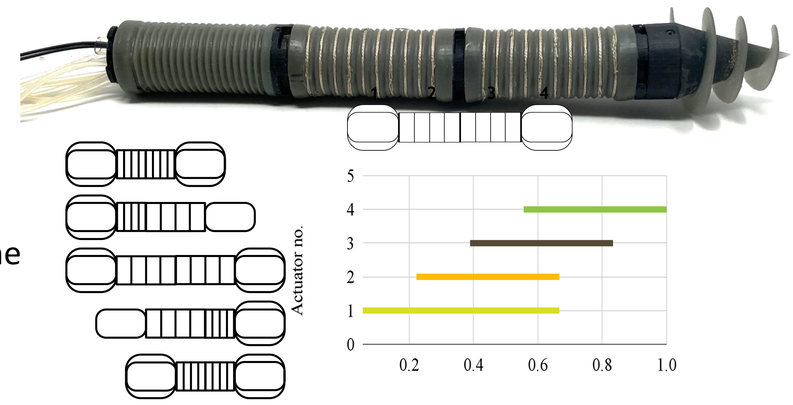
- Transdisciplinary research
- Advanced manufacturing
- Combining Geno, Pheno, and envirotyping
- Rhizosphere phenotyping
- Bigdata on crop breeding

**Key Innovations and New Contributions:**

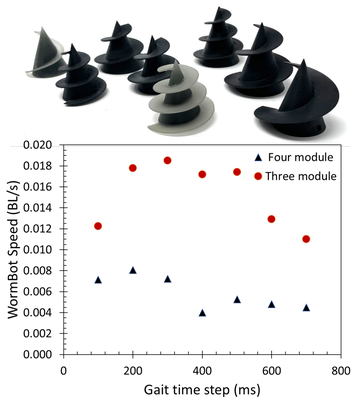
- High powered 3D printed fiber innervated soft actuators
- Spatio-temporal measurement of near-root and bulk soil environment
- Critical aspects of plant breeding, rhizosphere biology, and carbon cycling

**Soft-robotic Earthworm:**

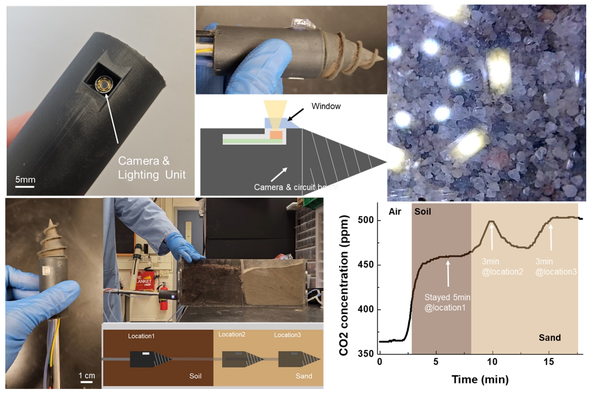
- Inspired by the earthworm,
- WormBot is actuated pneumatically
- Worm locomotion within the soil and on the surface
- Integrated sensors CO2 and vision sensors



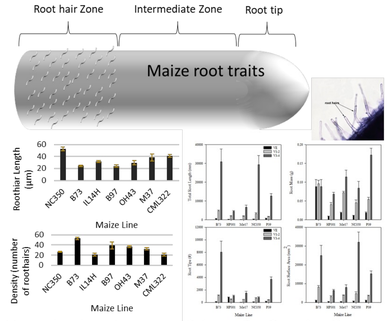

## Robot Speed Curve :




## CO2 and Vision sensing :




## Maize Root Morphology :




Mean values for maize root morphology traits-of, root length, root mass, number of root tips, and root surface area for B73, HP301, Mo17, NC350, and P39 genotypes in each development stage (VE, V1-2, V3-4).

## Root Chemical Phenotyping :

Root chemical phenotyping of five maize genotypes (B73, HP301, Mo17, NC350, P39) in sand at three development stages (VE, V1-2, V3-4).

| Compound | Compound Class | Mode |
|---|---|---|
| Shikimate acid | Phenolic Precursor | Negative |
| Maleic Acid | Phenolic Precursor | Negative |
| Benzoic acid | Phenolic | Negative |
| Phenolic acid | Phenolic | Negative |
| Succinic acid | Carboxylic Acid | Negative |
| Glucose | Sugar | Negative |
| Fructose | Sugar | Negative |
| Sucrose | Sugar | Negative |
| Tyrosine | Amino acid | Negative/Positive |
| Aspartic acid | Amino acid | Negative |
| Leucine/Isoleucine | Amino acid | Negative |
| Glutamic acid | Amino acid | Negative |
| Phenylalanine | Amino acid | Negative |
| Erythrose | Polyol-Sugar | |
| Caffeic Acid | Phenolic Precursor | Positive |
| p-coumarate | Phenolic Precursor | Positive |
| DIMBOA | Benzoxanoid | Positive |
| MBOA | Benzoxanoid | Positive |
| Valine | Amino Acid | Positive |
| Alanine | Amino Acid | Positive |
| Vanillyl alcohol | Benzyl alcohol | Positive |

**Impacts on Society:**

- Growers can directly benefit from crop breeding efficiency and root phenotyping
- Creating dialogue among plant scientists, engineers, growers, and computer scientists

**Education and Outreach:**

- Organizing a workshop on "AgRobotics" at IROS 2023
- Demonstration table at expanding your horizon (EYH 2023)

**Potential Impacts:**

- In situ measurements
- below ground phenotyping
- Genomics to field
- Predictive crop science

2023 FRR & NRI Principal Investigators' Meeting
May 2-3, 2023

Award ID#: