PROJECT DESCRIPTION FOR IOWA SOYBEAN RESEARCH CENTER:

ROOT AND MICROBIOME TRAITS TO TAILOR THE NEXT-GEN SOYBEAN CULTIVARS

AK SINGH AND GA BEATTIE

Soybean suffers from a fundamental flaw in the advancement of the rate of genetic gain because of a limited genetic base. Only 80 (<0.02%) of ~45,000 landraces account for 99% of the collective parentage of North American soybean cultivars, making it extremely challenging to increase yield; moreover, a majority of efforts have been based on improving "what we can see", i.e., the aboveground traits. It is not difficult to see the breeding conundrum: we have been trying to increase yield but technically using only aboveground traits and only a very narrow gene pool.

The root system, the "hidden half", plays a critical role in nutrient uptake and utilization, abiotic stress tolerance, and plant performance. The architecture and functional properties of root systems are determined not only by soybean genetics, but also by root-microbiome interactions and the soil environment, and particularly the availability of water and nutrients. The long-term goal of this project is to identify optimal root traits for soybean yield and productivity through knowledge of the genetic diversity and microbiome interactions influencing soybean root traits. We will pursue two broad objectives:

(I) Integrate sophisticated phenotyping technology and image analysis to study and improve root traits to improve soybean yield and production (AK Singh)

The proposed research will scan hundreds of diverse genetic accessions using both "shovelomics" and creative non-invasive phenotyping systems to explore useful root genetic diversity, and then use genome-wide approaches integrated with computer vision to determine optimal root traits (for example, specific root architecture). We will use the phenotyping platform and computer vision to attempt to relate below- and above-ground traits seamlessly leading to better integration of more useful root diversity in soybean genetic base and screen genotypes for: (a) *root morphological traits*: digital and real-time imaging for root development and root morphological traits to identify the most useful accessions for increased plant efficiency and yield, (b) *nutrient efficiency improvement*: nutrient stress high-throughput phenotyping to identify accessions with tolerance to major nutrient stresses. This will be integrated in our existing soybean cultivar development program.

Tasks: Identify useful genetic diversity in belowground (root) traits through digital imagery and genome-wide studies for increased root performance.

Outcomes: Significant advances in digital phenotyping (2-D and 3-D; temporal scale), genomic and statistical algorithms that will provide us with new ways to study and improve root traits through plant breeding efforts.

(II) Characterize the functional interactions between soybean root microbiomes and root system architecture to improve soybean growth and stress tolerance (GA Beattie)

The proposed research will generate the first high-resolution spatial and temporal maps of a root microbiome, thus advancing beyond the current state-of-the-field in which root microbiomes are mixed and averaged across entire root systems despite potentially highly localized functions. We will examine the functional implications of microbiome changes across this map using meta-transcriptomic data that reflects the microbial activities at the various sites over time. These studies will be done using soybean genotypes representing extremes in root system architecture (e.g., deep vs. shallow structures) and multiple environments to capture genotype x environment x microbiome interaction effects. Lastly, we will explore the impact of target microbes and microbial products in modulating root system architecture, plant growth, and plant stress tolerance using the genotypes and imaging tools generated in Objective I. These studies may yield candidate biologicals for soybean management systems that will complement the cultivar development activities.

Tasks: Characterize the level of compositional and functional specialization between microbiome members and root system sites (e.g., points of lateral root emergence, deep tap root regions), soybean developmental stages, and soil environmental conditions.

Outcomes: Knowledge of target root-microbiome interactions that will help optimize root traits and candidate biologicals for promoting soybean growth and stress tolerance.

Project Start date: Jan 1, 2017
Project End Date: Dec 31, 2018