Nebraska Soybean Board
Year-End Research Findings Report

Please use this form to summarize the practical benefits of your research project and what has been accomplished. Your answers need to convey why the project is important and how the results impact soybean production.

Project Title: Integrating high throughput field phenomics into Nebraska soybean breeding

Contractor & Principal Investigator: Yufeng Ge

Please check/fill in appropriate box: ☐ ***Continuation research project***
☐ ***Year 1 of 3 research project (for example: Year 1 of 2)***

1. ***What was the focus of the research project or educational activity?***

The focus of the research project is to develop high throughput field phenotyping system and to integrate the system into Nebraska soybean breeding program. The specific research aims of 2016 were to (1) Improve and expand the sensing/automation functions of a basic mobile field phenomics system, (2) conduct plant phenotypic measurements in two soybean breeding yield trial fields with the system during the 2016 growing season, and (3) explore the usefulness of the sensor-based phenomic data to enhance breeders' decision-making processes. As can be seen in section 2, we successfully achieved these research aims.

2. ***What are the major findings of the research or impacts of the educational activity?***

First, we successfully designed, developed, and improved the field phenotyping system. The system was consisted of three major components. The first component was a light-weight, flexible, and mobile structure (based on two bicycles put side by side) as the platform. The second component was a multi-sensor system that allowed the collection of sensor-based multi-modal trait measurements from soybean plots. The sensors being employed included RGB cameras (RGB images), NDVI sensors (canopy NDVI), ultrasonic height sensors (canopy height), reflectance spectrometers (canopy reflectance from 500 to 900 nm), infrared radiometers (canopy temperature), high-quality GPS, a solar radiation sensor, and air temperature/relative humidity sensor. The multi-sensor system can measure four plots of soybean simultaneously to maximize the measurement throughput. The third component of system was a custom developed LabVIEW program for sensor control, measurement synchronization, and data storage. Figure 1 to 3 below shows the platform, the sensor suite, and the LabVIEW software.

Figure 1. The high throughput field phenotyping system ready a soybean field for data collection.

*****This form must be completed and submitted with the fourth quarter report.***

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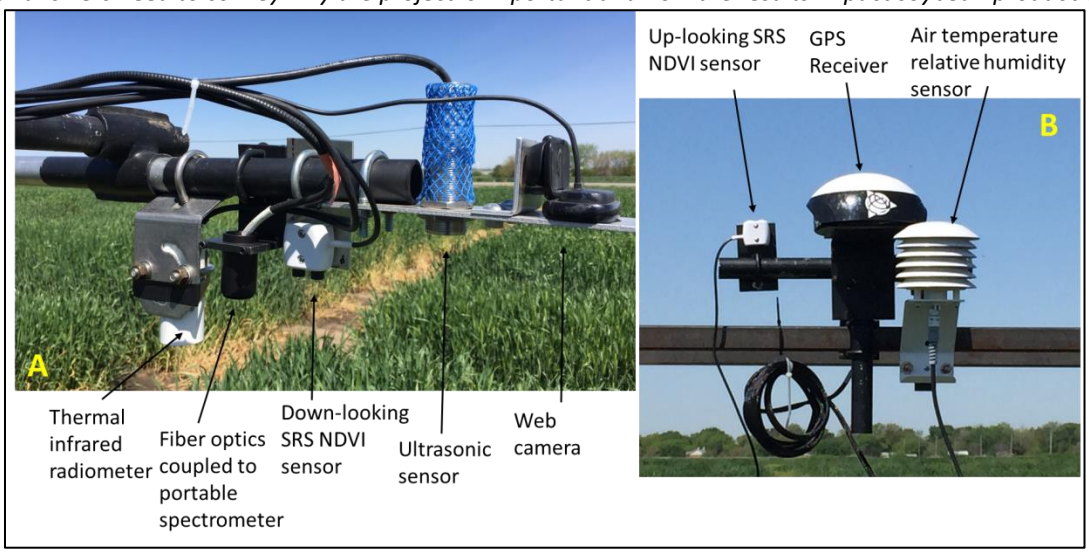

Figure 2. The sensor suite on the field phenotyping system.

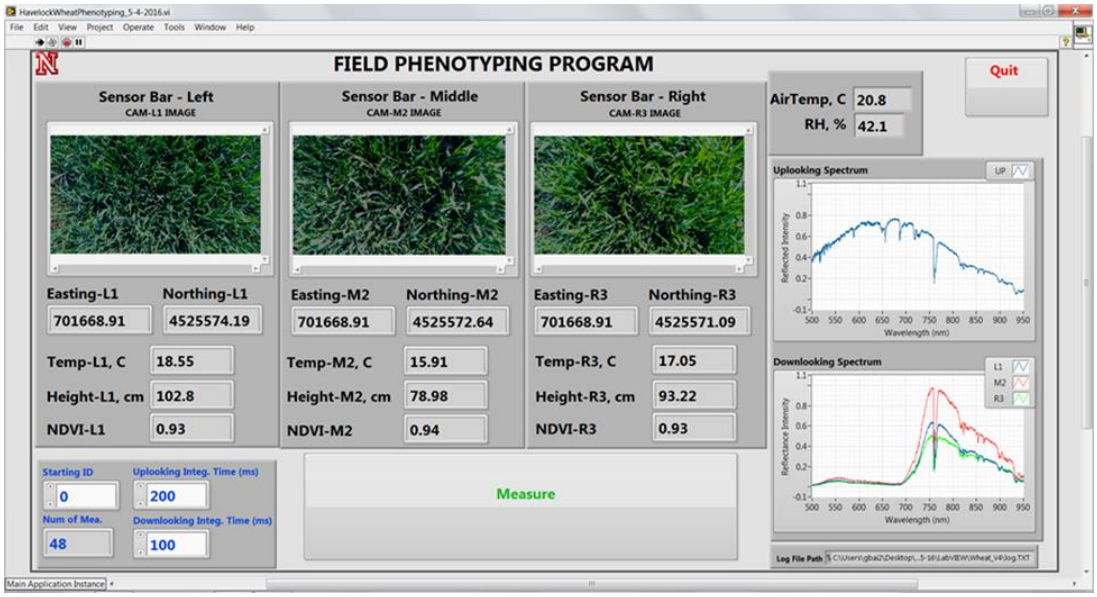

Figure 3. The front panel of the LabVIEW program of the field phenotyping sensor system.

Second, using the developed field phenotyping system, we collected field data from soybean plots at five different locations representing four studies (drought, nitrogen use, germplasm, and iron deficiency chlorosis). In this season, we collected sensor data from nearly 6500 field plots. Field access and data collections were coordinated with Dr. George Graef's breeding program. Table 1 below summarizes the field data collection activities in this season; and Figure 4 are some example pictures taken during the field activity with the field phenotyping system.

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Table 1. Summary of the field data collection activities with the high throughput field phenotyping system in 2016.

Experiments	Location	Early-season scan dates (V4-V5)	Late-season scan dates (R5)	Plot scanned (approximately)
Drought study	Mead	Jul/6, Jul/8	Aug/19, Aug/29	800
	Clay center	Jun-21	Aug/15	600
	Wymore	Jul/10	Aug/17	500
	Cotesfield	Jun/23, Jun/24	NA	600
Nitrogen study	Mead	Jul/6, Jul/8	Aug/19, Aug/29	650
	Clay center	Jun/21	Aug/15	600
	Wymore	Jul/10	Aug/17	500
	Cotesfield	Jun/23, Jun/24	NA	800
Germplasm study	Mead	Jul/6, Jul/8	Aug/19, Aug/29	800
IDC study	Valley	Jul/12 (V5)		520

Note: Cotesfield in the late-season was not possible because the field there was damaged by storm and thus limited the field accessibility.

Figure 4. Pictures taken for several field phenotyping data collection campaigns. Upper Left: Cotesfield Jun-23. Upper Right: Valley Jul-12. Lower Left: Wymore Aug-17.

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Third, we have started analysis of the data collected from the IDC study. It became obvious to us that images collected by the field phenotyping system can assist in the scoring of the IDC severity among the testing lines. We developed algorithms to automatically extract the hue component of soybean leafs and that is highly correlated with the manual score by an experienced researcher. We will continue to do data analysis when more yield and yield component data from different experiments become available to us.

Figure 5. Examples of using the RGB images collected from the high throughput phenotyping to assist in soybean IDC scoring. "Computer Score" means an experienced researcher sitting in front of the computer screen and do the score with the images. "Algorithm Score" means automated scoring based on the image processing algorithm.

3. Briefly summarize, in lay terms, the impact your findings have had, or will have, on improving the productivity of soybeans in Nebraska and the U.S.

Breeding programs are now relying more and more on genomic data to make selection decisions to improve genetic gain and potentially shorten breeding cycles. However, the potential of genomic data cannot be fully realized until meaning plant phenomic data can be generated, analyzed, and used. It is believed that integrating high-throughput phenomics will enable better utilization of both phenotype and genotype information and greatly improve the breeding efficiency, whether the goals are for yield enhancement, quality improvement, water/nitrogen use efficiency, or resistance to specific pests or diseases in targeted Nebraska environments. Therefore, this project will benefit all Nebraska soybean growers, by establishing more efficient soybean breeding programs to deliver superior varieties that meet growers' specific needs, or through shortening the time needed for cultivar development. In the long run, this research would enhance the growers' income and their overall competitiveness in the national and international markets.

4. Describe how your findings have been (or soon will be) distributed to (a) farmers and (b) public researchers. List specific publications, websites, press releases. etc.

Peer-reviewed Publication:

Bai, G., Ge, Y., Hussain, W., Baenziger, P.S., Graef, G., 2016. A multi-sensor system for high throughput field phenotyping in soybean and wheat breeding. Computers and Electronics in Agriculture 128, 181-192.

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Presentation made at Annual International Meeting of American Society of Agricultural and Biological Engineers (July 17-20, Orlando FL).

Bai, G., He, X., Ge, Y., 2016. Field phenotyping system in support of plant breeding programs in Nebraska.

5. Did the NE soybean checkoff funding support for your project leverage any additional state or Federal funding support? (Please list sources and dollars approved.)

Yes. The NE soybean checkoff funding support allowed us to generate preliminary data and important concepts and design/development of the field phenotyping platform that lead to these following additional federal funding supports:

(1) Daniel Schachtman and Yufeng Ge. Genomics and phenomics to identify yield and drought tolerance alleles for improvement of camelina as a biofuel crop. Sponsor: USDA-NIFA (DOE USDA Plant Feedstock Genomics for Bioenergy Joint Program). 09/2016 – 08/2019. Collaboration with USDA-ARS at Maricopa AZ and Danforth Plant Science Center. Total award is $1,000,000. UNL's share is $288,000.

(2) Yufeng Ge, James Schnable, Sibel Irmak, Jian Jin. Accelerating improvement of biomass sorghum as biofuel feedstock via high throughput phenotyping. Sponsor: USDA-NIFA (North Central Sun Grant Program). 09/2016-08/2018. Collaboration with Purdue University. Total award is $150,000.

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