MISSISSIPPI SOYBEAN PROMOTION BOARD
PROJECT 47-2018
2018 ANNUAL REPORT

Project Title: Ultra-Low Altitude Plant Sensing Through Unmanned Aerial Vehicles with Portable Hyperspectral Imagers for Detection of Glyphosate-Resistant and Susceptible Weeds in Soybean Fields

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ANNUAL REPORT OF PROGRESS/ACTIVITIES

Repetitive and intensive use of glyphosate has exerted a high selection pressure on weed populations, resulting in the evolution of 37 glyphosate-resistant (GR) weed species in the world. Ten species of GR weeds have appeared in Mississippi. Of these 10, a number are troublesome in soybean fields. Hyperspectral plant sensing techniques have been developed to effectively detect GR and glyphosate-susceptible (GS) weeds in soybean fields. However, in-field hyperspectral plant sensing is still time-consuming and laborious because the current sensors are either operated on a slow-moving tractor for imaging certain areas in the field, or handheld by a technician to measure canopy spectra at certain points in the field. This tedious manner of hyperspectral data acquisition is an obstacle for us to extend the research results to practical uses.

Remote sensing technology on unmanned aerial vehicle (UAV) has a great potential for precision crop management with ultra-high spatial resolution (a few centimeters to millimeters per pixel) imagery through the flight at ultra-low altitudes (tens of meters to a few meters). Therefore, a portable hyperspectral sensor mounted on a small UAV has the potential to overfly a soybean field and quickly determine the distribution of weeds, including GR and GS weeds. This information can be provided in a timely manner for Mississippi soybean producers and consultants to improve their site-specific weed management.

This project continues the effort started last year. The first year effort determined optimal flight altitude of UAV for detection of naturally-occurring GR weeds in soybean fields, and also identified limits of the spectral imaging systems. The goal of this second year is to further develop and improve UAV-based hyperspectral remote sensing techniques for rapid, consistent, and accurate differentiation between GR and GS weeds at the field scale. The target weeds will be Palmer amaranth (*Amaranthus palmeri* S. Wats.) and/or Italian ryegrass (*Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot), whichever weeds are naturally occurring in research soybean fields. The long term outcome for this research is a set of guidelines for how UAVs and hyperspectral sensors can be used by soybean producers and consultants to effectively identify different GR weeds in soybean fields.

OBJECTIVES:

1. To fly UAVs over the research soybean field to characterize the hyperspectral reflectance properties of

detected GR and GS weeds.
2. To classify GR and GS weeds from the hyperspectral data acquired from soybean fields.
3. To map the distribution of GR and GS weeds over the soybean fields based on the results of classification.
4. To evaluate technical and economic feasibilities of UAV imaging systems for detection of GR and GS weeds in practical soybean production.

PROGRESS:

Objective 1. To fly UAVs over the research soybean field to characterize the hyperspectral reflectance properties of detected GR and GS weeds.

As the summer of 2017, in the summer of 2018, an 800-ft 16-row stripe on the side of the 11-acre soybean field with naturally occurred weeds were imaged by a new Micasense Rededge-M multispectral camera flied on a DJI Phantom 4 Pro drone. This system provides images in near infrared, red edge, red, green and blue bands. Mississippi State University flied the field with HeadWall Hypercube on DJI Matrice 600 Pro for hyperspectral images. Based on the experiments last year this year we flied 20m or high to ensure the quality of the images.

This year we have ran three tests:

1. Spray 8 rows Liberty and 8 rows Roundup over Liberty Link beans (planted on May 2) on June 4, 2018. Imaging was conducted before and after spray
2. Spray 16 rows 1X (X=22 oz ai/ac) Roundup over Roundup Ready beans (planted on June 18) on 6-28-2018. Imaging was conducted before and after spray
3. Spray 8 rows 2X and 8 rows 4X Roundup over Roundup Ready beans on July 6, 2018. Imaging was conducted before and after spray

Objective 2. To classify GR and GS weeds from the hyperspectral data acquired from soybean fields.

Besides multispectral imaging hyperspectral imaging was conducted for tests 2 and 3, respectively as shown in the figure 1. The hyperspectral images will be further processed to extract the features of the GR and GS weeds.

Figure 1. Hyperspectral UAV images for test 2 and 3, respectively.

After image processing we got color-infrared drone images for each tests and labeled the GR and GS weeds with image classification (Figure 2).

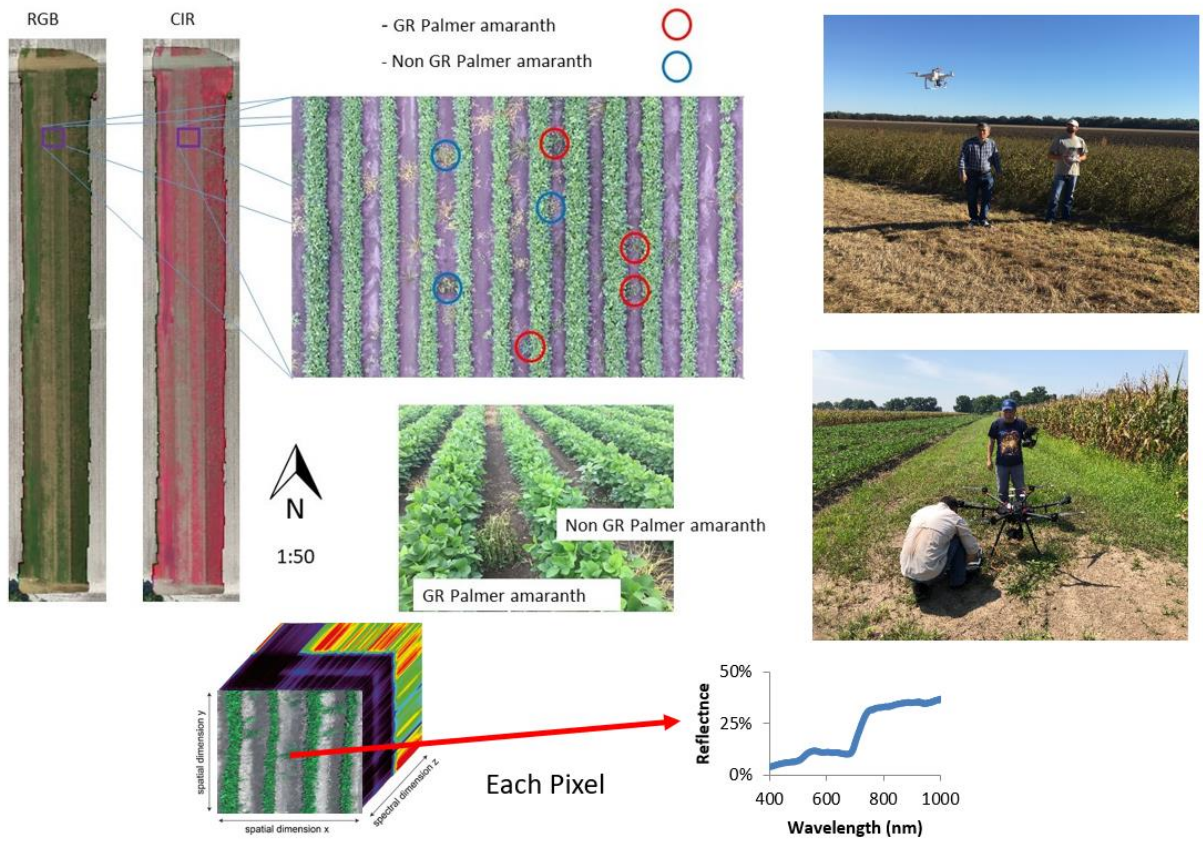

Figure 2. GR and GS image labels based on image classification of the UAV images for each test.

Objective 3. To map the distribution of GR and GS weeds over the soybean fields based on the results of classification.

With image classification labels the field was mapped with images for each test (Figure 3).

Figure 3. UAV image maps for GR and GR weed distribution for each test (conducted at the black rectangle enclosed area).

Objective 4. To evaluate technical and economic feasibilities of UAV imaging systems for detection of GR and GS weeds in practical soybean production.

Based on our tests and evaluation we concluded that UAV imaging is a technique which is feasible both technically and economically for detection GR and GS weeds for practical soybean production. Although hyperspectral imaging is a relatively expensive technique, as long as sensitive bands were determined from hyperspectra, inexpensive multispectral imaging can be used to conduct high-throughout scan over a quite large area of soybean fields. Actually, this year, although MSPB grant expired, we still repeated the experiment like last two years to run over the same 800-ft 16-row area on the west side of the 11-acre soybean field with naturally occurring weeds. The area were directly imaged by a Parrot Sequoia

multispectral camera flied on a DJI Phantom 3 Pro drone before and after Roundup spraying. This system provides images in near infrared, red edge, red and green blue bands to compare and verify the performance of the system.