MISSISSIPPI SOYBEAN PROMOTION BOARD
PROJECT NO. 68-2016 (YEAR 2)
2016 FINAL REPORT

TITLE: Detection of glyphosate-resistant and susceptible weeds through hyperspectral plant sensing in soybean fields

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BACKGROUND AND OBJECTIVES

Although Glyphosate [*N*-(phosphonomethyl) glycine] is the most widely used herbicide in both frequency and amount applied to fields planted with glyphosate-resistant (GR) soybean, its repeated and intensive use has exerted a high selection pressure on weed populations. This has resulted in the evolution of GR weeds.

GR Italian ryegrass (*Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot) is a troublesome weed in soybean. Italian ryegrass is an erect winter annual with a biennial-like growth habit. It grows vigorously in winter and early spring and is highly competitive. GR Italian ryegrass populations could seriously jeopardize preplant burndown options and planting operations in reduced-tillage soybean crop production systems of Mississippi.

Use of glyphosate cannot control GR Italian ryegrass field populations. The GR and glyphosate-susceptible (GS) Italian ryegrass plants look alike; thus it is impossible to visually distinguish GR plants from GS plants. The objective of this project is to develop hyperspectral imagery-based remote sensing technology for rapid, consistent, and accurate differentiation of GR and GS Italian ryegrass plants in soybean fields. The results of this project will provide guideline data that will allow soybean producers and consultants to effectively deal with GR Italian ryegrass and other GR weeds in soybean fields.

The results from this project in the past year indicated that the spectral reflectance of field-grown GR Italian ryegrass was significantly different from the spectral reflectance of field-grown GS Italian ryegrass. The overall classification accuracy between greenhouse-grown GR and GS Italian ryegrass was equal to or higher than 75%. Therefore, we conducted the 2016-2017 project to see if these positive results for distinguishing GR Italian ryegrass are transferrable to other GR weed species such as Palmer amaranth and Johnsongrass.

Objectives.

1. To characterize and summarize the hyperspectral reflectance properties of GR and GS Italian ryegrass, Palmer amaranth, and Johnsongrass.
2. To assess the classification accuracy of an unknown set of GR and GS weeds (test set) using the model built from a known set of GR and GS weeds (training set).
3. To evaluate the results from the experiments to optimize the number of bands and to determine consistent principal wave bands.

PROGRESS

Objective 1 – A greenhouse experiment was conducted to characterize the hyperspectral reflectance properties of GR and GS Italian ryegrass plants with different doses of glyphosate sprays and the hyperspectral imaging and plant dry-weight measurements at 4, 24 and 48 HAT (hours after treatment), and 1 and 3 WAT (weeks after treatment). Hyperspectral imaging was conducted in a lab in the greenhouse using Pika II hyperspectral imager (Resonon, Bozeman, MT) (Fig. 1). The purpose of the experiment was to compare the methods of hyperspectral remote sensing and biological determination of ED50 (median effective dose) of GR and GS Italian ryegrass. However, the plant image segmentation program we made before was not working properly for the present data we collected due to strong optical reflection of soil background in the plant pots. The work is underway to migrate the program to process the data set properly.

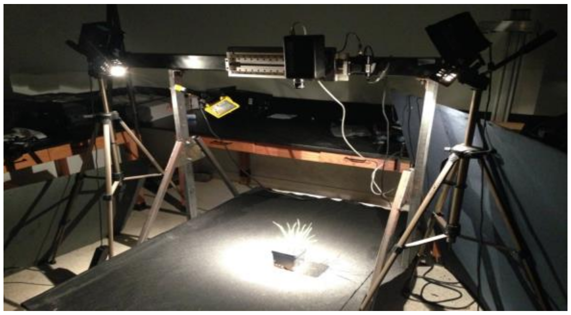

Figure 1. Pika II hyperspectral imaging of Italian ryegrass

An outdoor experiment was also conducted to differentiate greenhouse-grown GR and GS Johnsongrass using a handheld spectroradiometer (ASD Inc., Boulder, CO) (Fig. 2). The hyperspectral measurements were conducted 3, 4 and 5 WAE (weeks after plant emergence). For the experiment, 64 Johnsongrass plants, 32 GR and 32 GS, were prepared and measured. At 5 WAE the plants were imaged with the Pika II hyperspectral imager and measured with the SPAD meter (Konika Minolta Sensing, Inc., Sakai, Osaka, Japan) for readings of relative chlorophyll of the plants. The collected data are being processed.

Figure 2. ASD hyperspectral measurement of greenhouse-grown Johnsongrass under the sun light.

Objective 2 – The maximum likelihood classification was conducted for plant sample differentiation with greenhouse-grown and field-grown GR and GS Palmer amaranth and Italian ryegrass. Tables 1-4 show the classification accuracies of greenhouse-grown and field-grown GR and GS Palmer amaranth and greenhouse-grown Italian ryegrass. Fig. 3 shows the hyperspectral curves of field-grown GR and GS Italian ryegrass. The results indicated that hyperspectral data can be used to differentiate GR and GS Palmer amaranth and Italian ryegrass, although the accuracy of Palmer amaranth classification is fairly higher than Italian ryegrass because Palmer amaranth has much broader leaves than Italian ryegrass (Fig. 4).

Confusion matrix of Palmer amaranth greenhouse study for classification validation

Palmer amaranth	Plant Number	Classification		Accuracy
		GR	GS	
GR	25	23.5	1.5	94%
GS	22	1.4	20.6	94%
Overall				94%

Confusion matrix of Palmer amaranth field study for classification validation

Palmer amaranth	Plant Number	Classification		Accuracy
		GR	GS	
GR	63	61	2	97%
GS	63	2	61	97%
Overall				97%

Confusion matrix of Italian ryegrass greenhouse study for classification validation

Italian ryegrass	Plant Number	Classification		Accuracy
		GR	GS	
GR	30	24.3	5.7	81%
GS	27	5.6	21.4	79%
Overall				80%

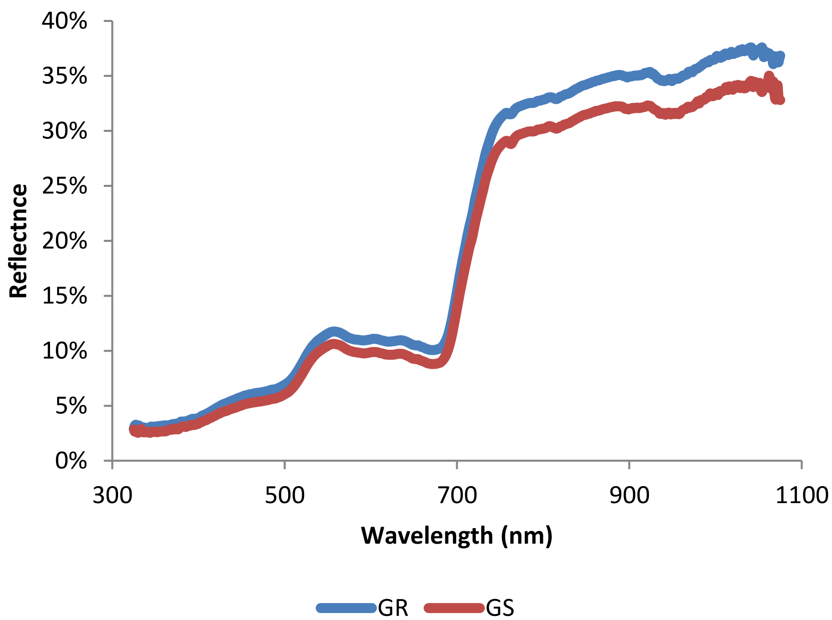

Figure 3. Hyperspectral curves of GR and GS Italian ryegrass from field measurements.

Palmer amaranth Italian ryegrass

Figure 4. Plant leaf comparison of Palmer amaranth and Italian ryegrass.

Objective 3 – To optimize the number of bands and to determine consistent principal wave bands, more classifications were run at other WAEs for Palmer amaranth and Italian ryegrass. Graphs of histogram and cumulative percentage of the occurrence of the selected bands are shown as in Fig. 5.

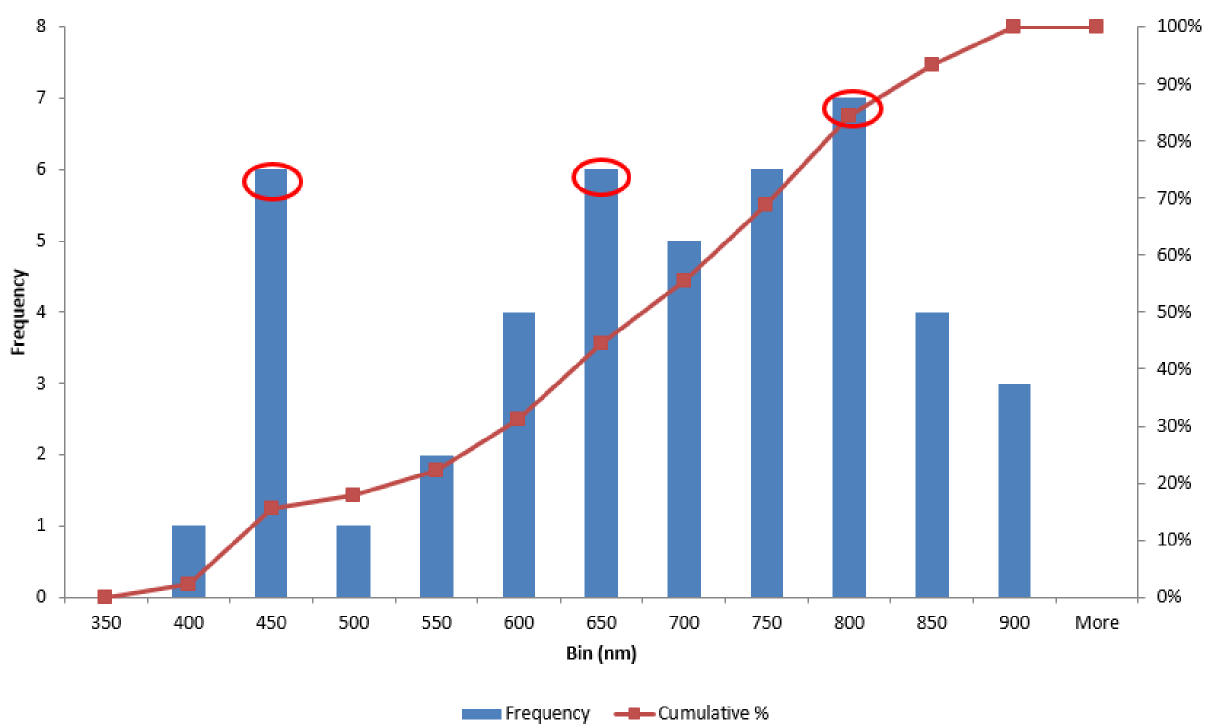

Figure 5. Histogram and cumulative percentage of the occurrence of the selected bands from the hyperspectrums of Palmer amaranth and Italian ryegrass.

The graphs show the wavelength distribution for detection of GR and GS Palmer amaranth and Italian ryegrass and the principal bands are around 450 nm, 650 nm, and 800 nm. This information is important for simplification of the sensor system in order to develop a portable multispectral device which is inexpensive for farmers to use in the field, with further validation through meta-analysis of more band selection data.

IMPACTS AND BENEFITS TO MISSISSIPPI SOYBEAN PRODUCERS

We characterized the hyperspectral reflectance properties of GR and GS Palmer amaranth and Italian ryegrasss and evaluated the accuracy of the classification models and optimized the selected wavelengths to provide band information for further development. Similar work for Johnsongrass is underway. The positive results from this project confirm that the success on GR Italian ryegrass is transferrable to other GR weed species such as Palmer amaranth and possibly later for Johnsongrass. The completion of this study provides solid information for design and development of a portable optical device which is inexpensive for farmers to use to rapidly detect populations of GR and GS weeds in soybean fields.

END PRODUCTS

A measuring protocol and selected and optimized wave band information for rapid differentiation of greenhouse- and field-grown GR and GS weeds which are common in soybean fields. Papers are being prepared to present at the coming weed science and agricultural engineer societies' meetings.