Digital Imaging Technology to Classify Herbicide-Resistant and Susceptible Kochia (*Bassia scoparia*)

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INTRODUCTION

- Kochia (*Bassia scoparia*) is an invasive weed species that can cause high yield losses in some major field crops [1].
- Herbicides are the primary method being used to control kochia [1].
- New techniques to recognize herbicide-resistant from susceptible kochia biotypes could be highly useful for site-specific weed management strategies [2].
- Digital imaging and AI technology can perform various functions via utilizing advanced sensing systems and data analytics [2, 3].
- By combining different sensing systems, it is possible to characterize weed growth parameters at high spatial, spectral, and temporal resolution [2, 3].

OBJECTIVES & HYPOTHESIS

- Identification of herbicide-resistant and susceptible weed biotypes (e.g. kochia) prior to in-crop herbicide application.
- Potential of digital imaging tools (RGB and hyperspectral sensors) and machine learning (ML) algorithms to differentiate herbicide-resistant and susceptible weeds.

MATERIALS AND METHODS

Samples and System Setup:

- The experimental trials were performed in an indoor greenhouse. We assessed spectral imaging technologies for discrimination of kochia with and without resistance to glyphosate or fluroxypyr.
- Two different sensors were evaluated simultaneously, including high spectral resolution-based hyperspectral imaging (HSI) and high spatial resolution-based low-cost Raspberry Pi (RPi) cameras.

Experimental Equipment:

- The proximal hyperspectral images (204 channels) of experimental kochia plants were collected on multiple days using the Specim-IQ® camera system (397nm-1003nm wavebands) under standardized light conditions (**Fig. 1**).
- An array of Raspberry Pi (RPi) computers (**Fig. 2**) was deployed on the shelving units to regularly monitor kochia plants characteristics throughout the experimental cycle (**Fig. 3**).

Fig. 1 Specim-IQ® HSI sensor

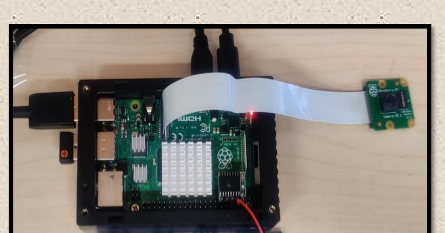

Fig. 2 Raspberry Pi (RPi) camera

Fig. 3 Greenhouse experimental setup of kochia plants

MATERIALS AND METHODS

Imagery Data Collection and Processing:

- Kochia plants were treated with glyphosate (Roundup WeatherMAX®, Bayer CropScience, 900 g ae ha^{-1}) or fluroxypyr (Prestige™ XCA, Corteva Agriscience, 140 g ae ha^{-1}) using a moving-nozzle cabinet sprayer when they reached 5-8 cm in height.
- Hyperspectral images of the kochia plants were obtained immediately prior to the herbicide treatment (baseline) along with 1, 3 and 7 days after treatment (DAT).
- Individual kochia plants were annotated using *Label Studio* to extract reflectance. The temporal spectra were randomly split into training and test datasets at 80:20 ratio for ML model development.
- The RPi computers were integrated with imaging sensors (Sony 8MP). The units were programmed to capture multiple images at a fixed time interval (~4hrs) throughout the experimental cycle.
- The RGB bands proved sufficient information to extract three prominent attributes as, Green leaf index (*GLI*), plant density (*D*) and foliar area (*Fa*).

Fig. 4 HSI camera system to measure kochia plants reflectance data

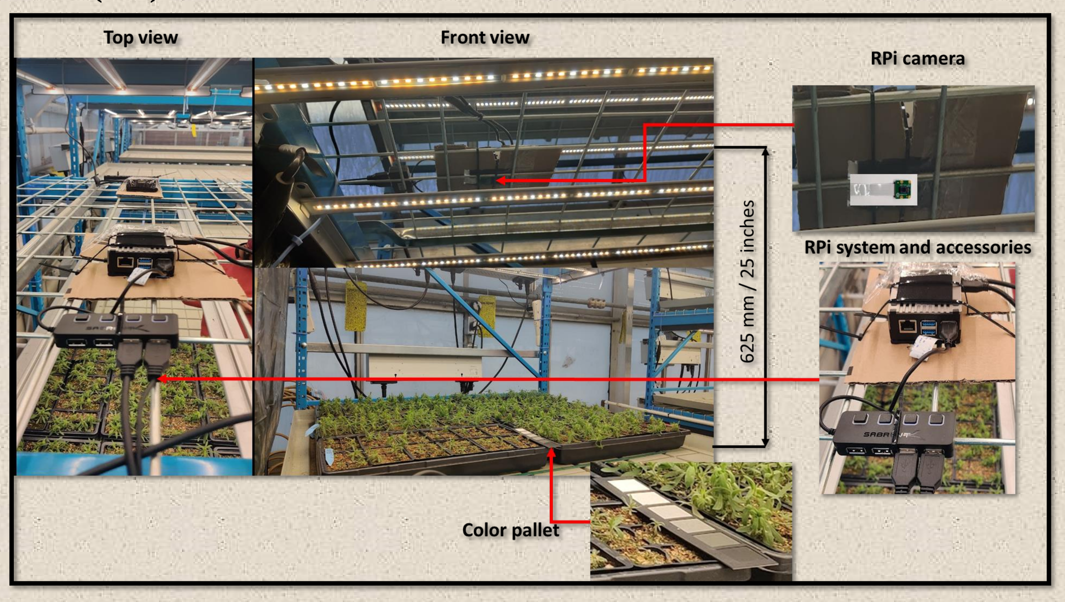

Fig. 5 RPi computers setup in the greenhouse over kochia planted tray

PRELIMINARY RESULTS AND ANALYSIS

Hyperspectral Results:

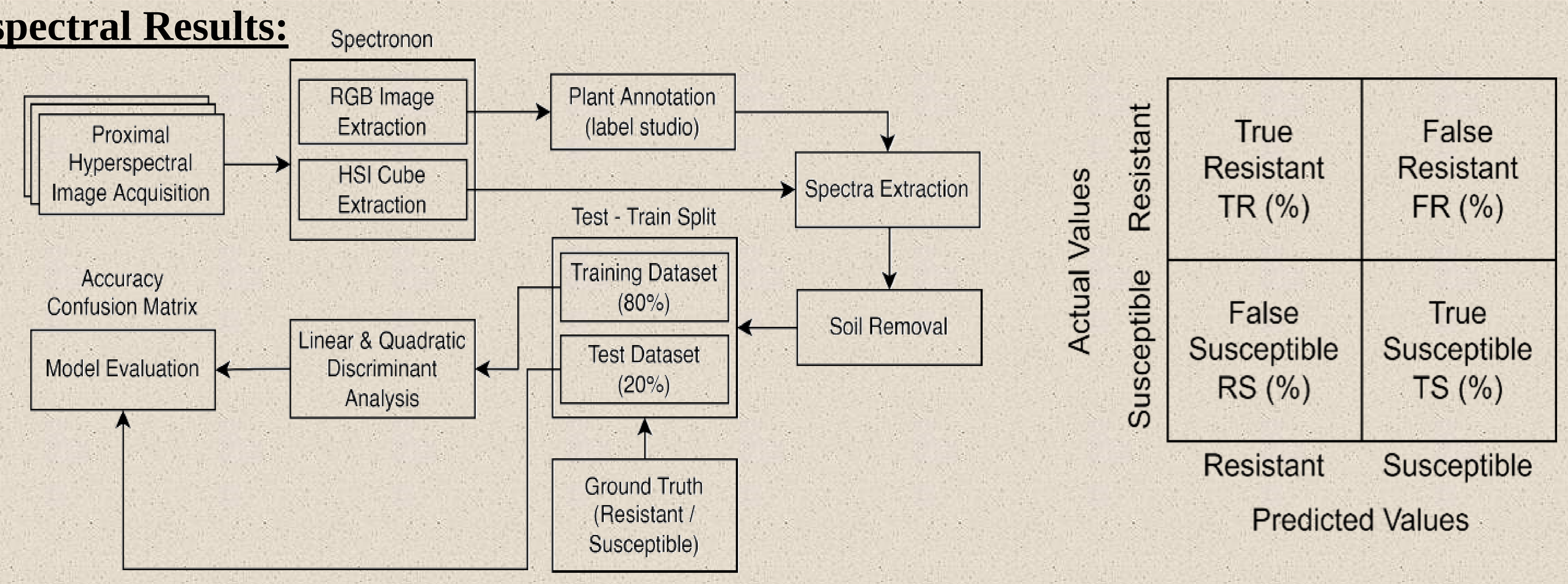

Fig. 6 Schematic representation of the hyperspectral data analysis workflow (left) and Confusion matrix (right)

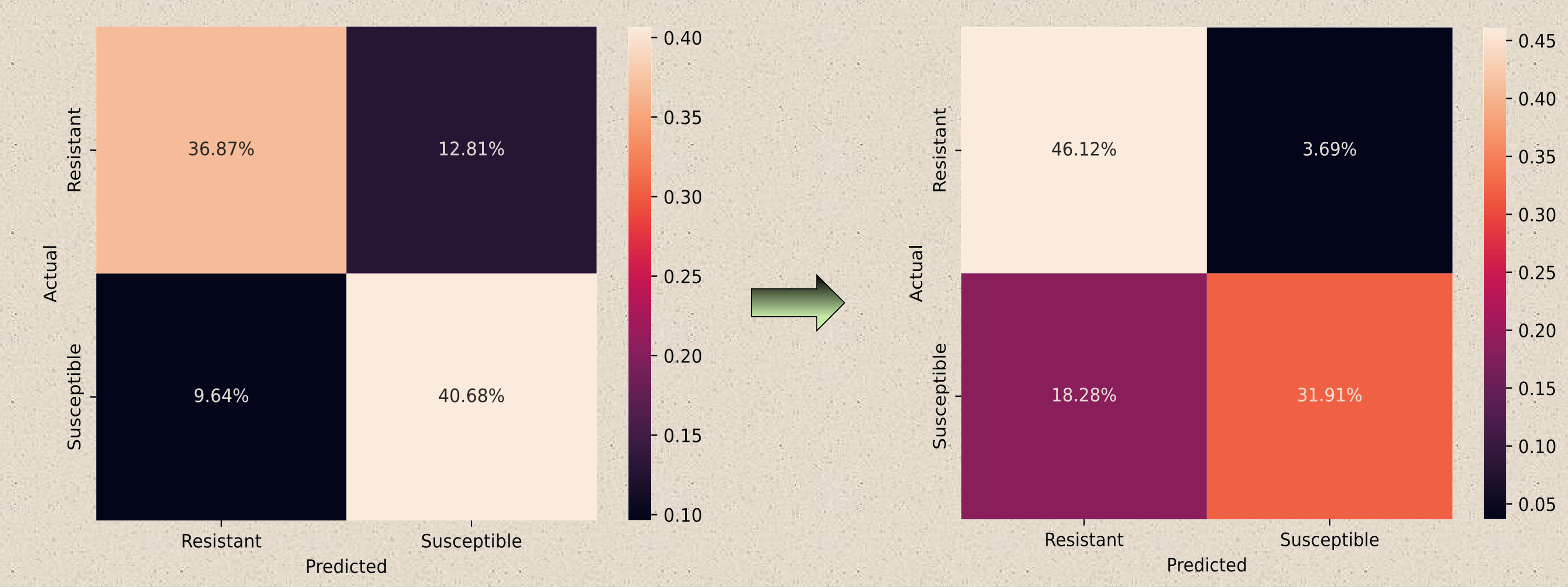

Fig. 7 Confusion matrices by active ingredients (*glyphosate*), before (left) and after (right) treatment

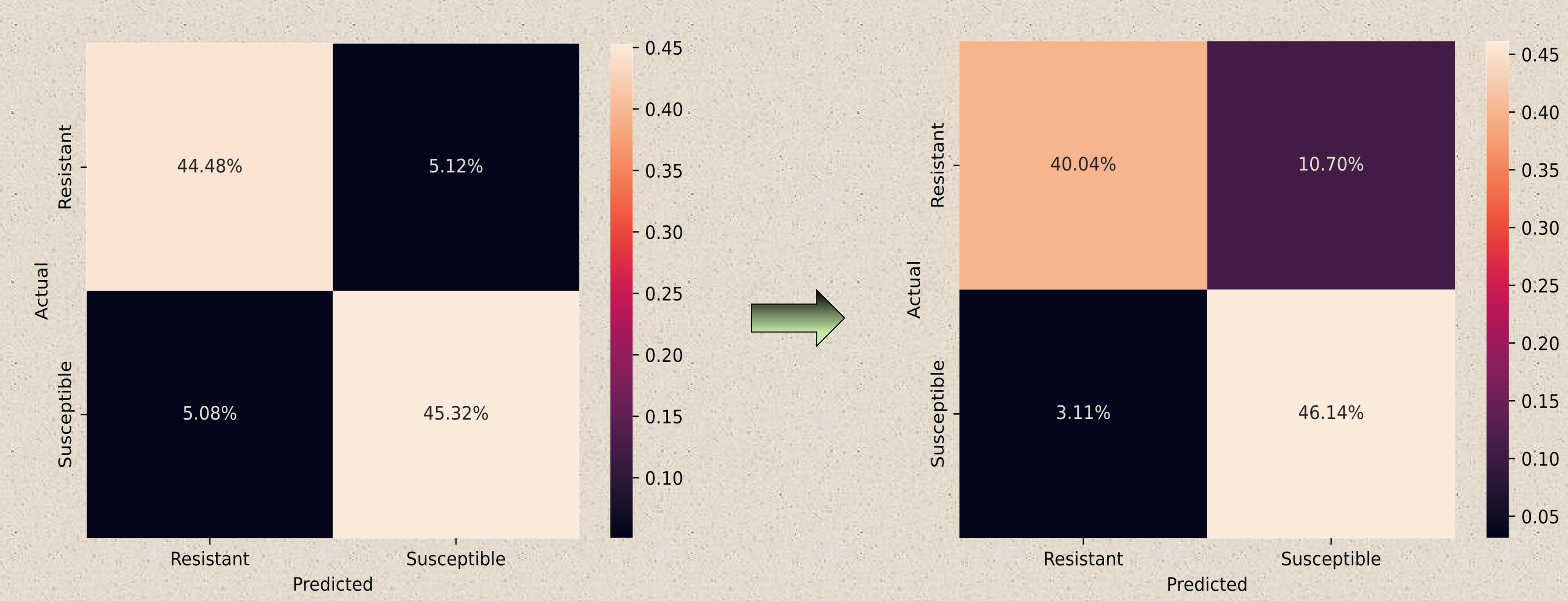

Fig. 8 Confusion matrices by active ingredients (*fluroxypyr*), before (left) and after (right) treatment

Methods	Classification Accuracy	Experimental Trial 1 & 3 (Glyphosate) Before treatment (%)	Experimental Trial 1 & 3 (Glyphosate) After treatment (%)	Experimental Trial 2 (Fluroxypyr) Before treatment (%)	Experimental Trial 2 (Fluroxypyr) After treatment (%)
LDA	Training	78.61	73.86	83.14	84.55
	Test	79.39	73.94	83.06	84.48
QDA	Training	76.04	77.70	90.33	86.05
	Test	77.54	78.03	89.79	86.18

Table 1 Training and test classification accuracies for LDA and QDA models developed

- The training dataset was used to train Linear Discriminant Analysis (LDA) and Quadratic Discriminant Analysis (QDA) models using a 10-fold cross-validation technique.
- The QDA models performed better than their linear counterparts. The QDA model achieved a classification accuracy of 77.54–78.03% for glyphosate and 86.18–89.79% for fluroxypyr.

RPi Results:

Fig. 9 RPi image processing and analysis workflow, **(a)** RPi raw image, **(b)** Background removal, **(c)** Automatic plants identification, **(d)** Plant clustering, **(e)** Individual plant extraction, **(f)** Extracted single plant

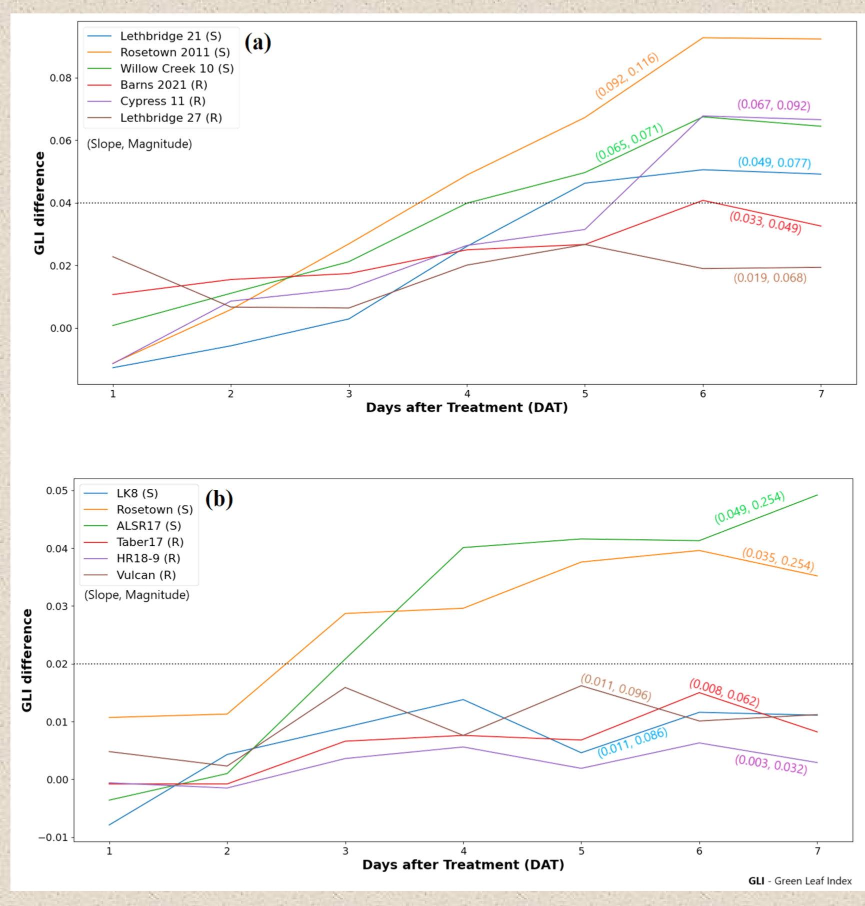

Fig. 10 RPi sensor based GLI difference among kochia population, **(a)** GLI difference from the untreated control (*glyphosate*), **(b)** GLI difference from untreated control (*fluroxypyr*)

DISCUSSION AND CONCLUSIONS

- The model results indicated that the hyperspectral imaging is a promising approach to distinguish resistant from susceptible kochia biotypes.
- The RPi-based greenness leaf index (*GLI*) difference of stressed plants (susceptible) from their untreated control are higher than that of healthy plants (resistant).

FUTURE RESEARCH

- It is essential to identify new resistant biotypes that could be managed by alternative herbicides.
- We are running glyphosate and fluroxypyr experimental trials with more population. This will help to make the model robust and versatile in predicting across wider complex populations.

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ACKNOWLEDGEMENTS

The authors thank *Mattea Pittman* and *Dr. Hongquan Wang* from Lethbridge Research and Development Centre (AB) for providing consistent support during this study. This research was funded by ***Western Grains Research Foundation (WGRF)***, Saskatoon, SK.

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