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Research Paper

In-situ plant hyperspectral sensing for early detection of soybean injury from dicamba

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Drift of dicamba onto non-target crops is a major concern because it is highly active on susceptible crops even at low doses. Early detection of crop injury is critical in crop management. A field study was conducted to determine spectral characteristics of soybean (Progeny P4819LL) treated with dicamba. Drift deposition of dicamba was simulated by direct application at 0.05 to 1.0 times of the recommended label rate (0.56 kg [ai] ha^{-1}) to soybean at the 5- to 6-trifloliolate leaf stage, approximately 6 weeks after planting. The canopy spectral measurements were taken at 24, 48, and 72 h after treatment (HAT) using a portable spectroradiometer in the 325–1075 nm spectral range on 3 randomly selected plants within each plot with device optimisation and data calibration. The results indicated that it was difficult to clearly differentiate the dose response of soybean to different dicamba spray rates within 72 HAT. Regardless of spray rates the soybean treated with dicamba could be clearly differentiated from untreated soybean from 24 to 72 HAT through spectral vegetation index analysis with anthocyanin reflectance and photochemical reflectance indices with accuracies at 24, 48, and 72 HAT ranging from 76 to 86%. Simulated dicamba drift injured soybean and reduced its yield by 71 and 90% at 0.05 and 0.1 times recommended rate, respectively. This study demonstrated that hyperspectral remote sensing has a potential in early detection of soybean injury from exposure to off-target dicamba drift at sub lethal rates in the field.

1. Introduction

Dicamba (3, 6-dichloro-2-methoxybenzoic acid), an auxinic herbicide used for control of several broadleaf weeds in grain crops. Several broadleaf weeds, especially pigweeds (*Amaranthus* spp.), have evolved resistance to glyphosate, a widely used herbicide in glyphosate-resistant crops. Dicamba-tolerant (DT) soybean and cotton are currently under

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Nomenclature

Abbreviations

ANOVA	analysis of variance
DT	dicamba-tolerant
GR	glyphosate-resistant
HAT	hours after dicamba treatment
NIR	near-infrared
USDA	United States Department of Agriculture
VI	vegetation index
VNIR	visible-near infrared
WAT	weeks after dicamba treatment

Vegetation indices

ARI	anthocyanin reflectance index
CARI	chlorophyll absorption ratio index
NDVI	normalised difference vegetation index
PRI	photochemical reflectance index
SIPI	structural independent pigment index
TVI	triangular vegetation index
WI	water index

development, and when they are commercialised, dicamba can be used in these crops to manage broadleaf weeds resistant to glyphosate. However, the off-target drift of dicamba could cause severe injury to non dicamba-tolerant crops. In January 2015, the USDA (United States Department of Agriculture, Washington DC, USA) announced deregulation of Monsanto Roundup Ready 2 Xtend™ soybean (Monsanto Company, St, Louis, MO, USA), which is the first industrial biotech-stacked soybean trait with tolerance to dicamba and glyphosate herbicides, and Bollgard II® XtendFlex™ cotton, which is the first triple stack herbicide-tolerance technology in cotton, with tolerance to dicamba, glyphosate, and glufosinate herbicides. Although the launch of DT trait cotton and soybean is still pending approval of new dicamba formulations by US EPA (U.S. Environmental Protection Agency, Washington DC, USA), off-target dicamba drift from routine use in DT crops onto susceptible crops is a concern. In the state of Mississippi, there was one dicamba drift complaint in each of 2012 and 2013 (Source: John Campbell, Bureau of Plant Industry, Mississippi Department of Agriculture and Commerce). It can be anticipated that with the adoption of DT crops, the complaints of off-target drift of dicamba may increase significantly.

For effective weed management, the detection and assessment of crop injury from herbicides are required. Conventionally, the detection and assessment were conducted through field sampling and measurement of plant biological responses to spray amount. However, such methods are tedious and labour-intensive endeavours. Remote sensing technology has been widely developed and applied in agriculture (Huang & Thomson, 2015; Huang, Thomson, Lan, & Maas, 2010; Pinter et al., 2003) and can provide a rapid, cost-effective method for detecting and assessing crop injury caused by herbicide drift. Henry, Shaw, Reddy, Bruce, and Tamhankar (2004) indicated that a number of vegetation indices formulated from the band information extracted from hyperspectral reflectance could distinguish between healthy and injured soybean and corn plants to which glyphosate and paraquat had been applied. Huang, Thomson, Ortiz, Reddy, Ding, & Zablotowicz et al. (2010) examined the effect of glyphosate drift from aerial application on non-glyphosate-resistant (non-GR) cotton by spray drift sampling and aerial multispectral remote sensing. Ortiz, Thomson, Huang, Reddy, and Ding (2011) studied the effect of glyphosate drift from aerial application on non-GR soybean, cotton and corn, using vegetation indices generated from aerial multispectral remote sensing. Huang, Reddy, Thomson, and Yao (2015) assessed soybean injury from glyphosate using airborne multispectral remote sensing. Early detection of crop injury from herbicide is important for farmers to know the injury potential before the symptom becomes visible so that they can take timely corrective actions to prevent yield losses. Studies have indicated that crop injury from glyphosate could be detected starting at 24 h after treatment (HAT) for soybean (Huang, Thomson, Molin, Reddy, & Yao, 2012; Yao, Huang, Hruska, Thomson, & Reddy, 2012) and cotton (Zhao & Huang et al., 2014; Zhao & Guo et al., 2014). So far, little research has been done on the capability of remote sensing for early detection of soybean or cotton injury from dicamba.

This study was undertaken to evaluate plant hyperspectral reflectance measured in situ and reveal the potential and limitation of using this technique for early detection of soybean injury from dicamba. The specific objectives of the study were to characterise hyperspectral reflectance properties of soybean treated with and without dicamba, and investigate the parameters from in-field measured hyperspectral data for early detection of soybean injury from simulated dicamba drift at various doses.

2. Materials and methods

2.1. Study site

A field study was carried out on a 4.5-ha area (central latitude: 33.445062° and central longitude: −90.869967°) at the USDA Agricultural Research Service Crop Production Systems Research Farm, Stoneville, MS, USA. Maize was grown on the surroundings of the experimental area as a border to minimise spray drift from periodic applications of herbicides in neighbouring fields as well as to minimise dicamba drift to neighbouring fields (Fig. 1). Maize was planted in late March 2014 in the middle of the experimental area to divide it into two subplots. In the two isolated areas, 32-row plot of soybeans (Progeny P4819LL, Progeny Ag Products, Wynne, AK, USA) were planted on May 7, 2014. The soybean field in the east side of the entire field was used as the experimental field while the soybean field in the west side was used as backup (in case of unsuccessful dicamba treatment) and as a reference.

2.2. Experimental design and operation

The experimental field was divided into thirty-two plots planted with soybean (Fig. 1). Each plot consisted of eight rows with rows 0.97 m wide and 24 m long. In the thirty-two plots,