SHORT COMMUNICATION

NDVI to Detect Sugarcane Aphid Injury to Grain Sorghum

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ABSTRACT Multispectral remote sensing has potential to provide quick and inexpensive information on sugarcane aphid, Melanaphis sacchari (Zehntner), pest status in sorghum fields. We describe a study conducted to determine if injury caused by sugarcane aphid to sorghum plants in fields of grain sorghum could be detected using multispectral remote sensing from a fixed wing aircraft. A study was conducted in commercial grain sorghum fields in the Texas Gulf Coast region in June 2014. Twenty-six commercial grain sorghum fields were selected and rated for the level of injury to sorghum plants in the field caused by sugarcane aphid. Plant growth stage ranged from 5.0 (watery ripe) to 7.0 (hard dough) among fields; and plant injury rating from sugarcane aphid ranged from 1.0 (little or no injury) to 4.0 (>40% of plants displaying injury) among fields. The normalized differenced vegetation index (NDVI) is calculated from light reflectance in the red and near-infrared wavelength bands in multispectral imagery and is a common index of plant stress. High NDVI indicates low levels of stress and low NDVI indicates high stress. NDVI ranged from −0.07 to 0.26 among fields. The correlation between NDVI and plant injury rating was negative and significant, as was the correlation between NDVI and plant growth stage. The negative correlation of NDVI with injury rating indicated that plant stress increased with increasing plant injury. Reduced NDVI with increasing plant growth probably resulted from reduced photosynthetic activity in more mature plants. The correlation between plant injury rating and plant growth stage was positive and significant indicating that plant injury from sugarcane aphid increased as plants matured. The partial correlation of NDVI with plant injury rating was negative and significant indicating that NDVI decreased with increasing plant injury after adjusting for its association with plant growth stage. We demonstrated that remotely sensed imagery acquired from grain sorghum fields using an airborne multi-spectral imaging system was sensitive to injury to sorghum plants caused by sugarcane aphid.

KEY WORDS Homoptera, Aphididae, population, monitoring

Introduction

An outbreak of the sugarcane aphid, *Melanaphis sacchari* (Zehntner), was detected in grain sorghum fields along the Gulf Coast and Lower Rio Grande Valley in Texas, and in Louisiana, Mississippi, and Oklahoma in the summer of 2013 and infestations occurred again in this region, but were more widespread in summer 2014 (Villanueva et al. 2014). In the Plains States, the aphid is currently distributed in the lower Rio Grande Valley, the Gulf Coast, central Texas Blacklands, and northern counties bordering the Red River, and in several Oklahoma counties extending as far north as southern Kansas. Although no yield data from replicated trials have been obtained, yield losses of grain sorghum up to 50% have been reported (Villanueva et al. 2014).

Infestations of the aphid have been observed to start on lower leaves of sorghum plants and then to progress to upper leaves, and sometimes to the grain sorghum head (Villanueva et al. 2014). Direct injury caused by the aphid can reduce plant biomass, grain yield, and grain quality (Van den Berg et al. 2003, Singh et al. 2004). Indirect injury results from the abundant honeydew produced, which turns leaves sticky and shiny. The infested leaves then become coated with sooty mold fungus. Honeydew and mold accumulation probably reduce photosynthesis by the plant, and can hamper harvesting operations by clogging combines and making harvest work and machine maintenance difficult (Villanueva et al. 2014).

Timely and precise detection of sugarcane aphid infestations in sorghum may be necessary to detect range expansion and to decrease economic losses caused by the pest. Early detection of sugarcane aphid infestations in sorghum fields could be enhanced by multispectral remote sensing. Multispectral remote sensing has potential to provide quick and inexpensive information on aphid pest status in sorghum fields. Multispectral remote sensing has been used extensively to detect and quantify plant stress using the visible and near-infrared portion of the electromagnetic spectrum (Lillesand et al. 2008), and has been used to detect injury to plants caused by aphids in other crops, for example cotton and wheat (e.g., Yang et al. 2005; Elliott et al. 2007, 2009; Reisig and Godfrey 2006, 2010). The normalized differenced vegetation index (NDVI) is

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calculated from light reflectance in the red and near-infrared wavelength bands of multispectral imagery and is a common index of plant stress. High NDVI indicates low levels of stress and low NDVI indicates high stress (Lillesand et al. 2008). The purpose of this study was to determine if injury to sorghum plants in fields caused by sugarcane aphid could be detected using NDVI calculated from multispectral imagery acquired using a fixed wing aircraft-based multispectral imaging system.

Materials and Methods

Study Fields. A study was conducted in commercial grain sorghum fields in the Texas Gulf Coast area in Nueces, San Patricio, and Kleberg counties in June 2014. Twenty-six commercial grain sorghum fields were selected and rated for the level of injury to sorghum plants caused by sugarcane aphid. Fields were found by driving roads, stopping near the edge of arbitrarily selected sorghum fields, and surveying an ~50 × 50 m rectangular area within the field by walking through the area and assessing it for injury from sugarcane aphid. Currently very little is known about the spatial distribution of the aphid within sorghum fields, but plots were probably large enough to be representative of the aphid infestation in the field, or at least a large portion of it. The rectangular area was situated ~10 m into the field from the field edge and with two sides parallel to the field edge.

Visible injury to plants in fields caused by sugarcane aphid was primarily stunting of plants, desiccation of leaves, and honeydew and sooty mold accumulation on leaves. Plant injury from sugarcane aphid was rated on a scale of one to four. A rating of one indicated that <5% of plants within the rectangle had evidence of sugarcane aphid injury, two represented 5–20% of plants with injury, three represented 20–40% with injury, and four represented >40% of plants injured. The percentage of plants with injury was approximated visually by two (occasionally three) individuals who compared their assessments to settle on a rating for each field. No attempt was made to do a complete enumeration of injured and non-injured plants within the rectangle. There were no visible symptoms of acute toxic response to insect feeding, such as the chlorosis typically caused by greenbug, *Schizaphis graminum* (rondani) and yellow sugarcane aphid, *Sipha Flava* (Forbes), in any of the fields. The economic injury level for sugarcane aphid in grain sorghum has not been determined, but we suspect that significant yield loss occurred in fields rated three and four by our rating scale and that fields with damage rated one or two suffered low yield loss or none. The growth stage of sorghum plants in each field was also quantified using the following scale: 5.0 = watery ripe; 5.5 = milky ripe; 6.0 = soft dough stage; and 7.0 = hard dough stage.

We rated fields for injury that spanned the range of injury ratings described earlier. A coordinate was taken by GPS at the edge of each field centered on the 50 × 50 m rectangle. The coordinate was used to determine the location of the rectangle within each field for purposes of identifying its location when overflying the field to acquire multispectral imagery.

Image Acquisition and Processing. Multi-spectral imagery was obtained using a DuncanTech MS3100 digital camera-mounted directly downward in a camera hole through the fuselage of a Cessna 172 aircraft. The MS3100 is a three-band, 1392 × 1040 pixel digital camera developed by DuncanTech (Auburn, CA). The center wavelengths for the three bands (green, red and near infrared) recorded by the camera were 550, 650, and 800 nm with bandwidths of 70, 40, and 65 nm, respectively. Imaging was from ~900 m above ground level. At 900 m above ground level, an individual pixel in an image covered an area ~0.35 × 0.35 m at ground level. Imaging was accomplished on 13 June 2014, the same day or the day after fields were rated for injury, depending on the particular field. Images were georeferenced and geometrically corrected in ERDAS Imagine version 9.3 (ERDAS Inc, Norcross, GA) using 2012 National Agricultural Imagery Program (NAIP) data available online at the USDA-Farm Service Agency website (http://gis.apfo.usda.gov/naipcoverage).

Data Analysis. Each pixel in an image contains a digital number for each of the three bands recorded by the camera. The digital number measures the amount of light reflected from within the area of the crop canopy defined by the pixel in that particular band. NDVI, which is calculated from red and near-infrared bands of multi-spectral data, was calculated for each pixel in each image. The mean of NDVI was calculated from all pixels within the rectangle for a field using ERDAS Imagine.

We used Spearman's rank correlation coefficient to assess the strength of the relationship between NDVI, injury rating, and plant growth stage. Because plant growth stage and injury rating were significantly correlated, we also calculated the Spearman partial correlation coefficient between NDVI and injury rating, with the linear effect of plant growth stage removed, to determine if injury rating was correlated with NDVI apart from its correlation with plant growth stage. Correlations were calculated using the Proc Corr procedure in SAS (SAS Institute 2004).

Results and Discussion

Of the total of 26 fields, eight fields were assigned an injury rating of one, five fields were rated two, nine fields were rated three, and four fields were rated four. The mean injury rating was 2.3. Plant growth stage ranged from 5.0 (watery ripe) to 7.0 (hard dough) with a mean of growth stage of 6.3. NDVI ranged from −0.07 to 0.26 among fields with a mean of 0.06.

NDVI decreased approximately linearly with increasing plant injury (Fig. 1). The correlation between NDVI and plant injury rating was negative and significant ($r = -0.54$; $P = 0.005$), as was the correlation between NDVI and plant growth stage ($r = -0.50$;

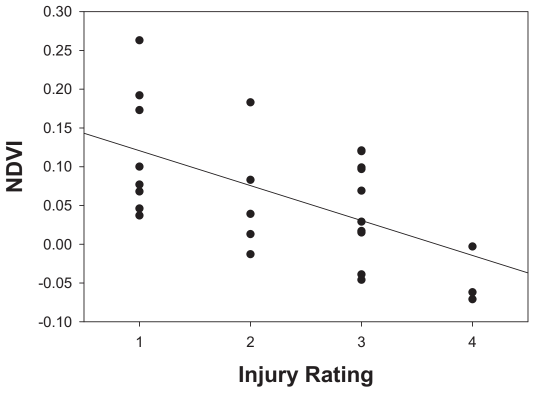

Fig. 1. Relationship between NDVI and sugarcane aphid injury to sorghum plants in 26 grain sorghum fields.

$P = 0.01$). These significant correlations indicate negative linear relationships of NDVI with plant injury and plant growth stage. The negative correlation of NDVI to injury rating indicated that plant stress increased (NDVI decreased) with increasing plant injury. Reduced NDVI with increasing plant growth stage probably was caused by reduced photosynthetic activity in more mature plants.

The correlation between plant injury rating and plant growth stage was positive and significant ($r = 0.44$; $P = 0.023$). The positive correlation between plant injury rating and plant growth stage indicated that the two variables had a positive linear association, such that injury severity increased as plants matured. A positive association between sugarcane aphid induced injury and plant growth stage makes sense, because both aphid infestations (and the injury they cause) and sorghum plant growth increase over time, or more specifically, with growing degree-days. In the absence of an intervention, such as an insecticide application, it is reasonable to expect the two variables to be positively correlated.

The correlation between injury rating and plant growth stage opens the possibility that the reduction in NDVI with increasing plant injury may have been related mainly to the increase in plant maturity rather than injury caused by sugarcane aphid. Therefore, we calculated the Spearman partial correlation between NDVI and injury rating, thus removing the linear effect of plant growth stage. The partial correlation was negative and significant ($r = -0.40$; $P = 0.045$) indicating that NDVI decreased with increasing plant injury apart from its association with plant growth stage.

We demonstrated that multi-spectral remotely sensed imagery acquired from grain sorghum fields using a multispectral imaging system based on a DuncanTech 3100 camera is sensitive to injury caused by sugarcane aphid. Previous studies in wheat and cotton (e.g., Yang et al. 2005, Mirik et al. 2012, Reisig and Godfrey 2010) indicate that wavelength bands in the red and near-infrared have potential for detecting aphid infestations, which was confirmed in this study for sorghum. The main contribution of this study was demonstrating that multispectral data acquired by an airborne imaging system was capable of detecting sugarcane aphid induced injury in production sorghum fields. One possible approach would be to use remote sensing over broad spatial areas (perhaps several counties in size) to identify fields potentially infested with sugarcane aphid and then use ground-based sampling to confirm the presence of the infestation and to verify if management action is needed to suppress the infestation. More research is needed to determine if such an approach is possible.

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