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# Processed multispectral imagery differentiates wheat crop stress caused by greenbug from other causes

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ABSTRACT

The greenbug, *Schizaphis graminum* (Rondani) (Hemiptera:Aphididae) is an important pest of small grains such as winter wheat (*Triticum aestivum*). The objective of this study was to determine the potential for multispectral imagery analyzed using spatial pattern metrics subjected to discriminant function analysis to differentiate patches of wheat plants within wheat fields infested by greenbug from stressed patches caused by other factors. Multispectral images of wheat fields were acquired using a Duncantech MS3100-CIR multispectral camera. Stress observed to wheat plants in wheat fields was grouped into categories: greenbug, drought and agricultural conditions. ERDAS Imagine software was used to process and analyze images, and FRAGSTATS was used to quantify spatial pattern. A set of 10 spatial pattern metrics were computed at the patch level for each stress factor. The analysis of spatial pattern metrics by discriminant function analysis revealed that the three types of stress could be reliably differentiated. The combination of multispectral data and spatial pattern metrics made it possible to differentiate patches in wheat fields infested by greenbug from patches caused by drought and agronomic conditions. The detection and differentiation of stressed patches may help in mapping stress within fields for the purpose of site-specific pest management and for monitoring systems to identify greenbug infestations at individual field and regional scales.



## 1. Introduction

The greenbug, *Schizaphis graminum* (Rondani) (Hemiptera:Aphididae) is an important pest of small grains such as winter wheat (*Triticum aestivum*) (Blackman and Eastop, 2007). Greenbug outbreaks occur nearly every year somewhere in the United States Great Plains. Fenton and Dahms (1951) recalled the 1950 outbreak as the most serious on record at that time, and noted that greenbug outbreaks in Oklahoma occurred every 4 years on average. Economic loss caused by the greenbug in Oklahoma, Texas, and Kansas was estimated at $100 million annually in the 1990's (Webster et al., 2000).

The greenbug infests wheat fields and induces stress to wheat plants by damaging plant foliage. The damage is thought to be caused primarily by the toxigenic saliva injected into the plant during feeding. This aphid also injures the plant by extracting large quantities of sap, causing water and nutrient depletion. (Cruz et al., 1998; Gray et al., 2007; Nault and Bradley, 1969). The leaves of wheat plants exhibit yellowish to red lesions, leading to a reduction in plant size and vigor, and sometimes plant death. Greenbug infestations grow and expand within a field from initial colonization sites as the aphid reproduces in the field. The infestation is visually detected later on during the jointing or heading phenological cycle of wheat plants that occurs between March and April. During that time, wheat fields infested by greenbug display yellowish areas within them, which we refer to as patches. These patches are areas within the field where there is more severely damage in some areas within the field than others due to non-uniform spatial distribution of greenbugs.

Traditional field scouting for aphid infestations is expensive and time consuming (Hodgson et al., 2004). Remote sensing technology can be used as an alternative to the traditional field assessment of greenbug infested wheat fields. This technology has shown its importance in quantifying and detecting stress to vegetation (Adams et al., 1999; Backoulou et al., 2011; Metternicht, 2003). Remote sensing has the potential to identify patches of stressed wheat plants within wheat fields inexpensively (Mirik et al.,

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2007). Remote sensing technology has been used in several studies to investigate plant stress induced by aphids in wheat fields. Yang et al. (2004) used multispectral radiometry to detect stress induced by the greenbug to wheat plants grown in a greenhouse. Elliott et al. (2007, 2009) used an airborne multispectral remote sensing to investigate stress induced by greenbug and Russian wheat aphid to wheat plants in commercial fields. Mirik et al. (2006) employed a hyperspectral spectrometer to differentiate uninfested from greenbug infested winter wheat in commercial fields. These studies demonstrated the utility of spectral information to distinguish aphid stressed from non-stressed wheat plants. When comparing stressed and non-stressed wheat plants, Mirik et al. (2007) found that stressed wheat plants responded differently at different wavelengths. The response of stressed wheat plants was high in visible wavelength and low in near infrared. Although spectral reflectance detected in multi-spectral remote sensing can be used to distinguish aphid stressed wheat plants quite easily, the analysis of spectral pattern likely presents challenges to distinguish one type of stress from another. For example, Yang et al. (2005) was unable to differentiate stress induced by the greenbug from that induced by drought based on analysis of spectral reflectance data. This difficulty suggested the need to investigate the utilization of additional information to contribute in differentiating various types of stress to wheat fields. According to Mirik et al. (2007), the analysis of spatial pattern offers potential to augment spectral pattern information to differentiate among stress factors. The analysis of spatial pattern is based on the geometric shape, size and distribution of spatial objects within a defined area of land. Spatial pattern metrics can be generated and used to provide information to differentiate patches of wheat plants affected by multiple types of stress. For example, Backoulou et al. (2011) developed a method that used spatial pattern metrics derived from multispectral imagery to quantify stress within wheat fields where Russian wheat aphid (*Diuraphis noxia* (Mordvilko)), drought, and agronomic conditions were major causes of stress. In another study Backoulou et al. (2011) investigated the potential of using spatial pattern metrics from multispectral imagery augmented with quantitative topographic and edaphic information to differentiate stress induced by Russian wheat aphid from other stress factors. Spatial pattern metrics have been also used in several other studies to evaluate damage induced by ice storms to forest, changes in forest fragmentation related to pest infestation, spatial distribution of diseases and pests in cropland, and to assess water quality (Coops et al., 2010; French et al., 2004; Grilli, 2008; Pasher and King, 2006; Uuemaa, et al. 2007). In other studies, the prevalence of aphids and virus disease in cropland has been equally, related to spatial variation in topography and soil type (Auslander et al., 2003; Foster et al., 2004; Hammon and Peairs, 1992; Nevo et al., 1999).

The objective of this study was to determine whether the analysis of multispectral image data by spatial pattern analysis could be used to differentiate stress induced by greenbug infestation within wheat fields from other common sources of plant stress occurring within fields. We used an approach similar to that previously described by Backoulou et al. (2011; 2013) for this purpose. We assumed that a disruption of the integrity of homogenous areas of healthy wheat plants caused by greenbug and other stress causing factors can be detected by analysis of spatial pattern metrics. We hypothesized that greenbug infestation causes a specific pattern of plant stress within wheat fields that can be distinguished stress resulting from other causes. Our hypothesis was tested by acquiring airborne multispectral images of wheat fields infested by greenbug that also exhibited other types of stress. These data were subjected to spatial pattern analysis, to determine whether we could differentiate stressed patches infested by greenbug from stressed patches resulting from other causes.

## 2. Materials and methods

### 2.1. Study area

The study was conducted in commercial wheat fields located in the vicinity of Vernon, 34°.8′N, −99°.71'W, Wilbarger County, Texas. In this region wheat is planted from September through October and harvested from May through June of the next year. The area has an average high temperature of 12.8 °C in winter and 37.2 °C in summer, and an average annual rainfall of 650 mm.

### 2.2. Data collection

Data used in this study were collected from 11 selected wheat fields in April 2013 between 12:00 and 2:00 pm. Data consisted of geographic location of each selected wheat field, geographic location of patches of wheat infested by greenbug, and multispectral digital images of the selected wheat fields. First, we surveyed the region to select wheat fields that presented patches of stressed wheat plants. We conducted ground truth surveys within each selected wheat field concurrent with imaging the fields. We observed two features regarding the condition of wheat plants in each field. First, stress was patchily distributed within each field. Some areas within a field were heavily damaged while other areas exhibited no evidence of stress. Second, we visually identified three major types of stress: (1) stress caused by Greenbug infestation, (2) stress caused by drought, and (3) stress caused by agronomic conditions.

We also observed that patches of wheat stressed by greenbugs appeared similar to patches of wheat plants stressed by drought. Both types of patch were composed of stunted wheat plants that exhibited erect, yellowed, bronze or brown leaves. But both differed by the fact that patches of wheat stressed by greenbugs appeared necrotic and greenbugs were present. Leaves of wheat plants in areas stressed by drought conditions appeared yellow or bronze in color. There were not a presence of greenbugs or were present in very low numbers that caused minimal damage to wheat plants in the patch. Damaged patches of wheat plants that were not considered as stressed by greenbugs or by drought were grouped in a single category designated as caused by agronomic conditions. In these patches greenbugs were not extant or were present in insignificant numbers. We used the term “agronomic conditions” to include damage that was caused by poor site preparation that included fertilization, plant germination, tillage, and perhaps other factors.

During ground truthing, the location and cause of each patch of stressed wheat were geographically recorded. We used Site Mate Basic (Farm Works Software, Hamilton, IN), a global positioning system (GPS) software installed on a Hewlett Packard iPaq h2215® (a handheld computer outfitted with a GPS receiver for ground truthing. The cause of stress for each patch was determined recorded in a data field in the handheld computer along with the geographic coordinates of the approximate center of the particular stressed patch.

Multispectral images of each selected wheat field were acquired with a Duncan Tech (Eunos Techpark, Singapore) model MS3100-CIR camera installed nadir below the fuselage of a Cessna 172 aircraft. The Duncan camera is a 3-CCD (charge coupled device) that is composed of three bands: near infrared, red and green (bands 1, 2 and 3, centered at 800, 650, and 550 nm with bandwidths of 65, 40, and 40 nm (Hi-Tech Electronics, 2008). The width and length of the study area within each field were determined by the field of view of the camera at the altitude the aircraft was flown. These images were acquired at an altitude of approximately 1500 m above ground level approximating an image resolution of 0.6 × 0.6 m for each pixel at that altitude.