Turk J Agric For
30 (2006) 421-428
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Spectral Sensing of Aphid (Hemiptera: Aphididae) Density Using Field Spectrometry and Radiometry

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Received: 22.09.2006

Abstract: The greenbug, *Schizaphis graminum* (Rondani), and bird cherry-oat aphid, *Rhopalosiphum padi* L., are aphid pests of wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), sorghum (*Sorghum bicolor* L.), oat (*Avena sativa* L.), and other cereals worldwide. Greenbug and bird cherry-oat aphid infestation in crops is unpredictable over space and time. From these 2 aphids, greenbug infestation causes significant reduction in yield, and consequently large amounts of insecticides are used to control greenbug populations. Therefore, a repeatable and rapid method is necessary for monitoring aphid populations. Remote sensing appears promising for the monitoring of aphid density in crops. The present research examined the potential use of spectral data to quantify aphid density (greenbug and bird cherry-oat aphid) in 3 winter wheat field experiments and 1 greenhouse experiment. A multispectral ground radiometer and a hyperspectral hand-held spectrometer were used to record reflectance data. In order to quantify the relationship between reflectance data and aphid density, 2 spectral indices were used in regression. The coefficients of determination (r^2) ranged from 0.48 to 0.76 for the hyperspectral-derived index and from 0.43 to 0.67 for the multispectral-derived index. The results indicate that multispectral and hyperspectral remote sensing appears functional to monitor aphid population density in production winter wheat fields.

Key Words: Remote sensing, spectral indices, multispectral radiometry, hyperspectral spectrometry, greenbug (*Schizaphis graminum* Rondani), wheat (*Triticum aestivum* L.)

Yaprak Biti (Hemiptera: Aphididae) Yoğunluğunun Portatif Spectrometri ve Radiometri Tayflarıyla Algılanması

Özet: Buğday yaprakbiti, *Schizaphis graminum* (Rondani) ve yulaf kuş-kirazı yaprak biti, *Rhopalosiphum padi* L., buğday (*Triticum aestivum* L.), arpa (*Hordeum vulgare* L.), süpürgedarısı (*Sorghum bicolor* L.), yulaf (*Avena sativa* L.), ve diğer tahılları dünya çapında tahrip eden zararlı yaprak bitleridir. Bu yaprakbitleri istilasının yer ve zamanını önceden tahmin etmek mümkün olmamaktadır. Bu iki yaprak bitlerinden biri olan buğday yaprakbiti istilası önemli ürün kaybına neden olmasından dolayı büyük meblağlarda böcek ilacı buğday yaprakbiti yoğunluğunu control altına almak amacı ile kullanılmaktadır. Bundan dolayı, tahıllardaki yaprakbitlerinin yoğunluğunu gözlemek için hızlı ve tekrarlanbilir bir yönteme gerek duyulmaktadır. Bu bağlamda, uzaktan algılama uygun bir yöntem olarak görünmektedir. Bu çalışma da üç buğday tarlasından ve bir laboratuvar deneyinden elde edilen tayf verilerinin yaprakbiti yoğunluğunu tahmin etme potensiyeli araştırılmıştır. Yansıyan ışın portatif spectrometre ve radiometre ile kaydedilmiştir. Yansıyan ışın ile böcek yoğunluğu arasındaki ilişkiyi ölçmek için iki tane tayf indeksi kullanılmıştır. Tayın katsayıları (r^2) hyperspectral indeks için 0.48'la 0.76 arasında ve multispectral indeks için ise 0.43'la 0.67 arasında olduğu bulunmuştur. Sonuç hyperspectral ve multispectral uzaktan algılamanın buğdaydaki yaprakbitleri yoğunluğunun gözlemlenmesin de etkili bir yöntem olduğu görülmüştür.

Anahtar Sözcükler: Uzaktan algılama, tayf indeksleri, spectrometri, radiometri, buğday yaprakbiti (*Schizaphis graminum* Rondani), buğday (*Triticum aestivum* L.)

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Introduction

The greenbug, *Schizaphis graminum* (Rondani), is a devastating aphid pest of wheat (*Triticum eastivum* L.), barley (*Hordeum vulgare* L.), sorghum (*Sorghum bicolor* L.), oat (*Avena sativa* L.), other cereals, and several species of cultivated and wild grasses in many areas of the United States (Beregovoy and Peters, 1994; Michels et al., 2002) and worldwide (Blackman and Eastop, 1984). Greenbug feeding on wheat causes distinct changes easily recognized by the yellowing of leaves and the occurrence of chlorotic spots. This is the result of the greenbug injecting a toxin into the plant's leaves as it feeds. When population density is high and feeding continues, plants may turn yellow or brown and eventually die (Royer et al., 1998). Greenbug damage symptoms are usually not uniform, occurring rather in spots across the field. The composite damage from greenbug feeding generally results in yellow areas in fields. The severity of greenbug damage in plants is based on density and length of feeding time. The severity of damage also depends on the vigor, size, and growth stage of the plant, temperature, moisture conditions, time of the year, and effectiveness of predators and parasites. Greenbug feeding also causes metabolic and physiological changes, e.g., lower rates of CO_2 assimilation, a decrease in water potential, and the amount of chlorophyll (Cabrera et al., 1995).

Greenbug infestations frequently reach damaging levels and cause severe damage to wheat. Therefore, the greenbug is considered one of the most destructive insects of wheat in the Great Plains region of the US. Large amounts of insecticides are used to keep greenbug population below the economic threshold level each year (Yang et al., 2004). Densities of 30 greenbugs per stem, feeding for a week, reduced at least 40% of grain weight in winter wheat (Kieckhefer and Kentack, 1988). Yield loss in winter wheat at the seedling stage was between 35% and 40% due to 15 greenbugs feeding per plant for 30 days (Kieckhefer and Gellner, 1992). In Oklahoma, annual losses in winter wheat due to greenbug infestation range from \$0.5 million to \$135 million (Webster, 1995).

Another aphid species commonly found in small grains and other grasses is the bird cherry-oat aphid, *Rhopalosiphum padi* L. It has been found in the US, Hungary, Sweden, China, Portugal, Czechoslovakia, and Scandinavia (Araya and Foster, 1987; Weibull, 1993; Riedell and Kieckhefer, 1995; Papp and Mesterházy, 1996; Chapin et al., 2001; University of California Statewide Integrated Pest Management Program, 2002). This aphid will probe the leaf, leaf sheath, or stem tissue with its mouth parts until it finds a suitable tissue such as phloem to extract plant sap (Riedell et al., 2003). Bird cherry-oat aphid feeding on a plant sometimes causes a golden yellow streaking on leaves (University of California Statewide Integrated Pest Management Program, 2002). In some instances, bird cherry-oat aphid feeding results in curling up of the flag leaf in a tight cork-screw fashion, which may trap awns and cause a fish-hook appearance of the head (University of California Statewide Integrated Pest Management Program, 2002). However, bird cherry-oat aphid infestations in wheat are often difficult to detect in the field because the wheat plants do not exhibit injury visible to the naked eye (Riedell and Kieckhefer, 1995). The extent of infestation, timing of infestation, aphid density, and growth stages of wheat determine the magnitude of yield loss (Riedell et al., 2003). Bird cherry-oat aphid feeding caused a 40%-60% reduction in spring wheat grain yield when mean densities of 10-20 aphids per tiller at the 2-leaf stage, and a 20%-50% reduction, with mean densities of 20-30 aphids per tiller at the boot stage (Kantack and Kieckhefer, 1979). The number of kernels of per plant and grain yield were reduced 19% and 21%, respectively, by bird cherry-oat aphid feeding in winter wheat (Riedell et al., 1999). Mallott and Davy (1978) stated that considerable reductions in the number of tillers and leaves, the leaf area, and the dry weight yield of barley plants occurred due to bird cherry-oat aphid infestation.

To decrease the economic losses due to greenbug and bird cherry-oat aphid infestations, the timely detection of aphid density in cereal crops is necessary, and thus critical for producers. Remote sensing has been proven to be helpful for detecting various stresses in different plant species. Previous research using remote sensing indicated that spectral vegetation indices could be used for detecting Russian wheat aphid (*Diuraphis noxia* Morlvilko), and greenbug stresses (Riedell and Blackmer, 1999; Yang et al., 2005). In a greenhouse study, Riedell and Blackmer (1999) found that leaf reflectance in the 625-635 nm and the 680-695 nm ranges, as well as the normalized total pigment to chlorophyll *a* ratio index (NPCI = $[R_{680} - R_{430})/(R_{680} + R_{430})]$ in which R_{680} and R_{430} are the reflectance values from band centers at 680 and

430 nm, respectively) were good indicators of chlorophyll loss and leaf senescent caused by greenbug and Russian wheat aphid feeding in wheat. Niño (2002) used a multispectral hand-held radiometer to predict greenbug densities in a greenhouse study. He showed that the associations measured by the correlation coefficients (*r*) between greenbug density and vegetation indices varied from weak ($r = 0.31$) to very strong ($r = 0.98$). A recent greenhouse study by Yang et al. (2005) examined the feasibility of a hand-held radiometer to detect greenbug damage in wheat. In their study, the band centered at 694 nm and the vegetation indices computed using bands centered at 694 and 800 nm were more sensitive to greenbug damage in wheat. They also observed high correlations (*r* ranged from -0.74 to -0.98) between the vegetation indices and greenbug density. A logical next step is to attempt to measure greenbug density using remote sensing in wheat growing in field conditions. Therefore, the objective of this study was to evaluate the relationships between 2 remote sensing instruments and aphid density in 3 production winter wheat field experiments and 1 greenhouse experiment in Oklahoma and Texas, respectively.

Materials and Methods

Data were collected in 3 production winter wheat fields in Oklahoma, and a greenhouse experiment in Texas. Oklahoma winter wheat field experiments were located southwest of Oklahoma City: 1 (Site 1 hereafter) in Grady County near Chickasha and 2 (Sites 2 and 3 hereafter) in Caddo County near Apache. The latitudes, longitudes, and altitudes were 35°05'N, 97°91'W, and 300 m for Site 1, 34°89'N, 98°46'W, and 403 m for Site 2, and 34°88'N, 98°36'W, and 347 m for Site 3, respectively. In each field, four 30 x 30 m plots were established with a minimum of a 10-m buffer zone between plots. One plot was treated with chlorpyrifos (Lorsban® 4E, Dow AgroSciences, 1.6 l ha^{-1}) along with imidacloprid [Provada®], Bayer AG, Leverkusen, Germany, 335 g ha^{-1}) once a month to remove aphids. The remaining plots were not treated to facilitate aphid infestation. Oklahoma winter wheat fields were monitored once a month. In addition to natural aphid infestations in these fields, a greenhouse experiment using flats-growing wheat was conducted at the Texas A&M University, Agricultural Experiment Station facilities at Bushland, TX, in the spring of 2005.

A total of four 30-m transects at 7-m intervals were set up and twenty-four 0.25-m^2 sample plots at 5-m intervals were located in one of the untreated plots at Sites 1 and 2 on 17-18 December 2003. Three 30-m transects at 10-m intervals were established and eighteen 0.25-m^2 sample plots at 5-m intervals were located in one of the untreated plots at Site 3 on 19 December 2003. There were 6 samples along each transect and the wheat crop was at approximately vegetative growth stage 25 measured by Zadok's scale (Zadok et al., 1974) at Sites 1-3. The greenhouse experiment involved 2 treatments: 1) greenbug and bird cherry-oat aphid-infested wheat, and 2) uninfested (control) wheat. There were 10 replications of each treatment. On 10 November 2005, 288 wheat seeds with seed spaced at 2.5 x 3.2 cm per flat were planted in 20 wooden flats (64 by 61 by 9 cm) containing field soil as the growth medium. Ten randomly selected flats were put in one section of the greenhouse and the remaining 10 flats were kept in another section of the greenhouse separated by a breezeway. On 12 January 2005, when the wheat was at approximately vegetative growth stage 25 measured by Zadok's scale (Zadok et al., 1974), 10 wheat flats were infested with greenbugs and bird cherry-oat aphids at densities of 100 and 10 in 3 flats, 200 and 20 in 2 flats, 500 and 50 in 3 flats, and 700 and 70 in the remaining 2 flats, respectively. The remaining 10 flats were kept free of greenbugs and bird cherry-oat aphids. All flats were watered 3 times per week. On 8 February 2005, flats of both treatments were taken outside the greenhouse for spectral measurements in the full sun.

Spectral measurements were obtained with an Ocean Optics S2000 hyperspectral hand-held spectrometer (Ocean Optics Inc. Dunedin, FL, USA) and a Cropscan multispectral field radiometer (Cropscan, Inc. Rochester, MN, USA). The Cropscan multispectral field radiometer (MSR16R) measures solar light intensity and canopy reflected light intensity simultaneously in 16 fixed wavebands with a 28° field of view. The Cropscan field radiometer has the following waveband centers: B_1 ($Band_1$) = 460 nm, B_2 = 485 nm, B_3 = 500 nm, B_4 = 560 nm, B_5 = 600 nm, B_6 = 660 nm, B_7 = 700 nm, B_8 = 750 nm, B_9 = 800 nm, B_{10} = 830, B_{11} = 880 nm, B_{12} = 940 nm, B_{13} = 1100 nm, B_{14} = 1260 nm, B_{15} = 1480 nm, and B_{16} = 1650 nm.

With the hyperspectral spectrometer, the dark current and white Spectralon reference readings were taken at the beginning of every 8-10 samples (approximately every 15 min). The spectrometer is a linear, charge-coupled device (CCD)-array detector that collects reflectance data from 339.71 to 1015.52 nm with a continuous spectral resolution ≈ 0.33 nm. The field of view of the spectrometer is 25°. To reduce the sheer volume of data recorded by the spectrometer from each plot, adjacent wavelengths were initially averaged to 1-nm intervals. To determine the best band centers and spectral resolutions in relation with aphid density, these band centers were then increased 9 times by averaging every 2, 3,…, 10 neighboring bands. The hyperspectral spectrometer was mounted on a pole and elevated about 0.75 m above the flat surface to collect reflected light from the wheat canopy over 0.37 m^2 sample areas. The same spectral measurements of the wheat canopy were applied for Sites 1-3 with the exception of spectrometer elevations over the sample plots. Spectrometer and radiometer elevations were kept about 0.65 m to record the reflectance over 0.25 m^2 sample plots for Sites 1-3 and 0.75 m for the greenhouse experiment. Reflectance data acquisition started at 11:30 and ended at 13:30 to keep the effect of the sun angle the same for all samples.

After spectral measurement, a 0.25 m^2 frame was placed on each of the sampling plots to determine aphid density data at Sites 1-3. There were bird cherry-oat aphids in addition to greenbugs at Sites 1-3. Therefore, aphid density data were collected and reported as total aphids throughout this paper for Sites 1-3 and the greenhouse experiment. At Site 1, 12 wheat plants were taken just outside of each plot and aphids were counted. On each of the 4 sides of the plots, aphid numbers were quantified on 3 wheat plants, totaling 12 plants. Subsequent to counting aphids on 12 plants, the number of wheat plants within each 0.25 m^2 plot was counted and aphid densities were estimated as follows: total aphids 0.25 m^{-2} = total tillers x total aphids on 12 tillers/12. At Site 2, aphids were counted in each of twenty-four 0.25-m^2 plots. At Site 3, aphids were counted in each of the first 12 of the 18 plots and the aphid density estimation method used for Site 1 was applied for the remaining 6 plots. In the greenhouse experiment, 20 tillers were randomly taken inside of each 0.37 m^2 flat and greenbugs and bird cherry-oat aphids were counted on them. Subsequent to counting greenbugs and bird cherry-oat aphids on 20 tillers, the numbers of wheat tillers within each flat were tallied and greenbug and bird cherry-oat aphids densities were determined as follows: total aphids 0.37 m^{-2} = total tillers x total aphids on 20 tillers/20.

The aphid index (AI) (Mirik et al., 2006a) and damage sensitive spectral index$_2$ ($DSSI_2$) (Mirik et al., 2006b) were computed in order to quantify their relationships with aphid density. Throughout this research, the band centers used to calculate these indices were replaced with wavebands available with hyperspectral and multispectral data. Indices were computed using waveband centers with a spectral resolution of 7 nm for hyperspectral data. The AI and $DSSI_2$ were calculated using the following formulae for the hyperspectral data:

$$AI = (R_{740} - R_{887})/(R_{691} - R_{698})$$

$$DSSI_2 = (R_{747} - R_{901} - R_{537} - R_{572})/((R_{747} - R_{901}) + (R_{537} - R_{572}))$$

and for the multispectral data:

$$AI = (R_{750} - R_{880})/(R_{500} - R_{560})$$

$$DSSI_2 = (R_{750} - R_{940} - R_{560} - R_{600})/((R_{750} - R_{940}) + (R_{560} - R_{600}))$$

where R_{750} and R_{887} are reflectance values from wavebands centered at 750 and 887 nm, respectively.

Regression analyses between indices and aphid densities were conducted using the Statistical Analysis System (SAS Institute Inc, Cary, NC, USA).

Results

Aphid density varied widely across the sites. The descriptive statistics for aphid density at all sites and the greenhouse experiment were generated and are summarized in Table 1. The highest average aphid density (31,778 ± 7.787 0.37 m^{-2}) was found in the greenhouse experiment, while Site 2 had the lowest mean aphid density (318 ± 30 0.25 m^{-2}). Site 1 had the second lowest mean aphid density (2357 ± 395 0.25 m^{-2}), followed by Site 3 (3640 ± 325 0.25 m^{-2}).

Regression analyses showed that there were good relationships between aphid densities and both hyperspectral and multispectral remotely sensed data transformed into vegetation indices. All regression

Table 1. Descriptive statistics of aphid density in winter wheat in 3 field experiments and 1 greenhouse experiment.

Statistics	Site 1	Site 2	Site 3	GrHs Exp
	TAD 0.25 m^{-2}	TAD 0.25 m^{-2}	TAD 0.25 m^{-2}	TAD 0.37 m^{-2}
Minimum	345	71	1794	6621
Mean	2357	318	3640	31,778
Maximum	6993	576	6594	84,025
SE	395	30	325	7787
LCI (0.95)	1539	256	2954	14,161
UCI (0.95)	3174	381	4325	49,396

Site 1: Grady County near Chickasha, OK, sampled on 17 December 2003, n = 24.

Site 2: Caddo County near Apache, OK, sampled on 18 December 2003, n = 24.

Site 3: Caddo County near Apache, OK, Sampled on 19 December 2003, n = 18.

GrHs Exp: Greenhouse experiment, Texas Agricultural Experiment Station at Bushland, TX, sampled on 8 February 2005, n = 10. TAD and GD: Total aphid (greenbug + bird cherry-oat aphid) density. SE: Standard Error of the mean; LCI: Lower Confidence Interval; UCI: Upper Confidence Interval.

models generated for the relationships between spectral indices and aphid densities were statistically significant (α = 0.05). This indicates that spectral indices can be important tools to estimate aphid density in operational winter wheat fields. The regression statistics are presented in Table 2. In general, hyperspectral data exhibited higher relationships with aphid density than did multispectral data with one exception, Site 1 (Table 2). The best relationship (r^2 = 0.76) was between $DSSI_2$ derived from the hyperspectral data and aphid density collected in the greenhouse experiment, whereas the same index derived from the multispectral data had an r^2 value of 0.67 (Table 2). The AI derived from both hyperspectral and multispectral data had lower relationships with aphid density (r^2 = 0.55 and 0.54, respectively), when compared with $DSSI_2$ for Site 1. The $DSSI_2$ and AI derived from hyperspectral data produced good relationships with aphid density collected at Site 2 (r^2 = 0.58 and 0.51, respectively), while the same indices calculated using multispectral data had r^2 values of 0.48 and 0.41, respectively. The relationship (r^2 = 0.41) between aphid density and AI derived from multispectral data for Site 2 was the weakest across the sites and the greenhouse experiment (Table 2).

The AI derived from multispectral data and $DSSI_2$ calculated using both hyperspectral and multispectral reflectance related equally with aphid density collected at Site 3 (r^2 = 0.52). However, AI derived from hyperspectral data exhibited a slightly higher relationship with aphid density (r^2 = 0.57) than $DSSI_2$ and AI calculated using multispectral data collected at Site 3 (Table 2). Hyperspectral- and multispectral-derived AI had the strongest relationship with greenbug density collected in the greenhouse experiment (r^2 = 0.60 and 0.56), respectively. In contrast, hyperspectral- and multispectral-derived $DSSI_2$ exhibited the weakest but a good relationship with greenbug density collected in the same experiment (r^2 = 0.48 and 0.43, respectively) (Table 2).

Discussion

Mirik et al. (2006a, 2006b) developed the AI and $DSSI_2$ to quantify greenbug density and damage to wheat, respectively. They argued that AI, among others, had consistent and statistically significant relationships with greenbug density across 2 field experiments and 1 greenhouse experiment studied. In that study by Mirik et al. (2006a), the r^2 values ranged from 0.59 to 0.69,

Table 2. Coefficient of determination (r^2) and probability associated with aphid density on winter wheat in 3 field experiments and 1 greenhouse experiment.

	Hyperspectral-Derived Index			
	$DSSI_2$		AI	
Site	r^2	P	r^2	P
1	0.76	< 0.0001	0.54	< 0.0001
2	0.58	< 0.0001	0.51	0.0001
3	0.52	0.0008	0.57	0.0003
GrHs Exp	0.48	0.0260	0.60	0.0080
	Multispectral-Derived Index			
	$DSSI_2$		AI	
Site	r^2	P	r^2	P
1	0.67	< 0.0001	0.55	< 0.0001
2	0.48	0.0002	0.41	0.0007
3	0.52	0.0008	0.52	0.0007
GrHs Exp	0.43	0.0300	0.56	0.0130

Multispectral-Derived $DSSI_2$: $(R_{750} - R_{940} - R_{560} - R_{600})/((R_{750} - R_{940}) + (R_{560} - R_{600}))$ and AI = $(R_{750} - R_{880})/(R_{500} - R_{560})$; $R_{750} - R_{940} - R_{560} - R_{600}$: Reflectance values from wavebands centered at 750, 940, 560, and 600 nm, respectively. Hyperspectral-Derived $DSSI_2$: $(R_{747} - R_{901} - R_{537} - R_{572})/((R_{747} - R_{901}) + (R_{537} - R_{572}))$ and AI: $(R_{740} - R_{887})/(R_{691} - R_{698})$. Site 1: Grady County near Chickasha, OK, sampled on 17 December 2003, n = 24. Site 2: Caddo County near Apache, OK, sampled on 18 December 2003, n = 24. Site 3: Caddo County near Apache, OK, Sampled on 19 December 2003, n = 18. GrHs Exp: Greenhouse experiment, Texas Agricultural Experiment Station at Bushland, TX, sampled on 8 February 2005, n = 10.

which strongly agreed with the results found in the present research. Similar to AI, $DSSI_2$ showed high correlations with greenbug damage (Mirik et al., 2006b). Since the greenbug damage is highly correlated with its population density, $DSSI_2$ can be a useful tool to monitor aphid density, as found in our study. Mirik et al. (2006b) reported correlation coefficients ranging from 0.43 to 0.82 between $DSSI_2$ and greenbug damage.

The results found in the present study also closely agreed with the findings published by Yang et al. (2005), who conducted 2 greenhouse experiments to detect greenbug stress in wheat using a field radiometer. The correlation coefficients between vegetation indices and greenbug density reported by Yang et al. (2005) varied from -0.74 to -0.98. Niño (2002) reported correlations between vegetation indices and greenbug density; correlation coefficients fluctuated from 0.31 to 0.98 depending on what vegetation indices were used and the time when the data were collected. For example, the correlation coefficients were 0.77 and 0.60 on 12 January 2001 and 0.82 and 0.97 on 6 March 2001 between greenbug density and normalized difference vegetation (NDV) and photochemical reflectance (PR) indices, respectively.

The spectral vegetation indices generated using the reflectance from certain waveband centers indicate that remote sensing may offer an opportunity to quantify aphid density in cereal crops. In general, hyperspectral remote sensing with hundreds of bands seems better than multispectral remote sensing data with several channels for aphid density detection in wheat. This was expected to some extent because a number of authors (Roberts et al., 1997; Asner, 1998; Thenkabail et al., 2000; Shippert, 2004) have discussed the superiority of hyperspectral remote sensing (e.g., Airborne Visible Infrared Imaging Spectrometer) over multispectral instruments (e.g., Landsat Thematic Mapper). The former collects spectral information in continuous, narrow spectral channels, while the latter ones measure spectral data at a few wide, non-continuous wavelengths separated by spectral segments where no measurements are taken; thus a single band represents the average of a relatively large portion of the spectrum. Therefore, a hyperspectral system was designed to separate the surface optical properties into hundreds of bands that can be investigated individually. These bands provide ample spectral information to identify and distinguish between spectrally similar but unique materials. Accordingly, hyperspectral reflectance data provide the potential for more detailed and accurate information than multispectral reflectance data (Shippert, 2004). Consequently, hyperspectral remote sensing instruments are viewed to identify, while multispectral remote sensing instruments are considered to discriminate surface materials (Martini, 2001).

This study evaluated the relationships between 2 remote sensing instruments and aphid density using spectral indices. The results indicate that spectral indices derived from both hyperspectral and multispectral remote sensing instruments have the potential to quantify and monitor aphid densities in wheat growing under production fields. Overall the results indicate that spectral vegetation indices can be useful for quantifying aphid numbers in wheat.

Acknowledgments

Our special thanks to Karl Steddom and Roxanne Bowling for their help and beneficial discussion. We extend our thanks to David Jones for reviewing an earlier version of the manuscript. We are grateful to Vanessa Carney, Johnny Bible, Robert Villarreal, Timothy Johnson, and Steven South for their technical assistance. This project was funded by the USDA-ARS Areawide Pest Management Program. Project Number: 500-44-012-00.

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