3. Research Component Summaries

a. *Remote Sensing of Greenbug and Russian Wheat Aphid Infestations*

i. Characterization Of Aphid-Induced Stress In Wheat Under Field Conditions Using Remote Sensing

Written by Mustafa Mirik
Other Participaants, Gerald J. Michels Jr., Norman C. Elliott, Sabina Kassymzhanova-Mirik, Roxanne Bowling, Vanessa Carney, Lana Castleberry, Johnny Bible, Bob Villarreal, Joy Newton, Denial Jimenez, Vasile Catana, Timothy D. Johnson

During the late fall of 2003 and spring of 2004, the feasibility of a commercially-available hyperspectral hand-held remote sensing instrument to predict aphid density and damage was studied. The following paper summarizes the major findings of the research and it was published in 2004 Bushland Agricultural Day (Summer Crop Field Day) Proceedings (p. 88-98).

Abstract: This work was carried out to investigate the relationship between remotely sensed data and aphid density in field conditions. A hyperspectral ground spectrometer was used to collect percent reflectance data over 0.25 m^2 aphid stressed and non-stressed wheat (*Triticum aestivum* L.) plots in the fields located in Texas, Oklahoma, and Colorado. Bird cherry-oat aphid (*Rhopalosiphum padi* Linnaeus*)*, greenbug (*Schizaphis graminum* Rondani), and Russian wheat aphid (*Diuraphis noxia*) were counted in each of the 0.25 m^2 aphid stressed wheat plots. Paired t-test indicated that percent reflectance values in the 400-900 nm region of the spectrum from aphid stressed and non-stressed wheat were statistically significant. In addition to the statistical comparison of percent reflectance, a total of 25 spectral vegetation indices were calculated from the reflectance data and regressed against the number of aphids. A wide array of relationships was found between spectral reflectance and aphid density. For example, the R^2 values were 0.85 for greenbug plus bird cherry-oat aphid and 0.97 for Russian wheat aphid. These preliminary results strongly indicated that remote sensing techniques, both hyperspectral and multispectral imageries, are highly promising to predict aphid density and discriminate aphid-induced stress form un-infested wheat in field conditions.

INTRODUCTION
Both hyperspectral and multispectral remote sensing technologies have undergone rapid development for a wide setting of applications including precision agriculture because they assist researchers in generating a variety of information at regional and global levels. In addition, various authors (Gemmell and Varjo, 1999; Bork et al., 1999) have argued that remote sensing has advantages over the traditional ground-based monitoring methods, because the latter is

laborious, slow, limited to the localized areas, subject to the great variation, and constrained by the lack of access. In addition, the same remotely sensed data can be used for multiple purposes by the same or different investigators.

In recent years, the use of remote sensing has dramatically increased the ability of scientists, managers, and decision-makers to study spatial data in terms of collecting, storing, manipulating, processing, visualizing, integrating, quantifying, monitoring, and managing the available information for present and future needs. Much effort has been assigned to estimate crop characteristics, such as green canopy health and cover, and to discriminate them in a spatially complete manner using visible and infrared spectral data. The goal of the present study was to evaluate the remotely sensed data to detect aphid infestation and estimate aphid density in wheat fields.

METHODOLGY

We collected aphid density; greenbug and Russian wheat aphids; and spectral reflectance data in and over stressed and non-stressed 0.25 m^2 wheat plots in TX, OK, and CO. Reflectance data and digital images were gathered by a hyperspectral ground spectrometer and a digital camera over aphid infested wheat and un-infested wheat nearby. Sometimes, at least 30 tillers were cut at ground level and transported to laboratory to count the number of aphids per 0.25 m^2 sample plot. The remaining tillers in each plot were tallied in the fields to estimate aphid density for each sample plot (Figure 1). The other times, aphid density was determined in the fields by counting all aphids within plots during the early growing season (Figure 1) or clipping all plants and counting aphid in the laboratory during the late growing season (Figure 1). All in all, aphid density was determined at 0.25 m^2 level for each sample. This methodology was applied to all sites for determining actual aphid density in this study.

Figure 1: Clipping wheat in a 0.25 m^2 plot to be transported to laboratory so as to count aphid (left), counting aphid on wheat plants in laboratory (middle) and in the fields (right).

RESULTS AND DISCUSSION

Reflectance patterns gathered by Ocean Optics ground hyperspectral spectrometer for greenbug stressed alone, combination of greenbug and abiotic-stressed and non-stressed wheat near Dumas, Texas were plotted across the visible and near infrared (NIR) range of the spectrum

(400-900 nm) and displayed in Figure 2. As it seen in Figure 2, Non-stressed wheat reflected less light than aphid stressed alone and combination of abiotic and aphid stressed wheat in the visible part of the spectrum but this trend switched in the NIR spectral window. The similar results were observed by plotting the visible and NIR reflectance data collected near Amarillo, Texas for Russian wheat aphid and abiotic stress and non-stress in wheat as well as exposed soil. Figure 2 depicts what was expected that healthy wheat absorbed more visible light for photosynthesis, while injured plants caused by aphid were not able to capture as high light as healthy wheat did for biomass accumulation. This result is in agreement with the findings of Riedell and Blacmer (1999) who reported the spectral properties of Russian wheat aphid and greenbug feeding effects in wheat at the leaf level.

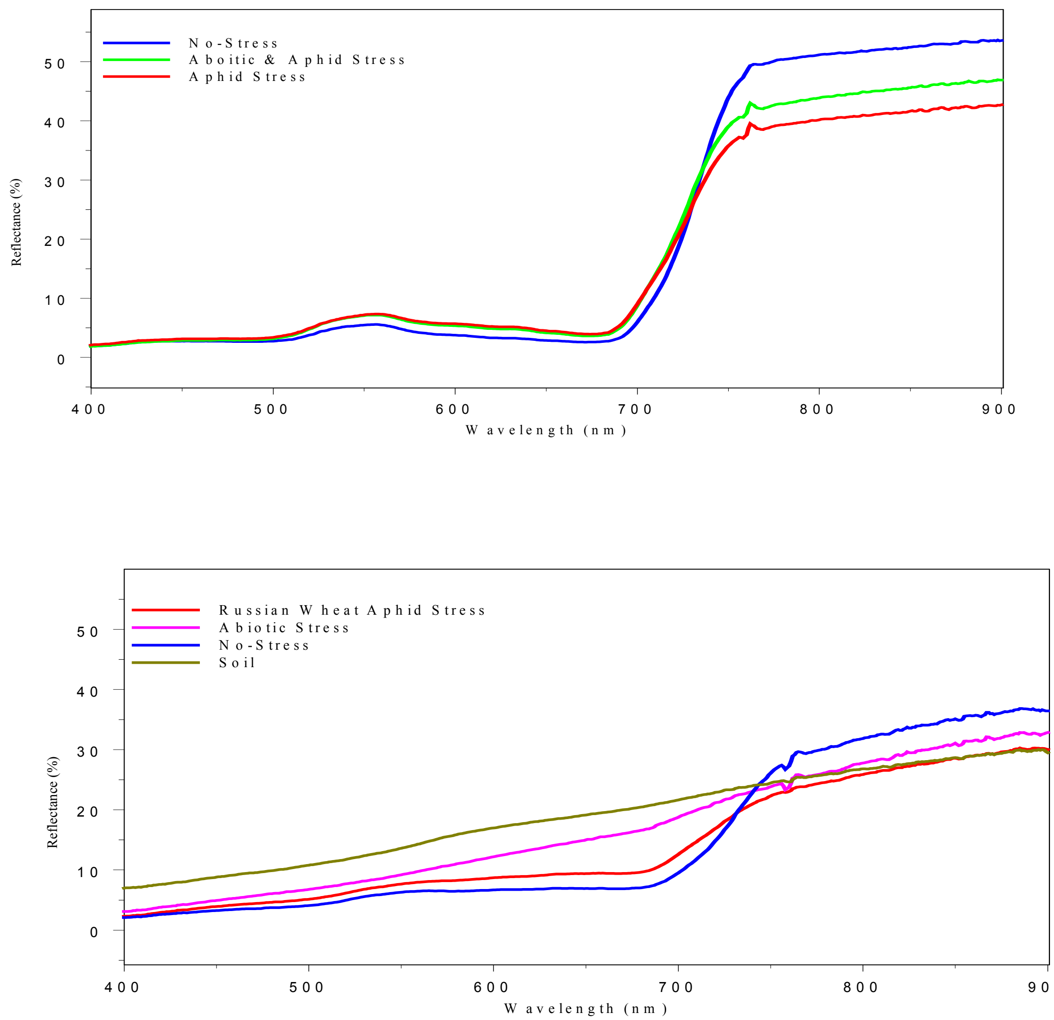
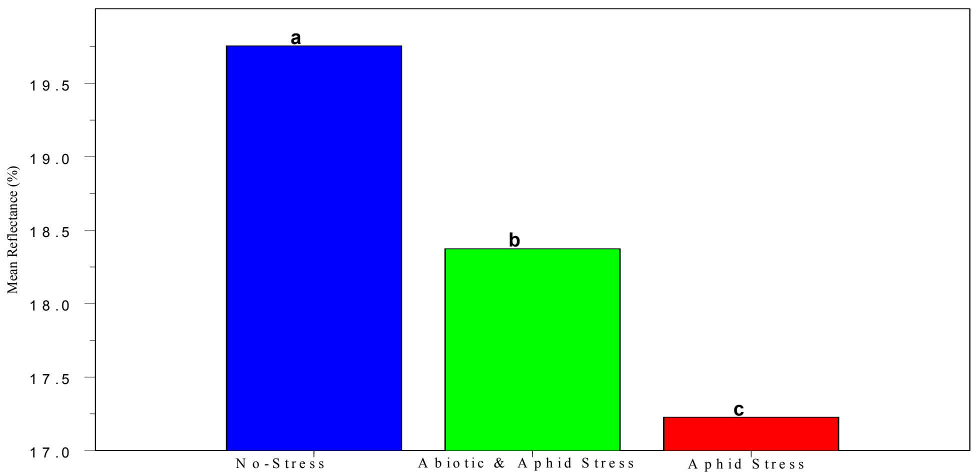


Figure 2: Spectral properties of greenbug-stressed alone, combination of abiotic and greenbug-stressed, and non-stressed wheat (top), Russian wheat aphid-stressed, water-stressed, healthy wheat, and exposed soil (bottom) across the visible and NIR spectrum.

Mean comparison of reflectance data collected for healthy, combination of greenbug and abiotic stress, and aphid stress alone in wheat crop was made and statistically significant difference was found among the entities in question across the visible and NIR spectrum (Figure 3). The same comparison was also made for the Russian wheat aphid stressed and healthy wheat and it resulted with the similar outcomes to greenbug (Figure 3). Both Figures, 2 & 3, strongly suggest that use of hyperspectral or multidate imageries to delineate aphid-induced stress in wheat because most of the image analyses are based on the statistical similarities and/or dissimilarities between or among the surface properties found in an imagery. For our case, surface properties are aphid stressed; or other types of stress; and non-stressed wheat in the fields.



Wavelength (nm)	Russian Wheat Aphid Stress	No Stress
400 - 500	a	b
500 - 600	a	b
600 - 700	a	b
700 - 800	a	b
800 - 900	a	b
400 - 900	a	a

Figure 3: Statistical comparison of three levels of stress measured by reflectance data: greenbug, combination of greenbug and abiotic (top), Russian wheat aphid stressed and non-stressed in wheat (bottom) in the visible and NIR range of the spectrum. Note: Different letters in adjacent columns indicate statistical significance at $\alpha = 0.05$

One of the digital images of greenbug infested wheat plots is shown in Figure 4. Digital images of greenbug-induced stress in wheat were analyzed using ASSESS (Image Analysis Software for Plant Disease Quantification) and percent greenbug damage was estimated as shown in Figure 4. A strong correlation (R^2 = 0.85) was found by regressing the percent damage against greenbug density (Figure 4). The negative slope of the regression line or increased percent greenbug damage while decreasing greenbug density in Figure 4 makes sense because most likely greenbug moved to new spots from injured plants or died due to reduction in food resources. This also appears to be a function of sampling date.

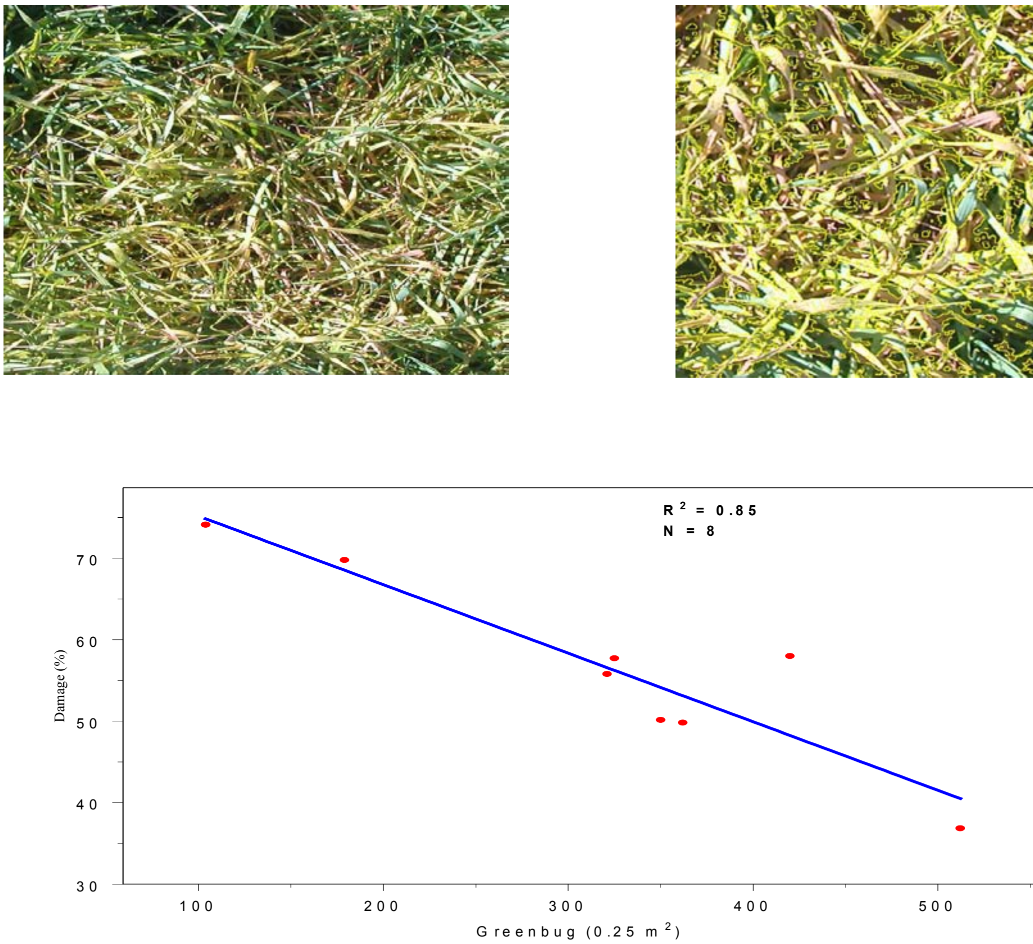


Figure 4: Greenbug-induced stress (upper left), estimation of damage caused by greenbug feeding (upper right), and the relationship between greenbug density and percentage damage (bottom) in wheat.

In order to investigate the relationship between aphid density and spectral data, 25 vegetation indices were calculated from reflectance data and regressed against aphid density. Very good to strong correlations explained by the R^2 values were found. The relationships explained by the R^2 values, spectral vegetation indices used to predict aphid density, and wavelength centers used to calculate spectral vegetation indices are given in Figure 5.

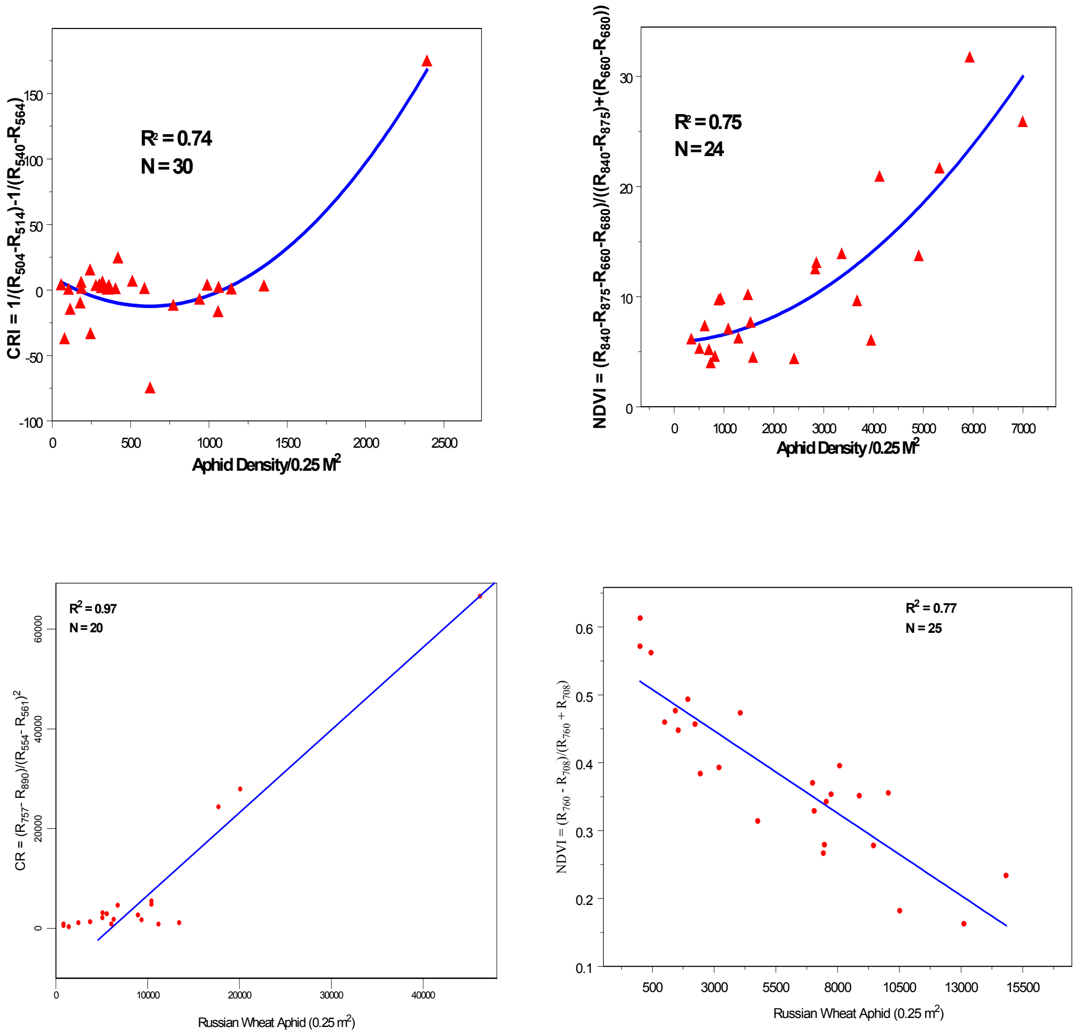
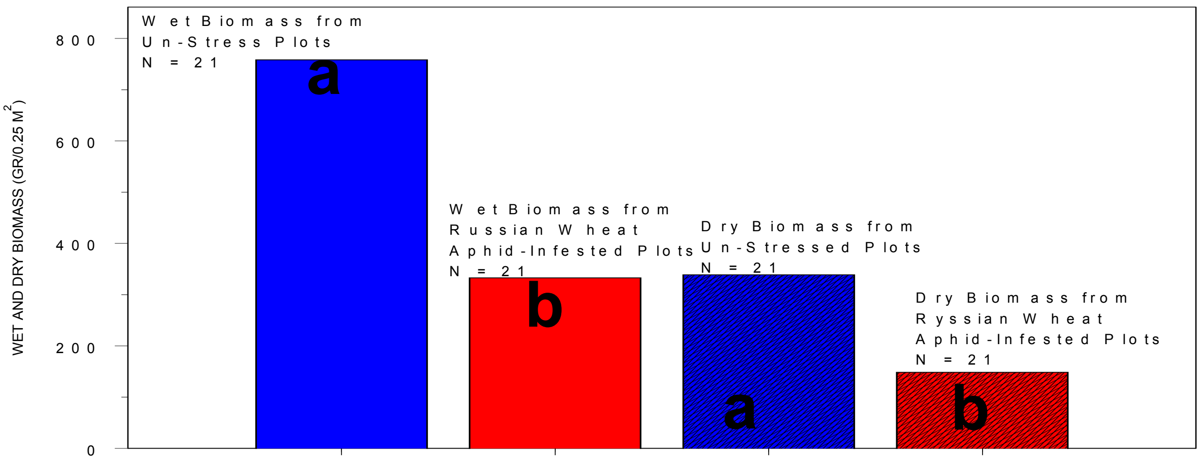


Figure 5: Plots of non-linear regression for aphid density (greenbug + bird cherry-oat aphid) and spectral vegetation indices (first two) and linear regression for Russian wheat aphid (last two). Data in the first plot were collected in a volunteer wheat field near Dumas TX, in the second plot data were gathered in a planted winter wheat field near Oklahoma City, OK, in the third plot data were obtained in a wheat field near Amarillo, TX, and in the last plot data were collected in a wheat field near Lamar, CO.

In addition to aphid and remote sensing data analysis, this work also dealt with prediction and comparison of wet and dry biomass from Russian wheat aphid infested and non-infested wheat near Amarillo, TX. It can be seen in Figure 6 that wet and dry biomass from Russian wheat aphid-stressed wheat were significantly different from non-stressed wheat. This result was also observed by Riedell and Blackmer (1999) who found reduction in dry weight of wheat leaves caused by Russian wheat aphid feeding when compare to Russian wheat aphid free leaves.



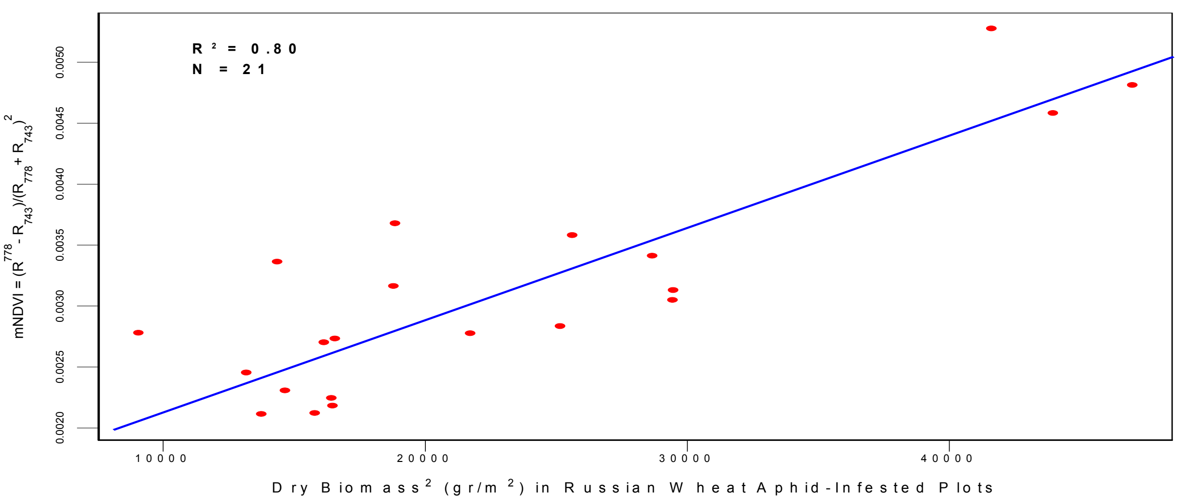


Figure 6: Dry and wet biomass from Russian wheat aphid-infested and un-infested plots (top) and the relationship between biomass gathered from Russian wheat aphid-infested plots and modified Normalized Difference Vegetation Index (mNDVI) (bottom).

CONCLUSIONS AND DIRECTIONS FOR FUTURE WORK

This work has shown that remote measurement of aphid-induced stress to estimate aphid density and separate the injured wheat from the healthy one at 0.25 m^2 canopy level in the field conditions was successfully employed.

Results reported in this work indicate feasibility of using remote sensing imageries at large scales to detect and discriminate aphid feeding damage in wheat and possibly in other crops.

We expect to work spectral measurements of interactions between aphid pest and host plants at larger scales using hyperspectral and multidate imageries.

Future work will continue to collect spectral data for aphid infestation on agricultural crops not only in the field conditions but also controlled environment.

Discrimination of three level of stress: water, nutrient, and aphid in wheat and sorghum will be the focus of the work in the near future.

Future work will also concentrate to develop and validate a spectral aphid stress index for major crops.

REFERENCES

Bork, E.W., N.E. West, K.P. Price, and J.W. Walker. 1999. Rangeland cover component quantification using broad (TM) and narrow-band (1.4 NM) spectrometry. J. Range Manage. 52 (2):249-257.

Gemmell, F. and J. Varjo. 1999. Utility of reflectance model inversion versus two spectral indices for estimating biophysical characteristics in boreal forest test site. Remote Sens. Environ. 68:95-111.

Peñuelas, J., R. Isla, I. Filella, and J. L. Araus. 1997. Visible and near-infrared reflectance assessment of salinity effects on Barley. Crop Sci. 37:198-202.

Reidell, W. E. and T. M. Blackmer. Leaf reflectance spectra of cereal aphid-damaged wheat. Crop Sci. 39:1834-1840.

ii. The search for a Distinct Spectral Signature for Greenbug and Russian Wheat Aphid Injured Wheat

Written by Zhiming Yang
Other Participants, Mahesh Rao, Norman Elliott, Dean Kindler, and Kris Giles.