Texas
Precision Agriculture

The Texas A&M University System – Agriculture Program

Annual Reports - 2000

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Primary Location: Bushland, TX.

Project Title: Use of Precision Irrigation and Remote Sensing to Manage and Monitor Disease in Pathogen Infested Soils

Reporting Period: 1/2000 – 12/2000

Objectives:

1. Evaluate how PET - based irrigation affects disease incidence and crop water use efficiency.
2. Determine whether multi-spectral analysis systems and other remote sensing instrumentation can differentiate between biotic and abiotic stresses.

A. Summary of Progress:

Irrigation and Disease: Take-all is a root disease of wheat caused by the soil borne fungus Gaeumannomyces graminis var. tritici. The disease is most prevalent under center pivot irrigation in continuous wheat fields that are heavily irrigated. Such fields are common in the 1N-reporting district of the Texas Panhandle. Unlike many diseases, take-all typically occurs in the same field locations year after year. Because take-all develops in reoccurring spots and is strongly influenced by irrigation, we felt it was an ideal disease for management using precision agriculture technologies.

A study was established under the center pivot irrigation system at the TAES research site in Bushland. The center pivot is equipped with LEPA nozzles and on-off valves. In conjunction with the on-off valves, water application can be managed by regulating pivot speed. The pivot is also equipped with thirty-two infrared transducers (IRTs) that are capable of measuring crop canopy temperature. In 1998, the continuous wheat wedge of the Bushland center pivot research site was infested with the take-all fungus. Disease developed in infested spots in 1998 and again in 1999. In April of 1999, take-all spots were geo-referenced for studies to be conducted during the 2000 growing season. During 2000, differential irrigation was applied to take-all areas and also to areas that were not infested with the pathogen. Take-all areas that had been geo-referenced in 1999 were located and spectral readings were made weekly using the Crop Scan hand held radiometer, and canopy temperature was recorded using the pivot-mounted IRTs. We also contracted with a commercial remote sensing firm, Earth Scan, to take satellite remote sensing images of our research plots.

Unlike 1998 and 1999, take-all never developed to any significant extent during the 2000 season. Even in plots that received 100% PET-based irrigation, only minimal disease developed, and diseased areas were not in the same locations as in previous years. Therefore, no differences were detected between healthy and previously diseased spots with any of the remote sensing techniques.

Although incidence of take-all was minimal, an unexpectedly high incidence of Fusarium root rot developed in plots receiving 50% PET-based irrigation. Satellite images from Earth Scan easily detected plots irrigated at 50% PET but we were unable to differentiate the difference between disease and drought stress with the data they provided (Figure 1). We are presently in the process of analyzing IRT data and correlating it to combine yield monitor data.

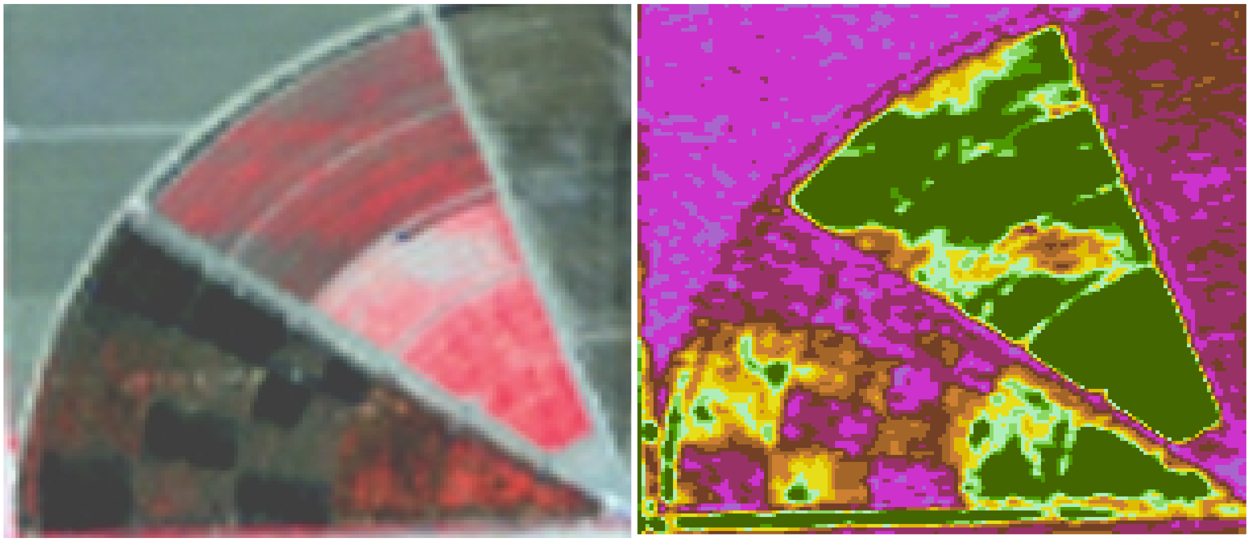

Fig. 1. Spectral image from the ICONOS satellite provided by Earth Scan, a commercial remote sensing provider. Plots irrigated at 50% PET are recognized as dark spots in the field. However, based on these images, differentiation between drought stress and root rot was not possible.

Remote Sensing – Differentiation between Biotic and Abiotic Stresses: If remote sensing is to be of value for detection of plant diseases we must be able to detect diseases before the symptoms are readily visible and differentiate between disease and abiotic stress. Existing technologies that are commercially available, and in use today, have limited resolution. Thermal infrared transducers only read in the thermal infrared region, and satellites, most handheld radiometers, and aerial imaging platforms only use a few broad wavebands. Higher resolution data will be needed if we are to detect spectral signatures that differentiate biotic and abiotic stresses.

Through collaboration with Resource 21 and Boeing, we acquired a hyperspectral radiometer capable of measuring light from 350 nm up to 2500 nm at 1 nm increments. Along with this instrument we acquired an integrating sphere, which allows readings to be taken on a single intact leaf under precisely controlled conditions (Figure 2). Our objective was to compare this technology with data available from airborne imagery, hand held radiometers, and pigment extract absorbance from a scanning spectrophotometer with the hope of finding a unique spectral signature associated with specific biotic stresses.

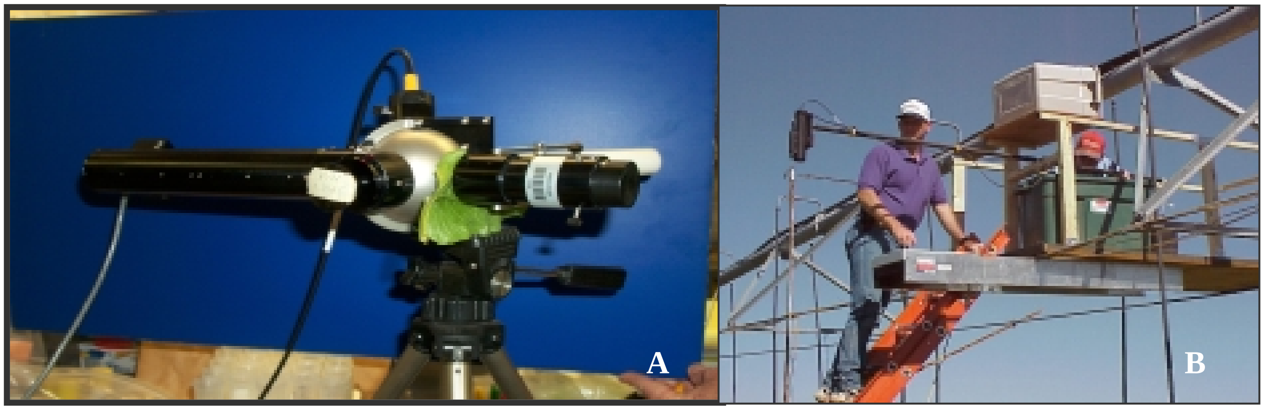

Fig. 2- Hyperspectral radiometer (A) and an integrating sphere (B) supplied by Resource 21 and Boeing. These imaging tools were used during the 2000 growing season to evaluate different remote sensing technologies for their ability to differentiate between biotic and abiotic stresses.

Beet necrotic yellow vein virus (BNYVV) causes a yellowing of sugar beet foliage that mimics nitrogen stress. We collected samples throughout the growing season that exhibited yellowing symptoms as well as apparently healthy samples. Readings were taken in the field with a 9-band hand-held radiometer and airplane and satellite images were arranged when possible. Once the samples were in the lab they were tested for the presence of BNYVV through ELISA. The leaves were read in the integrating sphere and then frozen. Pigment extracts have been made on several preliminary samples and read with a scanning spectrophotometer. When complete, the tissue will be analyzed for nitrogen content.

The hand held radiometer was unable to differentiate between asymptomatic plants that tested positive for BNYVV and asymptomatic plants that tested negative for BNYVV. Preliminary analysis of the hyperspectral data from the integrating sphere also appeared unable to differentiate between asymptomatic plants that tested positive for BNYVV and asymptomatic plants that tested negative for BNYVV. However, preliminary analysis of the data from pigment extracts showed differences between asymptomatic plants that tested positive for BNYVV and asymptomatic plants that tested negative for BNYVV (Figure 3). This indicates that the potential exists to remotely detect disease in the field but we are limited by our instrumentation. The sizes of the datasets are quite large and make analysis difficult. We are currently developing a database system, which will allow us to store and manipulate the large datasets generated by these technologies. It will be a network accessible, multi-user system, which will facilitate collaboration and sharing of data between all Precision Ag faculty.

Remote Sensing – Disease Quantification: In a separate study, we investigated remote sensing as a means of quantitatively measuring Cercospora leaf spot incidence and severity. The study was conducted in a Cercospora disease nursery containing a fungicide evaluation trial; with treatments ranging from highly effective fungicide rotations to disease check plots with no control. An individual with years of experience in visually rating cultivars for disease severity rated each replicated treatment in the nursery while we used the Crop Scan handheld multi-spectral radiometer for ratings. Preliminary results indicated that the hand-held radiometer was a more effective means of relating disease severity to final yield than visual disease ratings made by an experienced individual. Visual ratings showed the highest variability at intermediate levels of disease where individuals are less adept at estimating percentages. This work will be repeated in 2001.

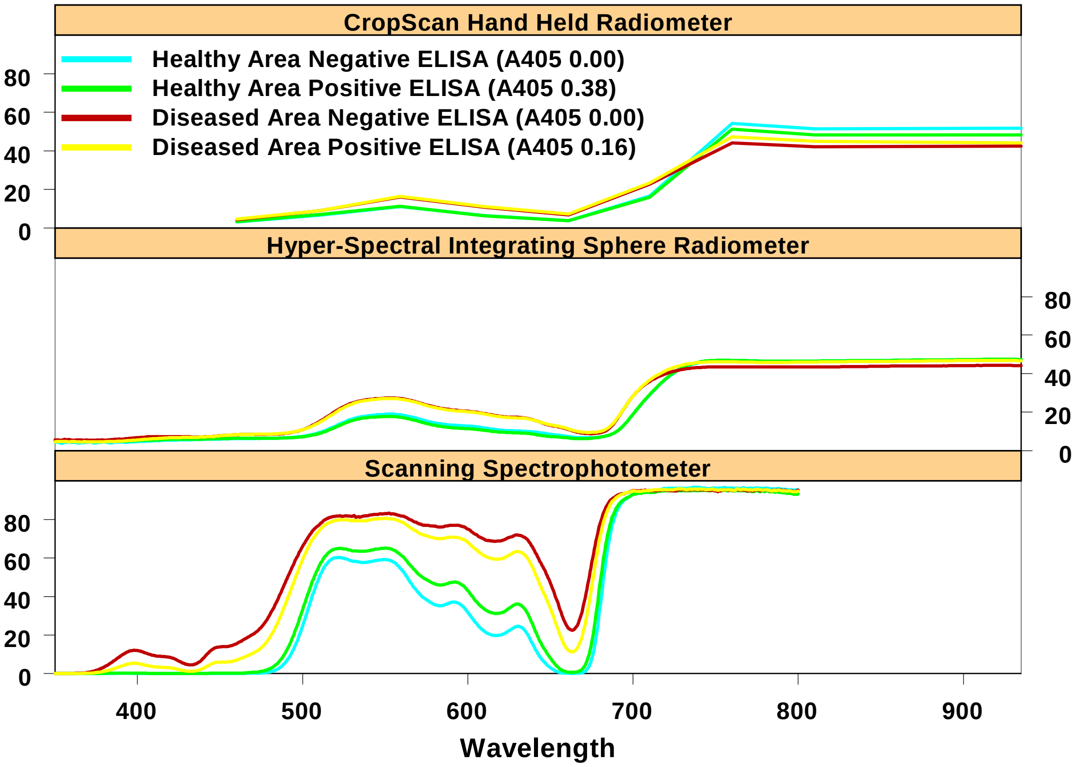

Fig. 3. Reflectance and absorbance data from healthy and diseased Sugar beets. Only spectrophometer readings could differentiate between Green virus-infected tissue from green virus –free tissue.

Remote Sensing – Definition of Management Zones - Ergot: Development of a model for ergot risk assessment, based on historic weather records, has been attempted before with mixed results. Although these models can be useful, predictions are often inaccurate because of the extreme spatial and temporal variability in environmental factors that impact disease development. One of the basic problems with this approach is that weather data often does not correlate well with disease incidence because weather stations may be far removed from the fields of interest. For instance, in the Texas Panhandle, it is not uncommon for one field to have a high incidence of disease while fields one to five miles away might be disease free. The weather station nearest any of these fields could be 25-50 miles away. In such a case, it is clear that strong correlations between disease incidence and any particular weather parameter would be a matter of chance. Therefore, the distance of a sorghum seed production field from the nearest weather station defines the management zone for sorghum ergot. However, with the advent of Doppler radar, it is possible to record meteorological events with a resolution of only a few square kilometers, a degree of accuracy that is normally unavailable with ground weather stations (Figure 4). National Weather Service (NWS) stations throughout the Southern Region maintain archives of past weather events from Doppler radar. In cooperation with the NWS in Amarillo and hybrid sorghum seed producers, we have identified sorghum fields that were infested with ergot during the last three years and are in the process of relating specific weather events, as recorded by Doppler radar, with disease. Seed companies have identified and recorded the location of diseased fields using GPS technology. Therefore, we now have the capability to input GPS coordinates of diseased fields into the Doppler radar program archives and search for weather events for those specific locations over any particular period of time. In the Texas Panhandle, widely scattered showers frequently occur during sorghum flowering periods and these showers may be the explanation for the variability in disease incidence. We believe that Doppler radar technology will provide the answer to this question.

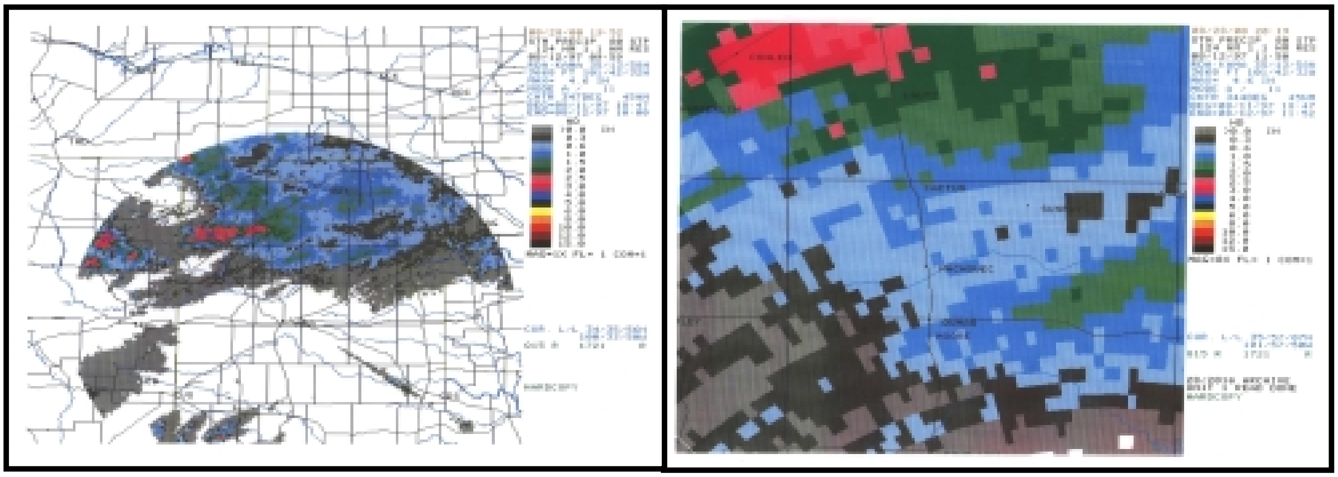

Fig. 4. Doppler radar images of area surrounding Amarillo, Texas. A) One hundred mile image provides complete coverage of most of the hybrid seed sorghum production areas in the Texas Panhandle. B) Images can be magnified to approximately one square mile resolution, and meteorological events for individual geo-referenced fields can be identified.

Remote Sensing – Definition of Management Zones – Soilborne Viruses. In a second study, we studied the distribution of BSBMV and BNYVV in sugar beet fields in Minnesota, Colorado, and Texas. Agriculturalist working for the various sugar companies are interested in identifying the best method of sampling for these pathogens because plants growing in heavily infested areas of a field can be plowed out. This selective removal of diseased plants can result in an overall improvement in crop yield and quality. Therefore, the size of the management zone is only limited by our ability to describe distribution of the pathogen in the field.

Fields infested with BNYVV, BSBMV, or both viruses were identified and grid sampled. Grid size was one acre, for the entire field, and smaller areas were intensively sampled with grid sizes of approximately 10'. The location of each soil sample taken from each grid was geo-referenced using a Satloc GPS receiver. BNYVV and BSBMV was baited from each soil sample and bait plants tested for the presence of each virus using ELISA. ELISA data for each geo-referenced soil sample was recorded into ArcView and used to generate geo-referenced field maps. Data was further analyzed using the GS+ geostatistical program to determine spatial distribution patterns of each virus. In only one field, auto correlation existed at a separation distance of approximately 30', but beyond this distance, there was no observable distribution pattern (Figure 5).

Data Management: Data management is a ubiquitous problem associated with research in precision agriculture. While all of our field data have spatial characteristics, they are frequently in different, incompatible units. Our yield monitor data is geo-referenced with latitude and longitude, satellite and aerial remote sensing images are referenced according to the universal transverse mercator system (UTM), and our infrared thermometers that are attached to the center pivot at Bushland are geo-referenced by distance from the pivot pad, and angle of the center pivot irrigation system. By converting all of this data to UTM, we can visualize these different factors.

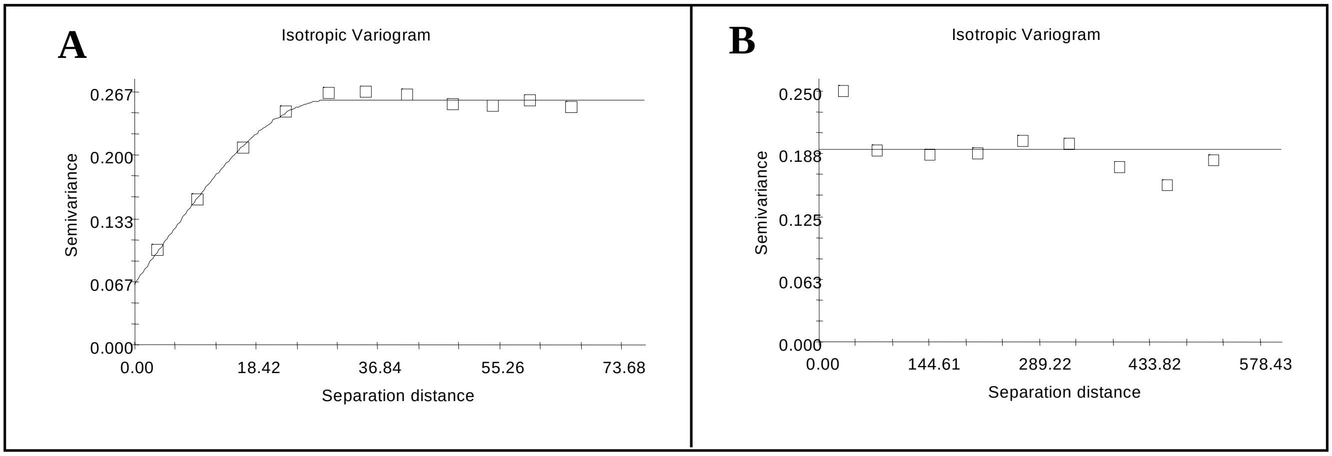

Fig. 5. Variograms of spatial distribution of BNYVV from intensively sampled (small grid) section of a field (A), and the whole field in an acre-sized (large) grid (B).

For plot-based studies, we must also be able to locate the boundaries of our plots to segregate these factors according to treatments and replicates. With rectangular plots this is easily accomplished with any GIS tool. However, with the Bushland center pivot, crops are planted in a circle to maximize irrigation efficiency and reduce runoff. Therefore, plots are not rectangular but small sections of a circle. By using a combination of drawings from AutoCAD along with ArcView, we have been able to generate plot boundaries for any given plot design (Figure 6). Whether our plots are six rows wide or twelve, we can take the appropriate AutoCAD template, overlay a geo-referenced ArcView image of our plots and quickly retrieve the data of interest. This technique allows us to convert rapidly from geo-referenced data to plot based data, thereby permitting easy statistical analysis of any particular data set.

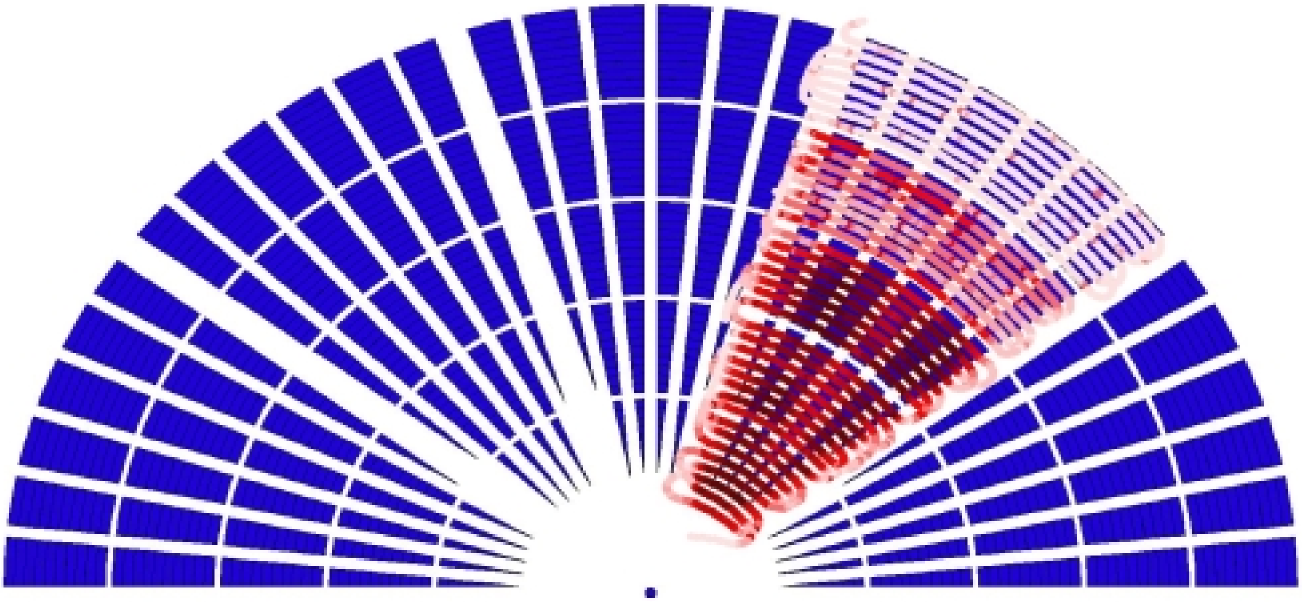

Fig. 6. Data from a yield monitor combine superimposed on a plot map. Each plot is labeled with the treatment and block. A spatial join of these images results in a table identifying each yield point from the combine with the treatment and block it came from.

B. Education / technology transfer:

During the year, members of the plant pathology project gave numerous PA presentations at field days, crop tours, commodity research meetings, and growers meetings. We also routinely provide tours to various groups such as scouts, schools, visiting scientists, etc. during which we give overviews of our PA project.

C. Milestones achieved:

We have made significant progress over the last three years in elucidating the effect of various PET-based irrigation levels on crop yields, water use efficiency and disease development. Corn, sorghum, sugar beets, and wheat have been included in the studies. We have found that with all grain crops, irrigation at 75% PET instead of 100% PET has typically resulted in equal or greater potential profit to growers because of reduced input costs. Water has been conserved and energy costs reduced. In addition, we have found that irrigation management has the potential to reduce the incidence and severity of several plant diseases and insect pests. In general, reduced irrigation frequency reduces incidence and severity of many soilborne plant pathogens more than reducing the total amount of irrigation water applied. The most significant aspect of this research has been the demonstration that producers cannot irrigate crops growing in pathogen-infested soils in the same manner they irrigate crops growing in pathogen-free soils. Soilborne plant pathogens reduce crop yield and quality and have an adverse effect on crop water use efficiency.

D. Publications:

Michels, Jr., G. J., G. Piccinni, C. M. Rush, and D. A. Fritts. 1999 Sensing Greenbug (Homoptera: Aphididae) Infestations In Winter Wheat With Infrared Transducers. Southwestern Entomology 24(4):269-279.

Piccinni, G. and C. M. Rush. 2000. Determination of Optimum Irrigation Regime and Water Use Efficiency of Sugar Beet Grown in Pathogen Infested Soil. Plant Dis. 84:1067-1072

Piccinni, G., C.M. Rush, K.M. Vaughn, and Lazar, M. D. 2000. Lack of Relationship Between Susceptibility to Common Root Rot and Drought Tolerance Among Several Closely Related Wheat Lines. Plant Disease. 83:25-28.

Piccinni, G., J.M. Shriver, and C.M. Rush. 2001. The relationship among seed size, planting date and common root rot in hard red winter wheat. Plant Disease. (accepted)

E. Precision agriculture proposals:

Identification and differentiation of biotic and abiotic stresses using multispectral remote sensing for application in IPM production systems. USDA-IPM $99,000.

Integrated management practices for protecting seed sorghum from ergot. Texas Sorghum Producers Board $25,000.

Application of precision agriculture technology for managing irrigated sorghum at several planting densities. Texas Sorghum Producers Board $15,000. Funded through PROFIT.

Effect of irrigation on disease incidence and severity in pathogen infested soils. BSDF $12,200.

Potential virulence of beet soil borne mosaic virus and interactions with necrotic yellow vein virus. Southern Minnesota ND R&D Board $15,500. Funded

Reducing losses to take-all of wheat by remote sensing and irrigation management. Texas Wheat Producers Board $12,000. Funded

Application of precision agriculture technology for managing irrigation and disease in drought tolerant Corn. Texas Corn Producers Board $15,000. Funded

Identification and differentiation of biotic and abiotic stresses using multi-spectral remote sensing for application in IPM production systems. NASA – Pre-Proposal $100,000.

Factors impacting development of a remote sensing dependent site-specific irrigation/ Chemigation system. Precision Ag. – TAES $194,438. Funded. Co-PI with Jerry Michels.

Airborne multi-spectral assessment of crop health and feedlot dust potential. NASA $50,000. Funded

Integrated Management of Stalk Rot in Sorghum by Genetic Resistance and Precision Irrigation. Texas Grain Sorghum Producers Board. $17,000. Funded through PROFIT.

Development of a model for risk assessment and fungicide application for management of sorghum ergot. Texas Sorghum Board $17,000.

Yield Tracker: A yield mapping and prediction information delivery system. IFAFS $800,606. Cooperator, funded with Bill Payne at $40,000.

F. Precision Agriculture meetings attended/papers (posters) presented:

G. J. Michels, G. Piccinni, C. M. Rush, and D. A. Frits. 2000. Using infrared transducers to sense greenbug infestations in winter wheat. Proceedings of the 5th International Conference on Precision Agriculture. Bloomington, MN. July 16-19,2000. (in press)

Piccinni, G., J.K. Burk, C.M. Rush, and G.J. Michels. 1999. Development of an Automated System for Infrared Detection of Plant Stress. p. 109. In Agronomy Abstracts. ASA, Madison, WI. ASA/CSSA/SSSA Joint 91st Annual Meeting, Salt Lake City, UT, Oct. 31 – Nov. 4, 1999.

G. J. Michels, G. Piccinni, C. M. Rush, and D. A. Frits. 2000. Using infrared transducers to sense greenbug infestations in winter wheat. 5th International Conference on Precision Agriculture. Bloomington, MN. July 16-19,2000.

Staff Writer. 1999. Satellite, plane photos aid farmers. Houston Chronicle, November 17, 1999, 6C.

Staff Writer. 2000. Satellite images of land take root with farmers. Albuquerque Journal. August 14, 2000 pg. 2.

Rush, C.M. 2000. Precision Agriculture. 2000 Spring Crops Field Day. AREC Bushland, TX.

G. Other developments:

Several personnel changes in 2000 significantly impacted the plant pathology PA project. Keden Burk, who was farm manager for the Bushland center pivot research site, left in early spring for another job in California. Keden had been associated with the PA project since it began and had assumed considerable responsibility in the overall project. His departure, just before planting time, greatly complicated all field activities in 2000. David Jones replaced Keden in May. David had worked in the program as Keden’s helper, but didn’t have the technical or farming experience that Keden had and this impacted our research.

Giovanni Piccinni, an assistant research scientist who had been with the plant pathology PA project since it began, also left early in 2000 and took a job with TAES in Uvalde. Giovanni, a plant stress physiologist, had taken leadership of the PA irrigation studies under the Bushland center pivot. His departure constituted a big loss to our program but we were still able to complete the field studies he had supervised.

Additional personnel changes that impacted the plant pathology PA project in 2000 included the hire of two assistant research scientists. Fekede Workneh joined our group in May. He has a Ph. D in plant pathology from UC Davis and his experience is in epidemiology and statistics. His research activities in PA will relate to site-specific management of plant disease as it relates to cultural and climatic variables associated with pathogen ecology and epidemiology. Karl Steddom was hired in June and he also has a Ph. D in plant pathology from UC Riverside. His background is in biological control but he has interest in data base management and remote sensing. Karl primarily will be involved in studies evaluating various remote sensing techniques for their ability to detect and differentiate biotic and abiotic stresses.