Patterns of Zone Management Uncertainty in Cotton using Tarnished Plant Bug Distributions, NDVI, Soil EC, Yield and Thermal Imagery

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INTRODUCTION Precision-based agricultural application of insecticide relies on a non-random distribution of pests; tarnished plant bugs (*Lygus lineolaris*) are known to prefer vigorously growing patches of cotton (e.g., Willers et al., 1999; Willers and Akins, 2000). Management zones for various crops have been delineated using NDVI (Normalized Difference Vegetation Index), apparent bulk soil electrical conductivity (EC_a - Veris), and yield data (e.g., Sudduth et al., 1995; Corwin and Lesch, 2003; Iqbal et al., 2005); however, estimations of uncertainty for these data layers are equally important considerations. The objective of this study was to evaluate the extent of spatially non-autocorrelated areas in an irrigated cotton field in the Mississippi Delta (5.8 acres - with substantial contrasts in soil texture and water-holding capacities) using NDVI, EC_a, yield, and thermal imagery as well as Tarnished Plant Bug (*Lygus lineolaris*) distribution maps (the latter taken at peak bloom).

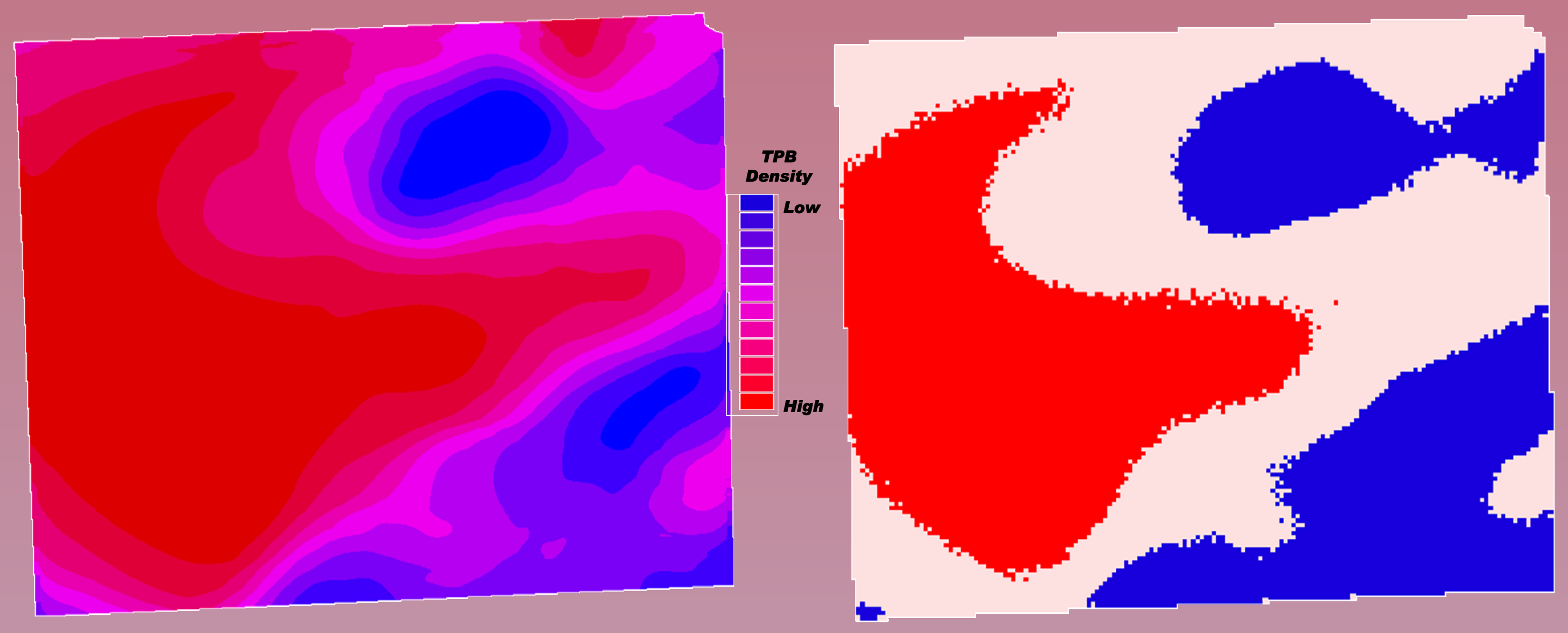

Figure 1. A cumulative TPB distribution map (shown at left) was based on counts acquired at or near peak bloom over three growing seasons at 32 locations (2001-2003). Note that the red and purple areas coincide with the bright (white to light gray) high NDVI areas (shown in Figure 2). Local Moran's I spatial analysis (LISA - shown on the right) of this cumulative TPB map highlights non-autocorrelated patches (depicted in gray) which represent areas with high degrees of heterogeneity between adjacent pixels (encompassing 2.61a). The red areas represent spatially autocorrelated high TPB counts (with an interpolated aerial extent of 1.67a), whereas the blue zones depict spatially autocorrelated low TPB counts (spanning an interpolated aerial extent of 1.47a).

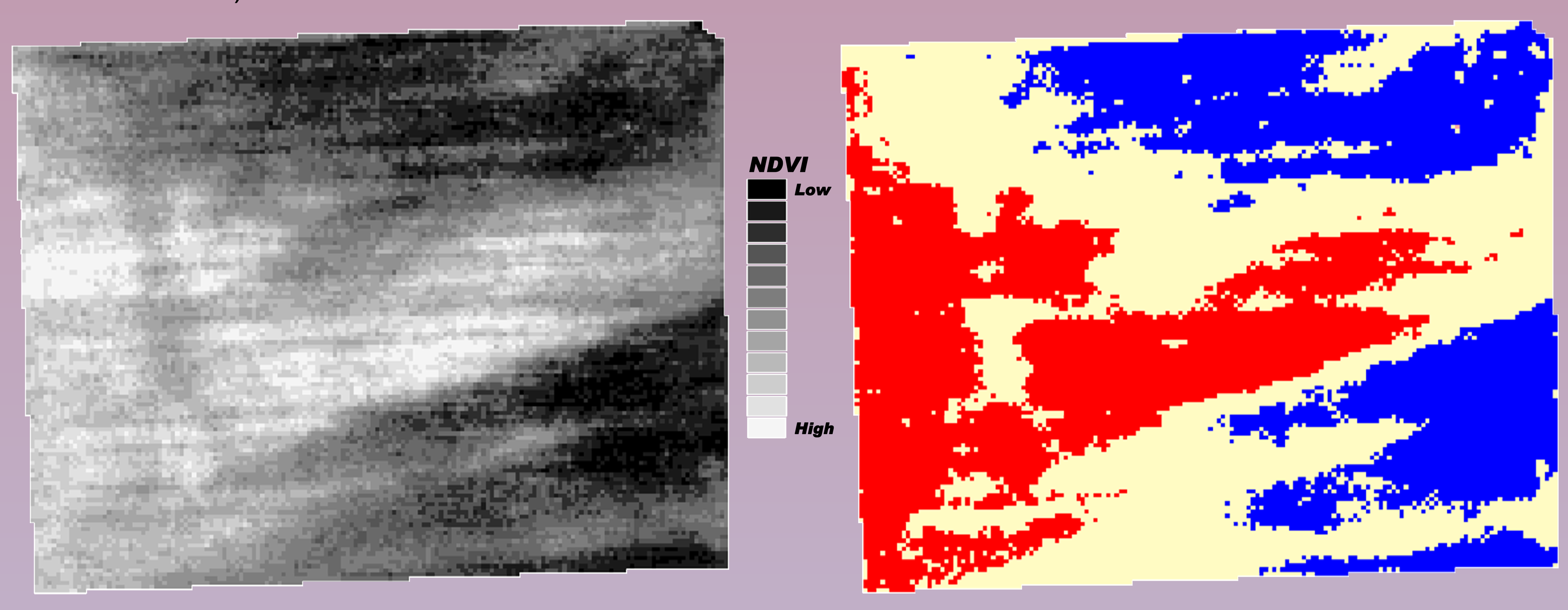

Figure 2. A cumulative NDVI (shown at left) was calculated from color infrared imagery obtained near peak bloom over three field seasons (2001-2003); white to light gray areas represent high-vigor cotton. Local Moran's I spatial analysis (LISA - shown on the right) of this cumulative NDVI highlights non-autocorrelated patches (depicted in gray) which represent areas with high degrees of heterogeneity between adjacent pixels (encompassing 2.62a). The red areas represent spatially autocorrelated high NDVI values (with an aerial extent of 1.61a), whereas the blue zones depict spatially autocorrelated low NDVI values (spanning 1.52a).

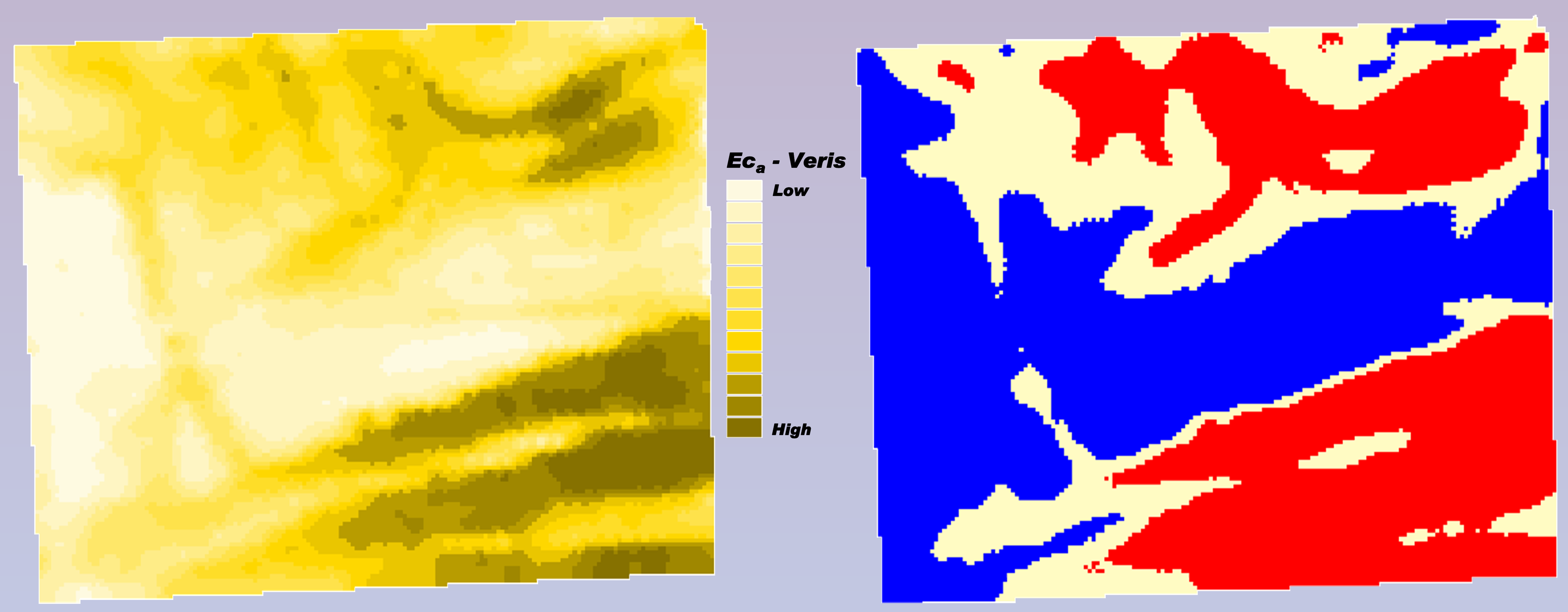

Figure 3. An apparent bulk soil electrical conductivity map (i.e., shallow EC_a interpolated to 1m resolution) was acquired using a Veris 3100 unit (October 2004). Local Moran's I spatial analysis (LISA - shown on the right) of this shallow EC_a map highlights non-autocorrelated patches (depicted in gray) which represent areas of uncertainty (encompassing 1.52a). The red areas represent spatially autocorrelated high EC_a values (with an aerial extent of 1.95a), whereas the blue zones depict spatially autocorrelated low EC_a values (spanning 2.28a).

METHODS TPB counts were acquired from 32 field locations at or near peak bloom for three successive years (2001–2003). All locations were recorded using GPS equipment (Trimble AG132). A cumulative TPB distribution map was generated from these point datasets (Fig. 1) using the Spline technique in ArcView (v. 3.3). Color infrared imagery of a 5.8-acre (2.3 ha) irrigated cotton field from Washington County, MS was acquired at peak bloom (2001– 2003) using a DuncanTech camera (at a ground resolution of 1.0 meter) and a cumulative NDVI was derived by compositing the aforementioned images (Fig. 2). A Veris survey was conducted in October 2004; transects were taken every 4 m and an interpolated EC_a map was generated (Fig. 3). Three years of yield data were normalized and then composited to produce a cumulative yield map (Fig. 4). Thermal imagery was acquired using an Electrophysics PV320T camera mounted in an agricultural aircraft and flown at an altitude of 460 m; images from two flight dates (at or near peak bloom, July 2006 and 2007) were used to derive a cumulative thermal map (Fig. 5). Subsequently, the TPB, NDVI, EC_a (Veris), yield, and thermal datasets were analyzed separately using Local Moran's I Spatial Autocorrelation (LISA; GeoDa v. 0.9.5-i5 – Anselin, 2004). http://www.csiss.org .

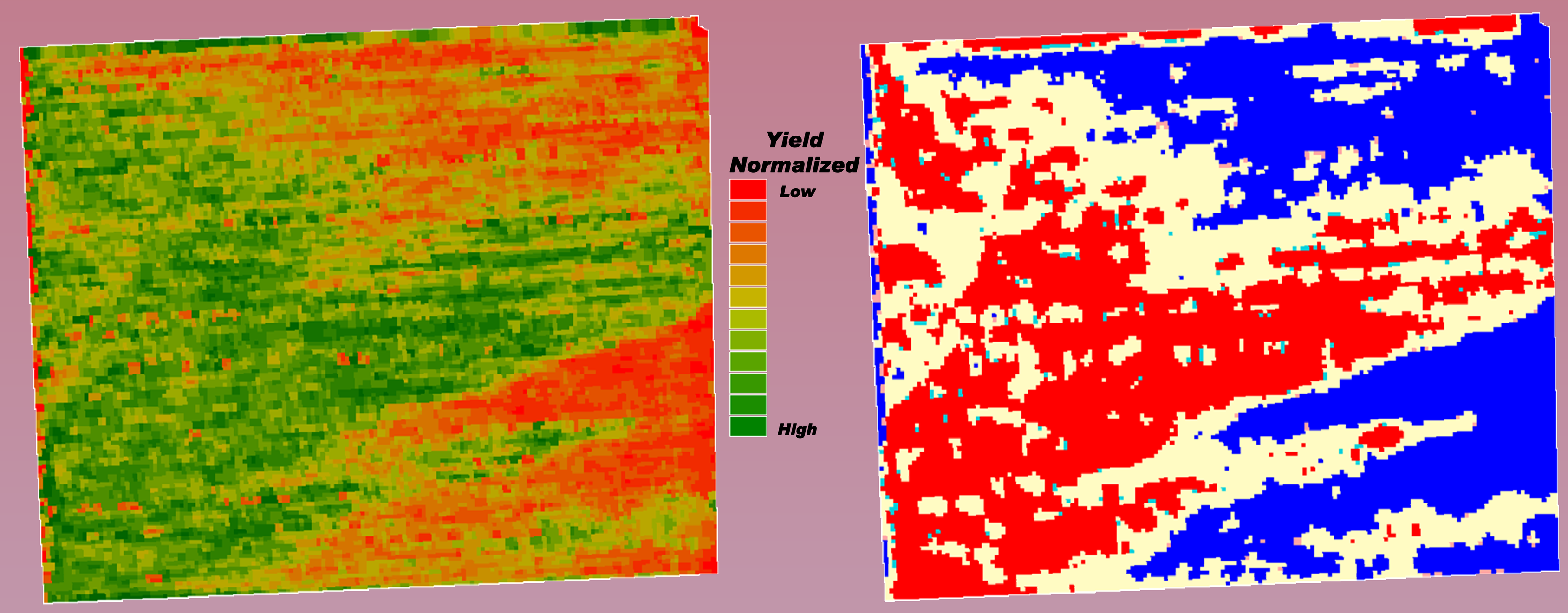

Figure 4. A cumulative normalized yield map (1.0 m resolution) was produced by compositing three years of yield data (2001-2003). Local Moran's I spatial analysis (LISA - shown on the right) of this yield map highlights highly dispersed, non-autocorrelated patches (depicted in gray) which represent areas of uncertainty (encompassing 2.00a). The red areas represent spatially autocorrelated high yield values (with an aerial extent of 1.93a), whereas the blue zones depict spatially autocorrelated low yield values (spanning 1.75a).

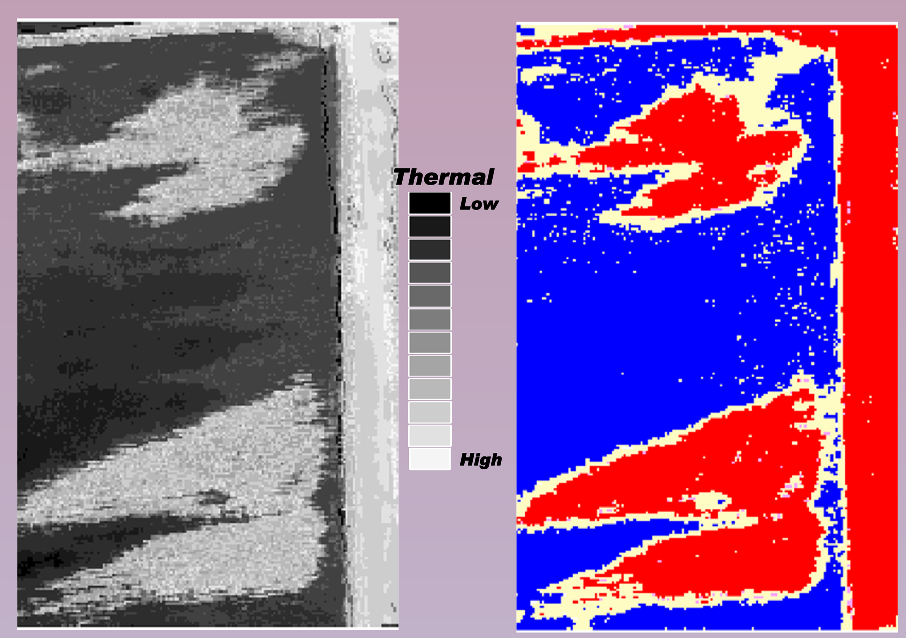

Figure 5. A cumulative thermal image (0.5 m resolution) was produced by compositing two images taken at peak bloom (July 2006 and July 2007). Local Moran's I spatial analysis (LISA - shown on the right) of this thermal composite map highlights non-autocorrelated patches (depicted in gray) which represent areas of uncertainty. Thin gray patches represent sharp transitions whereas irregularly-shaped, omni-directional patches define transitional areas that are highly-variable from one pixel to the next. The red areas represent spatially autocorrelated high thermal values; blue zones depict spatially autocorrelated low thermal values.

RESULTS and CONCLUSIONS Spatial analyses of TPB, NDVI, EC_a, thermal and yield maps using Local Moran's I highlighted non-autocorrelated regions that represent assessments of uncertainty. Spatial autocorrelation analysis is a very effective method to delineate these higher risk areas resulting from the soil-plant-atmosphere-water-pest interactions that contribute to the field response heterogeneities depicted in various maps (e.g., DeFauw et al., 2006; Thomson et al., 2007; English et al., 2007, 2008 and 2009). Thin linear non-autocorrelated patches represent abrupt transitions between zones. Large omni-directional non-autocorrelated patches depict highly heterogeneous habitats that may not be properly managed in a site-specific application (and in all likelihood not sprayed), thereby serving as refugia and loci for reinfestation of the field by TPBs. The Local Moran's I Spatial Autocorrelation (LISA) analysis represents a useful tool to augment the accuracy of scouting maps by defining zones of uncertainty and acquire additional information on the structure of these transitional areas between the well-defined or more stable management zones. A better understanding of these field-scale patterns will facilitate risk management decisions when deploying site-specific insecticides. These types of uncertainty assessments demonstrate that the fusion of multi-year datasets may allow predictive field-specific models to be created and then used by producers to more effectively manage risk and, in turn, help improve cotton production capacity in highly heterogeneous field settings.

References

Anselin, L. 2004. GeoData Analysis Software (GeoDa0.9.5i) http://www.csiss.org
Corwin, D.L. and S.M. Lesch 2003. Application of soil electrical conductivity to precision agriculture: Theory, Principles and Guidelines. Agron. J. 95:455-471.
DeFauw, S.L., P.J. English, F.A. Harris and J.L. Willers. 2006. Field-scale Stability Assessment of Cotton Productivity Zones Using NDVI Imagery, Soils, TDR, Veris and Yield Data. Proceedings of the Beltwide Cotton Conferences, pp. 2092-2104, National Cotton Council of America, Memphis, TN. [CD-ROM and NCC website]
English, P.J., S.L. DeFauw, J.L. Willers and J.W. Smith. 2007. Field-scale Stability Assessment of Multi-year Spatiotemporal Variability in Cotton for the Site-specific Management of Tarnished Plant Bugs (*Lygus lineolaris* Palisot de Beauvois). Poster Abstract for the 2007 Beltwide Cotton Production Conference, 9-12 January 2007, New Orleans, LA. [Abstract #6567, NCC website]
English, P.J., S.L. DeFauw, J.W. Smith and J.L. Willers. 2008. Management Zone Delineation and Image Resolution Issues in the Site-Specific Control of Tarnished Plant Bugs in Cotton. Abstracts of the 54th Annual Meeting of the Mississippi Entomology Association, 25-26 October 2007, Starkville, MS. Mid South Entomologist, January 2008
English, P.J., S.L. DeFauw, S.J. Thomson and J.W. Smith. 2008. A new method for the detection of water/heat stress in irrigated cotton using thermal imagery. Proceedings of the Beltwide Cotton Conferences, National Cotton Council of America, Memphis, TN. [Abstract #7637, posted on NCC website and distributed on CD]
English, P. J., S.L. DeFauw and S.J. Thomson. 2009. Structural Dynamics of Management Zones for the Site-Specific Control of Tarnished Plant Bugs in Cotton. Beltwide Cotton Production Conference. National Cotton Council, San Antonio, TX. 6-7 January 2009.
Iqbal, J., J.J. Read, A.J. Thomasson, and J.N. Jenkins. 2005. Relationships between soil-landscape and dryland cotton lint yield. Soil Sci. Soc. Am. J. 69:872-882.
Sudduth, K.A., D.F. Hughes and S.T. Drummond. 1995. Electromagnetic induction sensing as an indicator of productivity on claypan soils, p. 671-681. *In* P.C. Robert et al (eds.), Proc Int. Conf. on Site-specific Management for Agricultural Systems, Minneapolis, MN 27-30 March 1994. ASA, CSSA, SSSA, Madison, WI
Thomson, S.J., P.J. English and S.L. DeFauw. 2007. Thermal imaging using small-scale aerial platforms for assessment of crop water stress in humid subtropical climates. Proceedings of the 2nd Asian Conference on Precision Agriculture (ACPA), 2-4 August 2007, Pyeongtaek, Korea. [ACPA website]
Willers, J.L., M.R. Seal, and R.G. Luttrell. 1999. Remote sensing, line intercept sampling for tarnished plant bug (Heteroptera: Miridae). Journal of Cotton Science 3:160-170.
Willers, J.L. and J.S. Akins. 2000. Sampling for tarnished plant bugs in cotton. Southwestern Entomologist. Supplement 23:39-57.