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INTERACTIVE EFFECTS OF FIELD VARIABILITY, CROP RESPONSE, AND EQUIPMENT RESOLUTION ON ERRORS IN SITE-SPECIFIC INSECTICIDE APPLICATIONS

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Abstract

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, therefore, management zones may be readily defined using NDVI (Normalized Difference Vegetation Index). Field-scale NDVI variability is the combined result of crop response to intrinsic field properties (i.e., soils, drainage, and planting preparations, etc.) as well as weather-related conditions. Application precision depends on: (1) GPS (Global Positioning System) equipment accuracy; (2) lag times associated with a controller's ability to attain the target application rate; and, (3) sprayer boom width. The latter factor (boom width) has the greatest influence on application error under conditions where zones are either sprayed (at a single rate) or not sprayed. Generally, two types of errors exist in GPS-triggered applications: (1) areas were sprayed which did not need to be sprayed (Type OK) or (2) areas were not sprayed which needed to be sprayed (Type OS – the worst error to make). Analysis of a series of site-specific application simulations revealed that the overall error was usually reduced as boom resolution increased; however, increased levels of Type OS errors were detected at some narrower boom widths. Type OK and Type OS errors are not linearly related; this is clearly linked to the fact that a sprayer must travel through the field in a fixed path throughout the season. Optimal site-specific applications can be derived for each field setting; however, delivery optimization is not always associated with using the highest resolution boom segmentation.

Introduction

Cotton (*Gossypium hirsutum*) is one of the most intensively managed crops on the world market. Recent regional shifts in insect pest assemblages (prompted by the highly successful Boll Weevil Eradication Program and the extensive use of transgenic technologies) have mandated frequent alteration of insecticidal chemistries to maintain yields; these continually-evolving chemistries represent high-cost inputs to the producer. The linkage between sustained profitability, high yields, and good stewardship practices, therefore, hinges on precision-based agricultural applications of insecticides as well as a host of other field treatments necessary for top-quality cotton production. Site-specific 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 (Willers *et al.* 1999, Sudbrink *et al.* 2001), therefore, management zones may be readily defined using NDVI (Normalized Difference Vegetation Index) classication of imagery.

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Exploration of the interactive effects of field variability, crop response, and equipment resolution on errors in site-specific insecticide applications is warranted. The main objective of this study is to assess the utility of high resolution ground-based applications in order to optimize delivery of costly insecticides.

Methods

Imagery for Washington County, MS was collected using an ADS-40 Leica Geosystems camera at 0.5m resolution (mid-August 2004). Field acreage and boundary data were provided by the Mississippi Boll Weevil Eradication

Program. Images were processed using ArcView 3.3 with the Spatial Analyst extension (Environmental Systems Research Institute, Inc., Redlands, CA). NDVI was calculated by converting the image bands (R, and NIR) to grids, followed by operations performed using Map Calculator. A scout map was produced using twelve classes separated by natural breaks. Employing imagery displaying just the four highest NDVI classes, a series of site-specific applications were simulated at various boom segmentation lengths and a pre-set cell width of 2m. An entire cell was sprayed if at least 25% of its area dictated a spray. Spray delivery resolutions ranged from 2-16 rows (40 inch rows). Given this assemblage of constraints, a field prescription consisted of four possible outcomes: (1) sprayed a "spray zone"; (2) didn't spray a "no spray zone"; (3) sprayed a "no spray zone" (Type OK error); and, (4) didn't spray a "spray zone" (Type OS error).

Results

Data provided by the Mississippi Boll Weevil Eradication Program revealed that over one-third of the cotton fields in Washington County, MS are 25 acres or less (Figure 1). Variability throughout the Mississippi Valley Alluvial Plain can be exceedingly high even in the smallest fields (for example, the five-acre field profiled here encompasses 3 soil series, Tunica clay, Dundee silty clay loam, and Dubbs silt loam – Figure 2). Comparison of a series of site-specific application simulations revealed that the overall error was usually reduced as boom resolution increased; however, increased levels of Type OS errors (i.e., did not spray prescribed spray zones, designated as "NS/S") were detected at some narrower boom widths (Figure 3). In most cases, Type OK application errors were substantially higher than Type OS application errors. Type OK errors peaked at 20% in the 2-segment boom simulation, whereas the 1-segment boom simulation generated a substantially lower Type OK error percentage (12.74% - Figure 4). The best "balance" between error types was achieved in the 4-segment boom simulation (Figure 5).

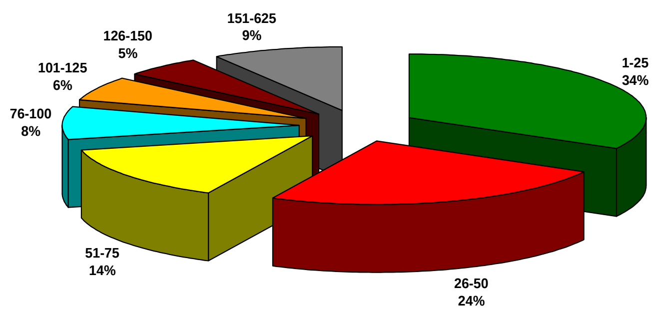


Figure 1. Summary of cotton field acreages in Washington County, MS. More than 50% of the fields are 50 acres or less; fields in excess of 150 acres comprise only 9% of the total.

Figure 2. NDVI image of a five-acre field illustrating crop response to soil variability and weather-related conditions. Light areas portray high vigor cotton, medium gray areas represent cotton plants of moderate vigor, and the darkest gray patches indicate low vigor cotton.

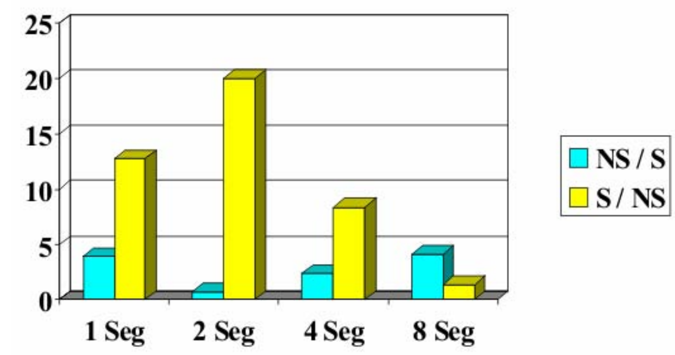
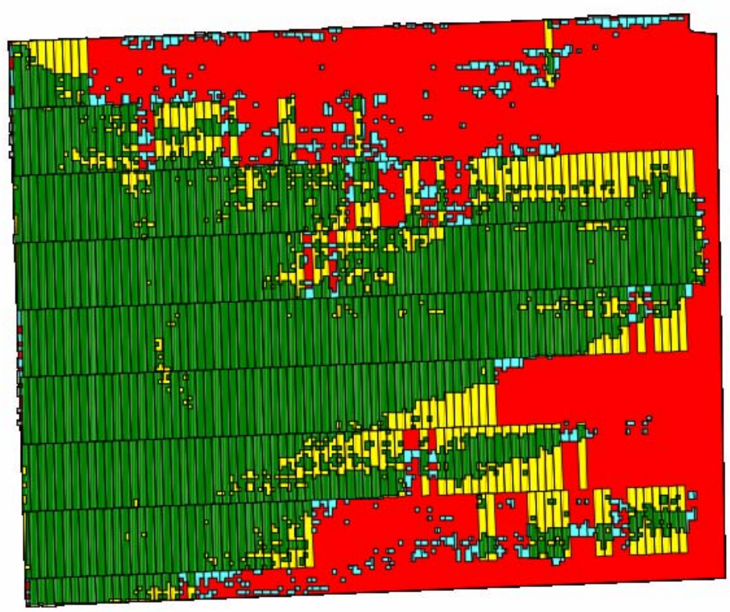


Figure 3. Summary of percentage spray errors simulated for a five-acre field at four boom segmentation lengths (varying in coverage from 16 rows down to 2 rows). The designation "NS/S" indicates a prescribed spray area that was not sprayed, Type OS error. The "S/NS" indicates a "no spray" area was sprayed, Type OK error.



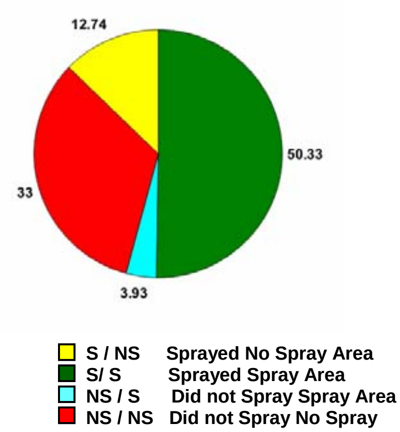


Figure 4. This NDVI-based image was used to create a scout map. Simulated scouting results were then used to produce a field prescription. The prescription was delivered using a 1-segment boom covering 16 rows. Note the relatively high percentage of areas sprayed (highlighted in yellow) which did not need to be sprayed (12.74% Type OK error).

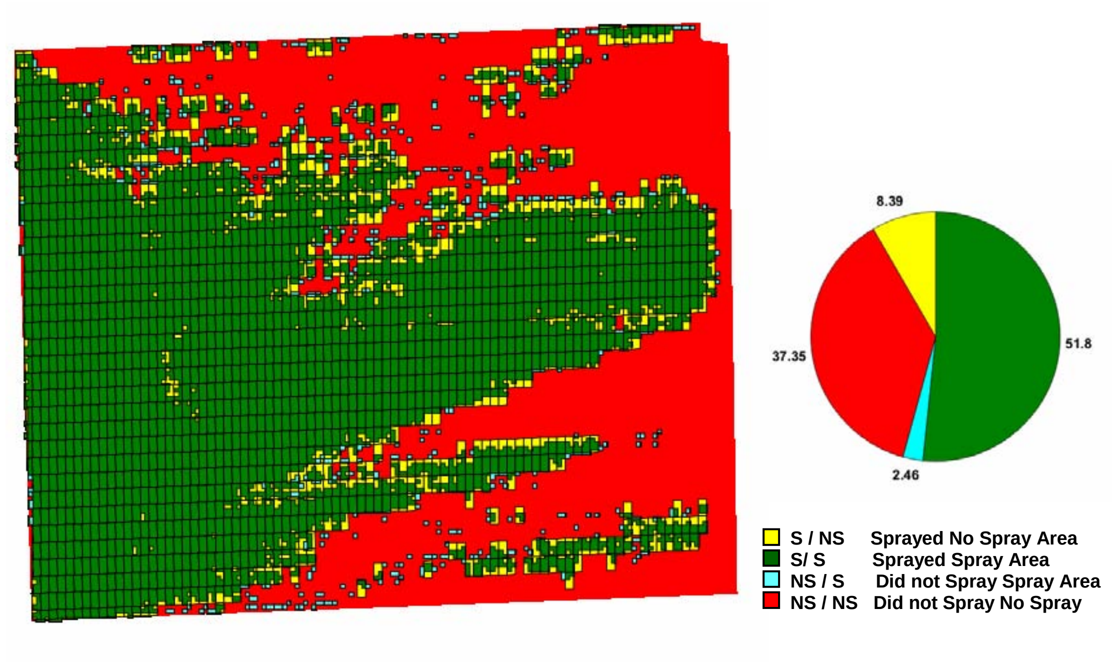


Figure 5. Field prescription applied using a 4-segment boom covering 4 rows per segment. When compared to the results summarized in Figure 4, this spray resolution provided the best "balance" between Type OK and Type OS errors.

Concluding Remarks

Optimal site-specific applications can be derived for each field setting; however, delivery optimization is not always associated with using the highest resolution boom segmentation. An increase in Type OS errors (designated as "NS/S" – Figure 3) was noted in the simulation configured for an 8-segment boom. In contrast, the simulated 2-segment boom application had the lowest percentage OS error, coupled with the highest OK error. The interactive effects of fixed-path spray rig travel combined with intrinsic field properties (e.g., distribution of soil series, drainage characteristics, fertility gradients, etc.), the inherent complexities of a cotton crop's response to weather-related conditions, and pest pressures set-up an asymmetrical relationship between Type OK and Type OS errors generated in any given field prescription. The simulation methodology introduced in this paper succinctly illustrates the cost effectiveness of precision agricultural insecticidal applications even in small-scale fields.

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