To the Graduate Council:

I am submitting herewith a dissertation written by Joyce Allison Tredaway entitled "Evaluation of a Site-Specific Weed Management Strategy." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Plant and Soil Science.

Thomas C. Mueller, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor
and Dean of The Graduate School

# EVALUATION OF A SITE-SPECIFIC WEED MANAGEMENT STRATEGY

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Joyce Allison Tredaway

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## DEDICATION

To my parents, Mr. and Mrs. Floyd P. Tredaway, whose encouragement, love, and prayers made this effort possible, I dedicate this dissertation.

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## ABSTRACT

Studies were conducted in 1997 and 1998 to compare conventional to site-specific weed management techniques. Field experiments were conducted in Knoxville, Tennessee. The study utilized a randomized complete block design with a split-plot treatment arrangement with nesting.

Preliminary research was conducted in 1996 to establish selective weed densities. Monocot and dicot densities were generated by applying selective herbicides. Weeds present included trumpetcreeper (*Campsis radicans*), common cocklebur (*Xanthium strumarium*), broadleaf signalgrass (*Brachiaria platyphylla*), and rhizome johnsongrass (*Sorghum halepense*). Field perimeters, plots, and weeds were mapped using global positioning systems (GPS).

In 1997 and 1998, weed density maps were used to determine atrazine applications in site-specific areas of the experiment. Site-specific areas determined to contain a high population of common cocklebur in 1996 received a 1x rate of atrazine. Low atrazine rates (0 in 1997 or 1/3x in 1998) were applied to remaining site-specific plots. Conventional plots received a 1x rate of atrazine. Broadleaf signalgrass was uniform throughout the field therefore both conventional and site-specific plots received the 1x rate of alachlor.

Early postemergence (POST) herbicides included nicosulfuron and dicamba. Conventional and site-specific plots received a 1x rate of nicosulfuron to control broadleaf signalgrass. Conventional plots received a 1x rate of dicamba to control common cocklebur. Dicamba was applied at 0, 1/3x, 2/3x, and 1x (0, 0.093, 0.19, and

0.28 kg ai/ha) to site-specific plots. These rates were determined by the density of common cocklebur at the time of POST applications.

For the 1998 field season, weed densities were counted using a 1 $m^2$ area for each sub-plot and recorded. A combine equipped with a yield monitor (AgLeader Yield Monitor 2000) and DGPS receiver (Trimble Ag 132) was used to harvest the corn. Yields were recorded using an AgLeader Yield Monitor 2000. Data were imported into ArcView for storage and generating yield maps.

Corn yields were similar between conventional and site-specific plots in 1997 and 1998 when averaged over treatments. Comparison of POST treatments within the field indicated a significant difference between conventional and site-specific plots. Corn yields were lowest when atrazine was not applied preemergence (PRE) and dicamba rates were 0 or 0.093 kg ai/ha.

These data demonstrated that site-specific weed management techniques may replace conventional techniques while maintaining yields. Site-specific weed management may result in reduced herbicide use, therefore lowering cost of weed control. Data indicates that a PRE herbicide was important in these weed control systems.

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# Part I.

# Introduction

Herbicides are used extensively to control unwanted vegetation in agronomic crops. They are generally applied to the entire field without taking into account field variability. Fields vary according to soil types, fertility, organic matter, elevation, topography, and weed densities. Using herbicides throughout the field may result in over-application in some areas and under-application in others. With increasing environmental concerns, applying herbicides on an as-needed basis may reduce the amount of active ingredient applied and save the producer money in herbicide costs. Increasing herbicide rates in areas of underapplication may also lead to increased efficacy and productivity in those areas.

Tools are available to implement precision farming or site-specific management. Global Positioning Systems (GPS), Geographical Information Systems (GIS), Variable Rate Applicators (VRA), and yield monitors enable the field to be micro-managed. Precision weed management involves applying appropriate herbicides and rates to weed infested areas of the field. This may be as simple as manually turning a sprayer on and off. However, the use of site-specific tools will enable variable rates of preemergence herbicides and postemergence herbicides to be automatically applied according to a "prescription".

The "prescription" will incorporate the previous years yield maps, weed maps, and soils data to determine the best treatments for each area of the field. It can improve efficacy and reduce the amount of active ingredients used, as well as aid in developing detailed maps of field variability. Site-specific weed management will enable a database of each field to be established and maintained. This database will be available for improving management decisions in the future.

Foremost for a successful weed management program are the following two considerations. One, crop yields in site-specific management areas must be comparable to conventional management areas. Two, the program must be economical while providing adequate control. The following sections will describe research conducted to compare conventional and site-specific weed management techniques. They will contain weed species and density data, yield data, and the calculation of percentage and quantity reductions of herbicides using a site-specific strategy.

**Part II**

**Conventional versus a site-specific weed management technique**[1]

[1] To be submitted for publication in Weed Technology. Authors: Joyce A. Tredaway, Thomas C. Mueller, Robert M. Hayes, H. Paul Denton, Michael D. Mullen, John B. Wilkerson, and William E. Hart. Graduate Research Assistant, Associate Professor, Professor, Professor, and Associate Professor, Dept. of Plant and Soil Science, Associate Professor and Associate Professor, Dept. of Agricultural and Biosystems Engineering, University of Tennessee, Knoxville, TN 37901. Email: jat@gnv.ifas.ufl.edu.

**Abstract.** A comparison was made between conventional and site-specific weed management techniques in 1997 and 1998 at Knoxville, TN in conventionally tilled corn. Corn yields in site-specific plots were generally comparable to conventional plots. In 1997, a yield difference was detected in site-specific plots based on atrazine applications when averaged across dicamba applications and interactions of the two herbicides. Corn yields were lower in site-specific plots receiving no atrazine or dicamba and in plots receiving no atrazine with 1/3x rate of dicamba, and corn yield may have been reduced due to greater common cocklebur competition in those plots. In 1998, atrazine applications on the site-specific plots reduced early season common cocklebur competition, and yields were comparable to conventional plots.

**Nomenclature:** Alachlor, *2*-chloro-*N*-(2,6-diethylphenyl)-*N*-(methoxymethyl)acetamide; atrazine, 6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine,2,4-diamine; clethodim, *E,E*-(±)-2-[1-[[(3-chloro-2-propenyl)oxy]imino]propyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one; dicamba, 3,6-dichloro-2-methoxybenzoic acid; lactofen, (±)-2-ethoxy-1-methyl-2-oxoethyl 5-[2-chloro-4-(trifluoromethyl)phenoxy]-2-nitrobenzoate; nicosulfuron, 2-[[[[(4,6-dimethoxy-2-pyrimidinyl) amino]carbonyl] amino]sulfonyl]-*N,N*-dimethyl-3-pyridinecarboxamide; broadleaf signalgrass, (*Brachiaria platyphylla* (Griseb.) Nash) #[2] BRAPP; common cocklebur, *Xanthium strumarium* L. # XANST; johnsongrass, (*Sorghum halapense* (L.) Pers.) # SORHA; trumpetcreeper, *Campsis radicans* (L.) Seem

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[2] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds*, Revised 1989. Available from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

Ex Bureau) # CMIRA; Corn, *Zea mays* L. 'Dekalb 689'; soybeans, *Glycine max* L. 'TN 486'.

**Additional index words:** Differential global positioning systems, geographical information systems, global positioning systems, site-specific, variable rate technology.

**Abbreviations:** DGPS, differential global positioning system; EPOST, early postemergence; GIS, geographic information system; GPS, global positioning system; LPOST, late postemergence; OM, organic matter; POST, postemergence; PRE, preemergence; VRA, variable rate applicator; WAT, weeks after treatment

## INTRODUCTION

Herbicides were applied to more than 95 percent of the U. S. corn acreage in 1997, which demonstrates that herbicide use is an integral part of efficient corn production (National Agricultural Statistics Service 1998). Environmental concerns for groundwater contamination, aquatic life, wildlife, and human toxicity are issues of importance that in turn cause the general public to desire decreased pesticide use. Many of these concerns could be minimized by properly following pesticide labels. However, efficiency would be maximized if herbicides were applied only to those areas of each field in need of treatment.

Conventional soil and crop management practices are usually applied on a field basis rather than taking into account variability within each field (Colvin et al. 1991). Precision management (often called site-specific) utilizes variable rate technology. This applies a production input across a field based upon some evaluation of the variability requirements for the optimum application rate for that input (Heuvel 1995). Equipment utilized may include automated seeders, fertilizer applicators, and/or chemical applicators to make spatially-variable applications to agricultural fields (Goering and Han 1993). Inputs are applied on an 'as needed' basis rather than the traditional blanket preventative application. Although field research reveals that a positive economic return to variable rate technology does not always occur (Sawyer 1994), using variable rates of herbicides can frequently improve farm efficiency and reduce the use of chemicals (Christensen and Krause 1995).

Precision agriculture not only encompasses the acquisition of highly technical equipment, but the wise use of information obtained from that technology (Heuvel 1995). Relevant technologies include global positioning systems (GPS), geographic information systems (GIS), variable rate applicators (VRA), weed sensors, and yield monitors. Site-specific technology can be used to micro-manage field operations at each location in each field.

A key component for all precision farming operations is the ability to determine instantaneous equipment position as it operates in the field, and to provide this information in a computer compatible format (Clark and McGuckin 1996). A GPS receiver ascertains the exact location in the field by measuring its distance from several satellites in space (Greer 1993). GPS allows geo-referencing weed population locations and provides the data for weed maps. These maps in connection with weather-data and expert-systems lead to predictions of treatment date, herbicide type, and herbicide rate while providing information to relocate the weed populations in the field (Auernhammer and Muhr 1991).

Location accuracy is necessary to use this information in the future. Relative location accuracy within a field may be acceptable when generating spatially-variable yield maps. An example of utilizing relative accuracy could be identifying areas of a field that are high and low producing (Wilkerson and Hart 1996). Absolute accuracy is essential when using real-time application.

Webster and Cardina (1997) conducted research to measure the accuracy of a GPS in locating the area of weed patches and to determine the accuracy in navigating back to a particular point in the field. They found errors ranging from 6 to 15% in estimating a circular area of 50 $m^2$. The GPS had sub-meter accuracy in navigating to the correct quadrant 73% of the time and allowed the operator to navigate within 1.58 m of the correct quadrant.

Surveying, mapping, positioning, and subsequent management of weed infestations can be expedited by the use of GPS technology (Lass and Callihan 1993). This information can be obtained for variable rate applications in two ways. One method is using historical data such as yield history, soil information, and pest history information. A computer/controller uses this information to properly apply the fertilizer or chemical to specific areas of the field. A second method is obtaining information for variable rate application by using real-time detection of variables such as weed species. This information provides instantaneous needs for herbicide applications which is received by a computer/controller and in turn sends a signal to the applicator to apply a "prescription dose" to that area of the field. A discussion of each method will follow.

Method one utilizes field historical data to aid in decision making. Past yield performance provides historical data that can be used to determine future input levels

(Pringle et al. 1993) and can be used alone or in combination with other spatial data (Bae et al. 1987). Using combines equipped with yield monitors and data loggers on GPS equipment has been reported previously (Klemme et al. 1992; Schnug et al. 1990; Vansichen and De Baerdemaeker 1991). Yield data provides a basis for developing machine control maps for selective operations such as fertilizer applications.

Variable rate application has been demonstrated in fertilizer application by using historical data. Varied nutrient applications can be based on data created from geo-referenced records of soil test values based on grid soil-sampling, soil-based yield potential, and nutrient applications that can then be coded into a computerized record keeping system (Reetz 1994). For a computerized system to have usable data, an accurate assessment of crop fertility is needed to improve nutrient efficiency by site-specific application (Fiez et al. 1994). In one study using an expert system linked to a GIS database, a cell-by-cell fertilizer rate map was provided to a farmer for evaluation and adjustment. Results from the study indicated that the average fertilizer rate was decreased in comparison to the uniform rate with no decrease in crop yield (He et al. 1992).

Method two uses real-time detection for variable rate application. Real-time, differentially-corrected data is required for on-the-go applications of fertilizers or pesticides. Studies have been conducted using real-time detection sensors such as height selective sprayers and sensor-controlled hooded sprayers to apply herbicides on-the-go.

Two such studies were conducted at the University of Georgia (Green et al. 1996) where site-specific weed management techniques were evaluated for use in crops grown in the Southeastern states. In both experiments, a height selective sprayer was used to map and spray fields infested with Texas panicum (*Panicum texanum* Buckl.). In the first experiment, mapping techniques indicated that 16% of the field was infested with Texas panicum tall enough to be detected by the height selective sprayer. This resulted in an 84% reduction of sethoxydim (2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one) use on a field basis. The second experiment mapping techniques indicated that 35% of the field was infested with Texas panicum tall enough to be detected by the height selective sprayer, resulting in a 62% reduction in sethoxydim use on a field basis.

Hanks and Beck (1998) developed and evaluated methods that utilized weed-sensing technology with a hooded sprayer in row-crop production systems. Real-time weed detection was accomplished by using the spectral differences in green living plants and bare soil to apply herbicide only where weeds were present. Savings in herbicide spray solution applied using sensors ranged from 63 to 85%, compared to conventional hooded spray systems with continuous application. Weed control in the sensor-controlled spray system was equal to the conventional system.

Site-specific management must be addressed from an economic standpoint. Wibawa et al. (1993) conducted a study on variable rate fertilization based on grid soil sampling. They found that variable rate fertilization did not produce greater yield of barley (2160 kg/ha) than the conventional method (2020 kg/ha) in 1989. However, in 1990, barley yield with variable rate application (4960 kg/ha) was greater than the conventional method (4550 kg/ha). The conventional method had a greater net return because of the increased cost of sampling and testing soil for the variable rate treatments.

Little economic benefit was found from variable nitrogen applications if nitrogen recommendations were calculated assuming a constant unit nitrogen requirement on winter wheat (*Triticum aestivum* L.)(Fiez et al.1994). Unit nitrogen requirements are expressed as the product of (i) the efficiency of recovery of soil nitrogen by the crop and (ii) the efficiency with which the plant nitrogen is converted into grain yield (Bock and Hergert 1991). If an experimentally determined unit nitrogen requirement was used, variable rate applications increased net returns by up to $6.00/ha.

When recommended fertilizer treatments were applied as soil unit treatments rather than as field treatments, studies indicated similar barley (*Hordeum vulgare* L.) yields. Additional returns of $8.80 to $9.50/ha were obtained when optimum soil treatments were applied rather than the uniform field treatment in two of the five fields evaluated. This data indicates that additional returns could be generated by fertilizing according to a soil unit rather than by the field (Carr et al. 1991).

As illustrated above, there are possible economic benefits using site-specific management. The big question may be how much producers are willing to pay for the benefits. In a grower survey of Midwestern United States farmers conducted by Mike Buckley & Associates, Inc. (Giacchetti 1996), 75% of the respondents said they were willing to pay $2.00/ha for the benefits of precision agriculture and 50% were willing to pay $4.00/ha. The costs incurred by the farmer in addition to some added equipment costs include labor for intensive grid soil sampling which ranges from $2.00 to $3.00/ha, scouting for insects, weeds, and diseases which costs approximately $1.50/ha, and using a variable rate application of fertilizer, lime, and herbicides which cost between $1.00 and $3.00/ha (Giacchetti 1996). However, the total cost of production must include the reduction in chemical use. As illustrated in Green et al. (1996) and Hanks and Beck (1998), site-specific weed management reduced herbicide use quite extensively.

Spatially-variable field operations can also provide legal and political advantages (Schueller 1996). Commercial spatially-variable field operations are primarily justified in North America on an economic basis, but regulations may eventually be the driving force behind such operations. There may be additional regulatory limits on pesticide application to locations where they are 'needed' and may someday be prescribed. This is similar in general concept to the special use permits or geographic restrictions currently applied to some pesticides (Schueller 1996).

Another milder form of regulation would be the generalization of the 'bubble' concept of environmental impacts, i.e., limiting the total amount of release from an entire complex rather than for the individual application. This could mean that a farmer would be allotted a limited amount of pesticides for each farm. In such a situation, spatially variable applications could be particularly advantageous (Schueller 1996).

Research has not been conducted using historical weed information for variable rate herbicide applications. Yields between site-specific management strategies and conventional types have not been evaluated based on historical weed data. Therefore, the objectives of this research were to (i) measure crop yield differences as affected by different weed populations, and (ii) evaluate the potential for herbicide use reduction of site-specific weed management, where herbicide use and/or rates are varied according to weed densities present rather than applying a uniform rate throughout the field.

## MATERIALS AND METHODS

Research was conducted at the Holsten unit of the Knoxville Experiment Station in Knoxville, Tennessee for a comparison of conventional and a site-specific weed management technique. A 4-ha field site was established in 1996 which had variations in soil type and drainage.

The objective in 1996 was to establish differential weed populations of species and densities. Corn was planted at 56,000 plants/ha on May 15, 1996 and soybeans were planted at 70 kg/ha on June 1, 1996 in a northeast-southwest orientation in the conventionally tilled field site (Figure 1). Row spacing was 76 cm. A randomized complete block design with a split-plot treatment arrangement was utilized with eight replications. The main plot was the crop and the sub-plot was the weed species.

Johnsongrass, broadleaf signalgrass, common cocklebur, and trumpetcreeper were the primary weeds present. Different weed densities were generated by dividing each plot into two portions and spraying selective herbicides to generate plots containing primarily dicot weeds and plots containing primarily monocot weeds (Figure 1). Nicosulfuron and clethodim were applied at 35 g ai/ha and 140 g ai/ha, respectively to select for dicot weeds in corn and soybeans, respectively. Monocots were selected in corn and soybeans by applying dicamba (280 g ai/ha) and lactofen (220 g ai/ha), respectively.

In June 1996, the field perimeters and weedy areas within the field were mapped using a GeoExplorer GPS receiver[3], and data were downloaded into the Pathfinder[3]

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[3] Trimble Navigation Limited, 645 N. Mary Avenue, Sunnyvale, CA 94086.

[3] Pathfinder Series Post-Processing Utilities, Trimble Navigation, Sunnyvale, CA 94088-3642.

software program and then transferred into ArcView[4] as a text file. Precise longitude and latitude of field perimeters and sub-plot distribution were necessary to combine yield, weed density data, and perimeter data. To accommodate this need, a drawing of field perimeters with sub-plots was generated in AutoCAD[5]. As the acceptance of precision farming increases, better GIS programs may be available to avoid this step.

Common cocklebur is an extremely competitive weed that has reduced corn yield up to 27% (Beckett et al. 1988). At the end of the 1996 season, common cocklebur density was high (> 150 plants/m$^2$) in areas planted in soybeans. Due to the high density of common cocklebur, weed patches were mapped using the GeoExplorer GPS unit and data were post-corrected (Figure 2). Data were entered in ArcView to use in the weed management plan for the 1997 and 1998 seasons and to facilitate plot establishment. Broadleaf signalgrass was uniform throughout the field therefore, site-specific weed management techniques were used only for common cocklebur control.

Due to the locations of the heavy common cocklebur areas, plot orientation for 1997 and 1998 was perpendicular (northwest-southeast orientation) to those of 1996 (Figure 3). Precise locations of the previous year's plots were determined using a DGPS receiver

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[4] Environmental Systems Research Institute, Inc., 380 New York Street, Redlands, CA 92373-8100.

[5] Autodesk, Inc., 111 McInnis Parkway, San Rafael, CA 94903.

connected to an HP 620LX[6] palmtop computer. The palmtop computer was used with Pocket Survey[7] mapping software.

In 1997 and 1998, a randomized complete block design with a split-plot treatment arrangement with nesting was utilized. The main plot was the strip which was assigned a weed management technique (conventional or site-specific) (Figure 3). The sub-plot was the herbicide treatment. Herbicide treatments were nested in the strips because all herbicide treatments did not occur with each herbicide regime. The strips were divided into 224 subplots 7.3 m wide (8 rows spaced 91 cm apart) by 27 m long. The field was conventionally tilled and corn was planted on May 12, 1997 and May 19, 1998.

Herbicides were applied using a three-point hitch tractor-mounted VRA (Figure 4). In the 1997 season, a variable rate sprayer was manually controlled and in 1998, it was computer controlled, as illustrated in Figure 5. The VRA was a discrete spraying system equipped with one boom with two sets of 14 nozzles mounted 52 cm apart. Each set of nozzles were independently controlled. The boom used XR8001VS and XR8002VS nozzles (Figure 4). The rate was changed during application by using a cab mounted controller and motor-driven valves (Figure 5). Thus, flow through the XR8001VS nozzles produced a 1/3x (75 L/ha) application rate. Likewise, flow through the XR8002VS nozzles produced a 2/3x (150 L/ha) application rate. When both sets were activated simultaneously, a 1x (225 L/ha) rate was applied. Tractor speed was 5.2 km/hr and boom pressure was at 207 kPa, producing an application volume of 225 L/ha at the 1x rate.

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[6] Hewlett-Packard Company, 3000 Hanover Street, Palo Alto, CA 94304.

[7] Case Corporation, 700 State Street, Racine, WI 53404.

Herbicides may be applied at variable rates based on soil texture, organic matter (O M), and pH. To determine if atrazine rates should be varied across the field, the soil series were determined using National Resource Conservation Service soil survey maps. All soils contained in the field were loams. Soil organic matter and pH were determined for each sub-plot in the field (Figures 6 and 7, respectively).

Systematic sampling is suggested by several researchers as the best method to sample a field (Peck and Nelsted 1973; Petersen and Calvin 1986; Sabbe and Marx 1987). Each sub-plot (7.3 m by 27 m) was designated as a grid for sampling soil. A random pattern of grid-cell sampling was used within each plot. Three 15-cm soil cores were extracted from each sub-plot and mixed. Composite soil samples were air-dried and sieved. Total carbon was measured using a 0.25 gram sample and analyzed by a Leco CNS 2000[8]. Total carbon was converted to % OM using a factor of 1.724 (Nelson and Sommers 1996). Remaining soil was used to determine soil pH. Electrodes were calibrated using pH 7.0 and 4.0 buffer solutions. Ten grams of soil were measured and mixed with 20 ml of Nanopure water. The suspension was stirred and allowed to equilibrate for 20 min. The suspension was stirred again and pH measurements were taken and recorded (Table *A - 1*).

PRE treatments included atrazine (2.24 kg ai/ha) and alachlor (2.24 kg ai/ha) (Figure 8). Alachlor was applied (2.24 kg ai/ha) to the entire field due to the uniform broadleaf signalgrass. Conventional plots received 2.24 kg ai/ha of atrazine. Rates for site-specific plots were determined using the 1996 common cocklebur mapping data. Areas with high

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[8] LECO Corp., 3000 Lakeview Avenue, Saint Joseph, MI 49085.

common cocklebur density (Figure 2) received atrazine at the 2.24 kg ai/ha rate and areas with low density received 0 (1997) or 0.75 (1998) kg ai/ha.

Postemergence (POST) herbicide treatments were applied on June 23, 1997 and June 16, 1998. POST treatments included nicosulfuron (35 g ai/ha) on all plots due to high broadleaf signalgrass density and dicamba at 0, 0.093, 0.19, or 0.28 kg ai/ha in site-specific plots (Figure 9). In 1997, site-specific herbicide rates were determined using a qualitative evaluation of common cocklebur densities. In 1998, site-specific herbicide rates were determined by using a range of common cocklebur densities (plants/$m^2$) with appropriate herbicide rates (Table 1). Conventional strips received 0.28 kg ai/ha of dicamba. Excessive rainfall caused nitrogen loss in 1998 and conventional and site-specific plots were side-dressed with supplemental nitrogen (140 kg/ha).

Data collected included common cocklebur densities (plants/ $m^2$) in 1998 (Table *A - 2*), visual estimates of common cocklebur control recorded 14 days after PRE applications and 14 days after POST applications in 1998 (Table *A - 2*), and corn yield (kg/ha) in 1997 and 1998 (Figures 10 and 11). Visual estimates of common cocklebur control utilized a scale of 0 to 100% (0 = no control, 100 = complete control). In 1998, data were recorded 2 weeks after treatment (WAT) for PRE and used to determine POST treatments (Table *A - 2*).

The amount of herbicide active ingredient applied to the site-specific plots was calculated and was compared to the same size plots on which herbicide active ingredient was applied in the conventional manner (Table 2). The usage was then compared between site-specific and conventional and the percent herbicide active ingredient reduction determined for the site-specific plots. A calculation was then made of the actual quantity (kg) saved on the site-specific plots. These calculations were made for the years 1997 and 1998 on atrazine and dicamba treatments.

A combine equipped with a yield monitor (AgLeader Yield Monitor 2000) and differential global positioning system (DGPS) receiver (Trimble Ag 132)[3] was used to harvest corn on November 10, 1997 (Figure 10) and October 13,1998 (Figure 11). An error occurs due to lag times in grain recordings when entering and leaving the field. The time in registering yields for end plots resulted in these plots receiving incorrect readings, therefore, end plots were excluded from statistical and herbicide reduction analysis. In 1997, the center plot in the field was cut perpendicular to the row direction. This enabled a check point for location verification during harvest. These plots were excluded from the analysis.

The SAS (1996) Proc Mixed procedure was used to analyze the data. Corn yield data were subjected to analysis of variance and means were compared with pairwise contrasts at the 0.05 level of probability. In 1997 and 1998, data were analyzed by all possible combinations (A. Saxton, personal communication). These analyses include comparison of conventional and site-specific when averaged over all herbicide treatment combinations, atrazine treatments averaged over dicamba treatments, dicamba treatments averaged over atrazine treatments, and interaction of atrazine and dicamba treatments. The statistical model used is shown in Table 3, to illustrate the different comparisons involved in the statistical analysis. In 1998, an additional analysis of common cocklebur effect on yield was examined.

An overall LSD value cannot be calculated because different standard errors occur with each treatment (A. Saxton, personal communication). Thus, an LSD grouping is used in the tables rather than an LSD value. The LSD grouping indicates the differences between treatments at the 0.05 level of probability.

A spatial covariance structure was defined with a spherical structure of the latitude and longitude (Littell et al. 1996) (Figure *B - 1*). In addition, a repeated statement was used to account for the variability due to spatial location in the field. Statistical analysis involved spatial data analysis and prediction to account for natural and extraneous variation in the field (Gilmour et al. 1997; Gotway and Stroup 1997). Spatial variability refers to variation among observations in space. Positive spatial correlation is the tendency of observations closer together to be more alike than observations farther apart (Littell et al. 1996).

## RESULTS AND DISCUSSION

Soil pH and OM were variable between the sub-plots, however, differences were not enough to justify changing the atrazine rate based on label information. Organic matter ranged from 1.03 to 3.27 (Figure 6), which was typical for these soils. Prior to 1996, this field had been in continuous no-till corn production with minimal lime application for 5 years. Analysis of soil pH yielded all pH values less than 7.00 (Figure 7). Actual soil pH and OM values are reported in Table *A - 1*.

In the site-specific plots in 1997 PRE atrazine usage was reduced in the 4 ha area 42.5% or 0.95 kg from a base use of 2.24 kg. Because no atrazine was applied on reduced rate plots, this was calculated differently than the other herbicide applications. For example, this was determined by dividing the hectares on which the reduced rate (0 kg/ha) was applied (0.74 ha) by the (1.74 total ha) which equaled 42.5%. The total amount (kg) reduced was calculated by multiplying the percent of area of 0 rate by the base rate of 2.24 kg ai/ha which equaled a 0.95 kg reduction by using site-specific weed management techniques for atrazine applications in 1997. In the 1997 use of dicamba, there was a reduction of 46.8% or 0.13 kg in site-specific plots of the 4 ha area. The percent reduction for this and the remaining data were determined by similar calculations to those detailed in Table 2.

The 1998 preemergence data revealed a reduction in atrazine use on site-specific plots of 31.7% below the conventional plots. Terms of quantity (kg), the reduction was 0.71 kg from a base of 2.24 kg. The variable rate application of dicamba in 1998 resulted in a reduction of 49.0% or 0.14 kg in the 4 ha area.

Corn yields in 1997 are shown in Figure 10. 1997 yields were calculated in all possible combinations for this experiment (Table 4). Corn yields in conventional (5700 kg/ha) and site specific (4700 kg/ha) plots were similar (P = 0.08) (Table 4) when averaged over all herbicide treatment combinations (Table *B - 1*) in 1997. Corn yield was significantly lower (P = 0.0001) (Table 4) when atrazine was not applied to site-specific plots (3800 kg/ha) than in conventional (5700 kg/ha) and site-specific (5700 kg/ha) receiving 2.24 kg ai/ha of atrazine (Table 5). These differences indicate that early-season weed competition may have caused the site-specific yields to be lower where no PRE atrazine was applied. The data demonstrate that a PRE herbicide for broadleaf control is important in this corn weed control system (Table 5).

A significant interaction (P = 0.03) occurred between dicamba treatments and the overall comparison of conventional and site-specific plots in 1997 (Table 4). Yields were lower (3900 kg/ha) when dicamba application rates were 0.093 kg ai/ha (Figure 12)(Table *B -2*).

The interaction of atrazine and dicamba treatments among conventional and site-specific plots did not show differences (P = 0.09 ) among corn yields in 1997 at the 0.05 level of probability (Table 4). However, LSD comparison of means at the 0.05 probability level showed that yields were lower (2800 and 2600) in site-specific plots receiving no atrazine and 0 or 0.093 kg ai/ha dicamba, respectively (Figure 13) (Table *B - 3*) . In general, all site-specific plots which did not have an atrazine application had lower yields than those receiving 2.24 kg ai/ha atrazine with the exception of the plots receiving 0.19 kg ai/ha of dicamba. Again, this data illustrates the importance of applying a preemergence broadleaf herbicide in this field.

No differences (P = 0.27) (Table 6) were detected in corn yields in 1998 between conventional (6400 kg/ha) and site-specific (6700 kg/ha) weed management techniques when averaged over all herbicide treatment combinations (Figure 11) (Table *B - 4*). In 1998 data were analyzed in all possible combinations (Table 6) for this experiment. These include all combinations used in 1997. Atrazine treatments averaged over dicamba treatments (P = 0.31), dicamba treatments averaged over atrazine treatments (P = 0.89), and interaction of atrazine and dicamba treatments (P = 0.78) had no differences between conventional and site-specific weed management techniques (Table 6) (Tables *B - 5, B - 6*, and *B - 7*, respectively).

In addition, a covariant analysis of the effect common cocklebur densities (14 DAT of dicamba application) had on corn yield was conducted. Although weed density can effect yields, no differences (P = 0.05) were detected in the analysis of this field (Table 6).

The effects of herbicide treatments on common cocklebur density were also examined. Overall, the herbicide treatment, whether conventional or site-specific did not have an effect on common cocklebur density (P = 0.08) (Tables *B - 8* and *B - 9*). However, in evaluation of the dicamba applications on site-specific and conventional applications, a difference was detected in the site-specific plots receiving 0.28 kg ai/ha of dicamba, regardless of the atrazine rate applied preemergence (Tables *B - 8, B - 10,* and *B - 12*). All other dicamba treatments resulted in no difference in common cocklebur density (Tables *B - 8, B - 11,* and *B - 12*). Because dicamba rates were based on common cocklebur density rather than being randomly assigned, inherent bias in the results creates these differences (A. Saxton, personal communication). Therefore, with the reduced rates of dicamba, equivalent control of common cocklebur will be obtained. This data in connection with the previous yield effect data indicates that using a preemergence herbicide will enable comparable yields with a reduced rate of dicamba in areas of lower cocklebur population, making variable rate applications feasible.

In 1998, corn yields were comparable between conventional and site-specific weed management techniques. There are many potential benefits in using site-specific weed management. These include potential herbicide reduction which in turn reduces the potential environmental loadings. With increasing environmental restrictions on herbicide use, site-specific weed management may be an effective alternative. Not only can land be utilized more efficiently, but chemical inputs can be applied in a more effective manner.

Research in a new innovative area of technology encompasses many learning experiences. When performing field-scale research, consideration should be given to sprayer design features. For example, in 1997 the solenoid valves used on the VRA prematurely malfunctioned from sand present in the water supply tank. In 1998, motor driven ball valves replaced the solenoid valves to avoid any operational difficulties, and they performed reliably. Consideration should also be given to sprayer design features such as a bottom drain plug, connectors, and nozzle tips. This will enable more efficient field research.

Equipment installation may also be necessary in older model combines. This may require ordering new parts to integrate properly with new technology. Any items installed on equipment should be thoroughly tested prior to use. Newer combines have this equipment as factory options.

The tools used in site-specific farming offer many potential benefits. However, this is often not easily accomplished. For example, producing maps in GIS mapping programs can be very labor intensive. The mapping software program Precision Map 2000 was user-friendly, but when importing data into Arc View, incompatibilities became apparent and the data transition was not seamless.

Although initial costs of equipment and scouting are relatively high, the value of the information obtained is immeasurable. The database information will not only aid in weed management but also in planning, fertility, and land utilization for the future. This information will be available for many generations to use so that each year will perhaps be more productive than the last.

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Table 1. Common cocklebur density ranges and corresponding dicamba rates used for postemergence applications in 1998.

| Common cocklebur density | Dicamba rate | No. of Plots |
|---|---|---|
| plants/m$^2$ | kg ai/ha | |
| 0 - 22 | 0 | 24 |
| 23 - 65 | 0.093 | 20 |
| 66 - 150 | 0.19 | 29 |
| 151 | 0.28 | 22 |

Table 2. Calculations for 1997 dicamba reduction (% and kg) in site-specific plots when compared to conventional plots.

| Herbicide regime | Rate | Units/rate | Dicamba used |
|---|---|---|---|
| | kg ai/ha | ha | kg |
| Conventional | 0.28 | 1.74 | 0.49 |
| Site-specific | 0 | 0.40 | 0 |
| Site-specific | 0.093 | 0.36 | 0.03 |
| Site-specific | 0.19 | 0.54 | 0.10 |
| Site-specific | 0.28 | 0.44 | 0.12 |
| Subtotal for site-specific | | | 0.26 |
| Conventional herbicide used (0.49) - Subtotal (0.26) = | | | |
| Actual Reduction | | | 0.23 |
| Actual Reduction (0.23 kg) / Conventional herbicide used (0.49 kg) * 100% = Reduction (%) | | | 46.8% |
| Conventional rate (0.28) * Reduction (%) = Reduction (kg) | | | 0.13 kg |

Table 3. Statistical model and variables used in 1997 and 1998 analyses.

$$Y_{ijklm} = \mu + B_i + S_j + BS_{ij} + P(S)_{jk} + O(S)_{jl} + PO(S)_{jkl} + e_{ijklm}$$

Variables defined as:

Y = corn yield (kg/ha)

B = Block

S = Strips

P = Preemergence Herbicide Treatments

O = Postemergence Herbicide Treatments

Table 4. Summarized analysis of variance (test of fixed effects) of 1997 corn yield data.

| Source | Type III F | Pr > F |
|---|---|---|
| Conv. vs. S.S.[a] | 3.86 | 0.0777 |
| (Conv. vs. S.S.) * PRE[b] | 16.73 | 0.0001 |
| POST (Conv. vs. S.S.)[c] | 2.97 | 0.0337 |
| PRE * POST (Conv. vs. S. S.)[d] | 2.16 | 0.0955 |

[a] Overall comparison of conventional vs. site-specific yields.

[b] Comparison of atrazine treatment effect on corn yields when averaged over dicamba treatments in conventional and site-specific plots.

[c] Comparison of dicamba treatment effect on corn yields when averaged over atrazine treatments in conventional and site-specific plots.

[d] Interaction of atrazine and dicamba treatment effects on corn yields in conventional and site-specific plots.

Table 5. Comparison of conventional and site-specific yields interaction with atrazine treatments averaged over dicamba treatments in 1997[a].

| Herbicide Regime | Observations | Atrazine Rate | Standard Error[b] | Yield (LS Means) | LSD Grouping[a] |
|---|---|---|---|---|---|
| | no. | kg ai/ha | kg/ha | kg/ha | |
| Conventional | 88 | 2.24 | 646 | 5700 | A |
| Site-specific | 38 | 0 | 697 | 3800 | B |
| Site-specific | 50 | 2.24 | 703 | 5700 | A |

[a] Letters not followed by same letter are significantly different at 0.05 probability level.

[b] Due to using a spatial analysis, standard errors differ with every treatment. An LSD value can not be calculated due to the different standard errors, therefore an LSD grouping is used to show if treatments are significantly different ($\propto = 0.05$).

Table 6. Summarized analysis of variance of 1998 corn yield data.

| Source | Type III F | Pr > F |
|---|---|---|
| Conv. vs. S.S.[a] | 1.45 | 0.2562 |
| Common cocklebur density[b] | 3.84 | 0.05 |
| (Conv. vs. S.S.) * PRE[c] | 1.03 | 0.3124 |
| POST (Conv. vs. S.S.)[d] | 0.21 | 0.8903 |
| PRE * POST (Conv. vs. S. S.)[e] | 0.36 | 0.7822 |

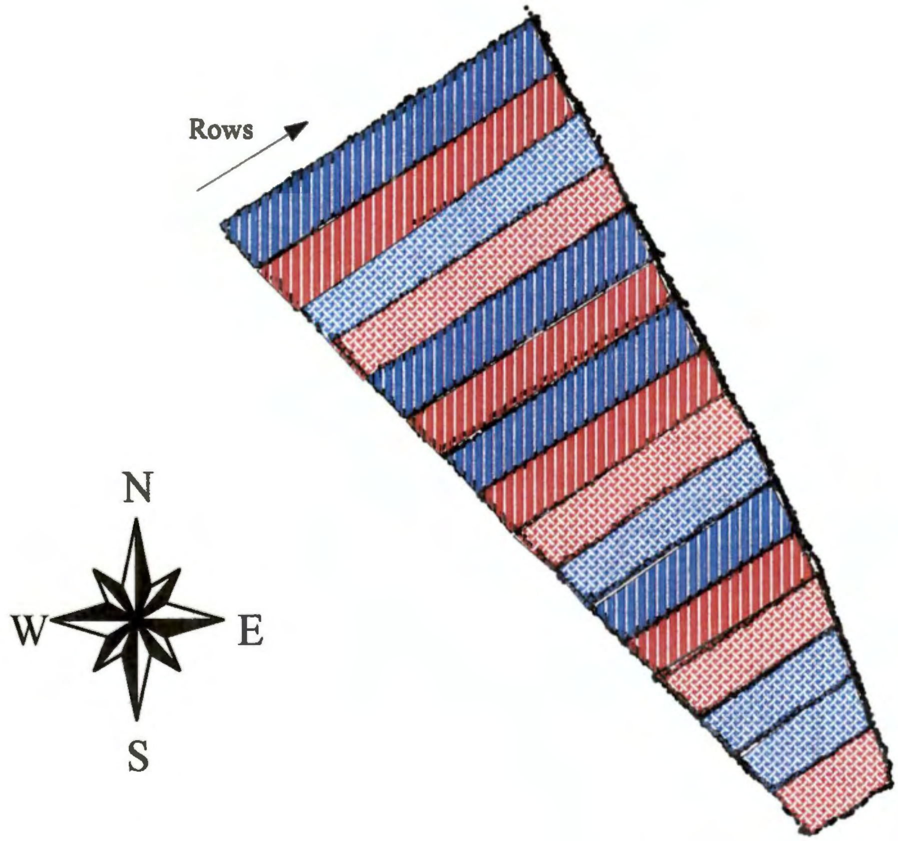
[a] Overall comparison of conventional vs. site-specific Yields.

[b] Covariant analysis comparing the effect of common cocklebur density (6/30/98) on conventional and site-specific corn yields.

[c] Comparison of atrazine treatment effect on corn yields when averaged over dicamba treatments in conventional and site-specific plots.

[d] Comparison of dicamba treatment effect on corn yields when averaged over atrazine treatments in conventional and site-specific plots.

[e] Interaction of atrazine and dicamba treatment effects on corn yields in conventional and site-specific plots.



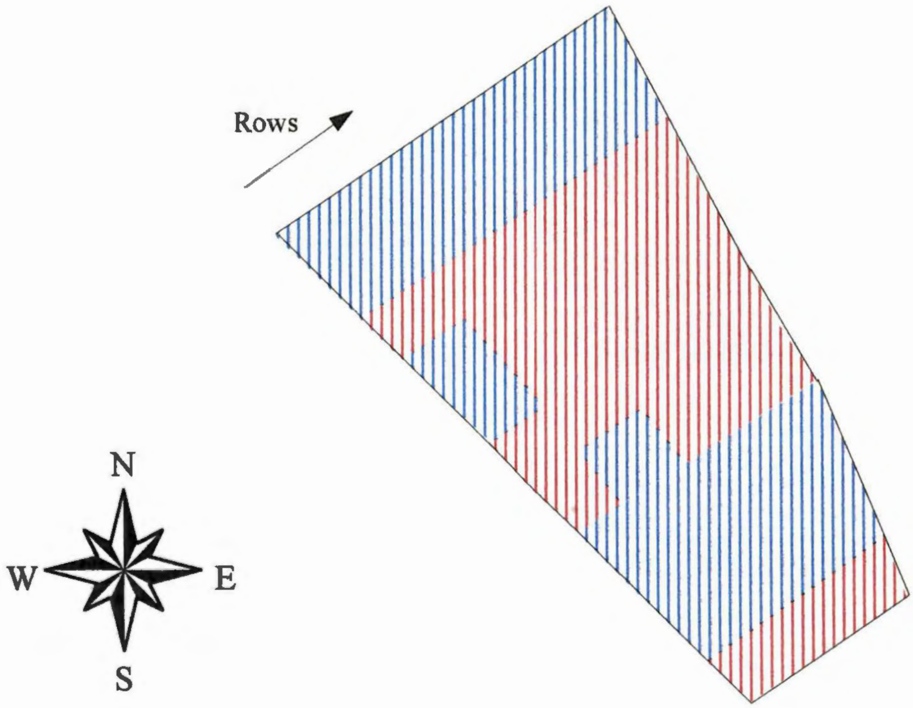

Areas planted to corn in 1996.

Areas planted to soybeans in 1996.

Densities generated to contain monocot weeds.

Densities generated to contain dicot weeds.

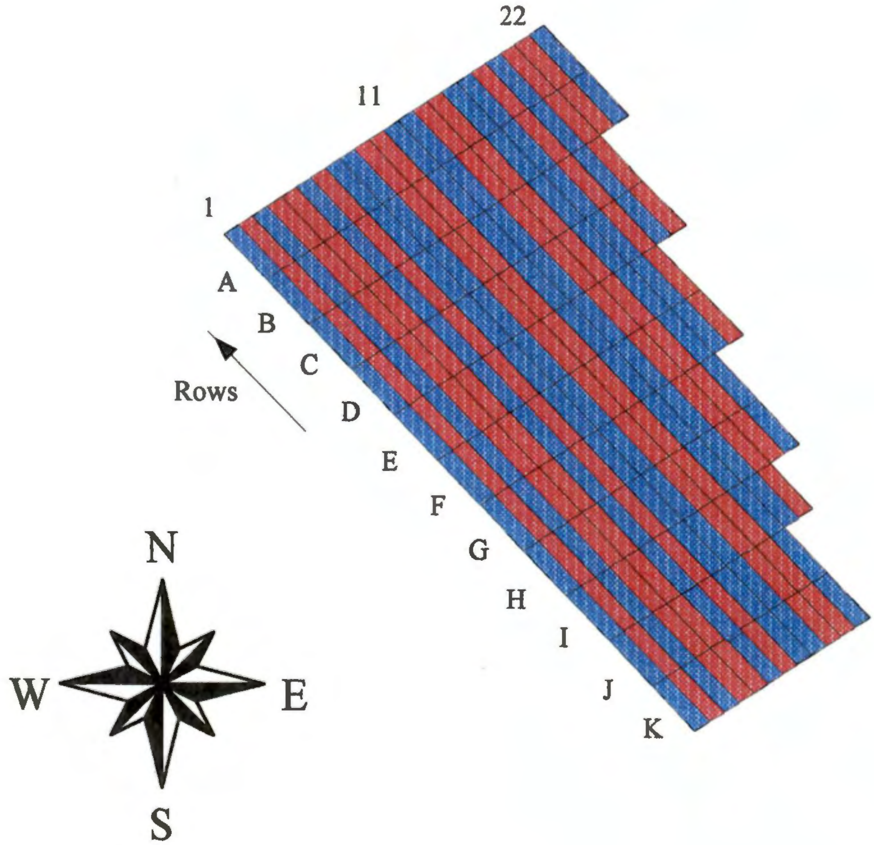
Figure 1. Field plot layout used in 1996.




High common cocklebur density (> 150 plants/m$^2$)

Low common cocklebur density (< 150 plants/m$^2$)

Figure 2. Common Cocklebur density map from 1996 used to determine atrazine application rates in 1997 and 1998. Site-specific areas containing high common cocklebur density in 1996 received 2.24 kg ai/ha atrazine in 1997 and 1998. Site-specific areas containing low common cocklebur density in 1996 did not receive atrazine in 1997 and received 0.67 kg ai/ha atrazine in 1998. Conventional areas received 2.24 kg ai/ha in both years.




Sub-plots receiving conventional herbicide treatments.

Sub-plots receiving site-specific herbicide treatments.

Figure 3. Map of conventional and site-specific sub-plots in field plot layout used in 1997 and 1998.

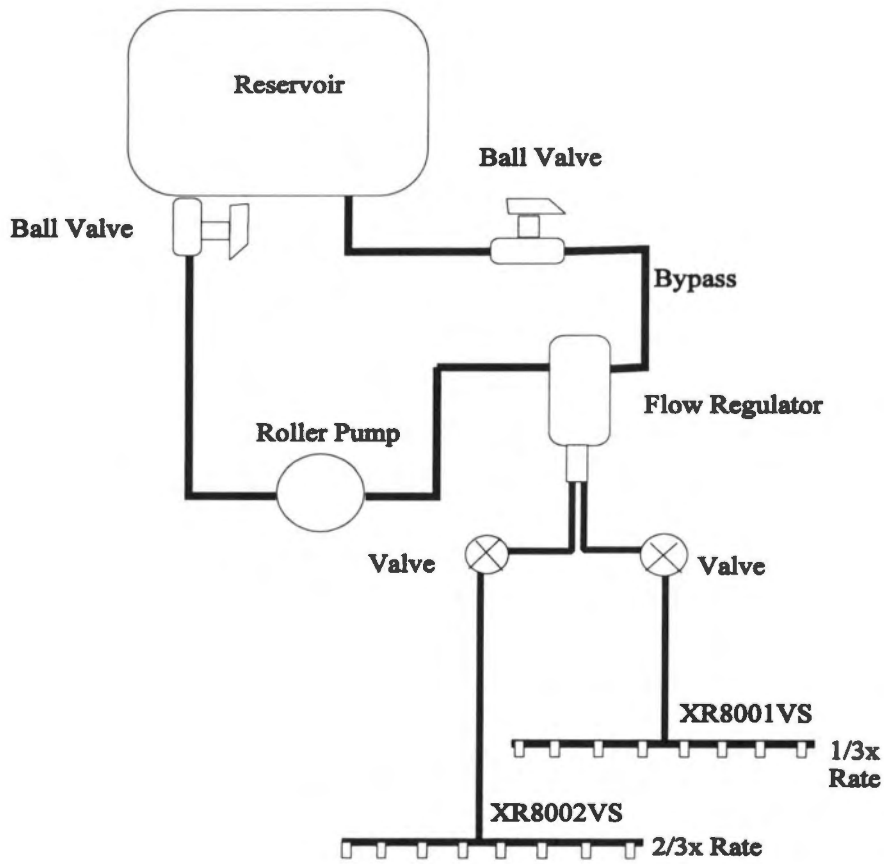



Figure 4. Illustration of a one boom segment of the variable rate applicator (VRA). One boom has two nozzle bodies (XR8001VS and XR8002VS tips) which enables 1/3x rate with 8001 tips, 2/3x rate with 8002 tips, and 1x rate with both tips discharging simultaneously. Actual VRA contained 14 nozzle positions (28 nozzles) spaced 52 cm apart.

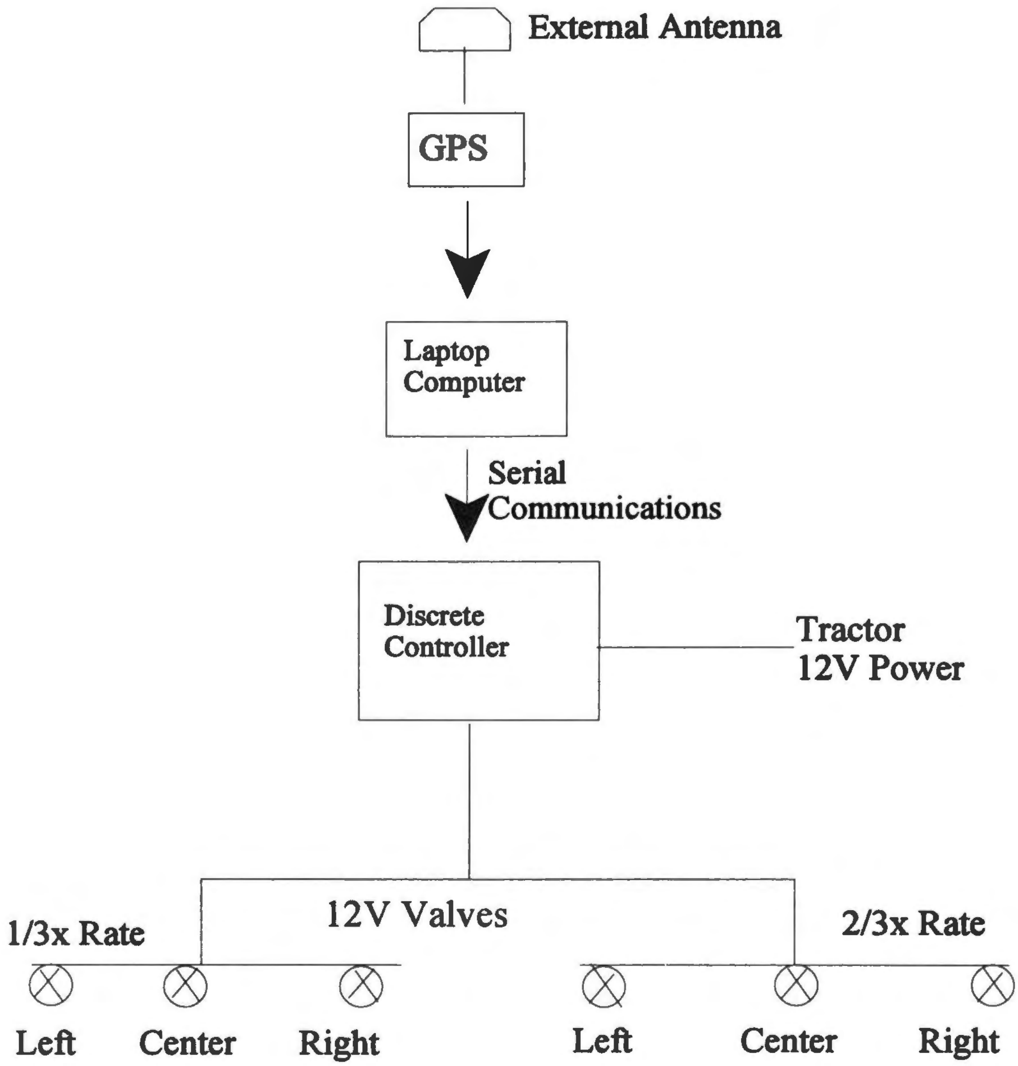



Figure 5. Schematic of discrete control system with Global Positioning System (GPS) and Variable Rate Applicator (VRA) used for 1998 herbicide applications.

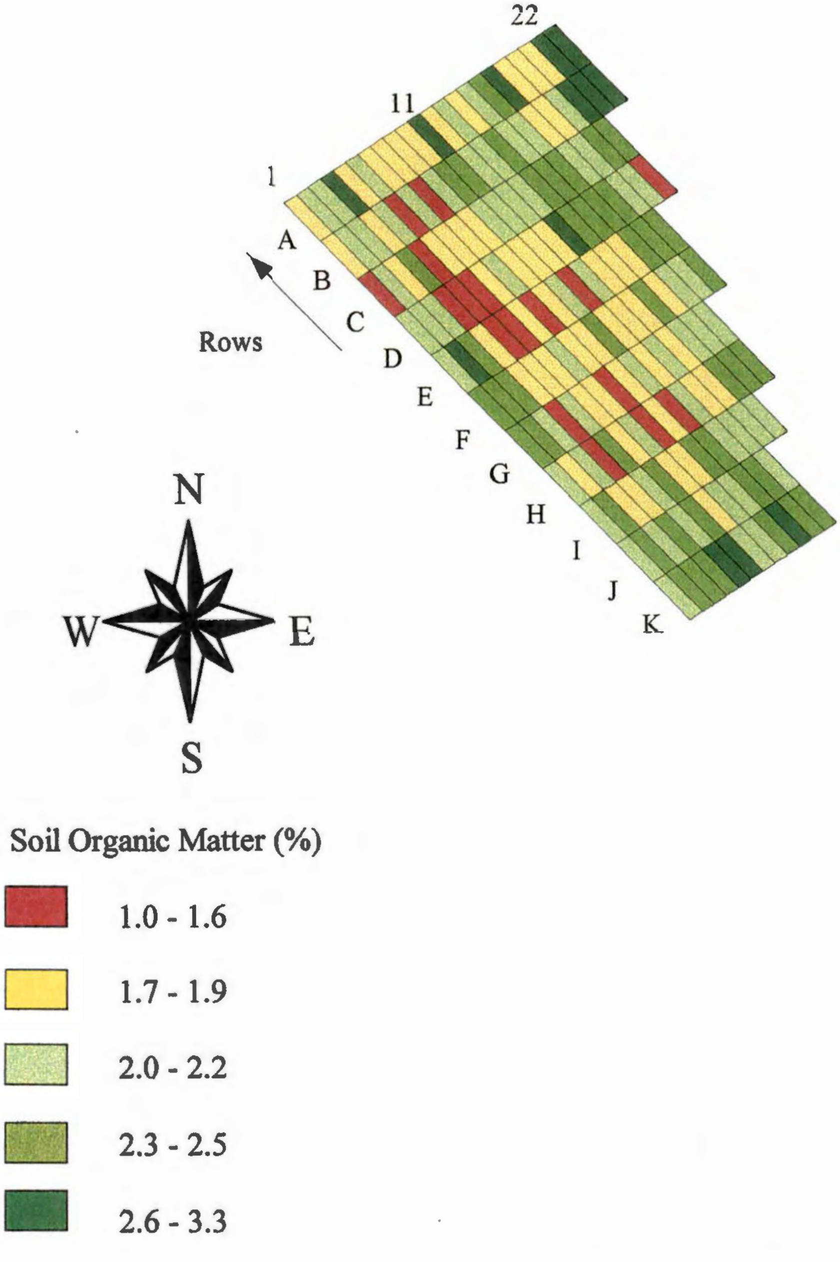



Figure 6. The distribution of soil organic matter (%) in 1998.

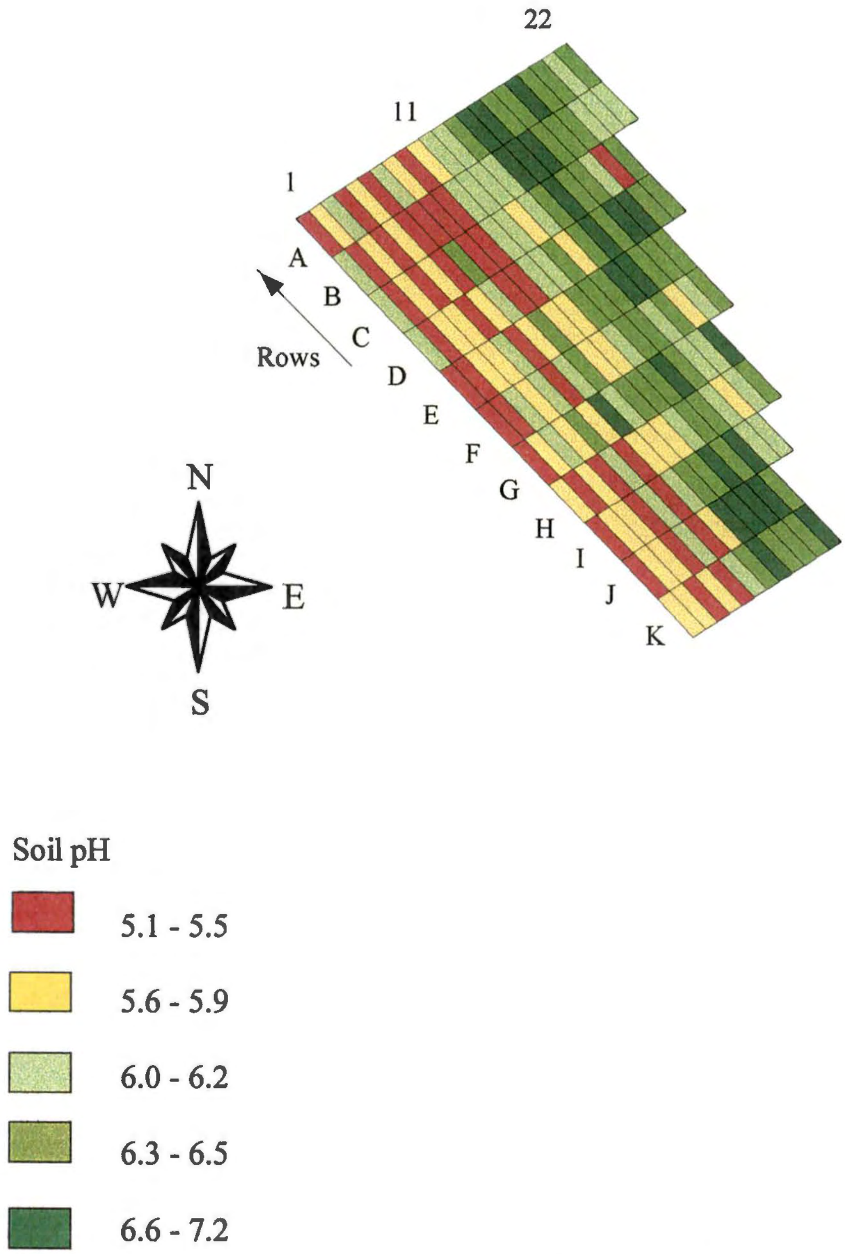



Figure 7. Soil pH ranges throughout the field in 1998.

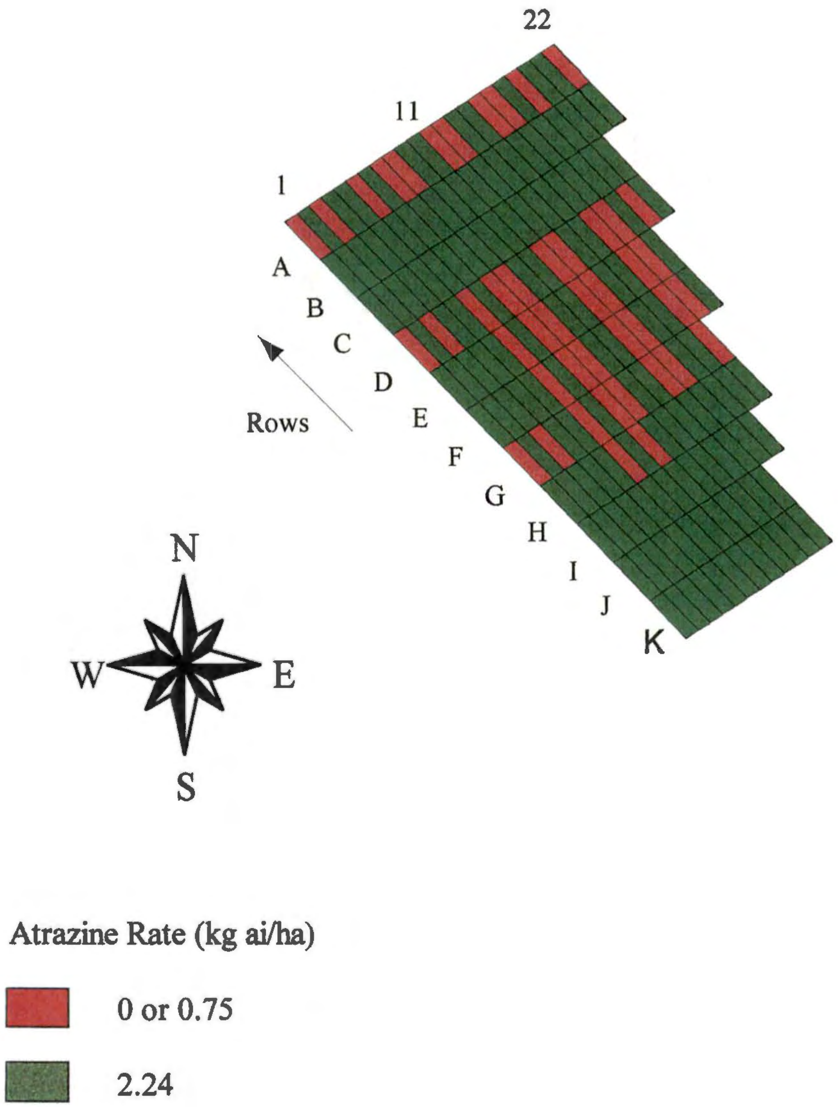



Figure 8. Map of atrazine applications used in 1997 and 1998 field plots. Red areas did not receive atrazine in 1997 and received 0.75 kg ai/ha in 1998. Green areas received 2.24 kg ai/ha of atrazine in 1997 and 1998.

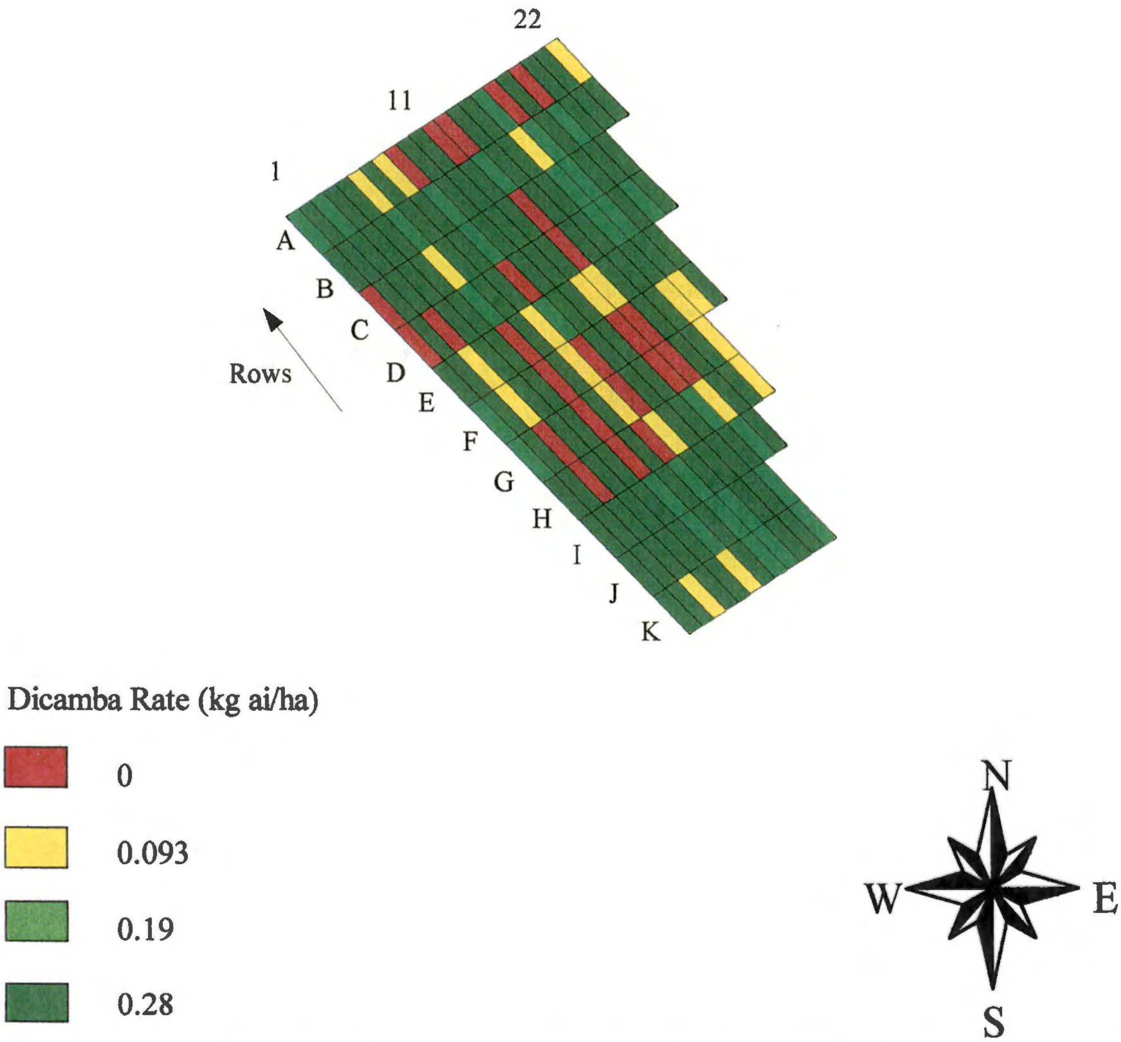



Figure 9. Dicamba application map of field plots. The same herbicide rate was applied to each sub-plot in 1997 and 1998. Conventional plots received 0.28 kg ai/ha. Site-specific application rates ranged from 0 to 0.28 kg ai/ha depending on common cocklebur density at time of application.

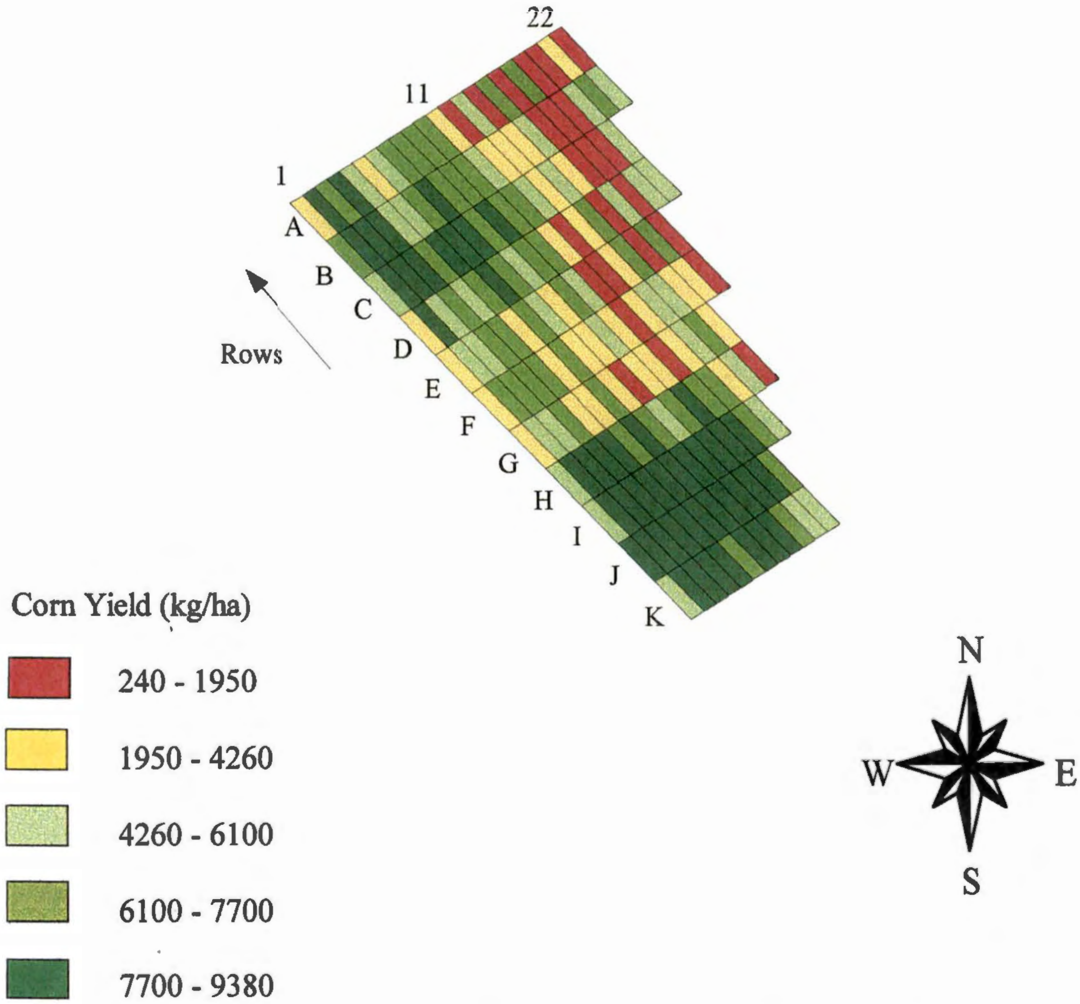



Figure 10. Yield map representing 1997 corn yields. In 1997, corn in Row F was harvested perpendicular to row direction to serve as a reference point during harvesting. When corn was harvested and data were recorded, this check point was used to verify spatial accuracy of yield data. Therefore, Row F was omitted from statistical analysis.

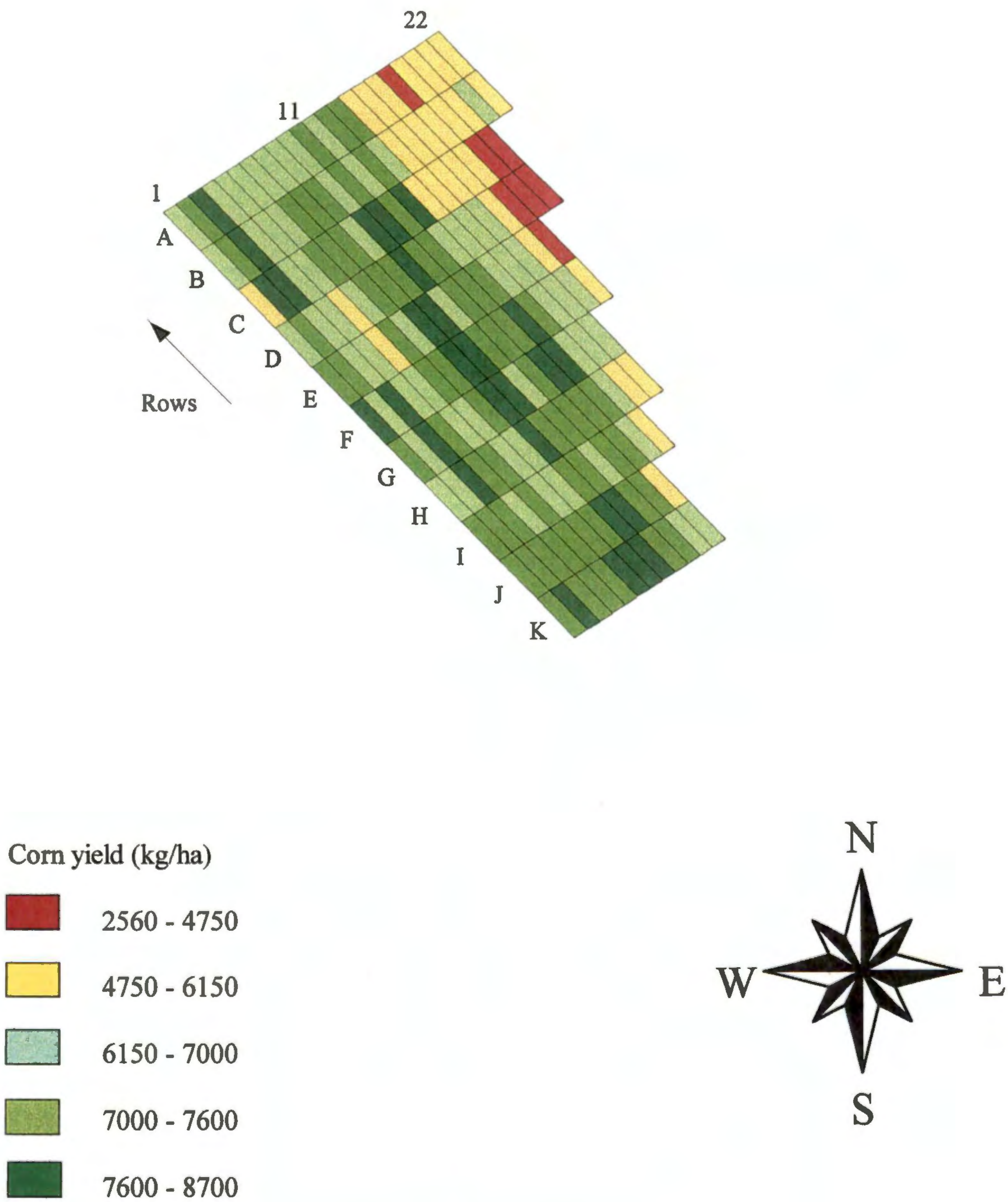



Figure 11. Yield map representing 1998 corn yields.

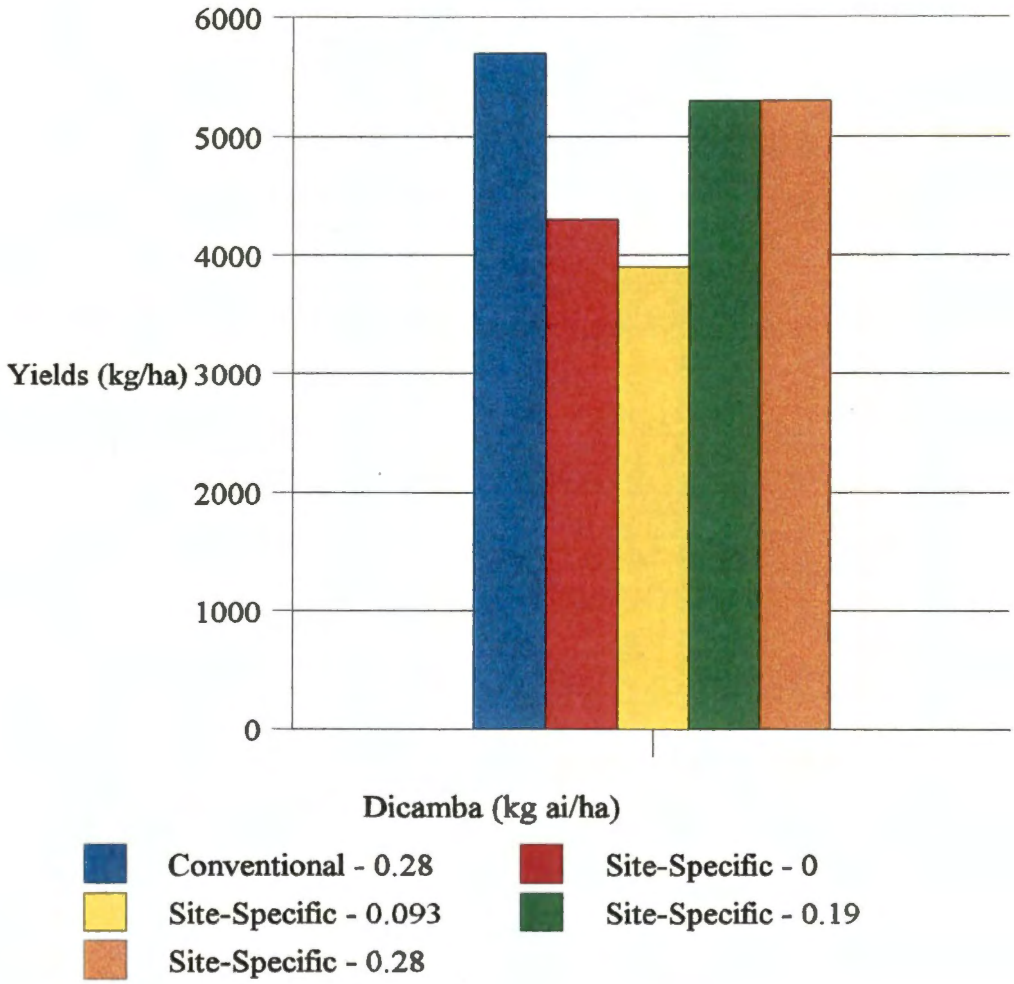



Figure 12. Comparison of conventional and site-specific yields with dicamba treatments averaged over atrazine treatments in 1997. Tabular data containing the number of observations, standard errors, yields (LS means), and LSD groupings are in Table *B - 2*. Average overall yields were 4900 kg/ha.

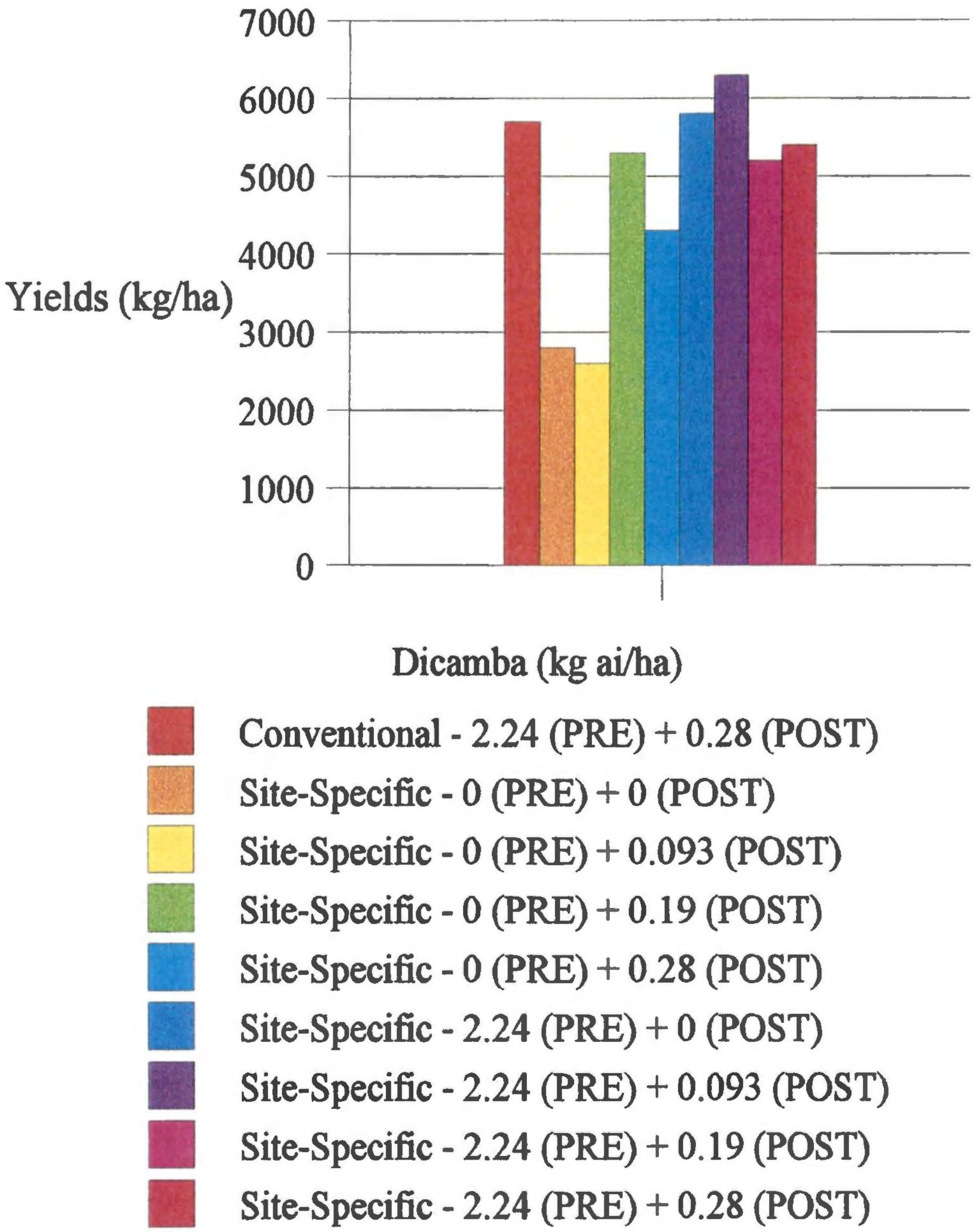



Figure 13. Conventional and site-specific yields with atrazine and dicamba interactions in 1997. . Tabular data containing the number of observations, standard errors, yields (LS means), and LSD grouping are in Table *B - 3*. Average overall yields were 4800 kg/ha.

# Appendix A

## Tables

*Table A - 1.* Soil pH and % organic matter by sub-plot in 1998.

| Plot # | pH | OM |
|---|---|---|
| | | % |
| A1 | 5.55 | 1.86 |
| A2 | 6.04 | 1.88 |
| A3 | 5.91 | 1.70 |
| A4 | 6.16 | 2.02 |
| A5 | 5.35 | 2.08 |
| A6 | 5.31 | 2.46 |
| A7 | 5.50 | 2.30 |
| A8 | 5.64 | 2.02 |
| A9 | 5.59 | 2.20 |
| A10 | 5.57 | 2.20 |
| A11 | 5.75 | 2.16 |
| A12 | 5.79 | 2.37 |
| A13 | 5.67 | 2.40 |
| A14 | 5.67 | 2.22 |
| A15 | 5.46 | 1.81 |
| A16 | 5.64 | 2.28 |
| A17 | 5.47 | 2.29 |
| A18 | 5.27 | 2.52 |
| A19 | 5.41 | 2.01 |
| A20 | 5.14 | 2.08 |
| A21 | 5.37 | 2.14 |
| A22 | 5.87 | 2.07 |
| B1 | 6.15 | 2.02 |
| B2 | 5.86 | 2.08 |
| B3 | 5.74 | 1.96 |

*Table A - 1.* Soil pH and % organic matter by sub-plot in 1998 (continued).

| Plot # | pH | O. M. |
|---|---|---|
| | | % |
| B4 | 5.87 | 2.03 |
| B5 | 5.81 | 2.23 |
| B6 | 6.15 | 2.20 |
| B7 | 6.07 | 2.14 |
| B8 | 5.89 | 2.09 |
| B9 | 5.68 | 1.94 |
| B10 | 5.69 | 2.13 |
| B11 | 5.60 | 2.45 |
| B12 | 5.81 | 2.33 |
| B13 | 5.59 | 2.39 |
| B14 | 5.33 | 1.80 |
| B15 | 5.47 | 1.63 |
| B16 | 5.79 | 1.66 |
| B17 | 5.68 | 1.77 |
| B18 | 5.74 | 1.72 |
| B19 | 5.76 | 1.62 |
| B20 | 5.50 | 2.26 |
| B21 | 5.17 | 1.80 |
| B22 | 5.48 | 2.64 |
| C1 | 5.88 | 1.90 |
| C2 | 5.85 | 2.10 |
| C3 | 5.65 | 1.68 |
| C4 | 5.57 | 1.49 |

*Table A - 1.* Soil pH and % organic matter by sub-plot in 1998 (continued).

| Plot # | pH | OM |
|---|---|---|
| | | % |
| C5 | 5.93 | 1.58 |
| C6 | 6.14 | 1.95 |
| C7 | 6.45 | 2.07 |
| C8 | 6.01 | 2.39 |
| C9 | 5.98 | 2.06 |
| C10 | 5.95 | 2.14 |
| C11 | 5.33 | 2.54 |
| C12 | 5.95 | 2.75 |
| C13 | 5.34 | 2.48 |
| C14 | 5.27 | 2.42 |
| C15 | 5.42 | 1.87 |
| C16 | 5.64 | 1.92 |
| C17 | 5.50 | 1.94 |
| C18 | 5.57 | 1.68 |
| C19 | 5.68 | 1.68 |
| C20 | 5.44 | 1.83 |
| D1 | 5.39 | 1.67 |
| D2 | 5.48 | 2.01 |
| D3 | 5.95 | 1.92 |
| D4 | 5.47 | 2.14 |
| D5 | 6.21 | 1.78 |
| D6 | 6.13 | 1.84 |
| D7 | 5.88 | 1.97 |

*Table A - 1.* Soil pH and % organic matter by sub-plot in 1998 (continued).

| Plot # | pH | OM |
|---|---|---|
| | | % |
| D8 | 6.12 | 2.05 |
| D9 | 6.54 | 1.79 |
| D10 | 5.73 | 2.14 |
| D11 | 6.06 | 1.86 |
| D12 | 5.87 | 1.91 |
| D13 | 6.27 | 2.14 |
| D14 | 6.51 | 2.12 |
| D15 | 6.62 | 2.04 |
| D16 | 6.41 | 1.80 |
| D17 | 5.72 | 1.64 |
| D18 | 6.13 | 1.64 |
| D19 | 6.39 | 1.96 |
| D20 | 6.29 | 1.58 |
| E1 | 5.34 | 2.06 |
| E2 | 5.31 | 1.81 |
| E3 | 5.58 | 1.52 |
| E4 | 5.66 | 1.77 |
| E5 | 5.59 | 1.92 |
| E6 | 5.56 | 2.03 |
| E7 | 5.19 | 1.91 |
| E8 | 5.44 | 1.76 |
| E9 | 5.86 | 1.80 |
| E10 | 5.80 | 1.80 |

*Table A - 1.* Soil pH and % organic matter by sub-plot in 1998 (continued).

| Plot # | pH | OM |
|---|---|---|
| | | % |
| E11 | 6.26 | 1.82 |
| E12 | 5.75 | 1.79 |
| E13 | 6.33 | 2.43 |
| E14 | 6.51 | 2.06 |
| E15 | 6.40 | 2.35 |
| E16 | 6.28 | 2.63 |
| E17 | 6.73 | 2.27 |
| E18 | 6.63 | 2.32 |
| F1 | 6.15 | 1.69 |
| F2 | 6.25 | 2.16 |
| F3 | 5.64 | 2.26 |
| F4 | 5.78 | 2.01 |
| F5 | 6.03 | 1.90 |
| F6 | 6.01 | 2.02 |
| F7 | 5.93 | 2.25 |
| F8 | 5.83 | 1.96 |
| F9 | 6.14 | 2.56 |
| F10 | 6.04 | 2.23 |
| F11 | 6.18 | 2.13 |
| F12 | 6.11 | 1.72 |
| F13 | 6.26 | 1.67 |
| F14 | 6.08 | 1.76 |
| F15 | 6.27 | 1.71 |
| F16 | 6.42 | 2.06 |

*Table A - 1.* Soil pH and % organic matter by sub-plot in 1998 (continued).

| Plot # | pH | OM |
|---|---|---|
| | | % |
| F17 | 6.45 | 2.07 |
| F18 | 6.61 | 2.37 |
| G1 | 6.42 | 2.23 |
| G2 | 6.59 | 2.33 |
| G3 | 6.41 | 2.13 |
| G4 | 6.55 | 2.20 |
| G5 | 6.44 | 1.99 |
| G6 | 6.51 | 2.01 |
| G7 | 6.22 | 1.72 |
| G8 | 6.23 | 2.19 |
| G9 | 6.37 | 1.77 |
| G10 | 5.79 | 2.08 |
| G11 | 6.11 | 2.16 |
| G12 | 6.15 | 1.92 |
| G13 | 6.28 | 2.11 |
| G14 | 6.19 | 2.05 |
| G15 | 6.19 | 2.08 |
| G16 | 5.85 | 3.27 |
| H1 | 6.22 | 1.90 |
| H2 | 6.48 | 2.00 |
| H3 | 6.36 | 1.85 |
| H4 | 5.93 | 2.00 |
| H5 | 6.01 | 2.18 |

*Table A - 1.* Soil pH and % organic matter by sub-plot in 1998 (continued).

| Plot # | pH | OM |
|---|---|---|
| | | % |
| H6 | 6.20 | 2.09 |
| H7 | 5.84 | 2.24 |
| H8 | 6.11 | 2.08 |
| H9 | 6.16 | 2.36 |
| H10 | 6.56 | 1.94 |
| H11 | 6.39 | 2.38 |
| H12 | 6.40 | 2.22 |
| H13 | 6.54 | 2.33 |
| H14 | 6.60 | 1.97 |
| H15 | 6.84 | 2.01 |
| H16 | 6.80 | 2.03 |
| I1 | 6.70 | 2.30 |
| I2 | 7.00 | 2.24 |
| I3 | 6.96 | 2.00 |
| I4 | 6.47 | 1.94 |
| I5 | 6.19 | 2.13 |
| I6 | 5.95 | 2.27 |
| I7 | 6.21 | 2.23 |
| I8 | 6.60 | 2.10 |
| I9 | 5.83 | 2.05 |
| I10 | 6.22 | 2.22 |
| I11 | 6.41 | 2.21 |
| I12 | 6.47 | 2.28 |

*Table A - 1.* Soil pH and % organic matter by sub-plot in 1998 (continued).

| Plot # | pH | OM |
|---|---|---|
| | | % |
| I13 | 6.64 | 2.07 |
| I14 | 6.35 | 2.28 |
| J1 | 6.29 | 2.61 |
| J2 | 6.38 | 1.92 |
| J3 | 6.30 | 2.04 |
| J4 | 6.53 | 2.42 |
| J5 | 6.29 | 2.23 |
| J6 | 6.16 | 2.12 |
| J7 | 6.30 | 2.28 |
| J8 | 6.37 | 2.31 |
| J9 | 6.65 | 2.02 |
| J10 | 6.07 | 2.13 |
| J11 | 6.31 | 1.93 |
| J12 | 6.53 | 1.86 |
| K1 | 6.45 | 1.86 |
| K2 | 6.29 | 2.09 |
| K3 | 5.59 | 2.32 |
| K4 | 6.25 | 2.13 |
| K5 | 6.38 | 1.59 |
| K6 | 6.35 | 2.26 |
| K7 | 6.07 | 2.63 |
| K8 | 6.32 | 1.98 |
| K9 | 6.11 | 2.55 |

*Table A - 1.* Soil pH and % organic matter by sub-plot in 1998 (continued).

| Plot # | pH | OM |
|---|---|---|
| | | % |
| K10 | 6.17 | 2.66 |
| K11 | 6.08 | 2.81 |
| K12 | 6.29 | 2.86 |

*Table A - 2.* Visual evaluation of common cocklebur control and density (per 1 $m^2$) recorded 14 DAT of PRE and POST herbicides in 1998.

| Plot # | Common Cocklebur Control - 6/3/98 | Common Cocklebur density - 6/3/98 | Common Cocklebur Control - 6/30/98 | Common Cocklebur density - 6/30/98 |
|---|---|---|---|---|
| | % | plants/$m^2$ | % | plants/$m^2$ |
| A1 | 95 | 140 | 90 | 14 |
| A2 | 95 | 194 | 85 | 29 |
| A3 | 95 | 0 | 99 | 0 |
| A4 | 90 | 161 | 99 | 2 |
| A5 | 80 | 183 | 99 | 2 |
| A6 | 99 | 0 | 99 | 0 |
| A7 | 90 | 75 | 99 | 1 |
| A8 | 85 | 97 | 99 | 1 |
| A9 | 80 | 75 | 99 | 1 |
| A10 | 85 | 215 | 99 | 2 |
| A11 | 99 | 0 | 99 | 0 |
| A12 | 99 | 0 | 99 | 0 |
| A13 | 95 | 215 | 95 | 11 |
| A14 | 95 | 118 | 99 | 1 |
| A15 | 95 | 86 | 95 | 4 |
| A16 | 90 | 215 | 99 | 2 |
| A17 | 85 | 258 | 90 | 26 |
| A18 | 85 | 172 | 95 | 9 |
| A19 | 80 | 258 | 85 | 39 |
| A20 | 90 | 280 | 85 | 42 |
| A21 | 85 | 333 | 80 | 67 |
| A22 | 95 | 0 | 99 | 0 |
| B1 | 90 | 129 | 99 | 1 |
| B2 | 90 | 258 | 99 | 3 |

*Table A - 2.* Visual evaluation of common cocklebur control and density (per 1 $m^2$) recorded 14 DAT of PRE and POST herbicides in 1998 (continued).

| Plot # | Common Cocklebur Control - 6/3/98 | Common Cocklebur density - 6/3/98 | Common Cocklebur Control - 6/30/98 | Common Cocklebur density - 6/30/98 |
|---|---|---|---|---|
| | % | plants/$m^2$ | % | plants/$m^2$ |
| B3 | 99 | 0 | 99 | 0 |
| B4 | 95 | 0 | 99 | 0 |
| B5 | 99 | 0 | 99 | 0 |
| B6 | 99 | 0 | 99 | 0 |
| B7 | 95 | 75 | 99 | 1 |
| B8 | 90 | 194 | 99 | 2 |
| B9 | 99 | 0 | 99 | 0 |
| B10 | 95 | 183 | 95 | 9 |
| B11 | 85 | 183 | 90 | 18 |
| B12 | 99 | 0 | 90 | 0 |
| B13 | 95 | 65 | 95 | 3 |
| B14 | 90 | 54 | 85 | 8 |
| B15 | 99 | 0 | 99 | 0 |
| B16 | 99 | 0 | 95 | 0 |
| B17 | 90 | 258 | 80 | 52 |
| B18 | 95 | 183 | 85 | 27 |
| B19 | 95 | 54 | 80 | 11 |
| B20 | 90 | 65 | 99 | 1 |
| B21 | 90 | 260 | 99 | 4 |
| B22 | 99 | 0 | 99 | 0 |
| C1 | 99 | 0 | 99 | 0 |

*Table A - 2.* Visual evaluation of common cocklebur control and density (per 1 $m^2$) recorded 14 DAT of PRE and POST herbicides in 1998 (continued).

| Plot # | Common Cocklebur Control - 6/3/98 | Common Cocklebur density - 6/3/98 | Common Cocklebur Control - 6/30/98 | Common Cocklebur density - 6/30/98 |
|---|---|---|---|---|
| | % | plants/$m^2$ | % | plants/$m^2$ |
| C2 | 95 | 65 | 65 | 23 |
| C3 | 90 | 151 | 99 | 2 |
| C4 | 99 | 0 | 90 | 0 |
| C5 | 99 | 0 | 85 | 0 |
| C6 | 95 | 22 | 95 | 1 |
| C7 | 99 | 0 | 99 | 0 |
| C8 | 95 | 86 | 99 | 1 |
| C9 | 95 | 65 | 99 | 1 |
| C10 | 99 | 0 | 95 | 0 |
| C11 | 95 | 0 | 95 | 0 |
| C12 | 99 | 0 | 99 | 0 |
| C13 | 99 | 0 | 99 | 0 |
| C14 | 99 | 0 | 99 | 0 |
| C15 | 99 | 0 | 99 | 0 |
| C16 | 99 | 0 | 99 | 0 |
| C17 | 99 | 5 | 95 | 18 |
| C18 | 95 | 75 | 99 | 1 |
| C19 | 90 | 226 | 95 | 11 |
| C20 | 95 | 97 | 99 | 1 |
| D1 | 95 | 108 | 99 | 1 |
| D2 | 95 | 151 | 99 | 2 |

*Table A - 2.* Visual evaluation of common cocklebur control and density (per 1 $m^2$) recorded 14 DAT of PRE and POST herbicides in 1998 (continued).

| Plot # | Common Cocklebur Control - 6/3/98 | Common Cocklebur density - 6/3/98 | Common Cocklebur Control - 6/30/98 | Common Cocklebur density - 6/30/98 |
|---|---|---|---|---|
| | % | plants/$m^2$ | % | plants/$m^2$ |
| D3 | 95 | 118 | 95 | 6 |
| D4 | 95 | 140 | 95 | 7 |
| D5 | 90 | 118 | 95 | 6 |
| D6 | 99 | 0 | 95 | 0 |
| D7 | 95 | 32 | 99 | 0 |
| D8 | 90 | 65 | 85 | 10 |
| D9 | 95 | 54 | 90 | 5 |
| D10 | 80 | 65 | 95 | 3 |
| D11 | 99 | 0 | 99 | 0 |
| D12 | 95 | 75 | 99 | 1 |
| D13 | 95 | 204 | 99 | 2 |
| D14 | 99 | 0 | 95 | 0 |
| D15 | 99 | 0 | 99 | 0 |
| D16 | 95 | 0 | 99 | 0 |
| D17 | 95 | 75 | 95 | 4 |
| D18 | 99 | 0 | 99 | 0 |
| D19 | 90 | 43 | 99 | 0 |
| D20 | 95 | 32 | 99 | 0 |
| E1 | 95 | 169 | 80 | 54 |
| E2 | 99 | 0 | 99 | 0 |
| E3 | 95 | 54 | 90 | 5 |

*Table A - 2.* Visual evaluation of common cocklebur control and density (per 1 $m^2$) recorded 14 DAT of PRE and POST herbicides in 1998 (continued).

| Plot # | Common Cocklebur Control - 6/3/98 | Common Cocklebur density - 6/3/98 | Common Cocklebur Control - 6/30/98 | Common Cocklebur density - 6/30/98 |
|---|---|---|---|---|
| | % | plants/$m^2$ | % | plants/$m^2$ |
| E4 | 90 | 258 | 95 | 13 |
| E5 | 99 | 0 | 99 | 0 |
| E6 | 95 | 97 | 99 | 1 |
| E7 | 95 | 223 | 85 | 48 |
| E8 | 95 | 0 | 95 | 0 |
| E9 | 95 | 0 | 99 | 0 |
| E10 | 90 | 226 | 99 | 2 |
| E11 | 95 | 194 | 99 | 2 |
| E12 | 95 | 43 | 95 | 2 |
| E13 | 99 | 0 | 95 | 0 |
| E14 | 95 | 75 | 99 | 1 |
| E15 | 95 | 108 | 95 | 5 |
| E16 | 99 | 0 | 95 | 0 |
| E17 | 95 | 108 | 90 | 11 |
| E18 | 95 | 22 | 85 | 3 |
| F1 | 99 | 0 | 99 | 0 |
| F2 | 95 | 258 | 99 | 3 |
| F3 | 99 | 0 | 99 | 0 |
| F4 | 99 | 0 | 99 | 0 |
| F5 | 99 | 0 | 99 | 0 |
| F6 | 99 | 0 | 99 | 0 |

*Table A - 2.* Visual evaluation of common cocklebur control and density (per 1 $m^2$) recorded 14 DAT of PRE and POST herbicides in 1998 (continued).

| Plot # | Common Cocklebur Control - 6/3/98 | Common Cocklebur density - 6/3/98 | Common Cocklebur Control - 6/30/98 | Common Cocklebur density - 6/30/98 |
|---|---|---|---|---|
| | % | plants/$m^2$ | % | plants/$m^2$ |
| F7 | 99 | 0 | 99 | 0 |
| F8 | 95 | 226 | 90 | 23 |
| F9 | 95 | 0 | 99 | 0 |
| F10 | 99 | 0 | 99 | 0 |
| F11 | 99 | 0 | 99 | 0 |
| F12 | 95 | 43 | 99 | 0 |
| F13 | 95 | 0 | 99 | 0 |
| F14 | 95 | 151 | 99 | 2 |
| F15 | 95 | 301 | 99 | 3 |
| F16 | 99 | 0 | 99 | 0 |
| F17 | 99 | 0 | 99 | 0 |
| F18 | 95 | 97 | 99 | 1 |
| G1 | 95 | 0 | 99 | 0 |
| G2 | 95 | 161 | 95 | 8 |
| G3 | 95 | 183 | 99 | 2 |
| G4 | 95 | 172 | 99 | 2 |
| G5 | 99 | 0 | 99 | 0 |
| G6 | 95 | 22 | 95 | 1 |
| G7 | 95 | 108 | 99 | 1 |
| G8 | 99 | 0 | 99 | 0 |

*Table A - 2.* Visual evaluation of common cocklebur control and density (per 1 $m^2$) recorded 14 DAT of PRE and POST herbicides in 1998 (continued).

| Plot # | Common Cocklebur Control - 6/3/98 | Common Cocklebur density - 6/3/98 | Common Cocklebur Control - 6/30/98 | Common Cocklebur density - 6/30/98 |
|---|---|---|---|---|
| | % | plants/$m^2$ | % | plants/$m^2$ |
| G9 | 99 | 0 | 99 | 0 |
| G10 | 90 | 86 | 85 | 13 |
| G11 | 95 | 118 | 90 | 12 |
| G12 | 95 | 215 | 95 | 11 |
| G13 | 99 | 140 | 95 | 7 |
| G14 | 99 | 11 | 95 | 1 |
| G15 | 99 | 22 | 90 | 2 |
| G16 | 99 | 54 | 95 | 3 |
| H1 | 95 | 32 | 99 | 0 |
| H2 | 95 | 0 | 99 | 0 |
| H3 | 95 | 0 | 99 | 0 |
| H4 | 99 | 0 | 99 | 0 |
| H5 | 99 | 0 | 95 | 0 |
| H6 | 90 | 129 | 99 | 1 |
| H7 | 95 | 75 | 99 | 1 |
| H8 | 95 | 65 | 99 | 1 |
| H9 | 90 | 129 | 95 | 6 |
| H10 | 95 | 22 | 95 | 1 |
| H11 | 99 | 0 | 99 | 0 |
| H12 | 95 | 43 | 99 | 0 |

*Table A - 2.* Visual evaluation of common cocklebur control and density (per 1 $m^2$) recorded 14 DAT of PRE and POST herbicides in 1998 (continued).

| Plot # | Common Cocklebur Control - 6/3/98 | Common Cocklebur density - 6/3/98 | Common Cocklebur Control - 6/30/98 | Common Cocklebur density - 6/30/98 |
|---|---|---|---|---|
| | % | plants/$m^2$ | % | plants/$m^2$ |
| H13 | 90 | 129 | 85 | 19 |
| H14 | 90 | 161 | 99 | 2 |
| H15 | 95 | 43 | 99 | 0 |
| H16 | 99 | 0 | 99 | 0 |
| I1 | 95 | 0 | 99 | 0 |
| I2 | 95 | 43 | 90 | 4 |
| I3 | 95 | 54 | 85 | 8 |
| I4 | 90 | 65 | 90 | 6 |
| I5 | 85 | 161 | 95 | 8 |
| I6 | 90 | 97 | 90 | 10 |
| I7 | 90 | 75 | 95 | 4 |
| I8 | 95 | 43 | 95 | 2 |
| I9 | 95 | 54 | 90 | 5 |
| I10 | 99 | 0 | 90 | 0 |
| I11 | 99 | 0 | 99 | 0 |
| I12 | 99 | 0 | 99 | 0 |
| I13 | 99 | 0 | 99 | 0 |
| I14 | 95 | 32 | 99 | 0 |
| J1 | 95 | 22 | 95 | 1 |
| J2 | 85 | 183 | 99 | 2 |
| J3 | 90 | 43 | 80 | 9 |

*Table A - 2.* Visual evaluation of common cocklebur control and density (per 1 $m^2$) recorded 14 DAT of PRE and POST herbicides in 1998 (continued).

| Plot # | Common Cocklebur Control - 6/3/98 | Common Cocklebur density - 6/3/98 | Common Cocklebur Control - 6/30/98 | Common Cocklebur density - 6/30/98 |
|---|---|---|---|---|
| | % | plants/$m^2$ | % | plants/$m^2$ |
| J4 | 90 | 108 | 99 | 1 |
| J5 | 90 | 65 | 99 | 1 |
| J6 | 95 | 0 | 99 | 0 |
| J7 | 90 | 129 | 99 | 1 |
| J8 | 90 | 190 | 95 | 15 |
| J9 | 99 | 0 | 99 | 0 |
| J10 | 90 | 75 | 95 | 4 |
| J11 | 90 | 151 | 95 | 8 |
| J12 | 95 | 140 | 85 | 21 |
| K1 | 95 | 22 | 90 | 2 |
| K2 | 95 | 101 | 99 | 3 |
| K3 | 90 | 215 | 99 | 2 |
| K4 | 85 | 161 | 90 | 16 |
| K5 | 99 | 0 | 99 | 0 |
| K6 | 99 | 0 | 99 | 0 |
| K7 | 80 | 215 | 85 | 32 |
| K8 | 80 | 258 | 95 | 13 |
| K9 | 90 | 65 | 90 | 6 |
| K10 | 90 | 151 | 95 | 8 |
| K11 | 90 | 180 | 95 | 14 |
| K12 | 95 | 75 | 95 | 4 |

## Appendix B

## Statistics

*Figure B - 1.* Statistical program used to analyze data.

```
Data one;
input block plot striptrt pretrt posttrt yield lat long om pH density;
cards;

;
proc mixed;
 class striptrt block pretrt posttrt;
 model yield = striptrt posttrt(striptrt) pretrt*striptrt pretrt*posttrt(striptrt) / predicted;
 random block   block*striptrt;
 repeated /type = sp(sph) (lat long);
 lsmeans  striptrt posttrt(striptrt) pretrt*striptrt pretrt*posttrt(striptrt);
 make 'predicted' out=rrr noprint;
make 'diffs' out=ppp;
make 'lsmeans' out=mmm noprint;
run;
%include 'a:pdmix612.sas';
%pdmix612(ppp,mmm);
proc univariate plot normal data=rrr;
var _resid_;
run;
```

The variable 'striptrt' refers to either conventional or site-specific. The variable 'posttrt' indicated the POST herbicide program, and the variable 'pretrt' indicated the PRE herbicide program. The 'pretrt' and 'posttrt' refer to the preemergence and postemergence rates nested in the site-specific treatment. The 'pretrt*posttrt (striptrt)' refers to the interaction of preemergence and postemergence rates nested in site-specific plots. The model statement used was yield = striptrt posttrt(striptrt) pretrt*striptrt pretrt*posttrt(striptrt)/ predicted.

*Table B - 1.* Conventional and site-specific yields averaged over all herbicide treatments in 1997[a].

| Herbicide Regime | Observations | Yield (LS Mean)[b] | Standard Error | LSD Grouping[b] |
|---|---|---|---|---|
| | no. | kg/ha | kg/ha | |
| Conventional | 87 | 5700 | 646 | A |
| Site-Specific | 87 | 4700 | 660 | A |

[a] Letters not followed by same letter are significantly different at 0.05 probability level.

[b] Due to using a spatial analysis, standard errors differ with every treatment. An LSD value can not be calculated due to the different standard errors, therefore an LSD grouping is used to show if treatments are significantly different ($\propto = 0.05$).

*Table B - 2.* Conventional and site-specific yields with dicamba treatments averaged across atrazine treatments in 1997[a].

| Herbicide Regime | Observations | Dicamba | Yield (LS Mean)[b] | Standard Error | LSD Grouping[b] |
|---|---|---|---|---|---|
| | no. | kg ai/ha | kg/ha | kg/ha | |
| Conventional | 88 | 2.24 | 5700 | 646 | A |
| Site-Specific | 19 | 0 | 4300 | 829 | AB |
| Site-Specific | 18 | 0.093 | 3900 | 742 | B |
| Site-Specific | 28 | 0.19 | 5300 | 716 | A |
| Site-Specific | 22 | 2.24 | 5300 | 783 | A |

[a] Letters not followed by same letter are significantly different at 0.05 probability level.

[b] Due to using a spatial analysis, standard errors differ with every treatment. An LSD value can not be calculated due to the different standard errors, therefore an LSD grouping is used to show if treatments are significantly different ($\alpha = 0.05$).

*Table B - 3.* Comparison of 1997 atrazine and dicamba treatments between conventional and site-specific plots[a].

| Herbicide Regime | Observations | Atrazine | Dicamba | Yield (LS Mean)[b] | Standard Error | LSD Grouping[b] |
|---|---|---|---|---|---|---|
| | no. | kg ai/ha | kg ai/ha | kg/ha | kg/ha | |
| Conventional | 88 | 2.24 | 0.28 | 5700 | 650 | AB |
| Site-specific | 16 | 0 | 0 | 2800 | 760 | C |
| Site-specific | 9 | 0 | 0.093 | 2600 | 850 | C |
| Site-specific | 8 | 0 | 0.19 | 5300 | 870 | AB |
| Site-specific | 4 | 0 | 0.28 | 4300 | 1050 | BC |
| Site-specific | 3 | 2.24 | 0 | 5800 | 1200 | AB |
| Site-specific | 9 | 2.24 | 0.093 | 6300 | 760 | A |
| Site-specific | 20 | 2.24 | 0.19 | 5200 | 860 | AB |
| Site-specific | 18 | 2.24 | 0.28 | 5400 | 730 | AB |

[a] Letters not followed by same letter are significantly different at 0.05 probability level.

[b] Due to using a spatial analysis, standard errors differ with every treatment. An LSD value can not be calculated due to the different standard errors, therefore an LSD grouping is used to show if treatments are significantly different ($\alpha = 0.05$).

*Table B - 4.* Conventional and site-specific yields averaged over all herbicide treatments in 1998[a].

| Herbicide Regime | Observations | Yield (LS Mean)[b] | Standard Error | LSD Grouping[b] |
|---|---|---|---|---|
| | no. | kg/ha | kg/ha | |
| Conventional | 95 | 6400 | 312 | A |
| Site-Specific | 95 | 6600 | 314 | A |

[a] Letters not followed by same letter are significantly different at 0.05 probability level.

[b] Due to using a spatial analysis, standard errors differ with every treatment. An LSD value can not be calculated due to the different standard errors, therefore an LSD grouping is used to show if treatments are significantly different ($\alpha = 0.05$).

*Table B - 5.* Conventional and site-specific yields with atrazine treatments averaged across dicamba treatments in 1998[a].

| Herbicide Regime | Observations | Atrazine | Yield (LS Mean)[b] | Standard Error | LSD Grouping[b] |
|---|---|---|---|---|---|
| | no. | kg ai/ha | kg/ha | kg/ha | |
| Conventional | 95 | 2.24 | 6400 | 312 | A |
| Site-Specific | 45 | 0.67 | 6700 | 321 | A |
| Site-Specific | 50 | 2.24 | 6600 | 324 | A |

[a] Letters not followed by same letter are significantly different at 0.05 probability level.

[b] Due to using a spatial analysis, standard errors differ with every treatment. An LSD value can not be calculated due to the different standard errors, therefore an LSD grouping is used to show if treatments are significantly different ($\propto = 0.05$).

*Table B - 6.* Comparison of conventional and site-specific yields with dicamba treatments averaged across atrazine treatments in 1998[a].

| Herbicide Regime | Observations | Dicamba | Yield (LS Mean)[b] | Standard Error | LSD Grouping[b] |
|---|---|---|---|---|---|
| | no. | kg ai/ha | kg/ha | kg/ha | |
| Conventional | 95 | 0.28 | 6400 | 312 | A |
| Site-Specific | 24 | 0 | 6600 | 353 | A |
| Site-Specific | 20 | 0.093 | 6900 | 331 | A |
| Site-Specific | 29 | 0.19 | 6600 | 326 | A |
| Site-Specific | 22 | 0.28 | 6600 | 346 | A |

[a] Letters not followed by same letter are significantly different at 0.05 probability level.

[b] Due to using a spatial analysis, standard errors differ with every treatment. An LSD value can not be calculated due to the different standard errors, therefore an LSD grouping is used to show if treatments are significantly different ($\propto = 0.05$).

*Table B - 7.* Comparison of 1998 atrazine and dicamba treatments between conventional and site-specific plots[a].

| Herbicide Regime | Observations | Atrazine | Dicamba | Yield (LS Mean)[b] | Standard Error | LSD Grouping[b] |
|---|---|---|---|---|---|---|
| | no. | kg ai/ha | kg ai/ha | kg/ha | kg/ha | |
| Conventional | 95 | 2.24 | 0.28 | 6400 | 310 | A |
| Site-specific | 21 | 0.75 | 0 | 6700 | 330 | A |
| Site-specific | 11 | 0.75 | 0.093 | 6800 | 350 | A |
| Site-specific | 9 | 0.75 | 0.19 | 6700 | 360 | A |
| Site-specific | 4 | 0.75 | 0.28 | 6800 | 420 | A |
| Site-specific | 3 | 2.24 | 0 | 6600 | 450 | A |
| Site-specific | 9 | 2.24 | 0.093 | 6500 | 340 | A |
| Site-specific | 20 | 2.24 | 0.19 | 6500 | 360 | A |
| Site-specific | 18 | 2.24 | 0.28 | 6600 | 330 | A |

[a] Letters not followed by same letter are significantly different at 0.05 probability level.

[b] Due to using a spatial analysis, standard errors differ with every treatment. An LSD value can not be calculated due to the different standard errors, therefore an LSD grouping is used to show if treatments are significantly different ($\alpha = 0.05$).

*Table B - 8.* Comparison of overall effects of herbicide treatments on common cocklebur density recorded 14 days after POST treatment application[a].

| Herbicide Regime | Observations | Common Cocklebur density (LS Mean)[b] | Standard Error | LSD Grouping[b] |
|---|---|---|---|---|
| | no. | plants/$m^2$ | plants/$m^2$ | |
| Conventional | 95 | 4 | 1.1 | A |
| Site-Specific | 95 | 7 | 1.3 | A |

[a] Letters not followed by same letter are significantly different at 0.05 probability level.

[b] Due to using a spatial analysis, standard errors differ with every treatment. An LSD value can not be calculated due to the different standard errors, therefore an LSD grouping is used to show if treatments are significantly different ($\propto = 0.05$).

*Table B - 9.* Summarized analysis of variance (test of fixed effects) of 1998 common cocklebur density data recorded 14 days after POST treatment application.

| Source | Type III F | Pr > F |
|---|---|---|
| Conv. vs. S.S.[a] | 3.83 | 0.0789 |
| (Conv. vs. S.S.) * PRE[b] | 0.35 | 0.5532 |
| POST (Conv. vs. S.S.)[c] | 5.66 | 0.0010 |
| PRE * POST (Conv. vs. S. S.)[d] | 2.16 | 0.8583 |

[a] Overall comparison of conventional vs. site-specific yields.

[b] Comparison of atrazine treatment effect on corn yields when averaged over dicamba treatments in conventional and site-specific plots.

[c] Comparison of dicamba treatment effect on corn yields when averaged over atrazine treatments in conventional and site-specific plots.

[d] Interaction of atrazine and dicamba treatment effects on corn yields in conventional and site-specific plots.

*Table B - 10.* Comparison of effects of dicamba treatments averaged over atrazine treatments on common cocklebur density recorded 14 days after POST treatment application[a].

| Herbicide Regime | Observations | Dicamba | Common Cocklebur density (LS Mean)[b] | Standard Error | LSD Grouping[b] |
|---|---|---|---|---|---|
| | no. | kg ai/ha | plants/m$^2$ | plants/m$^2$ | |
| Conventional | 95 | 0.28 | 4 | 1.1 | B |
| Site-Specific | 24 | 0 | 0.2 | 3.0 | B |
| Site-Specific | 20 | 0.093 | 6 | 2.2 | B |
| Site-Specific | 29 | 0.19 | 7 | 2.0 | B |
| Site-Specific | 22 | 0.28 | 16 | 2.7 | A |

[a] Letters not followed by same letter are significantly different at 0.05 probability level.

[b] Due to using a spatial analysis, standard errors differ with every treatment. An LSD value can not be calculated due to the different standard errors, therefore an LSD grouping is used to show if treatments are significantly different ($\alpha = 0.05$).

*Table B - 11.* Comparison of effects of atrazine treatments averaged over dicamba treatments on common cocklebur density recorded 14 days after POST treatment application [a].

| Herbicide Regime | Observations | Atrazine | Common Cocklebur density (LS Mean)[b] | Standard Error | LSD Grouping[b] |
|---|---|---|---|---|---|
| | no. | kg ai/ha | plants/$m^2$ | plants/$m^2$ | |
| Conventional | 95 | 2.24 | 4 | 1.1 | A |
| Site-Specific | 45 | 0.67 | 8 | 1.8 | A |
| Site-Specific | 50 | 2.24 | 6 | 1.9 | A |

[a] Letters not followed by same letter are significantly different at 0.05 probability level.

[b] Due to using a spatial analysis, standard errors differ with every treatment. An LSD value can not be calculated due to the different standard errors, therefore an LSD grouping is used to show if treatments are significantly different ($\propto = 0.05$).

*Table B - 12.* Comparison of effects of atrazine and dicamba treatments between conventional and site-specific plots on common cocklebur density recorded 14 days after POST treatment application[a].

| Herbicide Regime | Observations | Atrazine | Dicamba | Common Cocklebur density (LS Mean)[b] | Standard Error | LSD Grouping[b] |
|---|---|---|---|---|---|---|
| | no. | kg ai/ha | kg ai/ha | plants/$m^2$ | plants/$m^2$ | |
| Conventional | 95 | 2.24 | 0.28 | 3.8 | 1.1 | C |
| Site-specific | 21 | 0.75 | 0 | 0.6 | 2.1 | C |
| Site-specific | 11 | 0.75 | 0.093 | 4.8 | 3.0 | C |
| Site-specific | 9 | 0.75 | 0.19 | 7.9 | 3.3 | ABC |
| Site-specific | 4 | 0.75 | 0.28 | 18 | 4.9 | A |
| Site-specific | 3 | 2.24 | 0 | 0 | 5.6 | C |
| Site-specific | 9 | 2.24 | 0.093 | 6.2 | 3.3 | BC |
| Site-specific | 20 | 2.24 | 0.19 | 5.5 | 2.2 | C |
| Site-specific | 18 | 2.24 | 0.28 | 14 | 2.3 | AB |

[a] Letters not followed by same letter are significantly different at 0.05 probability level.

[b] Due to using a spatial analysis, standard errors differ with every treatment. An LSD value can not be calculated due to the different standard errors, therefore an LSD grouping is used to show if treatments are significantly different ($\propto = 0.05$).

## Appendix C

## Standard Operating Procedures

## Trimble GeoExplorer II GPS Receiver

## and Pathfinder software

**GeoExplorer II:**

1. Turn unit on.
2. Check GPS status; satellite tracking; at least 4 satellites and PDOP < 4.
3. Select Data capture.
4. Open rover file and walk around area to be mapped.
5. Close rover file.
6. Repeat 4 and 5 for every area to be mapped.
7. For each area that is mapped, write down the name of the files and associate an area with the filename. For example, A7032514.a is a sicklepod area.

**In Pathfinder:**

1. Connect GeoExplorer to computer at A (on back).
2. Turn explorer on.
3. In Pathfinder, select communication port under the COMM menu. Select Com1, OK.

**To post process:** (KUB - 637-2095)

1. In terminal or communications, designate com1, hardware, and 19200 baud rate.
2. Type: atdt 8,637-2095.
3. Log in = name, password
4. At main board: type d.

5. Type base file name: ex. K7032514.exe (K= Knoxville, 7 = 1997, 03 = month, 25 = day, 14 = GPS hour; if more than 1 hr must do for each hour).
6. Select transfer binary file
7. Save to a:
8. In DOS, at a: type k7032514.exe to implode file or if saved to c: do the same.

**In Pathfinder:**

1. Select Util. Select Reference Position.
2. Enter the drive, directory, and base filename (ex. K7032514.ssf) OK
3. Select differential corrections from the Utils menu.
4. Rover: select appropriate rover files - OK
5. Repeat 4 for every file which was mapped.

**To display data:**

1. Select output then select display.
2. Select files enter the drive, directory, and files spec - OK
3. Select join - OK

**To bring into ArcView:**

1. Select output, select GIS.
2. Select generic 3. Select file, input files, choose the file(s)_.cor.
3. Select file, output path.

4. Select run and select preview graphics. If correct, select execute conversion from the run menu.

**In accessories select notepad:**

1. Select file, select open _.gn3.
2. At top type: user-id, x-coordinate, y-coordinate, GPS date & time.
3. Save as _.txt

## AG 132 DGPS Receiver

## and Pocket Survey

**Assembling DGPS Equipment:**

1. Attach antenna to surveying pole by turning antenna in a clockwise direction.
2. Connect antenna cable to antenna; then route cable to the receiver.
3. Connect battery cable to receiver in Port A; route to battery.
4. Connect Palmtop to DGPS receiver.

1. Turn Palmtop on.
2. Using the attached pen, open Pocket Survey.

**DGPS Receiver:**

1. Receiver will be on when connected to battery. The four keys on the receiver keypad navigate through the menu hierarchy.
2. The *Home* screen displays important GPS and DGPS status indicators. To display satellite differential information, press the return button until an S appears in the lower-left corner of the screen. The display will show S 1556.825 S/N 15. The "S" indicates whether receiver is in Satellite Differential mode. The "1556.825" indicates the frequency for tracked satellite. The "S/N 15" indicates the signal-to-noise ratio of DGPS signal. Use the table below to determine what the signal-to-noise values indicate.

| Value | Description |
| --- | --- |
| Below 4 | Unusable |
| 4 - 8 | Fair |
| 8 - 10 | Excellent |

**GPS Status Screens:**

1. To view the status of the GPS information, press > until *GPS Screens* appears. Press down button to view the available screens. The location screen will appear as follows: D 37°23.41111, N . The "D" indicates differential is the type of position recorded. The "37°23.41111, N" indicates the latitude. On the next line appears: 3 122°02.26673,W. The "3" indicates the three-dimensional position. The "122°02.26673,W" indicates the longitude. (See Ag GPS 132 manual, pages (3-9)-(3-10).

2. To insure quality readings, the DOP's must be checked. These may be viewed in the *DOP's* screen. The screen will appear as follows:

| | | |
| --- | --- | --- |
| DOPs | P 2.6 | H 1.4 |
| | V 3.9 | T 3.0 |

3. When viewing DOP information, lower number are better. The "P" number indicates the Position Dilution of Precision (PDOP). PDOP indicates the three-dimensional quality of the GPS solution. The "H" indicates the Horizontal Dilution of Precision (HDOP). HDOP indicates the quality of the horizontal GPS position. The "V" stands for Vertical Dilution of Precision (VDOP). It indicates the quality of the vertical position. The "T" is the Time Dilution of Precision indicating the quality of time measurement. For more information on PDOP, see AgGPS 132 owner's manual, page 1-5.

Tasks using with Ag132 GPS receiver and Pocket Survey (from HELP section in Pocket Survey beta version).

**Sampling and Scouting**

1. Pocket Survey enables sample information to be reported from the field using GPS. Pick Toggle Sample Mode. It will display a dialog box listing the types of layers for which sample mode can be used.
2. Choose from Soil, Scouting, Boundary, and Generic. Pick <OK>. It will display a database screen in which you can enter some basic field information.
3. Enter whatever basic information you want to track and pick <Close>. It will display a new set of tools in the toolbar.

5. After you arrive at the location you want to log, press the space bar. Pocket Survey will display a dialog box in which you can enter the necessary information. Pick <Close> when finished entering information for that location.

Repeat #4 for the other locations in the field.

6. Press the Return arrow when you are done adding *all* sample locations. It will ask you to confirm your choice.
7. Pick <yes> and you are done.

*Notes:*

In the middle of a sampling session you can switch between sample modes (from soil sampling to scouting, for example) by picking the Toggle Sample Mode tool.

While you are in Soil Sample mode you cannot use or edit other layers until you pick the Return arrow.

While Sample Mode is on, Pocket Survey will display the current layer at the bottom of the screen. Make a note of it - you will need to return that layer to edit the data you have gathered or add more data points.

Depending on the layer you choose in step #2, above, you will be limited to the objects you can draw while the Sample Mode is on, but you can draw using the freehand tool.

**Gridding a Field**

1. Before you begin, you must save your file with File > Save or File > Save As.
2. To add a grid, first select a polygon (usually your field perimeter), then pick Tools > Add Grid to Selection (or pick the Grid icon). Pocket Survey will display a message box.
3. Pick <OK>, then pick two points that define a line that will tell Pocket Survey at what angle to draw the grid. Pocket Survey will display a confirmation dialog box.
4. If the line you drew is correct, click Yes; if you need to redraw your line, click No and draw the line again. After you pick <Yes>, Pocket Survey will display a dialog box in which you define your grid, using these steps.

   a. Picking the cell size method and entering the size or number of grids

   From the cell size method group box in this dialog box, pick either:

   - **Fixed Number**: You tell Pocket Survey how many grids you want in the field; Pocket Survey will size them as necessary.
   - **Fixed Size**: You tell Pocket Survey, in feet, how large each grid should be.
   - **Fixed Area**: You tell Pocket Survey how many acres each grid should be.

   Based on your cell size method selection, Pocket Survey will change the group area labeled Cell size in the previous illustration. Enter the number, size, or are in that group box.

   b. Picking the cell type

   Choose from one of the listed cell types.

b. Choosing whether or not to show the target points

Target points mark the center of each grid and give you a target for GPS soil sample collection. If you want them on the map, check the Show Target Points check box in the Grid Generation dialog box.

5. After your choices in the Grid Generation dialog box are complete, pick <Next> and Pocket Survey will display a summary.
6. If everything is correct, pick <Finish>. Otherwise, pick <Back> and make any necessary changes.

*Note:*

Adding a grid adds Target, Grid, and Sample Point layers to the current map.

**Redrawing the Grid**

If, after you finish the grid, you decide you do not like it, you can replace it with a different one. Repeat the process described in this tool. When you begin, Pocket Survey will ask if you want to delete the existing grid and points.

**Using GPS**

By using the Toggle GPS Mode command you can begin to draw maps on the screen using the GPS data.

**To use GPS, follow these steps:**

1. Start Pocket Survey.

2. While Pocket Survey is running, attach your GPS receiver to the serial port on your H/PC. Be sure to closely follow the setup and operating instruction for the receiver.
3. Pick the GPS icon (or pick Tools > Toggle GPS mode or press on the keyboard). Pocket Survey will display the GPS status box.
4. If GPS is working correctly, there will be numbers next to each item in the status box instead of question marks.
5. If this is the first time in this field with GPS (or if the field has not been previously georeferenced) pick Tools > GPS Reference Point. Then pick a point on the screen that tells Pocket Survey where you are currently. Note that this method of georeferencing forces North to be "up" on the screen and does not allow any higher order transformations. If GPS has been used in this field before, (or if the field has been previously georeferenced), skip this step.
6. Use one of the three GPS drawing tools to record your position information:
    - GPS Polygon: Pick this tool, drive the border of the polygon, pick it again to end.
    - GPS Polyline: Pick this tool, drive the polyline, and pick it again to end.
    - GPS Point: Pick this tool when you are at the correct location.
7. When you are finished using GPS, pick the GPS icon again to end.

*Notes:*

While GPS mode is toggled on, you will have slightly altered version of Pocket Survey's Drawing Tools, Zoom-In, Zoom-Out, and so on.

When Pocket Survey calculates distances using GPS, it draws a straight line between starting and ending points and then give you the result. However, this method does not take the curvature of the earth into account. As a result, short distances (under a km) are generally accurate, but longer distances will be under-calculated.

If unable to receive GPS information, make sure you have disabled the PC Connection option in the Windows CE Control Panel. Check the help section of Pocket Survey for instructions.

**Using Pocket Survey's Database**

You can use Pocket Survey's Database tool to add information (data records) to items on your map. For example, you will use this icon to add weed scouting information to the location.

**Adding data to an existing map object:**

1. Set the appropriate layer to current.

- Pick Edit > Layers. It will display the Edit Layers dialog box.

- Pick the layer where the object to which you want to add data exists (for example, Scouting for weed information) and pick <Set Current>. Next, pick <OK>.

2. Select the object.

- Click on an edge or vertex of the object to which you want to add information.

3. Pick the database tool and enter the data.

- If this is the first time you have added data to this item, Pocket Survey will display a confirmation dialog box. Pick <Yes> and Pocket Survey will display a dialog box in which you can enter the information that is appropriate for that type of object and layer (for example, weed data for scouting layer).
- Remember you must set the current layer for your object before you can select the object and choose the Database tool.

## Harvesting using Yield Monitor 2000

## and AG 132 GPS Receiver

**Naming Fields with the Monitor** (taken from Ag Leader Manual, Version 5.24-L)

| Step | Action |
|---|---|
| 1 | Press the FIELD key to display field only on the top line. |
| 2 | Use the RIGHT ARROW key to move the cursor to the right one or more spaces. |
| 3 | Press the top UP or DOWN ARROW key scroll through symbols, numbers, or letters you can use to name the field. Move the cursor to the right one space to enter another character. You can enter up to eight characters for a name. |
| 4 | Press the UP ARROW key to try to advance to the next field. If the next field has not been created, the top line displays "START NEW FIELD?" |
| 5 | Press the YES key to start a new field. The monitor beeps four times quickly, displays the field number and "SET GRAIN/PRESS YES" on the top line, and displays the grain type set for the previous field on the bottom left. |
| 6 | If the grain type displayed is not correct for this field, use the bottom-left UP or DOWN ARROW keys to change it. |
| 7 | When the grain type is set correctly, press the YES key. |
| 8 | Name the field and repeat steps 1 through 7 for each field you want to create. |

**Naming Loads with the Monitor**

Next is to create the loads within the fields. You need to consider how you want to logically subdivide the fields into loads.

| Step | Action |
|---|---|
| 1 | Press the LOAD key to display field and load on the top line. |
| 2 | With the cursor under the load, use the RIGHT ARROW key to move the cursor to the right one space. |
| 3 | Press the top-right UP ARROW key to change the blank space to either a symbol, number, or letter. You can enter up to eight characters for a load name. |
| 4 | Press the LOAD key to display field and load on the top line to create a load. |
| 5 | Press the top-right UP ARROW key to scroll to the next load. If the next load has not already been created, the monitor displays "START NEW LOAD?" on the top line. |
| 6 | Press the YES key to start a new load. |
| 7 | Name the new load and create and name loads for all the fields you have created. |
| 8 | Repeat steps 1 through 7 for each field you want to create. |

**Data Load and Display Load**

The monitor has two types of loads: display and data. The data load is the load into which information is recorded while you harvest. It is the load with an arrow to the right of the load number (example: F1-> L1->). All other loads have a colon to the right of the load number (example: F1-> L2:).

**Logging Map Data to a Card**

If you are using GPS with the yield monitor, you must use a memory card. Follow these steps to log to a memory card:

| Step | Action |
|---|---|
| 1 | Press the SETUP key until "LOGGING DEVICE = NONE or EXT or ?M CARD" appears on the display. |
| 2 | Press the top UP or DOWN ARROW key to select "?M CARD". |

*Using a GPS Receiver*

**General Guidelines for mounting receiver on the combine:**

1. Make sure the GPS antenna is in the middle of the combine.
2. The antenna should be the highest point on the combine.
3. Keep the antenna away from "electrical noise" sources.

**Connecting a Receiver to the Monitor**

The GPS receiver connects to the monitor through the monitor's nine-pin port. The power is supplied through the GPS cable that connects to the nine-pin monitor port. Make sure you use the cable marked "Ag Leader".

Any additional information about the use of the Yield Monitor may be found in the Ag Leader Yield Monitor 2000 manual, version 5.24-L.

# VITA

Joyce Allison Tredaway was born in Anniston, Alabama on July 30, 1971. She is the daughter of Mr. and Mrs. Floyd Tredaway. She was reared in Jacksonville, Alabama. She attended Jacksonville High school and graduated in June 1989. She entered Auburn University in September 1989 and received a Bachelor of Science in Agronomy and Soils in March 1993. Upon graduation, she accepted the position of Graduate Research Assistant in the graduate program at Auburn University in September 1993 and earned a Master of Science in Agronomy and Soils with emphasis in Weed Science in December 1995 under the direction of Dr. Michael G. Patterson. She enrolled in the graduate program as a Graduate Research Assistant at the University of Tennessee in April 1996 under the guidance of Dr. Thomas C. Mueller. Joyce is the author of two published journal articles and 11 published abstracts. She has made presentations at the Beltwide Cotton Conference, Southern Weed Science Society meetings, Weed Science Society of America meetings, Alabama Crop Management Association Conference, East Alabama Cotton field day, and Milan No-Till field day. She has served as the Graduate Student Representative on two Southern Weed Science Society committees and served as the University of Tennessee representative on the Southern Weed Science Society Student Board. She served as the Graduate Student Representative for the Agricultural Campus on the University of Tennessee library committee and was an active member of the Auburn University and University of Tennessee Weed Teams. Upon graduation, she will be employed at the University of Florida as the Extension Agronomic Weed Specialist.

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