The *Journal of Cotton Science 8:42–54 (2004)*
http://journal.cotton.org, © The Cotton Foundation 2004

WEED SCIENCE

Adaptation and Validation of HADSS for Cotton Production in Oklahoma

Shea W. Murdock, Don S. Murray*, Laval M. Verhalen, and Case R. Medlin

ABSTRACT

Glyphosate-tolerant and bromoxynil-resistant cotton (*Gossypium hirsutum* L.) give producers additional postemergence (POST) weed control options, but these technologies require producers to plan weed management practices in advance of planting the crop, thus increasing the complexity of the decision making process. The Herbicide Application Decision Support System (HADSS) is a computer program developed at North Carolina State University that is designed to help those confronted with making these decisions. The HADSS database from North Carolina was modified in 1999 to adapt it more closely to Oklahoma environmental conditions and cotton production systems. Seven field experiments were conducted in Oklahoma in 1999 and 2000 to validate those changes (i.e. to determine if HADSS can recommend POST treatments that are effective and economical in Oklahoma). HADSS treatments and results were compared with those made jointly by two Oklahoma State University weed scientists, designated as the "Expert". Similar herbicides and herbicide combinations were recommended by HADSS and the Expert, and occasionally they were identical. Control of eight weed species was similar for the HADSS or the Expert treatments when they received the same preplant incorporated (PPI) and preemergence (PRE) herbicide regimes. Within systems with the same PPI or PRE herbicides, HADSS and the Expert treatments resulted in similar cotton lint yields in 42 of 46 possible comparisons (91%). HADSS treatments had higher yields in the other four (9%) comparisons. Adjusted net returns were not different between HADSS and Expert treatments in 38 of 46 possible comparisons (83%). HADSS treatments gave higher returns in the remaining eight (17%) comparisons; half were due to higher yields and half were attributable to lower herbicide costs. The results indicate the adapted program can aid decision making for efficient and economical POST herbicide applications in Oklahoma cotton.

S. W. Murdock, Monsanto Company, 3202 104th Street, Lubbock, TX 79423; D. S. Murray, L. M. Verhalen, and C. R. Medlin, Department of Plant & Soil Sciences, Oklahoma State University, 368 Agricultural Hall, Stillwater, OK 74078
* Corresponding author: dmurray@okstate.edu

Weeds are the most important pests in U.S. agriculture based on the percentage of hectares treated with herbicides versus the percentage of hectares treated with other pesticides (Fernandez-Cornejo and Jans, 1999). Herbicides were applied to 95% of U.S. cotton crop in 2000 (USDA-NASS, 2001). Of the cotton acreage receiving herbicides in 1996, approximately 67% was treated with a POST herbicide (Fernandez-Cornejo and Jans, 1999). Herbicide-resistant cotton cultivars give producers additional POST herbicide options, but these technologies require producers to plan their weed management practices in advance of planting the crop, thus increasing the complexity of the decision making process.

Producers have many sources for weed-control recommendations, including herbicide labels, chemical dealers, crop consultants, and extension publications and personnel. Farm supply and chemical dealers are the primary sources of information on pest management for the major field crops (Fernandez-Cornejo and Jans, 1999). These sources generally base herbicide recommendations on relative efficacies for the weed species present. The herbicides recommended may control the weeds of concern, but they may not be the most economical treatments to use.

Profits from crop production are directly influenced by weed interference and indirectly by the cost and degree of weed control provided by the POST herbicide (Dieleman et al., 1996). Basing a herbicide application on economics requires information that producers may not have or know, such as the efficacy of each control option to the weed species present, all herbicide prices and rates labeled for use, competitiveness of the weeds with the crop, yield reductions that can be attributed to the weeds present, and weeds that remain after a treatment application (Auld and Tisdell, 1987; Coble and Mortensen, 1992; Marra and Carlson, 1983).

To determine whether a herbicide application is financially beneficial, an economic threshold must be established beyond which profitable and sustainable weed management decisions can be made (Coble and Mortensen, 1992). A producer's success with POST herbicides greatly depends on his/her ability to determine when weed densities exceed the economic threshold (Wilkerson et al., 1991). That point is complicated, difficult, and time consuming to calculate. Moreover, the threshold will differ between control options that differ in cost and also with differing crop yield potentials. The economic threshold increases as herbicide and application costs increase, assuming that other factors remain constant (Coble and Mortensen, 1992). Likewise, the economic threshold decreases as crop yield potential or market price increases. To establish a threshold for weeds, a producer must determine the species present and the approximate population, know the competitiveness of the weeds to the crop, know the efficacy and costs of the control options, and estimate the crop's yield potential and future market price (Marra and Carlson, 1983). This situation becomes even more complex with multispecies weed populations and with different weed sizes and stages of growth. Weed species vary in competitiveness with cotton (Green et al., 1987; Rowland et al., 1999; Rushing et al., 1985).

Several computer decision support systems have been developed to aid producers with making herbicide decisions (Bennett et al., 2003; Lybecker et al., 1991; Monks et al., 1995; Renner et al., 1999; Wiles et al., 1992; Wilkerson et al., 1991). Such decisions are a daunting task even for extension or research weed scientists who deal with the subject daily (Rankins et al., 1998). The decisions are difficult because of the large number of variables involved. Computerized decision support systems are ideally suited to efficiently integrate a multitude of factors to aid the decision process on POST herbicide applications (Monks et al., 1995; Mortensen and Coble, 1991; Wilkerson et al., 1991). These systems can predict the most economically beneficial treatment based on weed-crop interference, herbicide efficacy, yield loss prediction models, and economic databases for labeled herbicide options (Bennett et al., 2003). These comparisons would be extremely time-consuming, if not impossible, for a producer to calculate without the aid of a computer program.

Wilkerson et al. (1991) stated that some modifications must be made to a program developed in one region for it to be used efficiently in other regions of the country. For a decision support system to be optimally effective, it should be adapted to the area in which it will be used because the databases in the system are usually more accurate for the regions in which they were developed and validated. This permits a program to recommend herbicides that are labeled in the area and that will benefit the local user. When used outside of its region of adaptation (i.e. North Carolina), the computer program HERB did not accurately predict effects of weeds on soybean [*Glycine max* (L.) Merr.] yield (Castner and Banks, 1989; Green and Martin, 1992; Monks et al., 1995). Castner and Banks (1989) reported that HERB consistently overestimated net returns from herbicide treatments at three of nine experimental locations in Georgia. Validation work in Mississippi indicated that an unmodified HERB program predicted yield losses within 10% of actual soybean yield losses in only 10% of modeling runs and overestimated them 62% of the time (Ruscoe et al., 1994).

After adaptation, a decision support system can become more reliable. Mississippi State University adapted HERB to reflect conditions in that state (MSU-HERB) for soybean (Rankins et al., 1998). Results from their work indicated that changes in competitive indices and efficacy ratings could improve the utility of HERB for local environments. When a large difference existed between herbicides recommended by HERB and MSU-HERB, improved weed control in Mississippi resulted from herbicides suggested by MSU-HERB. Soybean yield and net economic gain following MSU-HERB recommendations were equal to or higher than HERB recommendations.

Evaluation of various decision support system programs has shown increased weed control, lower management costs, and increased net returns (Buhler et al., 1997; Forcella et al., 1996; Rankins et al., 1998; Scott et al., 2001, 2002). White and Coble (1997) cautioned that a decision support system is intended to supplement the knowledge and experience of the user and is not intended to replace it, so it should be used as a 'decision aid'. HERB was designed to aid the producer and not to relieve that person from making the final decision (Wilkerson et al., 1991).

HADSS, formerly HERB, was developed at North Carolina State University to aid producers, extension personnel, and private consultants in determining economical and effective POST herbicide treatments for weed control in corn (*Zea mays* L.), peanut (*Arachis hypogaea* L.), cotton, and soybean in specific states (Bennett et al., 2003; Wilkerson et al., 1991). After the user enters field and crop data into the program, HADSS provides information on potential crop loss, recommends the action to be taken, and predicts the economic results of taking that action versus alternative actions (Bennett et al., 2003).

Oklahoma State University received HADSS from North Carolina in 1999. Since that time, many changes have been made to the database to adapt the program to the state. An Oklahoma-adapted HADSS should allow cotton producers in the state (and in surrounding areas of Texas and Kansas) to improve POST weed management strategies, increase economic returns, and reduce unnecessary herbicide applications. Weed species lists, competitive indices, herbicide efficacies, and herbicide rates were altered to reflect Oklahoma environmental conditions and herbicide labels. The Oklahoma cotton database differs greatly from the North Carolina database. In some cases, less than 1% commonality in treatment efficacy and competitive indices still exists between the two databases (Price et al., 2002). The changes to the database were made using research data and literature (when available), and judgments of Oklahoma State University weed science and crop production specialists when data and literature were not available. This adjusted version of HADSS should represent Oklahoma cotton production systems and give herbicide recommendations more suitable to Oklahoma environmental and agronomic conditions than did the original version. The objective of this study was to validate this modified version of HADSS to determine if it could recommend POST herbicide applications that were as effective and economical as recommendations made by Oklahoma State University weed scientists.

MATERIALS AND METHODS

Eight field experiments were planted at three locations over 2 yr. The locations and years included the Agronomy Research Station near Perkins, OK, in 1999 and 2000, the Southwest Research and Extension Center near Altus, OK, in 1999, and the South Central Research Station near Chickasha, OK, in 2000. Soils utilized were a Navina loam (fine-loamy, mixed, active, Udic Argiustolls) with a pH of 6.1 and an organic matter content of 0.5% at Perkins, a Tillman clay loam (fine, mixed, superactive, thermic Vertic Paleustolls) and a Hollister clay loam (fine, smectitic, thermic Typic Haplusterts), respectively, with a pH of 8.1 and a 1.1% organic matter content at Altus, and a Dale silt loam (fine-silty, mixed, superactive, thermic Pachic Haplustolls) with a pH of 7.2 and an organic matter content of 0.5% at Chickasha.

Two experiments were planted at each location in each year. One of the two experiments was planted to the cotton cultivar Paymaster 1220 BG/RR (Paymaster Cottonseed, Stuttgart, AR), which is tolerant to glyphosate, while the other was planted to the cotton cultivar Stoneville BXN 47 (Stoneville Pedigreed Seed Company, Stoneville, MS), which is resistant to bromoxynil. The bromoxynil experiment at Perkins in 2000 was discarded because of a poor crop stand. Cotton was planted at a rate of 14 seed m^{-1} of row in plots that were 15 m long and four rows wide. Row widths were 1.0 m at Altus and 0.9 m at Perkins and Chickasha. Each experiment was fertilized according to soil test recommendations.

Experimental design at each location was a randomized complete block with 10 treatments and four replications. Reference treatments included a weedy check, which, in some cases, received a PPI herbicide application, and a weed-free check, which was maintained weed-free through the use of herbicides, hand weeding, and hoeing. The remaining eight treatments in each experiment consisted of four in which HADSS was used to select the POST herbicides applied and four in which Oklahoma State University weed scientists, designated as the "Expert," jointly selected the herbicide treatments. (Those scientists were the first and second authors of this paper.)

To evaluate the decision support system under many different weed infestations, soil-applied herbicide programs were varied within each trial and among trials, based on weed infestations in previous years. Soil-applied herbicides were applied so that 2 of the 4 HADSS-designated plots and 2 of the 4 Expert-designated plots received common soil-applied treatments. The remaining two HADSS- and

Expert-designated plots received different soil-applied herbicide programs to alter the weed spectrum and populations targeted by the POST herbicides.

At Perkins on 26 May 1999 (Tables 1 and 2), half of the treatments in each experiment, including the weed-free check, received an application of trifluralin (Treflan HFP; Dow AgroSciences LLC, Indianapolis, IN) at 1.1 kg a.i. ha^{-1}, which was incorporated with a rolling cultivator, and the experiments were planted the same day. At Altus in 1999 (Tables 3 and 4), trifluralin was applied in both experiments at 1.1 kg ha^{-1} on 1 March to preformed beds and incorporated with a rolling cultivator set to conform to the beds. Half the treatments, including the weed-free check, received a PRE application of prometryn (Caporal 4L; Syngenta Crop Protection, Greensboro, NC) at 2.2 kg a.i. ha^{-1} on 2 June immediately after planting. The entire experiments at Perkins (Table 5) and Chickasha (Tables 6 and 7) in 2000 received a PPI application of 0.8 and 1.1 kg ha^{-1} trifluralin, respectively. Then, half the treatments in those experiments, including the weed-free check, received an additional application of prometryn at 1.1 kg ha^{-1} at Perkins and 1.8 kg ha^{-1} at Chickasha immediately after planting on 23 May and 22 May, respectively. Scott et al. (2001) also used trifluralin PPI with an additional PRE herbicide in their HADSS evaluations.

All experiments were established on sites with a history of moderate to high weed populations. Throughout the growing season, the experiments were scouted as a whole. If those preliminary examinations revealed weed populations that would likely result in a POST herbicide application, the experiments were then scouted on a plot-by-plot basis. The center two rows of each four-row plot were examined to determine weed species, density (total number of each weed per plot), and height. The data were averaged across replications for each treatment and then converted to weed density in per 9.3-m^2, the format required by HADSS (Bennett et al., 2003). Weed densities were high in 1999, and three 1-m^2 counts were made in each plot. In 2000, the entire center two rows were counted and densities were extrapolated to the required format for HADSS. Weed height was averaged across replications and entered into HADSS in the appropriate format as small (0 to 5 cm), medium (5 to 10 cm), or large (>10 cm) (Bennett et al., 2003). A weed-free yield, also required by the decision support system, was estimated and entered based on the crop, current growing conditions, and average yield associated with that area of cotton production (Oklahoma Agricultural Statistics Service, 1999).

Weed species and densities were determined the day POST applications were made, and those results were used as a basis for HADSS and Expert herbicide applications. The Expert's recommendations were always made prior to entering the information into HADSS; therefore, the Expert's decision was unbiased and totally independent of HADSS. The Expert attempted to recommend herbicide treatments that would result in the highest net return, weed efficacy, or both. The Expert avoided treatment duplication by selecting different herbicides or rates for the two assigned treatments within a given soil-applied herbicide regime. HADSS treatments were selected from the treatment options based on the highest predicted net returns. Many times, the weed species and densities were similar among plots, which resulted in HADSS recommending identical treatments for the two assigned treatments within a given soil-applied herbicide regime. In 1999, duplication of HADSS recommendations was avoided by selecting the herbicide treatment with the next highest net return in the software program. In 2000, the first recommended treatment was always selected, which sometimes resulted in duplication. Occasionally, HADSS and the Expert made identical recommendations.

The experiments were periodically observed after the first POST applications. If inadequate weed control resulted, or if additional weeds emerged in numbers that could require an additional POST application, the fields were once again scouted and the appropriate action was taken. All the experiments, except the 2000 Perkins location, received an additional POST treatment.

All POST herbicides were applied with the appropriate nonionic surfactant (Latron Ag-98, containing 80% alkylaryl polyoxyethylene glycol; Rohm and Haas Co., Philadelphia, PA) or crop oil concentrate (Agri-Dex, a heavy range paraffinic oil, polyol fatty acid esters, and polyethoxylated derivatives; Helena Chemical Co., Memphis, TN). Herbicides were applied with a tractor-mounted, compressed-air sprayer calibrated to deliver 140 L ha^{-1} at 110 kPa. POST herbicides applied included the following: bromoxynil (Buctril 4EC; Bayer CropScience, Research Triangle Park, NC); fluazifop-P (Fusilade DX; Syngenta Crop Protection, Greensboro, NC); glyphosate (Roundup Ultra; Monsanto, St. Louis, MO); MSMA, (Helena

Chemical Company, Memphis, TN); and pyrithiobac (Staple; DuPont Crop Protection, Wilmington, DE) (Tables 1 through 7).

At Perkins in 1999, POST applications were made on 18 June (early POST) and 9 July (mid POST) in both experiments (Tables 1 and 2). Palmer amaranth (*Amaranthus palmeri* S.Wats.) populations in the weedy check at early POST were over 1000 plants in 9.3 m^2, and large crabgrass [*Digitaria sanguinalis* (L.) Scop.] was present at about 10 plants in 9.3 m^2. In the experiments with glyphosate-tolerant cotton (Table 1), fluazifop-P was recommended in two HADSS treatments and was applied at 1.1 kg a.i. ha^{-1} as a "followed by" option on 12 July, 3 days after the mid POST. Due to a sporadic large crabgrass population in the experiment with bromoxynil-resistant cotton (Table 2), all treatments received an application of fluazifop-P at 1.1 kg ha^{-1} on 12 July. The Perkins experiments were grown in a dryland production system.

At Altus in 1999, POST applications were made on 15 June and 13 July for early and mid POST applications, respectively (Tables 3 and 4). The weed populations per 9.3 m^2 in the weedy check at early POST were 118, 14, and 10 for pitted morningglory (*Ipomoea lacunosa* L.), johnsongrass [*Sorghum halepense* (L.) Pers.], and Palmer amaranth, respectively. Due to a sporadic johnsongrass population in the bromoxynil-resistant cotton experiment (Table 4), all treatments received an application of fluazifop-P at 1.1 kg ha^{-1} on 8 July. The experiments at Altus were furrow irrigated seven times during the season with approximately 10 cm of water per irrigation.

At Perkins in 2000, the early POST treatments were applied on 23 June (Table 5). The populations in the weedy check at early POST application for entireleaf morningglory (*Ipomoea hederacea* var. *integriuscula* Gray), devil's-claw [*Proboscidea louisianica* (Mill.) Thellung], common cocklebur (*Xanthium strumarium* L.), and velvetleaf (*Abutilon theophrasti* Medik) were 3, 9, 2, and 2 per 9.3 m^2, respectively. The experiment was irrigated twice (4 cm of water per irrigation) with a side-roll sprinkler system during the growing season.

At Chickasha in 2000, the experiments received early POST and mid POST herbicide applications on

Table 1. Weed control 8 wk after the last postemergence treatment (8 WAT), lint yield, and adjusted net return in glyphosate-tolerant cotton resulting from postemergence (POST) herbicides recommended by herbicide application decision support system (HADSS) vs. the Expert following a preplant incorporated herbicide treatment (PPI) herbicide at Perkins, OK in 1999

PPI herbicide[w]	Recommendation source	POST timing and herbicides (kg ha^{-1})[x]		Weed control 8 WAT (%)[y]		Lint yield (kg ha^{-1})	Adjusted net return ($ ha^{-1})
		Early (18 June)	Mid (9 July)	AMAPA	DIGSA		
Trifluralin	HADSS	glyphosate (0.9)	pyrithiobac (0.04)	95 a[z]	100 a	332 abc	355 ab
Trifluralin	Expert	glyphosate (0.7)	None	100 a	100 a	328 abc	395 a
Trifluralin	HADSS	None	pyrithiobac (0.04)	99 a	100 a	346 ab	414 a
Trifluralin	Expert	glyphosate (0.9)	Cultivation	99 a	100 a	339 abc	412 a
None	HADSS	glyphosate (0.9)	pyrithiobac (0.07) fb fluazifop-P (1.1)	94 a	94 ab	296 abc	277 bc
None	Expert	pyrithiobac (0.07) + MSMA (1.1)	pyrithiobac (0.07) + MSMA (1.1)	76 b	65 d	273 c	217 c
None	HADSS	None	pyrithiobac (0.07) fb fluazifop-P (1.1)	75 b	88 b	295 abc	233 c
None	Expert	glyphosate (0.7)	pyrithiobac (0.07)	82 b	79 c	283 bc	288 bc
Trifluralin	Weed-free check	--	--	100 a	100 a	354 a	--
None	Weedy check	--	--	0 c	0 e	14 d	--

[w] Trifluralin was applied at 1.1 kg ai ha^{-1} on 26 May, and cotton was planted the same day.

[x] Herbicide rates are expressed in kg a.i. ha^{-1}, except glyphosate, which is expressed in kg a.e. ha^{-1}. Fluazifop-P was applied to these plots on 12 July. Fb = followed by.

[y] AMAPA = Palmer amaranth; DIGSA = large crabgrass.

[z] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD (P = 0.05).

16 June and 13 July, respectively (Tables 6 and 7). Common cocklebur populations in the weedy check at early POST were 4 and 35 plants per 9.3 m^2 for the glyphosate-tolerant and the bromoxynil-resistant cultivars, respectively. The experiments were irrigated with a side-roll sprinkler system three times (3 cm of water per irrigation) during the growing season.

Visual estimates of POST weed control and crop injury were recorded 4, 6, and 8 weeks after treatment (WAT) with the last POST application using a scale of 0 (no control or injury) to 100% (complete control or death of the crop). All experiments were treated with either a defoliant and/or desiccant before harvest. The center two rows of each plot were harvested with a commercial brush-roll stripper, and lint yields were determined. Net returns from POST herbicide applications were determined using a 5-year moving average price for cotton lint of $1.43 kg^{-1} in 1999 and $1.26 kg^{-1} in 2000 (Oklahoma Agricultural Statistics Service, 1999, 2001) and using (then current) average herbicide prices obtained from two Oklahoma chemical suppliers. Herbicide variable cost was calculated as the total cost of all herbicides, adjuvants, and applications above what the weedy check received. Cost of application was calculated as $7.95 ha^{-1}, the average cost for a recent herbicide application in Oklahoma (Kletke and Doye, 2000). Adjusted herbicide net returns were calculated as total return (cotton lint yield x average price) minus herbicide variable cost minus total return from the weedy check treatment, and were used for economic comparisons among the POST treatments. HADSS calculates an "estimated" adjusted herbicide net return (i.e., predicted net return) to determine which herbicide treatment is most likely to be the most economical (Bennett et al., 2003; Wilkerson et al., 1991). Scouting costs were excluded. Seed technology costs were not assessed as variable costs to any of the treatments because the decision to plant a herbicide-tolerant crop was made at planting prior to the decision to apply a POST herbicide.

When a HADSS treatment duplication occurred, the treatments were combined in the analyses because they had received exactly the same herbicide(s) and rate(s) PPI, PRE, and POST. Due to unequal and unlike treatments and different weed species present,

Table 2. Weed control 8 wk after the last postemergence treatment (8 WAT), lint yield, and adjusted net return in bromoxynil-resistant cotton resulting from post-emergence (POST) herbicides recommended by the herbicide application decision support system (HADSS) vs. the Expert following a pre-plant incorporated herbicide treatment (PPI) herbicide at Perkins, OK in 1999

PPI herbicide[w]	Recommendation source	POST timing and herbicides (kg ha^{-1})[x]		Control 8 WAT AMAPA (%)[y]	Lint yield (kg ha^{-1})	Adjusted net return ($ ha^{-1})
		Early (18 June)	Mid (9 July)			
Trifluralin	HADSS	pyrithiobac (0.04)	None	98 a[z]	309 a	364 a
Trifluralin	Expert	pyrithiobac (0.07)	None	99 a	310 a	330 a
Trifluralin	HADSS	none	pyrithiobac (0.07)	94 a	317 a	340 a
Trifluralin	Expert	bromoxynil (0.6) + pyrithiobac (0.04)	pyrithiobac (0.07)	100 a	304 a	263 b
None	HADSS	pyrithiobac (0.07)	pyrithiobac (0.07)	66 b	190 b	92 c
None	Expert	bromoxynil (0.6)	pyrithiobac (0.07)	48 d	187 b	146 c
None	HADSS	pyrithiobac (0.07) + MSMA (1.1)	pyrithiobac (0.07)	68 b	231 b	136 c
None	Expert	bromoxynil (0.6) + pyrithiobac (0.04)	pyrithiobac (0.07)	55 c	211 b	143 c
Trifluralin	Weed-free check	--	--	100 a	328 a	--
None	Weedy check	--	--	0 e	12 c	--

[w] Trifluralin was applied at 1.1 kg ai ha^{-1} on 26 May, and cotton was planted the same day.

[x] Fluazifop-P was applied to all plots on 12 July at 1.1 kg a.i. ha^{-1} to control a sporadic population of large crabgrass.

[y] AMAPA = Palmer amaranth.

[z] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD (*P* = 0.05).

the weed control, lint yield, and adjusted net return data are presented separately by location. Data were subjected to ANOVA, and treatment means were separated by Fisher's protected LSD at $P = 0.05$ (release 8.2; SAS Institute, Cary NC, 1999).

RESULTS AND DISCUSSION

Weed control. The weed control data 8 WAT are presented. Weed species are discussed individually over all experiments in which they could be evaluated.

Palmer amaranth. With no PPI or PRE herbicides, POST control of Palmer amaranth at 8 WAT ranged from 48 to 94% (Tables 1 and 2). With trifluralin applied PPI, control by herbicides applied POST ranged from 85 to 100% (Tables 1, 2, 3, and 4). Palmer amaranth was controlled 100% when PPI, PRE, and POST herbicides were used (Tables 3 and 4). HADSS-recommended treatments in 10 of 16 comparisons exhibited control similar to the weed-free check, and the Expert suggestions resulted in control similar to the weed-free check in 11 of 16 such comparisons. In similar herbicide regimes (i.e., similar PPI, PRE, and POST combinations), HADSS recommendations resulted in Palmer amaranth control similar to the Expert recommendations in 22 of 32 possible comparisons (69%). HADSS recommendations resulted in superior control in seven of the remaining comparisons (22%), and the Expert was superior in three (9%). Effective management of Palmer amaranth required a PRE and a POST herbicide in studies by Keeling et al. (1991) and by Scott et al. (2001). In these experiments, consistent and complete control was achieved when using PPI, PRE, and POST herbicides, while control by PPI and POST herbicides in the absence of PRE herbicides was inconsistent and often inadequate.

Large crabgrass. Large crabgrass could be evaluated in only one experiment at Perkins in 1999 (Table 1). Control was 100% for both HADSS and Expert POST treatments following trifluralin PPI. Control by POST treatments alone ranged from 65 to 94%. Compared with the weed-free check, one of four HADSS treatments exhibited lower control, and recommendations made by the Expert resulted

Table 3. Weed control 8 wk after last postemergence treatment (8 WAT), lint yield, and adjusted net return in glyphosate-tolerant cotton resulting from postemergence (POST) herbicides recommended by the herbicide application decision support system (HADSS) vs. the Expert following a preemergence (PRE) herbicide at Altus, OK in 1999

PRE herbicide[w]	Recommendation source	POST timing and herbicides (kg ha^{-1})[x]		Weed control 8 WAT (%)[y]			Lint yield (kg ha^{-1})	Adjusted net return ($ ha^{-1})
		Early (15 June)	Mid (13 July)	AMAPA	IPOLA	SORHA		
Prometryn	HADSS	pyrithiobac (0.07)	pyrithiobac (0.07)	100 a[z]	100 a	91 b	1296 a	1114 ab
Prometryn	Expert	pyrithiobac (0.07) + MSMA (1.1)	pyrithiobac (0.04) + MSMA (1.1)	100 a	100 a	96 ab	1246 a	1059 b
Prometryn	HADSS	glyphosate (0.9)	pyrithiobac (0.07)	100 a	95 b	100 a	1289 a	1143 ab
Prometryn	Expert	pyrithiobac (0.07) + glyphosate (0.7)	pyrithiobac (0.04) + MSMA (1.1)	100 a	97 ab	100 a	1228 ab	1054 b
None	HADSS	glyphosate (0.9)	pyrithiobac (0.07)	91 bc	98 ab	98 ab	1270 a	1153 ab
None	Expert	pyrithiobac (0.07) + MSMA (1.1)	pyrithiobac (0.07) + MSMA (1.1)	98 ab	94 b	95 ab	1128 b	893 c
None	HADSS	glyphosate (0.9)	pyrithiobac (0.04)	86 c	95 b	96 ab	1284 a	1173 a
None	Expert	pyrithiobac (0.07)	pyrithiobac (0.04) + MSMA (1.1)	98 ab	95 b	98 ab	1128 b	902 c
Prometryn	Weed-free check	--	--	100 a	100 a	100 a	1277 a	--
None	Weedy check	--	--	0 d	0 c	0 c	381 c	--

[w] Trifluralin was applied at 1.1 kg ai ha^{-1} to all plots on 1 March. Prometryn at 2.2 kg a.i. ha^{-1} was applied following planting on 2 June.

[x] Herbicide rates are expressed in kg a.i. ha^{-1}, except glyphosate, which is expressed in kg a.e. ha^{-1}.

[y] AMAPA = Palmer amaranth; IPOLA = pitted morningglory; SORHA = johnsongrass.

[z] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD ($P = 0.05$).

in two of four treatments with lower control. Without trifluralin, both HADSS treatments achieved higher control than the corresponding Expert treatments. This difference can probably be attributed to the fluazifop-P recommended in both HADSS treatments at mid-POST. Previous research has demonstrated that fluazifop-P effectively controls large crabgrass (Smeda and Putnam, 1989).

Pitted morningglory. Pitted morningglory could be evaluated in the two Altus experiments in 1999 (Tables 3 and 4). PPI and POST treatments achieved 84 to 98% control of this weed. Adding a PRE treatment increased the control to 88 to 100%. HADSS had three of eight treatments that were equal to the weed-free check, and the Expert had four of eight. Within similar PRE or PPI plus PRE herbicide regimes, only one HADSS treatment resulted in control that was less than control from the Expert treatments.

Johnsongrass. Johnsongrass control could be evaluated in only one of the Altus experiments in 1999 (Table 3). Control from PPI and POST treatments ranged from 95 to 98%. Control ranged from 91 to 100% when a PRE herbicide was included. Only one recommended treatment, a HADSS treatment, was lower than the weed-free check.

Velvetleaf. Control of velvetleaf could only be evaluated at Perkins in 2000 (Table 5). It was controlled from 97 to 98% with the HADSS recommended treatments and 86 to 100% with the Expert treatments. All HADSS treatments were equal to the weed-free check, and three of four Expert treatments were equal to the weed-free check. The other Expert treatment provided less control than the weed-free check (86 vs. 100%).

Entireleaf morningglory. Entireleaf morningglory was evaluated at Perkins in 2000 (Table 5). Control ranged from 95 to 98% for PPI and POST treatments and from 98 to 100% for PPI, PRE, and POST treatments. All recommended treatments were equal to the weed-free check, except for one HADSS treatment that was significantly lower (95% control compared to 100%). Within similar herbicide

Table 4. Weed control 8 wk after last postemergence treatment (8 WAT), lint yield, and adjusted net return in bromoxynil-resistant cotton resulting from postemergence (POST) herbicides recommended by the herbicide application decision support system (HADSS) vs. the Expert following a preplant (PRE) herbicide at Altus, OK in 1999

PRE herbicide[w]	Recommendation source	POST timing and herbicides (kg ai ha^{-1})[x]		Weed control 8 WAT (%)[y]		Lint yield (kg ha^{-1})	Adjusted net return ($ ha^{-1})
		Early (15 June)	Mid (13 July)	AMAPA	IPOLA		
Prometryn	HADSS	pyrithiobac (0.07)	bromoxynil (0.6)	100 a[z]	88 bc	1275 a	1294 a
Prometryn	Expert	pyrithiobac (0.07) + MSMA (1.1)	pyrithiobac (0.07) + MSMA (1.1)	100 a	93 ab	1204 a	1117 a
Prometryn	HADSS	bromoxynil (0.6)	bromoxynil (0.6)	100 a	93 ab	1255 a	1323 a
Prometryn	Expert	bromoxynil (0.6)	pyrithiobac (0.07) + MSMA (1.1)	100 a	93 ab	1253 a	1253 a
None	HADSS	pyrithiobac (0.07)	bromoxynil (0.6)	88 b	84 c	1224 a	1266 a
None	Expert	pyrithiobac (0.07)	pyrithiobac (0.07) + MSMA (1.1)	100 a	90 bc	1200 a	1166 a
None	HADSS	pyrithiobac (0.07) + MSMA (1.1)	bromoxynil (0.6)	95 a	88 bc	1237 a	1268 a
None	Expert	bromoxynil (0.6)	pyrithiobac (0.07) + MSMA (1.1)	85 b	84 c	1178 a	1191 a
Prometryn	Weed-free check	--	--	100 a	100 a	1257 a	--
None	Weedy check	--	--	0 c	0 d	268 b	--

[w] Trifluralin was applied at 1.1 kg ai ha^{-1} to all plots on 2 June. Prometryn was applied at 2.2 kg a.i. ha^{-1} following planting on 2 June.

[x] Fluazifop-P was applied to all plots on 8 July at 1.1 kg a.i. ha^{-1} to control a sporadic population of johnsongrass.

[y] AMAPA = Palmer amaranth; IPOLA = pitted morningglory.

[z] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD ($P = 0.05$).

Table 5. Weed control 8 wk after the last postemergence treatment (8 WAT), lint yield, and adjusted net return in glyphosate-tolerant cotton resulting from postemergence (POST) herbicides recommended by the herbicide application decision support system (HADSS) vs. the Expert following a preemergence (PRE) herbicide at Perkins, OK in 2000

PRE herbicide[v]	Recommendation source[w]	POST herbicides (kg ha^{-1})[x]	Weed control 8 WAT (%)[y]				Lint yield (kg ha^{-1})	Adjusted net return ($ ha^{-1})
			ABUTH	IPOHG	PROLO	XANST		
Prometryn	HADSS	glyphosate (0.9)	98 a[z]	98 ab	97 ab	100 a	443 ab	83 bc
Prometryn	Expert	pyrithiobac (0.06)	100 a	98 ab	88 bc	100 a	467 ab	70 bc
Prometryn	Expert	pyrithiobac (0.09)	100 a	100 a	81 c	93 a	415 b	-11 c
None	HADSS	glyphosate (0.9)	97 a	95 b	99 a	98 a	447 ab	124 ab
None	Expert	glyphosate (0.9)	100 a	98 ab	98 a	93 a	502 a	191 a
None	Expert	pyrithiobac (0.05) + MSMA (1.1)	86 b	98 ab	91 ab	100 a	416 b	52 bc
Prometryn	Weed-free check	--	100 a	100 a	100 a	100 a	463 ab	--
None	Weedy check	--	0 c	0 c	0 d	0 b	315 c	--

[v] Trifluralin was applied preplant incorporated at 0.8 kg ai ha^{-1} to all plots. Prometryn was applied at 1.1 kg a.i. ha^{-1} following planting on 23 May.

[w] The two HADSS sources recommended the same post treatment, which also received the same PRE treatment.

[x] Herbicides applied early on 23 June. Herbicide rates are expressed in kg a.i. ha^{-1}, except glyphosate, which is expressed in kg a.e. ha^{-1}.

[y] ABUTH = velvetleaf; IPOHG = entireleaf morningglory; PROLO = devil's-claw; XANST = common cocklebur.

[z] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD (*P* = 0.05).

Table 6. Weed control 8 wk after the last postemergence treatment (8 WAT), lint yield, and adjusted net return in glyphosate-tolerant cotton resulting from postemergence (POST) herbicides recommended by the herbicide application decision support system (HADSS) vs. the Expert following a preemergence (PRE) herbicide at Chickasha, OK in 2000

PRE herbicide[v]	Recommendation source	POST timing and herbicides (kg ha^{-1})[w]		Control 8 WAT XANST (%)[x]	Lint yield (kg ha^{-1})	Adjusted net return ($ ha^{-1})
		Early (16 June)	Mid (13 July)			
Prometryn	HADSS	MSMA (1.1)	MSMA (1.1) *	94 az	456 b	178 bc
Prometryn	Expert	glyphosate (0.9)	pyrithiobac (0.05) + MSMA (1.1) *	91 ab	445 b	89 c
Prometryn	HADSS	MSMA (1.1)	None	80 bc	514 ab	267 ab
Prometryn	Expert	pyrithiobac (0.04)	pyrithiobac (0.07)	79 c	534 ab	186 bc
None	HADSS[y]	MSMA (1.1)	MSMA (1.1)*	94 a	480 ab	244 ab
None	Expert	MSMA (1.1)	None	75 c	548 ab	346 a
None	Expert	glyphosate (0.9)	None	76 c	591 a	378 a
Prometryn	Weed-free check	--	--	100 a	585 a	--
None	Weedy check	--	--	0 d	260 c	--

[v] Trifluralin was applied preplant incorporated at 1.1 kg ai ha^{-1} to all plots. Prometryn was applied at 1.8 kg a.i. ha^{-1} following planting on 22 May.

[w] Herbicide rates are expressed in kg a.i. ha^{-1}, except glyphosate, which is expressed in kg a.e. ha^{-1}. * indicates that crop injury was noted in these plots after a mid-POST MSMA treatment.

[x] XANST = common cocklebur.

[y] HADSS recommended the same POST treatment for both of these entries (which had also received the same PRE treatment).

[z] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD (*P* = 0.05).

regimes, HADSS vs. Expert recommendations were not significantly different.

Devil's-claw. Devil's-claw control was evaluated at Perkins in 2000 (Table 5). Control for PPI and POST treatments ranged from 91 to 99%. For PPI, PRE, and POST treatments, control ranged from 81 to 97%. Prometryn (the PRE treatment) apparently provided no additional control for devil's-claw. The HADSS recommended treatments ranged from 97 to 99%, while the Expert treatments ranged from 81 to 98%. Control in the HADSS treatments was similar to the weed-free check, and only two of four of the Expert treatments were similar to the weed-free check. Within similar PRE or PPI plus PRE herbicide regimes, HADSS treatments exhibited similar or better devil's-claw control than the Expert treatments.

Common cocklebur. Control of common cocklebur could be evaluated in three experiments (Tables 5, 6, and 7). A PPI herbicide followed by a POST herbicide controlled 75 to 100% of common cocklebur, and any PPI, PRE, and POST herbicide combinations controlled it 79 to 100%. HADSS treatments ranged from 80 to 100% control, and the Expert treatments ranged from 75 to 100%. Control of common cocklebur was equal to the weed-free check in 4 of 7 HADSS and in 6 of 12 Expert comparisons. When compared within similar PRE or PPI plus PRE herbicide regimes, control from the HADSS treatments was similar to the Expert treatments in 11of 14 comparisons (79%) and higher in the other three (21%). In two of those three cases, which did not include prometryn PRE, the Expert judged that a mid POST herbicide was not necessary for this weed (Table 6).

Cotton lint yield. In general, few differences were noted in cotton lint yield between the HADSS and the Expert treatments (Tables 1 through 7). HADSS treatments produced yields similar to the weed-free check in 20 of 23 comparisons (87%), and the Expert treatments did so in 21 of 28 (75%). Scott et al. (2001) derived similar results when yields from a soil-applied herbicide plus HADSS POST system produced yields similar to the weed-free check in 10 of 12 comparisons (83%). Within like PPI, PRE, or PPI plus PRE herbicide regimes, HADSS and the Expert treatments resulted in similar cotton lint yields in 42 of 46 possible comparisons (91%) (Table 8). HADSS treatments had greater yields in the other four cases (9%). Lint yields from all HADSS and Expert treatments and all weed-free checks were greater than the weedy checks (Tables 1 through

Table 7. Weed control at 8 wk after the last postemergence treatment (8 WAT), lint yield, and adjusted net return in bromoxynil-resistant cotton resulting from postemergence (POST) herbicides recommended by the herbicide application decision support system (HADSS) vs. the Expert following a preemergence (PRE) herbicide at Chickasha, OK in 2000

PRE herbicide[w]	Recommendation source[x]	POST timing and herbicides (kg ai ha^{-1})		Control 8 WAT XANST (%)[y]	Lint yield (kg ha^{-1})	Adjusted net return ($ ha^{-1})
		Early (16 June)	Mid (13 July)			
Prometryn	HADSS	MSMA (1.1)	bromoxynil (0.6)	83 b[z]	531 a	545 a
Prometryn	Expert	bromoxynil (0.6)	bromoxynil (0.6)	88 b	547 a	560 a
Prometryn	Expert	pyrithiobac (0.07)	bromoxynil (0.6) + pyrithiobac (0.07)	86 b	512 a	386 b
None	HADSS	MSMA (1.1)	bromoxynil (0.6)	85 b	551 a	606 a
None	Expert	pyrithiobac (0.07)	bromoxynil (0.4) + MSMA (1.1)	89 b	540 a	522 ab
None	Expert	bromoxynil (0.6)	pyrithiobac (0.07)	93 ab	516 a	490 ab
Prometryn	Weed-free check	--	--	100 a	550 a	--
None	Weedy check	--	--	0 c	49 b	--

[w] Trifluralin was applied preplant incorporated at 1.1 kg ai ha^{-1} to all plots. Prometryn was applied at 1.8 kg a.i. ha^{-1} following planting on 22 May.

[x] The two HADSS sources recommended the same POST treatment for both of these entries (which had also received the same PRE treatment).

[y] XANST = common cocklebur.

[z] Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD (*P* = 0.05).

7). Crop injury (estimated at 12, 13, and 9%) was detected in three treatments at Chickasha in 2000 (data not shown). The injury was likely induced by mid POST applications of MSMA and, when combined with weed interference, may have contributed to significantly lower yields in two of those three treatments (Table 6). Shankle et al. (1996) reported reductions in cotton lint yield with a MSMA POST application. Lower weed populations in the glyphosate-tolerant experiments at Perkins and Chickasha in 2000 resulted in smaller differences in cotton lint yield between the treatments and the weedy check (Tables 5 and 6).

Adjusted herbicide net returns. The adjusted net returns from the use of POST herbicides were similar to the results for cotton lint yield (Tables 1 through 7). Positive net returns were realized for all POST treatments except for one Expert treatment at Perkins in 2000 (Table 5). When no PPI herbicide was applied prior to POST treatments, the adjusted net returns were generally lower than the POST treatments that also received a PPI application (Tables 1 and 2). When comparing similar PPI or PPI plus PRE herbicide regimes, adjusted net returns between HADSS and Expert treatments were not different in 38 of 46 possible comparisons (83%) over all seven experiments. In the remaining eight comparisons, the adjusted net returns for HADSS treatments were significantly higher than the corresponding Expert treatments. In half of those eight cases with higher adjusted net returns, cotton lint yield was not different. Therefore, those higher returns can be attributed to lower herbicide costs associated with the HADSS treatments. The experiments at Perkins and Chickasha had smaller adjusted net returns due to less lint yield (Tables 1, 2, 5, 6, and 7) compared with Altus (Tables 3 and 4). Smaller differences in lint yield between the treatments and the weedy checks (due to low weed populations) reduced the adjusted net returns in the glyphosate-tolerant experiments at Perkins and Chickasha in 2000 (Tables 5 and 6). Low yield and low weed pressure combined to produce a negative net return for one Expert recommendation at Perkins in 2000 (Table 5). Low yield and injury from the mid-POST MSMA applications also resulted in low net returns at Chickasha in 2000 (Table 6).

Comparison of HADSS vs. the Expert. POST herbicide treatments recommended by HADSS resulted in similar herbicides, weed control, lint yield, and adjusted net returns to those treatments recommended by the Expert. In weed efficacy observations, HADSS recommended more efficacious treatments than the Expert in 16 of 90 (18%) (Table 8), but the Expert recommended more efficacious treatments in 5 of 90 (6%). Regardless of these differences, within similar PPI or PPI plus PRE herbicide regimes, lint yield and the adjusted net return were similar or greater for the HADSS treatments compared with the Expert treatments. These observations support the claim that recommending herbicides is typically a complex responsibility, particularly when recommendations are not based solely on herbicide efficacy, but include achieving the highest net return as the ultimate objective. With the use of computer-based software, such as HADSS, producers can validate their weed management plans based on years of research and be confident their profit potential is maximized. HADSS, as adapted for Oklahoma cotton production, can be an effective tool to aid producers in determining the need for

Table 8. Comparison of postemergence treatment outcomes on weed efficacy, cotton lint yield, and adjusted net return within each soil-applied herbicide program in bromoxynil-resistant and glyphosate-resistant cotton

	Weed control efficacy (%) Soil-applied herbicides[x]			Lint yield (kg ha^{-1}) Soil-applied herbicides			Adjusted net return ($ ha^{-1}) Soil-applied herbicides		
Outcome[y]	**None**	**PPI**	**PPI+PRE**	**None**	**PPI**	**PPI+PRE**	**None**	**PPI**	**PPI+PRE**
HADSS = Expert	**25 (2)[z]**	**77 (37)**	**88 (30)**	**100 (8)**	**100 (18)**	**80 (16)**	**100 (8)**	**73 (16)**	**88 (14)**
HADSS better	**75 (6)**	**17 (8)**	**6 (2)**	**0 (0)**	**0 (0)**	**20 (4)**	**0 (0)**	**27 (6)**	**12 (2)**
Expert better	**0 (0)**	**6 (3)**	**6 (2)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**	**0 (0)**
Total observations	**(8)**	**(48)**	**(34)**	**(8)**	**(18)**	**(20)**	**(8)**	**(22)**	**(16)**

[x] **PPI = preplant incorporated; PPI+PRE = preplant incorporated + preemergence.**

[y] **Outcomes from comparing results of recommendations by the herbicide application decision support system (HADSS) and the Expert were classified as equal (HADSS = Expert), HADSS being better than the Expert (HADSS better), or the Expert being better than HADSS (Expert better).**

[z] **The percentage of the total observations is followed by the number of observations in parentheses.**

POST herbicide application and in selecting POST herbicides. Using HADSS can be equivalent to having an Expert help the producer decide what POST herbicide applications to make in cotton, but this program should only be used as an "aid" to decision making and all current pesticide labels should be followed accordingly.

ACKNOWLEDGMENTS

Financial and technical support for this research was provided by USDA/CSREES and ARS through a subcontract from North Carolina State University and by the Southern Region IPM Grants Program (Grant number 00-34103-9665). Thanks are extended to Gail G. Wilkerson at North Carolina State University and members of her team at the time, Andrew C. Bennett and Andrew J. Price, for their assistance. Published with the approval of the Director of the Oklahoma Agricultural Experiment Station.

REFERENCES

Auld, B.A., and C.A. Tisdell. 1987. Economic thresholds and response to uncertainty in weed control. Agric. Syst. 25:219-227.

Bennett, A.C., A.J. Price, M.C. Sturgill, G.S. Buol, and G.G. Wilkerson. 2003. HADSS™, Pocket HERB™, and WebHADSS™: decision aids for field crops. Weed Technol. 17 (*In press*).

Buhler, D.D., R.P. King, S.M. Swinton, J.L. Gunsolus, and F. Forcella. 1997. Field evaluation of a bioeconomic model for weed management in soybean (*Glycine max*). Weed Sci. 45:158-165.

Castner, E.P., and P.A. Banks. 1989. Soybean herbicide decision model verification in Georgia. p. 324. *In* A.D. Worsham (ed.) Finding a common ground. Proc. South. Weed Sci. Soc., Nashville, TN. 16-18 Jan. 1989. SWSS, Champaign, IL.

Coble, H.D., and D.A. Mortensen. 1992. The threshold concept and its application to weed science. Weed Technol. 6:191-195.

Dieleman, A., A.S. Hamill, G.C. Fox, and C.J. Swanton. 1996. Decision rules for postemergence control of pigweed (*Amaranthus* spp.) in soybean (*Glycine max*). Weed Sci. 44:126-132.

Fernandez-Cornejo, J., and S. Jans. 1999. Pest Management in U.S. Agriculture. Agric. Handb. 717. U.S. Gov. Print. Office, Washington, DC.

Forcella, F., R.P. King, S.M. Swinton, D.D. Buhler, and J.L. Gunsolus. 1996. Multi-year validation of a decision aid for integrated weed management in row crops. Weed Sci. 44:650-661.

Green, J.D., and J.R. Martin. 1992. Field evaluations of computer aids for soybean weed control. p. 327. *In* W.W. Witt (ed.) Communicating Modern Weed Science. Proc. South. Weed Sci. Soc., Little Rock, AR. 20-22 Jan. 1992. SWSS, Champaign, IL

Green, J.D., D.S. Murray, and L.M. Verhalen. 1987. Full-season interference of silverleaf nightshade (*Solanum elaeagnifolium*) with cotton (*Gossypium hirsutum*). Weed Sci. 35:813-818.

Keeling, J.W., K.T. Siders, and J.R. Abernathy. 1991. Palmer amaranth (*Amaranthus palmeri*) control in a conservation tillage system for cotton (*Gossypium hirsutum*). Weed Technol. 5:137-141.

Kletke, D., and D.G. Doye. 2000. Oklahoma farm and ranch custom rates, 1999-2000. *In* Current Rep. CR- 205. Oklahoma Coop. Ext. Serv., Stillwater, OK.

Lybecker, D.W., E.E. Schweizer, and R.P. King. 1991. Weed management decisions in corn based on bioeconomic modeling. Weed Sci. 39:124-129.

Marra, M.C., and G.A. Carlson. 1983. An economic threshold model for weeds in soybeans (*Glycine max*). Weed Sci. 31:604-609.

Monks, C.D., D.C. Bridges, J.W. Woodruff, T.R. Murphy, and D.J. Berry. 1995. Expert system evaluation and implementation for soybean (*Glycine max*) weed management. Weed Technol. 9:535-540.

Mortensen, D.A., and H.D. Coble. 1991. Two approaches to weed control decision-aid software. Weed Technol. 5:445-452.

Oklahoma Agricultural Statistics Service. 1999. Oklahoma agricultural statistics, 1998. USDA Natl. Agric. Stat. Serv. and Okla. Dep. Agric., Oklahoma City, OK.

Oklahoma Agricultural Statistics Service. 2001. Oklahoma agricultural statistics, 2000. USDA Natl. Agric. Stat. Serv. and Okla. Dep. Agric., Oklahoma City, OK.

Price, A.J., G.G. Wilkerson, and A.C. Bennett. 2002. Regional validation of HADSS and progress toward regional adaptation. p. 131. *In* J.E. Street (ed.) Weed science education: the cost of ignorance. Proc. South. Weed Sci. Soc., Dallas, TX. 17-19 Jan. 1994. SWSS, Champaign, IL.

Rankins, A., Jr., D.R. Shaw, and J.D. Byrd, Jr. 1998. HERB and MSU-HERB field validation for soybean (*Glycine max*) weed control in Mississippi. Weed Technol. 12:88-96.

Renner, K.A., S.M. Swinton, and J.J. Kells. 1999. Adaptation and evaluation of the WEEDSIM weed management model for Michigan. Weed Sci. 47:338-348.

Rowland, M.W., D.S. Murray, and L.M. Verhalen. 1999. Full-season Palmer amaranth (*Amaranthus palmeri*) interference with cotton (*Gossypium hirsutum*). Weed Sci. 47:305-309.

Ruscoe, J.T., D.R. Shaw, J.D. Byrd, Jr., and J. Hall. 1994. Economic evaluation of HERB and SWC for Mississippi soybean weed management. p. 44. *In* P.A. Dotray (ed.) Feeding the world in the 21st century. Proc. South. Weed Sci. Soc., Atlanta, GA. 28-30 Jan. 2002. South. Weed Sci. Soc., Champaign, IL.

Rushing, D.W., D.S. Murray, and L.M. Verhalen. 1985. Weed interference with cotton (*Gossypium hirsutum*). II. Tumble pigweed (*Amaranthus albus*). Weed Sci. 33:815-818.

Scott, G.H., S.D. Askew, A.C. Bennett, and J.W. Wilcut. 2001. Economic evaluation of HADSS™ computer program for weed management in nontransgenic and transgenic cotton. Weed Sci. 49:549- 557.

Scott, G.H., S.D. Askew, J.W. Wilcut, and A.C. Bennett. 2002. Economic evaluation of HADSS™ computer program in North Carolina peanut. Weed Sci. 50:91-100.

Shankle, M.W., R.M. Hayes, V.H. Reich, and T.C. Mueller. 1996. MSMA and pyrithiobac effects on cotton (*Gossypium hirsutum*) development, yield and quality. Weed Sci. 44:137-142.

Smeda, R.J., and A.R. Putnam. 1989. Effect of adjuvant concentration and carrier volume on large crabgrass (*Digitaria sanguinalis*) control with fluazifop. Weed Technol. 3:105-109.

USDA- National Agricultural Statistics Service (NASS). 2001. Agricultural chemical usage, 2000 field crops summary. Rep. Ag Chem. 1(01)b. U.S. Gov. Print. Office, Washington, DC.

White, A.D., and H.D. Coble. 1997. Validation of HERB for use in peanut (*Arachis hypogaea*). Weed Technol. 11:573-579.

Wiles, L.J., G.G. Wilkerson, and H.J. Gold. 1992. Value of information about weed distribution for improving postemergence control decisions. Crop Prot. 11:547-554.

Wilkerson, G.G., S.A. Modena, and H.D. Coble. 1991. HERB: Decision model for postemergence weed control in soybean. Agron. J. 83:413-417.