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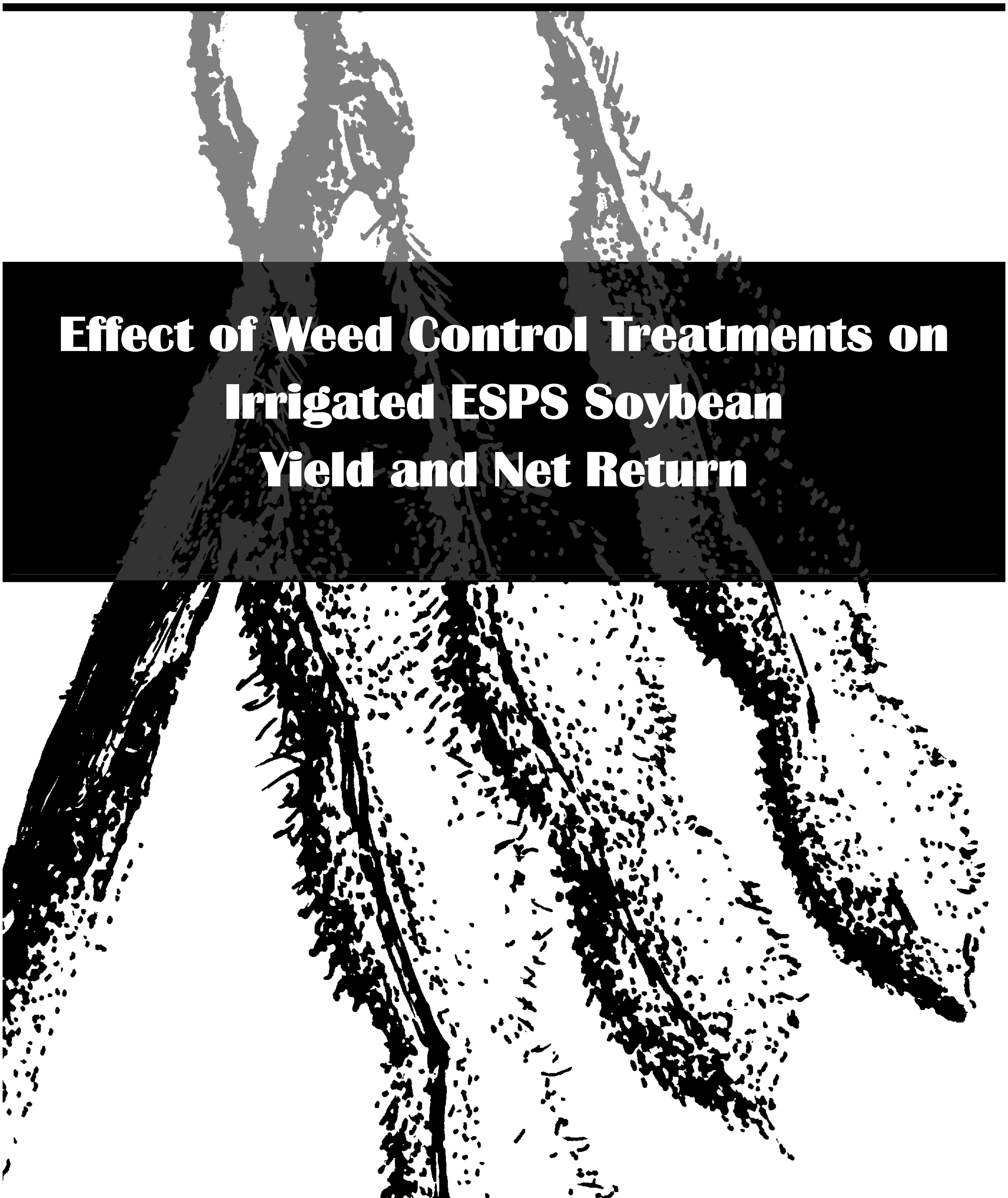
Effect of Weed Control Treatments on Irrigated ESPS Soybean Yield and Net Return



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ABSTRACT

The new model for soybean production in the midsouthern U.S. is the Early Soybean Production System (ESPS), which involves planting early-maturing varieties (MG IV-V) in April, as opposed to the conventional soybean production system (CSPS), which involves planting MG V-VII varieties in May and later. Field studies were conducted at Stoneville, Mississippi, on Sharkey clay soil with a MG IV soybean variety grown in a narrow-row system (NR) with 20-inch-wide rows and a MG V soybean variety grown in a wide-row system (WR) with 40-inch-wide rows to determine economical weed management systems for irrigated ESPS plantings. The 3-year study evaluated the effects of various combinations of broadleaf and grass herbicides applied preemergence (PRE) and postemergence (POST) on weed cover at harvest, soybean seed yield, and net return. Annual grasses and johnsongrass were the dominant weeds in all treatments of both NR and WR. In NR, treatments that included a broadleaf herbicide applied either PRE or POST in combination with a grass herbicide applied POST provided the highest net returns. In WR, use of either PRE broadleaf and grass herbicides or POST broadleaf and grass herbicides resulted in the best combination of weed control, yield, and net return. Broadleaf and grass herbicides applied both PRE and POST in NR and WR did not increase net returns above those resulting from either used alone.

Abbreviations:

CSPS — conventional soybean production system.
DAP — days after planting.
ESPS — early soybean production system.
MG — maturity group.
NR — narrow-row system.
POST — postemergence.
PRE — preemergence.
WR — wide-row system.
WTRT — weed control treatment.

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INTRODUCTION

The ESPS differs from the conventional production system in several ways: (1) necessary seedbed preparation tillage is done in the fall; (2) winter-spring weeds are killed with a preplant, foliar-applied herbicide; and (3) early-maturing MG IV and MG V varieties are planted into a stale, untilled seedbed in April (Heatherly 1999a). Conversely, the CSPS calls for May and June planting of later-maturing MG V to MG VIII varieties into a fall- or spring-tilled seedbed. The ESPS offers an alternative for soybean production in the midsouthern U.S. (Boquet 1998; Bowers 1995; Heatherly and Spurlock 1999).

The ESPS may utilize narrow-row (20 inches or less) culture (Heatherly and Bowers 1998) to accommodate MG IV varieties that grow short when planted early (Heatherly and Spurlock 1999), and this accommodation precludes effective use of POST cultivation for weed control (Reddy et al. 1999). However, taller-growing MG V varieties may still be used in wide rows in ESPS plantings to accommodate the row spacing used with other row crops in a farm operation.

With April planting, certain summer broadleaf weeds may not be emerged or they may be slow to emerge (Elmore et al. 1990). Thus, soybean in ESPS plantings may emerge before weeds even without an application of a PRE herbicide. This allows the option of applying herbicides POST for weed control on an as-needed basis instead of applying PRE herbicides. In essence, planting in April may lessen the weed management aspect of soybean production by avoiding some of the competitive weeds that emerge in May or later in CSPS plantings (Reddy et al. 1999). Thus, it is necessary to determine economically feasible weed control programs using broadcast-applied PRE and POST herbicides in narrow rows and band-applied PRE and POST herbicides in wide rows in the ESPS.

Soybeans provide relatively low gross return with a small margin for profit in the Midsouth (Williams 1999). This small profit margin dictates that all costs associated with production must be minimized, and that yield losses due to controllable pests such as weeds must be prevented within economic constraints. The producer's ultimate objective is to control weeds adequately to maximize crop yields; however, inputs used for weed management in soybean represent a significant cost (Buhler et al. 1997; Heatherly et al. 1994; Johnson et al. 1997). Thus, effective weed management programs must be determined so that yield losses due to weed interference are minimized at the lowest cost. In narrow-row soybean plantings made in a stale seedbed, these programs will almost exclusively involve herbicides. In wide-row plantings, weed management should use band-applied herbicides and between-row POST cultivation.

Use of combinations of PRE and POST herbicides is common in the CSPS (Askew et al. 1998; Heatherly et al. 1993; Heatherly et al. 1994; Hydrick and Shaw 1995; Oliver et al. 1993). Many of these combinations provide similar management of weeds, but their costs vary greatly (Buhler et al. 1997; Heatherly et al. 1993, 1994). This cost difference, coupled with differences in yield among weed management systems, can result in significant differences in net return among systems of weed control (Buhler et al. 1997; Heatherly et al. 1993, 1994; Johnson et al. 1997). Weed management systems must be determined for ESPS plantings in order to maximize benefits from this higher-yield-potential production system.

The objective of this study was to determine how weed cover and seed yield were affected by broadleaf and grass herbicides applied PRE and POST (alone and in combination) on ESPS plantings of irrigated narrow- and wide-row soybeans. The effect on yield was evaluated in relation to costs of and net returns from the various programs of weed control.

Materials and Methods

A study was conducted in the summers of 1992 through 1996 near Stoneville, Miss. Soil series was Sharkey clay (very fine, smectitic, thermic chromic Epiaquert), which is characterized by less than 1% organic matter, poor internal drainage, a high level of fertility, less than 0.3% slope, low bulk density, and textural uniformity with depth. All plots were 13.3 feet wide and 83 feet long. Row spacing was 20 inches for a MG IV indeterminate soybean variety (NR system) and 40 inches for a MG V determinate soybean variety (WR system). Within NR and WR, 10 weed management treatments were evaluated. These treatments were the same across NR and WR. Treatments were randomly assigned to plots within each system in the first year of the study, and they remained in the same location thereafter. Studies containing NR and WR were conducted as separate experiments each year but were located in the same field. Soybean was the preceding crop in all experiments.

RA 452 (NR system) soybean was planted on May 4, 1992, in a prepared seedbed and on April 29, 1993, in a stale, untilled seedbed (Heatherly 1999c). Weed management treatments were applied to plantings of RA 452 made in 1994 and 1995, but results from these 2 years were not used because of progressively declining stands during the growing season caused by *Phytophthora* root rot. DK 4875 replaced RA 452 in 1996 and was planted in a stale seedbed on April 10. DP 3589 (WR system) was planted April 11, 1994, April 17, 1995, and April 10, 1996, in a stale seedbed. Seeding rate was 5 seed per foot of 20-inch-wide rows and 10 seed per foot of 40-inch-wide rows.

Within each treatment each year, herbicides were selected and applied to minimize weed competition within the constraints of each individual treatment. Herbicides applied for PRE weed control were selected to manage weed populations that were known to occur at the site. Selection of herbicides for POST weed control was based on specific weed problems that occurred on a treatment-by-treatment basis during each growing season. Surfactants were used in accordance with herbicide manufacturers' recommendations. For each treatment in NR and WR, weed control costs were calculated for herbicides, surfactants, and their application, and for POST cultivation in the WR system.

Treatments included combinations of PRE and POST broadleaf herbicides and PRE and POST grass herbicides. PRE broadleaf, POST broadleaf, and PRE grass herbicides were applied in 20 gallons of water per acre. POST grass herbicides were applied in 10 gallons of water per acre. In the following paragraphs, herbicide applications are measured in amount of active ingredient per appropriate volume of water.

PRE broadleaf control was provided by Canopy, a premix of metribuzin at 0.4 pound and chlorimuron at 0.07 pound.

POST broadleaf control was provided by several different herbicides: (1) Storm, a premix of bentazon at 0.5 pound and acifluorfen at 0.25 pound; (2) Classic (chlorimuron) at 0.01 pound; (3) Reflex (fomesafen) at 0.38 pound; and (4) a tank mix of 2,4-DB at 0.2 pound and Lorox (linuron) at 0.5 pound. Some treatments in some years included two of these herbicides used in combination (see Table 1).

PRE grass control was provided by 1 pound of Prowl (pendimethalin) or 2 pounds of Dual (metolachlor).

POST grass control was provided by one of three herbicides: (1) Assure (quizalofop) at 0.1 pound; (2) Fusilade (fluazifop) at 0.19 pound; or (3) Poast Plus (sethoxydim) at either 0.14 pound or 0.19 pound.

The study evaluated 10 weed management treatments (WTRTs): WTRT 1 – PRE broadleaf control; WTRT 2 – POST broadleaf control; WTRT 3 – PRE and POST broadleaf control; WTRT 4 – PRE broadleaf and PRE grass control; WTRT 5 – PRE broadleaf and POST grass control; WTRT 6 – PRE grass and POST broadleaf control; WTRT 7 – POST broadleaf and POST grass control; WTRT 8 – PRE broadleaf and grass control and POST broadleaf control; WTRT 9 – PRE and POST broadleaf and POST grass control; and WTRT 10 – PRE and POST broadleaf and grass control (POST grass control inadvertently not applied in 1996). Herbicides applied to each treatment each year are shown in Table 1. Roundup (glyphosate at either 0.5 or 0.75 pound of active ingredient in 10 gallons water per acre) was applied preplant to kill emerged weeds in all stale seedbed plantings.

NR plots were evaluated in 1992, 1993, and 1996, while WR plots were evaluated in 1994, 1995,

Table 1. Weed control treatment (WTRT) and herbicides applied to irrigated MG IV soybeans grown in narrow rows (NR) and MG V soybeans grown in wide rows (WR) near Stoneville, MS, 1992-1996.

WTRT [1]	1992 [2]	1993 [2]	1994 [2]	1995 [2]	1996 [2]
1 PRE broadleaf	Canopy (NR)	Canopy (NR)	Canopy (NR & WR)	Canopy (NR & WR)	Canopy (NR & WR)
2 POST broadleaf	Storm (NR)	Storm (NR)	Storm (NR & WR)	Storm (NR)	Storm (NR)
		Classic (NR)	Reflex (NR & WR)	Reflex (WR)	2,4-DB + Lorox (NR & WR)
3 PRE broadleaf	Canopy (NR)	Canopy (NR)	Canopy (NR & WR)	Canopy (NR & WR)	Canopy (NR & WR)
POST broadleaf	Storm (NR)	Storm (NR)	Reflex (NR & WR)	Storm (NR)	2,4-DB + Lorox (NR & WR)
				2,4-DB + Lorox (WR)	
4 PRE broadleaf	Canopy (NR)	Canopy (NR)	Canopy (NR & WR)	Canopy (NR & WR)	Canopy (NR & WR)
PRE grass	Prowl (NR)	Dual (NR)	Dual (NR & WR)	Dual (NR & WR)	Dual (NR & WR)
5 PRE broadleaf	Canopy (NR)	Canopy (NR)	Canopy (NR & WR)	Canopy (NR & WR)	Canopy (NR & WR)
POST grass	Assure (NR)	Poast Plus (NR)	Poast Plus (NR & WR)	Fusilade (NR & WR)	Poast Plus (NR & WR)
6 PRE grass	Prowl (NR)	Dual (NR)	Dual (NR & WR)	Dual (NR & WR)	Dual (NR & WR)
POST broadleaf	Storm (NR)	Storm (NR)	Storm (NR & WR)	Storm (NR)	Storm (NR)
		Classic (NR)	Reflex (NR & WR)	Reflex (WR)	2,4-DB + Lorox (NR & WR)
7 POST broadleaf	Storm (NR)	Storm (NR)	Storm (NR & WR)	Storm (NR)	Storm (NR)
		Classic (NR)	Reflex (NR & WR)	Reflex (WR)	2,4-DB + Lorox (NR & WR)
POST grass	Assure (NR)	Poast Plus (NR)	Poast Plus (NR & WR)	Fusilade (NR & WR)	Poast Plus (NR & WR)
8 PRE broadleaf	Canopy (NR)	Canopy (NR)	Canopy (NR & WR)	Canopy (NR & WR)	Canopy (NR & WR)
PRE grass	Prowl (NR)	Dual (NR)	Dual (NR & WR)	Dual (NR & WR)	Dual (NR & WR)
POST broadleaf	Storm (NR)	Storm (NR)	Reflex (NR & WR)	Storm (NR)	2,4-DB + Lorox (NR & WR)
				2,4-DB + Lorox (WR)	
9 PRE broadleaf	Canopy (NR)	Canopy (NR)	Canopy (NR & WR)	Canopy (NR & WR)	Canopy (NR & WR)
POST grass	Assure (NR)	Poast Plus (NR)	Poast Plus (NR & WR)	Fusilade (NR & WR)	Poast Plus (NR & WR)
POST broadleaf	Storm (NR)	Storm (NR)	Reflex (NR & WR)	Storm (NR)	2,4-DB + Lorox (NR & WR)
				2,4-DB + Lorox (WR)	
10 PRE broadleaf	Canopy (NR)	Canopy (NR)	Canopy (NR & WR)	Canopy (NR & WR)	Canopy (NR & WR)
PRE grass	Prowl (NR)	Dual (NR)	Dual (NR & WR)	Dual (NR & WR)	Dual (NR & WR)
POST grass	Assure (NR)	Poast Plus (NR)	Poast Plus (NR & WR)	Fusilade (NR & WR)	
POST broadleaf	Storm (NR)	Storm (NR)	Reflex (NR & WR)	Storm (NR)	2,4-DB + Lorox (NR & WR)
				2,4-DB + Lorox (WR)	

[1]PRE = applied preemergent; POST = applied postemergent.
[2]Premix and tank mix combinations indicated by +.

and 1996. All POST herbicides were applied to NR between June 1 and June 17 (27 to 44 DAP) in 1992; between May 22 and June 11 (23 to 43 DAP) in 1993; and between May 20 and June 5 (40 to 56 DAP) in 1996. All POST herbicides were applied to WR between May 6 and June 7 (25 to 57 DAP) in 1994; between June 15 and June 19 (59 to 63 DAP) in 1995; and between May 31 and June 5 (51 to 56 DAP) in 1996.

Herbicides were broadcast-applied in the NR system using a canopied sprayer (Ginn et al. 1998a) or a directed sprayer (Ginn et al. 1998b). In the WR system, all herbicides were applied on a 20-inch-wide band centered on each row using either a canopied or a directed sprayer. Soil-applied PRE herbicide applications were followed by 1.75 inches of rain 13 days after application in 1992 and by at least 0.8 inch of rain within 5 days of application in 1993 through 1996.

Between-row areas in the 40-inch-wide rows were cultivated three times in 1994 and 1995 and twice in 1996. Weed control measures for all treatments in NR plots in 1994 and 1995 were applied according to the protocol of each of the 10 treatments, although plants in those plots were not harvested for yield determination.

Weather data (Table 2) were collected about 3 miles from the experimental site by the NOAA Midsouth Agricultural Weather Service Center from 1992 to 1995 and by Delta Research and Extension Center personnel in 1996. All plots were furrow-irrigated from soon after the beginning of bloom until near full seed stage (Heatherly 1999b). Irrigation was applied whenever soil water potential, as determined by tensiometers located at the 12-inch soil depth, averaged between -50 and -70 centibars.

Total weed cover by species was determined after soybean leaf senescence each year to determine the effectiveness of the treatments in the study area (Elmore and Heatherly 1988). Weed cover by species was estimated visually from either 10 (1992) or five (1993-1996) randomly chosen 20-square-inch sample areas in each plot. Estimates of weed cover in 10% increments from 0% to 100% were made to estimate cover for each weed species. If a specie was present in any of the samples of an individual plot, then its relative abundance was categorized as at least 0-10% (average of 5% cover) in that sample.

Estimates of total costs and returns were developed for each annual cycle of each experimental unit using the Mississippi State Budget Generator (Spurlock and Laughlin 1992). Total specified expenses were calculated using actual inputs for each treatment in each year of the experiment and included all direct and fixed costs, but they excluded costs for land, management, and general farm overhead that were assumed to be the same for all treatment combinations. Direct expenses included costs for herbicides, seed, labor, fuel, repair, rollout vinyl pipe, hauling harvested seed, interest on operating capital, and maintenance of machinery and irrigation system. Fixed expenses were ownership costs for tractors, implements, sprayers, self-propelled harvesters, and the irrigation system. Costs of variable inputs and machinery were based on prices paid by Mississippi farmers each year (i.e., machinery costs varied with year). Irrigation costs were based on a 160-acre furrow irrigation setup and included an annualized cost for the engine, well, pump, generator, gear head, land forming, and fuel tank and lines. Total fixed costs of the irrigation system consisted of insurance, annual depreciation, and interest on investment. Annual depreciation of all machinery and irrigation equipment was calculated using the straight-line method with zero salvage value. Annual interest charges were based on one-half of the original investment times an appropriate interest rate for each year of the study. Insurance was estimated at 1% of the original investment. Within each year’s experiment, expenses for all inputs other than weed control were essentially the same.

Income from each experimental unit was calculated using Mississippi’s market-year average price ($5.65 per bushel in 1992, $6.60 per bushel in 1993, $5.60 per bushel in 1994, $6.58 per bushel in 1995, and $7.13 per bushel in 1996). Average yearly prices rather than an average long-term price were used to reflect the effect of market forces on income for each individual year. Net return above total specified expenses was determined for each experimental unit each year.

Soybean plant height was recorded for each plot just before harvest. A field combine modified for small plots was used to harvest the two center rows of each WR system plot and the four center rows of each NR system plot. Soybean seed were harvested on Sept. 28, 1992, Sept. 21, 1993, Sept. 22, 1994, Sept. 20, 1995, and Sept. 10 (DK 4875) and 19 (DP 3589), 1996. Harvested seed were weighed and adjusted to 13% moisture content.

Experimental design was a randomized complete block, with four replicates of each WTRT within NR and WR. Analysis of variance was used to evaluate the significance of treatment effects on weed cover, seed yield, and net returns. As stated previously, WTRTs were reapplied to the same plots each year; therefore, year was treated as a subunit in the analysis of data. Mean separation was achieved with an $LSD_{0.05}$.

Results and Discussion

Weather and Soybean Development

RA 452 started blooming on June 22, 1992, and June 21, 1993, while DK 4875 started blooming on May 20, 1996. Full seed stage was reached on Aug. 21, 1992, Aug. 27, 1993, and July 26, 1996. DP 3589 started blooming on June 12, 1994, June 19, 1995, and June 7, 1996. Full seed stage was reached on Aug. 29, 1994, Sept. 5, 1995, and Aug. 27, 1996. Thus, reproductive development of DK 4875 occurred in June and July, while that of RA 452 and DP 3589 occurred in July and August. Plant height of RA 452 at maturity was 39 inches or greater for all treatments in 1992 and 30 inches or less for all treatments in 1993. In 1996, DK 4875 plant height was 23 inches or less for all treatments. Plant height of DP 3589 at maturity was 27 inches in 1994, 25 inches in 1995, and 26 inches in 1996.

Average maximum air temperatures for June, July, and August were 86, 90, and 86 °F, respectively, in 1992; 91, 96, and 94 °F in 1993; 92, 90, and 91 °F in 1994; 89, 91, and 95 °F in 1995; and 89, 91, and 89 °F in 1996 (Table 2). The 30-year (1964-1993) average maximum temperatures for June, July, and August were 90, 91, and 90 °F, respectively (Boykin et al. 1995). Thus, 1992 was cooler than normal, 1993 was hotter than normal, 1994 had near-normal temperature, 1995 had an above-average August temperature, and 1996 had near-average temperatures. Two irrigation applications (approximately 5 inches total) were made to NR in 1992, and four (approximately 10 inches total) were made to NR in 1993 and 1996. Three irrigation applications (approximately 8 inches total) were made to WR in 1994, four (approximately 11 inches total) were made in 1995, and five (approximately 11 inches total) were made in 1996.

Table 2. Average daily minimum and maximum air temperature, monthly rainfall, and pan evaporation at Stoneville, MS, 1992-1996, and 1964-1993 weather normals.[1]

Weather variable	1992	1993	1994	1995	1996	30-year normal
May						
Minimum air temperature (°F)	60	63	61	65	67	62
Maximum air temperature (°F)	82	82	82	86	88	82
Rainfall (in)	2.4	6.6	5.1	4.8	2.4	5.0
Pan evaporation (in)	8.4	7.2	7.6	7.7	10.6	7.7
Rainfall - pan evaporation (in)	-5.0	-0.6	-2.5	-2.9	-8.2	-2.7
June						
Minimum air temperature	68	72	73	68	70	69
Maximum air temperature	86	91	92	89	89	90
Rainfall	5.7	3.8	2.0	4.0	5.2	3.7
Pan evaporation	7.5	8.3	7.8	8.8	7.0	8.5
Rainfall - pan evaporation	-1.8	-4.5	-5.8	-4.8	-1.8	-4.8
July						
Minimum air temperature	73	76	72	73	73	72
Maximum air temperature	90	96	90	91	91	91
Rainfall	4.1	2.8	11.6	5.8	3.3	3.7
Pan evaporation	7.5	9.3	6.5	8.4	7.9	8.2
Rainfall - pan evaporation	-3.4	-5.5	-5.1	-2.6	-4.6	-4.5
August						
Minimum air temperature	66	74	67	74	69	70
Maximum air temperature	86	94	91	95	89	90
Rainfall	4.5	3.1	0.5	1.4	4.3	2.3
Pan evaporation	6.5	7.2	6.9	8.6	6.4	7.3
Rainfall - pan evaporation	-2.0	-4.1	-6.4	-7.2	-2.1	-5.0

[1](Boykin et al. 1995).

Weed Control and Cover (NR)

All treatments controlled target species at time of application. However, throughout the entire season of each year, there were significant differences in weed cover among narrow-row WTRTs (Table 3). In 1992, the treatment receiving only POST broadleaf herbicide (WTRT 2) was severely infested with barnyardgrass at soybean maturity, and total weed cover was 67%. WTRTs 8, 9, and 10 received broadleaf herbicides applied PRE and POST, along with grass herbicides applied PRE and/or POST, and they had weed covers of 8% or less at soybean maturity. WTRT 3 (broadleaf herbicides applied PRE and POST), WTRT 4 (broadleaf and grass herbicides applied PRE), and WTRT 7 (broadleaf and grass herbicides applied POST) had weed cover percentages that were 22% or less, and these were statistically similar to the weed cover values of WTRTs 8, 9, and 10. Barnyardgrass was the prominent weed species in plots of treatments that received either no grass control measures or grass herbicides applied PRE. Redvine was prominent in treatments where annual weeds were controlled.

In the 1993 NR, WTRTs 2, 6, and 7 required two POST applications of a broadleaf herbicide (Table 1) because of reinfestation following rain after the initial treatment. Weed cover at soybean maturity was 27% or more in all treatments (Table 3). This relatively high cover was the result of late-season weed development, because all WTRTs provided excellent control of target species at time of application. We speculate that this late-season weed development resulted from the opening of the soybean canopy during the maturing process that started in August. Percentage weed covers in WTRTs 1 through 7 were statistically similar. Barnyardgrass was a prominent species in 1993, but other broadleaf and grass species were also prominent in plots of all treatments. The apparent disparity in weed cover percentages between 1992 and 1993 was not the failure of herbicides to control weeds early in 1993, but rather a result of conditions in August 1993 that promoted weed development during the soybean maturing process.

In 1996, WTRTs 2, 6, and 7 in NR again required two applications of POST broadleaf herbicide (Table 1). Percentage weed cover in all treatments at soybean maturity was 30% or more (Table 3). This relatively high cover again was the result of late-season weed development that resulted from the failure of the short-statured DK 4875 to form a complete canopy and from the earlier opening of the soybean canopy during the maturing process in August. Percentage weed covers in WTRTs 1, 2, 4, 5, 6, and 8 were statistically similar. Johnsongrass was a prominent species in 1996 in plots of those treatments that received either PRE grass herbicide or no grass control. WTRTs 5, 7, 9, and 10 — in which grass herbicides were applied POST — had little or no johnsongrass present. The major grass species present in plots of these treatments was browntop millet. Broadleaf weeds were not a major component of percentage cover in any treatment.

Table 3. Total weed cover, major weed species present, and cover of major weed species as affected by weed control treatment (WTRT) for irrigated MG IV soybeans (NR) near Stoneville, MS, 1992-1996.

WTRT[1]	Pct. cover[2]	Major weed species[3] and percentage cover
1992		
1 PRE broadleaf	38 b	BYG, 17; BTM, 7; BSG, 3; SCG, 3; PMG, 3.
2 POST broadleaf	67 a	BYG, 41; BSG, 19; RED, 3.
3 PRE & POST broadleaf	22 bcd	BYG, 9; RED, 7; BSG, 3.
4 PRE broadleaf & grass	16 cd	BYG, 5; PMG, 3.
5 PRE broadleaf/POST grass	31 bc	RED, 10; PMG, 6; BTM, 3.
6 PRE grass/POST broadleaf	41 b	BYG, 18; BSG, 17.
7 POST broadleaf & grass	12 cd	IMG, 4; BYG, 3.
8 PRE & POST broadleaf/PRE grass	8 d	BYG, 3; RED, 2.
9 PRE & POST broadleaf/POST grass	7 d	RED, 4.
10 PRE & POST broadleaf & grass	8 d	RED, 3; PMG, 2.
$LSD_{0.05}$	21	
1993		
1 PRE broadleaf	56 a	BYG, 12; SCG, 10; JG, 10; HS, 7; BSG, 6.
2 POST broadleaf	51 ab	BYG, 19; JG, 10; BSG, 9.
3 PRE & POST broadleaf	41 abcd	BYG, 22; BTM, 6; BSG, 4; IMG, 4.
4 PRE broadleaf & grass	45 abcd	PMG, 9; JG, 7; HS, 6; BTM, 5; BYG, 5.
5 PRE broadleaf/POST grass	58 a	RED, 16; HS, 13; BYG, 5; JG, 5; PMG, 5.
6 PRE grass/POST broadleaf	58 a	BSG, 16; JG, 15; BYG, 7; PMG, 7.
7 POST broadleaf & grass	50 abc	BYG, 13; TEA, 8; BTM, 8; PMG, 6.
8 PRE & POST broadleaf/ PRE grass	27 d	BYG, 5; PMG, 5; BTM, 4; JG, 4; CCB, 4.
9 PRE & POST broadleaf/POST grass	36 bcd	BYG, 9; BTM, 8; RED, 7; PMG, 5.
10 PRE & POST broadleaf & grass	31 cd	CCB, 7; PMG, 7; RED, 6; BTM, 5.
$LSD_{0.05}$	19	
1996		
1 PRE broadleaf	46 abc	JG, 30; BYG, 4; BTM, 4; HS, 3.
2 POST broadleaf	51 ab	JG, 41; RED, 5.
3 PRE & POST broadleaf	36 bc	JG, 22; RED, 4; BTM, 4; PMG, 3.
4 PRE broadleaf & grass	58 a	JG, 35; HS, 7; PMG, 4; RED, 4; IMG, 3.
5 PRE broadleaf/POST grass	42 abc	RED, 16; IMG, 10; PMG, 9; BTM, 3.
6 PRE grass/POST broadleaf	63 a	JG, 60.
7 POST broadleaf & grass	30 c	BTM, 9; RED, 8; PMG, 7.
8 PRE & POST broadleaf/PRE grass	57 a	JG, 46; BTM, 6; PMG, 4.
9 PRE & POST broadleaf/POST grass	32 bc	BTM, 13; RED, 7; BYG, 5; PMG, 4.
10 PRE & POST broadleaf & grass	34 bc	BTM, 15; PMG, 7; RED, 5; JG, 5.
$LSD_{0.05}$	21	

[1]See Table 1 for herbicides applied. All herbicides broadcast-applied.
[2]Values within years followed by the same letter are not significantly different at $p \leq 0.05$.
[3]BSG = broadleaf signalgrass (*Brachiaria platyphylla*); BTM = browntop millet (*Brachiaria ramosa*); BYG = barnyard grass (*Echinochloa crus-galli*); CCB = common cocklebur (*Xanthium strumarium*); HS = hemp sesbania (*Sesbania exaltata*); IMG = ivyleaf morningglory (*Ipomoea hederacea*); JG = johnsongrass (*Sorghum halepense*); PMG = pitted morningglory (*Ipomoea lacunosa*); RED = redvine (*Brunnichia ovata*); SCG = southern crab grass (*Digitaria ciliaris*); and TEA = prickly sida (*Sida spinosa*).

Weed Control and Cover (WR)

Significant differences in weed cover among WTRTs in WR occurred in all years (Table 4). In 1994, the treatment receiving only POST broadleaf herbicide (WTRT 2) was severely infested with broadleaf signalgrass at soybean maturity, and total weed cover was 46%. Total weed cover in WTRT 10 (PRE and POST broadleaf and grass herbicides) was only 8%. Weed cover values in WTRTs 1, 3, 4, 5, 6, 7, 8, and 9 were similar and ranged from 13% to 25%. Broadleaf signalgrass and browntop millet were the prominent grasses present, while no annual broadleaf weed was prominent in any treatment. Redvine was prominent in treatments where annual weeds were controlled.

In 1995, weed cover at soybean maturity in WR was 20% or more in WTRTs 1, 5, 6, 7, and 9 (Table 4). Browntop millet was generally the most prominent annual grass. Johnsongrass was prominent in WTRT 6 (PRE grass herbicide). Pitted morningglory was the only prominent annual broadleaf (WTRT 1, PRE broadleaf herbicide only). This relatively high cover was the result of late-season weed development in the wide rows that resulted from irrigation that started before the canopy had closed, thus allowing reinfestation with weeds after all control measures had ceased.

In the 1996 WR, WTRTs 1, 5, and 6 had weed cover values that exceeded 25% (Table 4). Again, this relatively high cover was the result of weed development following the initial irrigation of soybeans with an incomplete canopy in the wide rows, because all WTRTs provided excellent control of target species at time of application. Percentage weed covers in WTRTs 2, 3, 4, 7, 8, 9, and 10 were statistically similar. Johnsongrass was a prominent species in plots of those treatments that received either PRE grass herbicide or no grass control. Browntop millet was the prominent annual grass, while broadleaf weeds were not a major component of percentage cover in any treatment.

Table 4. Total weed cover, major weed species present, and cover of major weed species as affected by weed control treatment (WTRT) for irrigated MG V soybeans (WR) near Stoneville, MS, 1994-1996.

WTRT[1]	Pct. cover[2]	Major weed species[3] and percentage cover
1994		
1 PRE broadleaf	21 b	BTM, 5; RED, 5; JG, 5; BSG, 2.
2 POST broadleaf	46 a	BSG, 36; RED, 5.
3 PRE & POST broadleaf	14 bc	BTM, 4; RED, 3; BSG, 3; TEA, 2.
4 PRE broadleaf & grass	13 bc	RED, 5; BTM, 3; BSG, 2.
5 PRE broadleaf/POST grass	17 bc	RED, 5; BTM, 4; BSG, 2; PMG, 2;
6 PRE grass/POST broadleaf	25 b	BSG, 7; BTM, 5; RED, 5; JG, 4; TEA, 3.
7 POST broadleaf & grass	19 bc	BTM, 5; RED, 4; JG, 3; BSG, 3; TEA, 2.
8 PRE & POST broadleaf/PRE grass	15 bc	BTM, 3; BSG, 3; PMG, 2; RED, 2; TEA, 2.
9 PRE & POST broadleaf/POST grass	14 bc	RED, 5; BTM, 4; PMG, 2.
10 PRE & POST broadleaf & grass	8 c	BTM, 4; TEA, 2.
$LSD_{0.05}$	12	
1995		
1 PRE broadleaf	35 a	PMG, 9; RED, 8; JG, 8; BTM, 8; IMG, 2.
2 POST broadleaf	10 d	BTM, 3; JG, 4.
3 PRE & POST broadleaf	10 d	BTM, 4; JG, 3.
4 PRE broadleaf & grass	9 d	BTM, 3; PMG, 3.
5 PRE broadleaf/POST grass	23 abcd	RED, 10; BTM, 5; PMG 4; IMG, 3.
6 PRE grass/POST broadleaf	28 ab	JG, 11; RED, 7; BTM, 6; PMG, 2.
7 POST broadleaf & grass	20 bcd	BTM, 7; RED, 5; PMG, 2; JG, 2.
8 PRE & POST broadleaf/ PRE grass	11 d	BTM, 5; PMG, 2; RED, 2.
9 PRE & POST broadleaf/POST grass	26 abc	BTM, 16; RED, 7.
10 PRE & POST broadleaf & grass	12 cd	BTM, 7.
$LSD_{0.05}$	14	
1996		
1 PRE broadleaf	26 abc	JG, 9; RED, 6; IMG, 4; BTM, 3; PMG, 3.
2 POST broadleaf	11 cd	JG, 6; PMG, 3.
3 PRE & POST broadleaf	14 abcd	JG, 5; PMG, 4; BTM, 3.
4 PRE broadleaf & grass	8 d	BTM, 2; PMG, 2.
5 PRE broadleaf/POST grass	28 ab	RED, 14; PMG, 6; IMG, 5; BTM, 3.
6 PRE grass/POST broadleaf	30 a	JG, 25; PMG, 2; RED, 2.
7 POST broadleaf & grass	8 d	RED, 3; BTM, 2; PMG, 2.
8 PRE & POST broadleaf/PRE grass	12 bcd	BTM, 5; PMG, 3; JG, 3.
9 PRE & POST broadleaf/POST grass	18 abcd	BTM, 8; RED, 4; PMG, 3.
10 PRE & POST broadleaf & grass	9 cd	BTM, 4; PMG, 2.
$LSD_{0.05}$	18	

[1]See Table 1 for herbicides applied. All herbicides band-applied.
[2]Values within years followed by the same letter are not significantly different at $p \leq 0.05$.
[3]BSG = broadleaf signalgrass (*Brachiaria platyphylla*); BTM = browntop millet (*Brachiaria ramosa*); IMG = ivyleaf morningglory (*Ipomoea hederacea*); JG = johnsongrass (*Sorghum halepense*); PMG = pitted morningglory (*Ipomoea lacunosa*); RED = redvine (*Brunnichia ovata*); and TEA = teaweed (*Sida spinosa*).

Although NR and WR were evaluated in separate years and thus were under dissimilar conditions, some comparisons can be made. In almost all cases, weed infestations at soybean maturity were lower in WR than in NR — despite the fact that more money was spent for weed control in all NR treatments except WTRT 1 (Table 5). Obviously, cultivation used in weed management in WR was a contributor to improved weed control in these early plantings. The bushier canopy of the MG V determinate variety used in WR provided more shading than the more upright MG IV indeterminate varieties used in NR, even though the MG IV varieties were in narrower rows. The shortness of DK 4875 in 1996 also was a contributing factor to the high weed cover values at maturity in NR that year. This problem may be rectified by using a taller MG IV variety in NR.

Weed cover at harvest is an important component of weed management decisions. In this study, weed matter consisted of only green plant material that was always removed by the combine during the threshing process so that foreign matter was low in harvested seed. However, significant weed presence at harvest can result in slower harvesting speed and thus reduce harvest efficiency. This is especially true if weed species like johnsongrass are dominant, such as the situations that occurred in several NR treatments in 1993 and 1996 and several WR treatments in 1995 and 1996. Weed species present at harvest and weed cover values in NR WTRT 5 (PRE broadleaf and POST grass herbicides), WTRT 7 (POST broadleaf and grass herbicides), and WR WTRT 7 (POST broadleaf and grass herbicides) thus offer the best combination of less problematic weeds and cover values for the most efficient harvest.

Table 5. Average seed yield, weed control cost (WCOST), and net returns (NETRET) for irrigated MG IV soybean (NR) and irrigated MG V soybean (WR) grown with different weed management (WTRT) near Stoneville, MS, 1992-1996.

WTRT [1]	1992-1993 NR			1996 NR			1994-1996 WR		
	Yield [2]	WCOST [3]	NETRET [2,4]	Yield [2]	WCOST [3]	NETRET [2,4]	Yield [2]	WCOST [3]	NETRET [2,4]
	bu/A	*$/A*	*$/A*	*bu/A*	*$/A*	*$/A*	*bu/A*	*$/A*	*$/A*
1 PRE broadleaf	43.2 abc	23.50	133 a	43.9 cde	23.90	186 bc	40.6 c	22.65	120 c
2 POST broadleaf	39.1 c	22.25	110 a	39.4 def	31.95	147 cde	47.0 ab	21.70	165 a
3 PRE & POST broadleaf	46.1 ab	38.45	134 a	46.0 bcd	39.25	184 bc	47.0 ab	31.50	151 abc
4 PRE broadleaf & grass	44.5 abc	34.40	128 a	38.4 def	40.05	130 de	48.7 a	30.57	163 ab
5 PRE broadleaf/POST grass	47.3 ab	35.20	144 a	52.4 ab	36.00	232 a	45.7 abc	29.95	145 abc
6 PRE grass/POST broadleaf	40.9 bc	36.00	105 a	37.4 f	47.75	114 e	42.9 bc	31.15	126 bc
7 POST broadleaf & grass	44.0 abc	34.40	125 a	54.3 a	43.70	238 a	47.4 ab	28.92	158 ab
8 PRE & POST broadleaf/PRE grass	49.0 a	49.80	140 a	34.2 f	55.45	106 e	44.9 abc	39.40	130 bc
9 PRE & POST broadleaf/POST grass	48.7 a	50.60	136 a	49.7 abc	51.40	197 ab	45.6 abc	38.75	135 abc
10 PRE & POST broadleaf & grass	47.8 a	61.90	118 a	47.0 bc	55.45	174 bcd	47.5 ab	42.25	143 abc
$LSD_{0.05}$	6.7		41	6.5		45	5.0		32

[1]See Table 1 for herbicides applied.
[2]Values in individual columns that are followed by the same letter are not significantly different at $p \leq 0.05$.
[3]Includes herbicides, adjuvants, and application for NR and WR. Includes POST cultivation costs of $10.14 per acre in 1994, $9.09 per acre in 1995, and $5.85 per acre in 1996 for WR. Does not include preplant foliar-applied herbicide that was applied to all treatments.
[4]Net return derived by subtracting all direct (including weed control costs) and fixed costs from gross returns.

Analysis across years indicated that yield and net returns were significantly affected by year and that the year-by-treatment interaction was significant. Further analysis using all combinations of 2-year data sets showed that this significant interaction resulted from the inconsistent performance of the 1996 study. Therefore, data are presented for 1996 alone and as the average of 1992 and 1993.

In all years of these irrigated plantings, POST broadleaf-only control (WTRT 2) resulted in high infestations with grass weeds (Table 3) and one of the lowest yields (Table 5). Use of only a PRE broadleaf herbicide (WTRT 1) resulted in high infestations with grass weeds (Table 3), but its yield in 1992-93 was among the highest with one of the lowest costs ($22.25 per acre). In 1996, after 5 years of treatment imposition, the grass infestation in this treatment resulted in yield and net return that were lower than those of the highest-yielding treatments. Evidently, PRE Canopy in WTRT 1 provided a level of effective early-season grass control, but over the long term, this control level was not adequate. Broadleaf herbicides applied PRE and POST (WTRT 3) resulted in a greater yield than broadleaf herbicides applied POST only (WTRT 2). Broadleaf herbicides applied PRE and POST (WTRT 3) did not increase yield more than the treatment with only a PRE broadleaf herbicide (WTRT 1). Grass herbicides applied PRE or POST in addition to PRE broadleaf herbicides (WTRTs 4 and 5) did not increase yield or lower percentage weed cover compared with an application of only a PRE broadleaf herbicide (WTRT 1). However, WTRT 5 (POST grass herbicide, PRE broadleaf herbicide) in 1996 did result in a significantly greater yield after 5 years.

A combination of a broadleaf herbicide applied POST and a grass herbicide applied PRE (WTRT 6) resulted in reduced yield, while a broadleaf herbicide applied POST and a grass herbicide applied POST (WTRT 7) did not. Percentage weed cover in WTRT 6 was greater than in WTRT 7 in 1992 and 1996 (Table 2), and grasses were the dominant species. Evidently, grass herbicide applied POST in WTRT 7 was more effective than was the grass herbicide applied PRE in WTRT 6.

Grass herbicide applied PRE in combination with broadleaf herbicides applied PRE and POST (WTRT 8) did not affect yield in 1992-1993, but this treatment was associated with reduced yield in 1996 (Table 5). Applying grass herbicides POST in addition to broadleaf herbicides applied PRE and POST (WTRT 9) resulted in similar yields in both periods. However, the combination of grass herbicide applied POST and broadleaf herbicide applied POST (WTRT 7) resulted in increased yield, whereas the combination of grass herbicide applied PRE and broadleaf herbicide applied POST (WTRT 6) did not increase yield. Combinations of broadleaf herbicides applied PRE or POST with grass herbicides applied POST (WTRTs 5 and 7) resulted in higher yields than combinations of broadleaf herbicides applied PRE or POST with grass herbicides applied PRE (WTRTs 4 and 6) in 1996.

Several combinations of broadleaf and grass herbicides applied PRE and POST resulted in highest yields, but a large difference in the costs of these combinations occurred. For example, the combination of a broadleaf herbicide applied PRE and a grass herbicide applied POST (WTRT 5) resulted in high yields in both periods (47.3 and 52.4 bushels per acre), but its $35 to $36 per acre cost was well below the cost of the most expensive treatment (WTRT 10). This resulted in greater net return from WTRT 5 in 1996. Evidently, the $62 and $55.50 per acre spent for weed control in WTRT 10 was unnecessarily high, since yield resulting from this treatment was not significantly greater than yields from other, less expensive treatments. Consequently, the net return from WTRT 10 was lower. Conversely, the $22 and $32 per acre spent for weed control in WTRT 2 was the wrong expenditure for maximum yield to be achieved. Thus, costs of and yields from treatments such as WTRTs 3, 5, and 7 seem to offer the best combination of moderate weed control cost and optimum yield.

Net return was used to determine the best combination of broadleaf and grass herbicides applied PRE and/or POST in this study. The various weed control combinations and associated costs and yields (Table 5) resulted in no significant difference among net returns in 1992-93, but they did significantly affect net returns after 5 years. In 1996, net returns were $238 per acre from WTRT 7, $232 per acre from WTRT 5, and $197 per acre from WTRT 9. All of these treatments had grass herbicides applied POST. On the other hand, net returns from WTRTs 4, 6, and 8 were $130 per acre, $114 per acre, and $106 per acre, respectively, and all of these treatments had grass herbicides applied PRE. Thus, use of a grass herbicide applied POST in combination with broadleaf herbicide applied either PRE or POST resulted in higher yields and net returns in this irrigated NR production system. Broadleaf herbicides applied PRE alone (WTRT 1), POST alone (WTRT 2), and PRE and POST combined (WTRT 3) — all without a grass herbicide — resulted in lower net returns than when used in combination with a grass herbicide applied POST (WTRTs 5 and 7). The use of both PRE and POST broadleaf herbicide applications (WTRT 3) did not increase net return more than the use of PRE or POST broadleaf herbicide applications alone (WTRTs 1 and 2). However, the trend was for higher net returns from herbicide applied PRE when a grass herbicide was not used. Broadleaf herbicide applied PRE in combination with grass herbicide applied POST (WTRT 5) resulted in higher net return than when a grass herbicide was applied PRE (WTRT 4). This same difference occurred when a broadleaf herbicide was applied POST in combination with grass herbicide applied either PRE or POST (WTRT 6 vs. 7). Use of more expensive treatments represented by WTRTs 8, 9, and 10 resulted in either no increase in net return or lower net returns than those realized from less expensive treatments.

These results indicate that lowest weed control costs and highest net returns were obtained when broadleaf herbicides were applied either PRE or POST in combination with a grass herbicide applied POST. This finding applies to an irrigated, narrow-row ESPS planting made on Sharkey clay.

Yield and Economics (WR)

Analysis across years indicated that yield and net returns were significantly affected by year, but the year-by-WTRT interaction was not significant. Therefore, data from wide-row experiments were combined across years for final analysis.

Use of only a PRE broadleaf herbicide (WTRT 1) was inexpensive, but it resulted in poor weed control (Table 4), low yield, and low net return (Table 5). Conversely, use of only a POST broadleaf herbicide (WTRT 2) resulted in the best combination of high yield, low weed control cost, and high net returns, although weed cover at maturity in 1995 was relatively high (Table 4). WTRT 4 (PRE broadleaf and grass control) resulted in excellent weed control, high yield, and high net return, although its associated weed control cost was about $9 per acre greater than for WTRT 2. Excellent weed control resulted from WTRT 10 (PRE and POST broadleaf and grass herbicides), but its associated high cost offset the returns from a relatively high yield so that net return was reduced below that of other treatments. WTRT 9 (PRE and POST broadleaf and POST grass herbicides) was also too expensive to parlay a relatively high yield into a corresponding greater net return. WTRT 6 (POST broadleaf and PRE grass herbicides) resulted in high weed cover at maturity and one of the lower yields and net returns. WTRT 8 (PRE and POST broadleaf and PRE grass herbicides) resulted in one of the lowest weed cover values at harvest, but its high cost and intermediate yield resulted in one of the lower net returns. WTRT 3 (PRE & POST broadleaf herbicides), WTRT 4 (PRE broadleaf and grass herbicides), WTRT 5 (PRE broadleaf and POST grass herbicides), and WTRT 7 (POST broadleaf and grass herbicides) all resulted in relatively low weed cover values, intermediate weed control costs, and yields and net returns that were among the highest.

A preferred system of weed management is one that costs the least, controls weeds the best, and results in the highest yield and net return. WTRT 4 (PRE broadleaf and grass herbicides) and WTRT 7 (POST broadleaf and grass herbicides) consistently fit these criteria. They always resulted in weed cover values that were among the lowest with a corresponding intermediate cost. Their yields and net returns were among the highest across the 3 years of the study. WTRT 2 (only POST broadleaf herbicides) resulted in low-cost weed management and a high yield and net return, but the resulting weed cover value in 1994 was the highest among all treatments. This increased weed cover could reduce harvesting efficiency and result in foreign matter in harvested seed if proper combine settings are not made.

These results indicate that best weed control and highest yields and net returns were obtained when broadleaf and grass herbicides were applied either PRE or POST (but not both). This finding applies to an irrigated, wide-row ESPS planting made on Sharkey clay.

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