Effects of Reduced Tillage and Crop Residues on Cotton Weed Control, Growth and Yield.

K.O. Adu-Tutu, W.B. McCloskey, S.H. Husman, P. Clay, M. Ottman, and E.C. Martin
University of Arizona, Tucson, AZ

Abstract

Conservation or reduced tillage practices in cotton-based crop rotation systems were studied in field experiments initiated at Marana, Coolidge and Goodyear by planting barley cover and grain crops in the fall of 2001. In the 2002 cotton season, conservation tillage practices reduced the number of cultural operations required to grow a cotton crop. Adequate cotton weed control was achieved in conservation tillage systems using only postemergence herbicides; weed-sensing, intermittent spray technology reduced the amount of herbicide spray volume used for weed control. Cotton yields in conservation tillage systems were similar to the yields in conventional tillage systems at two sites and greater at one site.

Introduction

Conservation tillage is defined as a production system that eliminates or reduces tillage operations to the minimum required to produce a crop and in which 30 percent of the previous crop residue remains on the surface after planting (Bryson and Keeley, 1992). The presence of crop residue over time may increase soil organic matter content, improve soil tilth, and increase the moisture holding capacity, cation exchange capacity and overall productivity of the soil (Boquet *et al*., 1997; Daniel *et al*., 1999; Smart and Bradford, 1999). Cotton farmers, including Arizona farmers, disk and use many other forms of mechanical soil disturbance every year (Bryson and Keeley, 1992) in conjunction with preemergence herbicides to prepare fields for cotton planting. After planting, mechanical cultivation is used for in-season weed control and maintenance of irrigation furrows.

Preemergence herbicides are applied in anticipation of weed populations, the density of which cannot be easily determined beforehand. This practice wastes chemical and increases the pesticide load on the environment. Postemergence herbicides are generally applied either broadcast or in bands to entire fields regardless of whether or not weeds are present, and they may not control weeds effectively in all situations. Froud-Williams (1988) reported increased occurrence and density of hard-to-control herbaceous perennial weeds and some highly specialized annuals and biennials after postemergence herbicide use in many no-till systems. Postemergence herbicides can be efficiently applied using chlorophyll/plant sensing herbicide sprayers (Hanks and Beck, 1998). Hanks and Beck (1998) found that the amount of glyphosate (Roundup) spray applied was reduced 63 to 85% by using weed-sensing spray technology in cotton fields. Since herbicide is sprayed only where weeds exist, higher rates of herbicides and more potent herbicide tank mixtures can be used without greatly increasing cost.

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Farmers consider cultivation or tillage to be necessary for aerating the soil and promoting plant growth, breaking the surface crust, breaking or penetrating hardpans, controlling weeds between crop rows, and maintaining furrows for efficient irrigation. Kaddah (1977) found that reduced-tillage cotton had higher yield and greater profits than conventional cotton, indicating that not all of the many tillage practices conducted in conventional systems are necessary for cotton production. Clay *et al*. (2000) and Husman *et al*. (2000) found that reduced-tillage practices could save money in ultra-narrow row cotton production. Further research is needed on sustainable conservation tillage cotton production practices that may reduce production costs, improve yields and conserve the environment in the west and particularly in Arizona.

The goal of this project is to provide cotton growers in the southwestern U.S. with the necessary economic, agronomic and physical information required to adopt conservation tillage practices, to utilize cover crops or double-crop small grains with cotton, and to utilize weed-sensing sprayer technology. To achieve this goal, five objectives have been established: (1) evaluate the planting of cotton into cover crop residues or into small grain crop stubble without pre-season tillage; (2) evaluate a weed-sensing sprayer and postemergence herbicide weed control program in minimum-till cotton; (3) evaluate changes in soil properties, such as organic matter content, crusting, water infiltration and associated changes in fertility and irrigation practices; (4) collect and compare operational, agronomic and cost data for minimum-till and conventional tillage production systems; and (5) disseminate information on alternative production practices. This report summarizes the results of field experiments conducted on farmer-cooperators' farms and on an experiment station in the first year of the project (fall 2001 to fall 2002).

Materials and Methods

Field experiments were initiated in October and November of 2001 by planting barley and oat crops on three commercial farms: Fast Track Farms in Coolidge, A Tumbling T Ranch in Goodyear and John Thude Farms Partnership's Paradise Ranch in Stanfield, and at the University of Arizona Marana Agricultural Center experiment station. Water management problems at Paradise Ranch led to loss of the first cotton planting, and data for the 2001-2002 growing season will not be presented in this report. Treatments varied among the three remaining sites, and were strongly influenced by the choice of the farmer-cooperator.

Coolidge

At Fast Track Farms (cooperator: Greg Wuertz), the tillage/cover crop treatments were: (1) conventional tillage/winter fallow followed by conventional cotton; (2) minimum tillage/oat cover crop, followed by no-till cotton planting; and (3) minimum tillage/Solum barley cover crop followed by no-till cotton planting. Prior to initiating the experiment, beds were listed with a hip-lister and mulched with a modified Sundance implement; a rotary hoe was used twice to prepare the final seedbed. The Solum barley and oat cover crops were planted at 111 and 71 lb/A seeding rate, respectively, on 19 November 2001 using a standard Case International Harvester 5400 grain drill and were irrigated once with 12 acre-in of water during the winter. The cover crops were sprayed with glyphosate at a rate of 1.12 lb ae/A (40 oz/A of Roundup Ultramax) on 5 March 2002 with a John Deere 6000 Hi-Cycle to kill the plants prior to planting cotton. Cotton cultivar DeltaPine 422 BR was dry-planted at a 50,000 seed/A seeding rate in the winter fallow, conventional tillage plots using a John Deere MaxEmerge II planter on 19 April 2002 and irrigated to germinate the seed on 25 April 2002. Yetter Farm Equipment 2976 residue manager/coulter assemblies were bolted onto the MaxEmerge II planter units in order to plant the cotton in the barley and oat cover crop residues on the same date and they appeared to work well for this purpose in the coarse textured soil at this site.

A proposed pre-emergence Prowl (pendimethalin) application was not made at any of the sites because the large amount of barley and oat cover crop residues and grain crop stubble present in the conservation tillage plots was perceived to be sufficient to bind and inactivate the herbicide before it could reach the soil surface, be incorporated and provide weed control. Thus, weed control in all conservation tillage treatments at all sites was obtained using only postemergence herbicides, while cultivation and postemergence herbicides were used in the conventional tillage treatments.

At Coolidge, a topical, broadcast application of glyphosate at 1 lb ae/A (Roundup Ultramax at 34.7 oz/A) was made on all plots on 14 May 2002 when the cotton was at the 4 true leaf stage. The winter-fallow, conventional tillage cotton treatment was cultivated on 27 May 2002, 18 June 2002 and 2 July 2002 using a rolling cultivator and on 15 July 2002 using a rod weeder. On 20 June 2002, the furrows in the conservation tillage plots were sprayed using a 6-row sprayer equipped with five 28 in and two 20 in Redball Conservation Spray-hoods equipped with three or two 95 degree even flat fan nozzles, respectively. Two of the 28 in spray hoods were modified by installing three WeedSeeker weed-sensing, intermittent spray units (NTech Industries, Inc.) each with a single 6503 flat fan nozzle in each hood to selectively detect and automatically spot treat weeds in the furrows. This allowed comparison of the WeedSeeker spray units with the continuous spray nozzles in other hoods in terms of spray volume applied and control of predominant weeds. The spray volumes in gallons per acre (GPA) were measured using digital flow meters (Great Plains Industries, Inc.). Each spray hood had either one (20 in hoods) or two (28 in hoods) 80 degree flat fan nozzles on single swivels mounted at the rear of the hood to post-direct spray at the base of the cotton plants in the seed line. Glyphosate at 1.5 lb ae/A (Roundup UltraMax at 52 oz/A) + ammonium sulfate (AMS) at 2% w/w was applied with the WeedSeeker and conventional spray hoods in the minimum tillage plots to spray weeds in the furrow. Glyphosate at 0.75 lb ae/A (Roundup UltraMax at 26 oz/A) + AMS at 2% w/w was simultaneously sprayed at the base of the cotton plants. On 16 July 2002, three different herbicide treatment regimes were applied using both conventional and WeedSeeker spray hoods in subplots of the conservation or minimum tillage plots. All three treatments contained glyphosate at 1.5 lb ae/A (Roundup UltraMax at 52 oz/A) + AMS at 2% w/w that was tank mixed with either Prometryne at 0.8 lb ai/A, carfentrazone-ethyl at 0.016 lb ai/A (Aim at 1.0 oz/A) or carfentrazone-ethyl at 0.025 lb ai/A (Aim at 1.6 oz/A). In all subplot treatments, glyphosate at 0.75 lb ae/A (Roundup UltraMax at 26 oz/A) + AMS at 1% w/w was applied post-direct to the base of the cotton plants. A layby application of glyphosate at 0.7 lb ae/A (Roundup Ultramax at 24 oz/A) + prometryn at 0.75 lb ai/A (CottonPro at 24 oz/A) was made in all plots on 29 July 2002 using a six-row Redball 420 layby sprayer.

The Coolidge experiment was harvested on 28 October 2002. Twelve rows of cotton were picked using a John Deere 9976 6-row picker, and the seedcotton was weighed in a Caldwell Boll Buggy (EL Caldwell and Sons, Inc.) equipped with a Weigh-Tronix scale (Model WI-152). Seedcotton was ginned with a 25-saw cotton gin.

Goodyear

Treatments at A Tumbling T Ranch (cooperator: Ron Rayner) were: (1) fall no-till planting of a Poco barley grain crop followed by a spring no-till planting of cotton; (2) fall minimum tillage prior to planting a Poco barley grain crop followed by a spring no-till planting of cotton; and (3) fall minimum tillage prior to planting a Poco barley grain crop followed by minimum tillage prior to planting cotton in the spring. The Poco barley grain crop was planted on 26 December 2001. Minimum tillage at Goodyear consisted of disking the plots twice. Cotton was planted on 20 May 2002 with the grower's MaxEmerge II planter, which was already adapted through minor modification for no-till cotton planting into grain stubble on level ground. Cotton cultivar DeltaPine 451 BR was planted at a seeding rate of 18 lb/A. Several herbicide treatments were applied topically to subplots in each main plot on 6 June 2002: glyphosate at 0.75 or 1.12 lb ae/A (Roundup UltraMax at 26 or 40 oz/A) + AMS at 1% w/w, clethodim at 0.125 lb ai/A (8 oz/A of Select) + crop oil concentrate (COC) (Herbimax) at 1% v/v or fluazifop-butyl at 0.125 lb ai/A (8 oz/A of Fusilade DX) + COC (Herbimax) at 1% v/v. Glyphosate (Roundup UltraMax) at 0.75 or 1.12 lb ae/A + AMS at 1% w/w was applied topically to all plots on 21 June 2002 at the 4 to 6 leaf cotton growth stage. On 24 to 26 July 2002, when the cotton was at the peak bloom growth stage, subplots of each plot were sprayed at layby with either the hooded sprayer described above or with the farmer-cooperator's defoliation boom which had been modified for layby herbicide applications. Glyphosate (Roundup WeatherMax) at 1.125 lb ae/A (32 oz/A) + Prometryne at 0.8 lb ai/A + AMS at 1% w/w was sprayed under WeedSeeker or conventional Redball conservation spray hoods while simultaneously spraying glyphosate at 0.91 lb ae/A (Roundup WeatherMax at 26 oz/A) + AMS at 1% w/w post-directed at the base of the cotton plants. Alternatively, glyphosate at 1.12 lb ae/A (Roundup UltraMax at 40 oz/A) + AMS at 1% w/w was sprayed with the farmer's modified defoliation boom.

The Goodyear experiment was harvested on 8 November 2002. Seedcotton in the eight center cotton rows of each plot were picked with a John Deere 9965 4-row picker and weighed in a Crust Buster Weigh Buggy (Speed King, Inc.) equipped with a Weigh-Tronix scale (Model 915). A 25-saw gin was used for ginning the seedcotton.

Marana

Treatments at the Marana Agricultural Center were: (1) conventional tillage following cotton plots that were fallow during the winter followed by conventional tillage and cotton planting in April (early planting); (2) conventional tillage plots that were fallow in the winter followed by conventional tillage and cotton planting in May at the same time as treatment 4 (late planting); (3) minimum tillage or no-till planting of a barley cover crop followed by a no-till early cotton planting (there were three subplots: one brittle stem barley subplot and two Solum barley subplots); and (4) minimum tillage or no-till planting of a Solum barley grain crop followed by a no-till late cotton planting. Field preparation at Marana consisted of disking (twice), ripping (twice), disking (twice) after spreading fertilizer, listing beds and running a cultipacker over the beds in the fall. Beds in the conventional tillage treatments were re-disked and re-listed before cotton was planted on them in the spring. The barley cover and grain crops at Marana were planted at a 72 lb/A seeding rate and were irrigated twice during the winter and once during the spring. The cover crops were sprayed with glyphosate at 1.12 lb ae/A (40 oz/A of Roundup UltraMax) on 1 March 2002 (Solum barley) and 15 March 2002 (brittle stem barley) and the Solum barley grain crop was harvested on 3 May 2002. Following preirrigation and mulching of the plots, cotton cultivar DeltaPine 422 BR was planted using 12.6 lb/A of seed in the winter fallow, conventional tillage treatments on 17 April 2002 (early planting) and on 3 May 2002 (late planting). The early and late planted conservation tillage/no-till cotton planting treatments were planted on the same dates using a 14 lb/A seeding rate. A standard 4-row John Deere MaxEmerge planter was used in the conventional tillage plots on both the early and late planting dates. Four Yetter Farm Equipment 2976 residue manager/coulter assemblies were bolted to the planter units and the same planter was used to plant the no-till cotton treatments. In the fine-textured soil at Marana which was hard when dry, the MaxEmerge planter was not heavy enough to force the residue manager-coulter-planter units into the dry beds. Thus, it was necessary to add about 200 lb to each planter unit to accomplish satisfactory penetration of the soil and placement of the cotton seed. The early and late no-till cotton was planted into dry soil to a depth of about 0.5 in and irrigated after planting to germinate the seed ("dry planted"). The winter fallow-conventional tillage treatments were pre-irrigated and the cotton was planted to moisture with a dry soil mulch placed over the seed line that was removed about 5 days after planting ("wet-planted").

As noted above for the Coolidge site, a proposed pre-emergence Prowl (pendimethalin) application was not made because of the large amount of barley residues and stubble present in the conservation tillage plots. Thus, weed control in all conservation tillage treatments was obtained using postemergence herbicides, while preemergence herbicides applied on 15 March 2002 [pendimethalin at 0.72 lb ai/A (Prowl at 28 oz/A) and prometryn at 0.88 lb ai/A (Prometryne at 28 oz/A)], four cultivation operations (4 June 2002, 12 June 2002, 3 July 2002, and 15 July 2002), and hand weeding were used in the winter fallow/conventional tillage treatments. A topical, broadcast application of glyphosate (Roundup UltraMax) at 0.75 lb ae/A (26 oz/A) + AMS at 2% w/w was made in the minimum tillage/barley cover crop-early cotton treatment on 8 May 2002 at the 3 to 4 true leaf cotton growth stage. A similar application was made on 29 May 2002 in the no-till late planted treatment. On 27 June 2002, glyphosate at 0.75 lb ae/A + AMS at 2% w/w was applied post-directed to the cotton seed line and glyphosate at 1.5 lb ae/A + AMS at 2% w/w was applied under RedBall Conservation Spray-Hoods using the hooded sprayer described above in Coolidge. Two of the spray hoods were removed and others moved to accommodate the 4-row planter configuration at Marana. As noted above, two of the spray hoods contained WeedSeeker intermittent spray units (NTech Industries, Inc.). On 15 July 2002, a layby application of glyphosate (0.75 lb ae/A) + Prometryne at 1.6 lb ai/A + AMS at 1% w/w was made in all treatments using a Redball 420 layby sprayer.

The early-planted cotton was harvested on 16 October 2002, and the late-planted cotton was harvested on 30 October 2002. The eight center cotton rows of each plot were picked with a John Deere 9910 2-row picker. The seedcotton was weighed and ginned using the procedure described for the Coolidge experiment.

Results and Discussion

At Coolidge, the oat and barley cover crops were of similar height and produced similar amounts of biomass (Table 1). On an individual plant basis, oat plants were much shorter in stature and appeared to produce far less biomass than the Solum barley plants. However, there were so many barley volunteers in the oat cover crop that most of the biomass in the oat cover crop was produced by barley, accounting for the lack of differences between treatments. The Solum barley appeared to be a superior cover crop compared to oats when produced on limited resources at Coolidge. At Marana, Solum barley plants were significantly taller than brittle stem barley plants (Table 2); however, there was no statistical difference in their biomass. The brittle stem barley subplots were terminated two weeks later than the Solum barley subplots and this may have contributed to the lack of differences in the amounts of dry matter produced. The barley grain yield at Marana was 7,613 lb/acre. At Goodyear, cover crop assessments were not made and grain yields were not measured in the spring of 2002.

Cotton was planted into small grain biomass and stubble using standard John Deere MaxEmerge planters equipped with Yetter 2976 residue managers which moved residue and cut a seed line with a fluted coulter resulting in good seed placement in the dry beds. At Marana where the soil is a clay loam, 200 lb had to be added to the each planter unit on the 4-row planter to achieve good operation of the residue managers and soil penetration of the coulter and planter units. At Coolidge, the combination of a 6 row planter and a sandy loam soil resulted in good soil penetration and it was not necessary to add extra weight to the planter. At Goodyear where the soil is a silty clay loam, minor modifications (e.g., increased spring tension) of a John Deere MaxEmerg planter facilitated planting into Poco barley stubble. Overall the results from the three sites indicated that the no-till cotton planting methods did not negatively affect cotton seedling emergence compared to conventional tillage/planting methods (Tables 3). Interestly, stand reductions occurred in conventional and minimum tillage treatments rather than in no-till treatments. At Marana, emergence was significantly less in the conventional tillage-late cotton planting treatment compared to the other treatments. Both the early and late planted conventional tillage treatments were wet-planted and during the period between the early and late plantings (16 days) there was some loss of moisture from the beds. In addition, greater air and soil temperatures in the late planted treatment dried out the seed-bed before germination and emergence were completed, despite planting the seed into moisture. The traditional practice in these types of Marana soils (i.e., fine-textured soils) in the normal April planting window is to plant to moisture; however, in the future, late cotton plantings following grain harvest will be dry planted and irrigated to obtain a stand based on our experience in 2002. In Goodyear, cotton establishment was slightly reduced by disking the barley stubble twice prior to planting compared to the no-till planted cotton treatments. This may have been due to a lower quality planting surface and the absence of the beneficial effects of barley residues on germinating cotton seedlings.

WeedSeeker weed sensing intermittent spray units in Redball conservation spray hoods were compared to conventional continuous spray nozzles in other conservation spray hoods in terms of the spray volume applied and annual morningglory (*Ipomoea hederacea*) control which was the predominant weed at Marana. Spray volumes of either application system did not vary significantly between the similar conservation tillage treatments but the WeedSeeker hoods applied 74 to 91% less spray volume and herbicide (Roundup UltraMax) than the conventional nozzle hoods (Table 4). Weed density was low in these treatments possibly due to the earlier topical broadcast herbicide application and the presence of cover crop residues. Hanks and Beck (1998) also observed a 63 to 85% reduction in the amount of Roundup spray applied using the WeedSeeker weed-sensing technology. Although weed control was initially similar in all treatments, annual morningglory control in the Solum barley cover system (61.25%) was significantly lower than in the other treatments. At the final evaluation, the late-planted cotton/Solum barley grain crop system achieved 99% control, and was statistically better than the other treatments (Table 4). This latter result may have been due to the later planting date and thus smaller weeds being present at the time of application.

At Coolidge, there was a statistically insignificant saving of 3 to 4 gallons per acre (GPA) of herbicide spray using the WeedSeeker system compared to the conventional nozzle hoods at the first post-directed spray date in the oat and barley cover crop systems for the control of horse purslane (*Trianthema portulacastrum*) and common purslane (*Portulaca oleracea*) (Table 5). However, on 16 July 2002, the WeedSeeker system provided significant 15 to 20% spray volume savings compared to continuous spray technology in the oat and barley cover crop systems. The small spray volume savings at Coolidge relative to Marana was probably due to the poor control of common purslane by the first topical broadcast application of Roundup Ultramax and a lack of a preemergence herbicide treatment in the conservation tillage treatments. This poor control resulted in a high density of large-sized plants and near continuous spraying by the WeedSeeker spray units during the next herbicide application. The conventional tillage system resulting in the best control of common and horse purslane by combining mechanical and chemical weed control methods (Table 6). There were no differences in weed control between the WeedSeeker-equipped hoods and the conventional nozzle equipped hoods. At Goodyear, initial control of volunteer barley and horse purslane using Roundup UltraMax at 26 or 40 oz/A was significantly better than using Select or Fusilade at 8 oz/A, and Roundup UltraMax tended to give better control of volunteer barley and horse purslane at 40 oz/A than at 26 oz/A (Table 7). The weed density at the Goodyear site was relatively low, and Roundup UltraMax applied in July resulted in 84 to 100% control of volunteer barley, junglerice (*Echinochloa colona*), horse purslane and volunteer alfalfa (Table 8).

Cotton plant heights at Marana in July were significantly greater in the early-planted cotton/minimum tillage plots compared to the other treatments, but plant heights later in the season did not significantly differ among the treatments (Table 9). Height-to-node ratios (HNR) were statistically similar among the treatments. At Coolidge, conventional tillage cotton plants were significantly shorter than the conservation tillage cotton plants (Table 10). While HNR were similar among the treatments initially, the conventional tillage plants later had lower HNR than the conservation tillage plants (Table 10). At Goodyear, the treatments in which cotton was planted without tillage in the spring (i.e., spring no-till) were characterized by taller plants and greater HNR (Table 11). Thus, at all sites, treatments with the least amount of tillage were characterized by taller plants with increased HNR.

Seed cotton yields at Marana showed that early-planted cotton in either a conventional or reduced tillage system significantly out-yielded late-planted cotton (Table 12). Early-planted cotton lint yield in the conventional tillage system (1140 lb/A) was similar to that of the early-planted cotton in the reduced tillage system (1089 lb/A). The late-planted cotton in the conventional tillage system produced the least amount of lint (827 lb/A); the late-planted cotton in the reduced tillage system produced 927 lb/A. Clark and Carpenter (1998) and Silvertooth *et al*. (1998) observed cotton yield reductions when cotton was planted late at Marana and Maricopa, Arizona. At Coolidge, the conservation tillage systems with either an oat (1007 lb/A) or barley (1089 lb/A) cover crop substantially out-yielded the conventional tillage system (880 lb/A) in terms of lint production by 14.4 % and 23.8 %, respectively (Table 13), the results being similar to what Kaddah (1977) has documented. The higher yields were probably due to the greater amount of irrigation water applied in the conservation tillage treatments (Martin et al., 2003). There were no differences in cotton yields among the tillage systems at Goodyear (Table 14). Although percent lint was significantly lower in the fall no-till, spring no-till treatment than the other treatments, lint yield did not significantly vary among the treatments.

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Table 1. Barley and oat cover crop height and biomass measured on 14 March 2002 at Coolidge in the conservation tillage treatments Height was measured in 4 locations per plot from the ground to the tip of the longest leaf. Biomass was harvested from 40 ft^2 with 4 sub-samples per plot and oven dried at 150 F prior to weighing.

Tillage treatment/small grain system	Height (in)	Dry weight (lb/A)
Conservation tillage, oats/volunteer barley cover crop	13.2 a*	1921 a*
Conservation tillage, barley cover crop	13.0 a	1892 a
LSD (P=0.05)	ns	ns
OSL	0.847	0.928
CV (%)	11.7	24.67

*Values are means of 5 replications; means in a column followed by the same letter are not different at the P=0.05 significance level according to the Student-Newman-Keuls significant difference test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 2. Solum and Brittle Stem barley cover crop height and biomass measured on 25 and 28 March 2002 at the Marana Agricultural Center in the conservation tillage treatments. Height was measured in 4 locations per plot from the ground to the tip of the longest leaf. Biomass was harvested form 26.67 ft^2 with 4 subsamples per plot and oven dried at 150 F prior to weighing.

Tillage treatment/small grain system	Height (in) 25 March 2002	Dry weight (lb/A) 28 March 2002
Conservation tillage, Solum barley cover crop-subplot 1	18.0 a*	985 a*
Conservation tillage, Solum barley cover crop-subplot 2	18.0 a	1000 a
Conservation tillage, Brittle Stem barley cover crop	14.0 b	1120 a
LSD (P=0.05)	1.73	NS
OSL	0.002	0.835
CV (%)	6.0	33.0

*Values are means of 4 replications; means in a column followed by the same letter are not different at the P=0.05 significance level according to the Student-Newman-Keuls significant difference test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 3. Cotton emergence and establishment in the various tillage and barley cover/grain crop treatments at Coolidge, Goodyear and the Marana Agricultural Center. Stand counts were made in 10 1-m long subplots in each plot on 30 May 2002, 7 June 2002, and 21 May 2002 at the Coolidge, Goodyear and Marana locations, respectively.

Location	Grain/Tillage/Cotton System	Stand Count/m
Coolidge	Oat/volunteer barley cover crop, no-till cotton planting	10.3 a*
	Solum barley cover crop, no-till cotton planting	9.7 a
	Winter fallow/conventional tillage	10.0 a
	LSD (P=0.05)	1.53
	OSL	0.676
	CV (%)	10.5
Goodyear	Fall no-till Poco barley grain, spring no-till cotton	11.8 a*
	Fall minimum tillage Poco barley grain, spring no-till cotton	12.0 a
	Fall minimum tillage Poco barley grain, spring minimum tillage cotton	8.9 b
	LSD (P=0.05)	1.89
	OSL	0.012
	CV (%)	10.0
Marana	Conventional tillage, winter fallow, early cotton planting	11.6 a*
	Minimum tillage, Solum barley cover, early cotton planting	11.6 a
	Minimum tillage, Brittle stem barley cover, early cotton planting	10.8 a
	Conventional tillage, winter fallow, late cotton planting	7.6 b
	Minimum tillage, Solum barley grain crop, late cotton planting	11.9 a
	LSD (P=0.05)	2.49
	OSL	0.014
	CV (%)	15.1

*Values are means of 4 replications; means from the same location followed by the same letter are not different at the P=0.05 significance level according to the Student-Newman-Keuls significant difference test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 4. Glyphosate* spray volumes in gallons per acre (GPA) on applied on 27 June 2002 with NTech Industries WeedSeeker weeder sensing spray units or with standard continuous spray nozzles and percent control of annual morningglory at the Marana Agricultural Station in July and August 2002. There were no differences between spray technologies with respect to weed control.

Tillage/grain/cotton treatment	Spray technology	Spray volume (GPA)	Percent control 7/10/02	Percent control 8/2/02***
Minimum tillage, Solum barley cover crop, early cotton planting	Continuous	20.38 a[#]	61.25 b	73.8 b
	Weed sensing	4.33 b		
Minimum tillage, brittle stem barley cover crop, early cotton planting	Continuous	19.88 a	76.25 a	77.5 b
	Weed Sensing	5.13 b		
Minimum tillage, Solum grain crop, late cotton planting	Continuous	24.41 a	80.00 a	98.8 a
	Weed sensing	2.30 b		
Conventional tillage, winter fallow, early cotton planting**			88.72 a	73.8 b
Conventional tillage, winter fallow, late cotton planting**			85.00 a	82.0 b
	LSD (P=0.05)	3.95	12.03	13.40
	OSL	0.0001	0.003	0.012
	CV (%)	20.59	9.98	10.63

*Roundup UltraMax at 52 oz/A + AMS 2% w/w applied under Redball Conservation spray hoods with continuous spray nozzles or WeedSeeker weed-sensing spray units and Roundup UltraMax at 26 oz/A + AMS 1% w/w applied post-directed to the base of cotton plants.

**Conventional tillage plots were treated with preplant-incorporated herbicides and cultivated on 4 June 2002, 12 June 2002, 3 July 2002 and 15 July 2002.

*** A layby application of Roundup UltraMax at 26oz/A + Prometryne at 1.6 lb ai/A + AMS 1% w/w was made in all treatments on 15 July 2002.

[#]Values are means of 4 replications; means in a column followed by the same letter are not different at P=0.05 according to the Student-Newman-Keuls significant difference test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 5. Herbicide spray volumes in gallons per acre (GPA) applied by NTech Industries WeedSeeker weed sensing, automatic spot sprayer versus conventional continuous flat fan spray nozzles at the Coolidge conservation tillage experiment in 2002.

Tillage/cover crop system	Sprayer technology	GPA 6/20/02	GPA 7/16/02
Minimum tillage, oat/volunteer barley cover crop	Continuous	27.8 a*	24.7 a*
	Weed-sensing	23.1 a	20.9 b
Minimum tillage, barley cover crop	Continuous	27.9 a	25.8 a
	Weed sensing	24.8 a	20.6 b
	LSD (P=0.05)	ns	1.45
	OSL	0.262	0.0001
	CV (%)	21.2	4.59

*Values are means of 5 replications; means relating to the same tillage/cover crop system followed by the same letter are not different at the P=0.05 significance level according to the Student-Newman-Keuls significant difference test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 6. Percent control of horse purslane and common purslane following layby herbicide applications at Coolidge in 2002.

Cover crop/tillage treatment or herbicide treatment			Percent control on 30 July 2002	
			Horse purslane	Common purslane
Cover crop and tillage	(averaged across herbicide treatments)			
	Conservation tillage, oat cover		72.9 b	41.0 b
	Conservation tillage, barley cover		76.9 b	36.7 b
	Conventional tillage		87.0 a	79.0 a
		LSD (P=0.05)	7.00	6.18
		OSL	0.0007	<0.0001
		CV (%)	7.51	11.40
Herbicide	Herbicide applied to furrow* (averaged across cover crop treatment)			
	Prometryne @ 0.8 lb ai/A		71.4 b	39.0 b
	Aim @ 1.0 lb ai/A		76.5 b	37.5 b
	Aim @ 1.6 lb ai/A		76.5 b	40.0 b
	Conventional tillage		87.0 a	79.0 a
		LSD (P=0.05)	8.23	7.27
		OSL	0.0016	<0.0001
		CV (%)	7.51	11.40

*All herbicide treatments applied under the spray hoods contained Roundup UltraMax at 52 oz/A + AMS at 2% w/w; Roundup UtraMax @ 26 oz/A + Aim @ 1.0 oz/A + AMS @ 1% w/w was applied post-direct to base of the cotton plants. Conventional tillage plots were cultivated on 27 May 2002, 18 June 2002 and 2 July 2002 with a rolling cultivator, and on 15 July 2002 with a rod weeder. A layby application of Roundup UltraMax at 24 oz/A + Prometryne at 24oz/A was made in all treatments on 29 July 2002.

**Means in a column within the same cover crop/tillage or herbicide section followed by the same letter are not different at P=0.05 according to the Ryan-Einot-Gabriel-Welsch Range test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 7. Percent control of volunteer barley and horse purslane at Goodyear after a topical, broadcast application of Roundup UltraMax, Select or Fusilade on 6 June 2002 six-row tractor mounted broadcast sprayer.

Tillage/Herbicide system	Volunteer barley		Horse purslane	
	6/13/02	6/20/02	6/13/02	6/20/02
Fall No-Till, Spring No-Till; RUM* @ 26oz/A + AMS @ 1% w/w	80.0 b**	33.8 b	95.0 a	60.0 b
Fall No-Till, Spring No-Till; RUM @ 40oz/A + AMS @ 1% w/w	86.3a	40.0 a	98.0 a	73.8 a
Fall Reduced Till, Spring No-Till; RUM @ 26 oz/A + AMS @1% w/w	81.3 b	36.3 b	95.0 a	63.8 b
Fall Reduced Till, Spring No-Till; RUM @ 40 oz/A + AMS @1% w/w	82.5 b	41.3 a	98.0 a	76.3 a
Fall Reduced Till, Spring Reduced Till; RUM @ 26 oz/A + AMS @1% w/w	80.0 b	32.5 b	95.0 a	65.0 b
Fall Reduced Till, Spring Reduced Till; Select @ 8 oz/A + Herbimax @ 1% v/v	45.0 c	0 .0 c	82.5 b	0.0 c
Fall Reduced Till, Spring Reduced Till; Fusilade @ 8 oz/A + Herbimax @ 1% v/v	43.8 c	0.0 c	82.5 b	0.0 c
LSD (P=0.05)	2.48	3.37	2.29	4.63
OSL	0.0001	0.0001	0.0001	0.0001
CV (%)	2.34	8.65	1.67	6.44

*RUM=Roundup UltraMax, AMS=ammonium sulfate, and Herbimax is a crop-oil-concentrate; 26 and 40 oz/A of Roundup Ultramax are equal to 0.75 and 1.12 lb ae/A of glyphosate, respectively; 8 oz/A of Select or Fusilade is equal to 0.125 lb ai/A of these herbicides.

**Values are means of 4 replications; means in a column followed by the same letter are not different at P=0.05 according to the Student-Newman-Keuls significant difference test. LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 8. Percent weed control at Goodyear after a topical, broadcast glyphosate* application at the 4 to 6 leaf cotton growth stage on 21 June 2002.

Tillage system	Volunteer barley	Junglerice	Horse purslane	Volunteer alfalfa
Fall No-Till, Spring No-Till	87.5 a**	94.5 a	96.3 a	95.0 a
Fall Reduced Till, Spring No-Till	83.8 a	89.5 a	94.8 a	85.0 a
Fall Reduced Till, Spring Reduced Till	100.0 a	92.8 a	94.5 a	92.5 a
LSD (P=0.05)	ns	ns	ns	ns
OSL	0.0644	0.4480	0.9469	0.3075
CV (%)	8.89	5.73	8.48	9.53

*Glyphosate 0.75 and 1.12 lb ae/A (Roundup UltraMax 26 or 40 oz/A) was applied topically to the two spring no-till and the fall reduced-till, spring reduced till treatments, respectively.
**Values are means of 4 replications; means in a column followed by the same letter are not different at P=0.05 according to the Student-Newman-Keuls significant difference test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 9. Cotton plant height and height-to-node ratios (HNR) in the cover and grain crop/tillage systems at the Marana Agricultural Station in July and August 2002.

Cotton/Tillage system	Height (in)* 7/22/02	Height (in)* 8/13/02	HNR* 7/22/02	HNR* 8/13/02
Conventional tillage, early cotton planting, winter fallow	37.55 b	39.91 a	1.6 a	1.6 a
Reduced tillage, early cotton planting, Solum barley cover	40.69 a	42.36 a	1.7 a	1.6 a
Reduced tillage, early cotton planting, brittle stem barley cover	40.46 a	43.06 a	1.7 a	1.7 a
Conventional tillage, late cotton planting, winter fallow	30.84 b	40.77 a	1.5 a	1.6 a
Reduced tillage, late cotton planting, Solum barley grain crop	30.08 b	40.13 a	1.4 a	1.6 a
LSD (P=0.05)	3.339	ns	ns	ns
OSL	0.0001	0.5279	0.0381	0.5067
CV (%)	3.88	7.41	7.97	5.1

*Values are means of 10 observations; means in a column followed by the same letter are not different at P=0.05 according to the Student-Newman-Keuls significant difference test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 10. Cotton plant height and height-to-node ratios (HNR) in the cotton-cover crop/tillage systems at Coolidge in July and August 2002.

Tillage/cover crop System	Height (in)* 07/26	Height (in) 08/21	Height (in) 10/04	HNR 07/26	HNR 08/21	HNR 10/04
Conservation tillage, oats cover	35.8 a	40.9 a	43.3 a	1.5 a	1.5 a	1.57 a
Conservation tillage, barley cover	36.2 a	42.3 a	44.8 a	1.6 a	1.6 a	1.62 a
Conventional tillage	31.6 b	35.6 b	39.8 b	1.4 a	1.4 b	1.41 b
LSD (P=0.05)	2.550	3.256	3.04	ns	0.09	0.090
OSL	0.0060	0.0035	0.0138	0.0370	0.0062	0.0017
CV (%)	5.06	5.64	4.88	4.27	3.95	4.04

*Values are means of 10 observations; means in a column followed by the same letter are not different at P=0.05 according to the Student-Newman_Keuls significant difference test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 11. Cotton plant height and height-to-node ratios (HNR) in the tillage systems at Goodyear in August and September 2002.

Tillage System	Height (in)* 08/05/02	Height (in) 09/10/02	HNR 08/05/02	HNR 09/10/02
Fall No-Till, Spring No-Till	37.9 a	45.4 a	1.7 a	1.7 a
Fall Reduced Till, Spring No-Till	37.6 a	43.9 a	1.7 a	1.7 a
Fall Reduced Till, Spring Reduced Till	34.3 b	41.4 b	1.5 b	1.5 b
LSD (P=0.05)	1.357	1.905	0.10	0.09
OSL	0.0012	0.0062	0.0228	0.0050
CV (%)	2.14	2.53	3.53	3.19

*Values are means of 10 observations; means in a column followed by the same letter are not different at P=0.05 according to the Student-Newman_Keuls significant difference test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 12. Cotton yields in the various cotton-barley/tillage systems at the Marana Agricultural Center in 2002. The early-planted cotton was harvested on 16 October, 2002, and the late-planted cotton was harvested on 30 October, 2002.

Cotton/Tillage system	Seed cotton lb/A	% Lint	Lint (lb/A)
Conventional tillage, early cotton planting, winter fallow	3493 a*	32.65 a	1140 a
Reduced tillage, early cotton planting, barley cover	3296 a	33.05 a	1089 ab
Conventional tillage, late cotton planting, winter fallow	2510 b	32.98 a	827 c
Reduced tillage, late cotton planting, Solum barley grain crop	2786 b	33.25 a	927 bc
LSD (P=0.05)	503	ns	162
OSL	0.0059	0.6708	0.0064
CV (%)	10.41	2.07	10.22

*Values are means of 4 replications; means in a column followed by the same letter are not different at P=0.05 according to the Student-Newman-Keuls significant difference test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 13. Cotton yields in the various cotton-cover crop/tillage systems harvested on 28 October 2002 in Coolidge.

Tillage/cover crop System	Seed cotton (lb/A)	% Lint	Lint (lb/A)
Conservation tillage, oats cover	2963 ab	33.96 a	1007 a
Conservation tillage, barley cover	3196 a	34.12 a	1089 a
Conventional tillage	2638 b	33.32 a	880 b
LSD (P=0.05)	329	ns	119
OSL	0.0138	0.3302	0.0113
CV (%)	7.7	2.48	8.25

*Values are means of 5 replications; means in a column followed by the same letter are not different at P=0.05 according to the Student-Newman-Keuls significant difference test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.

Table 14. Cotton yields in the different tillage systems at Goodyear in 2002. Cotton was harvested on 8 November 2002.

Tillage System	Seed cotton (lb/A)	% Lint	Lint (lb/A)
Fall No-Till, Spring No-Till	2984 a	30.61 b	913 a
Fall Reduced Till, Spring No-Till	3063 a	31.70 a	971 a
Fall Reduced Till, Spring Reduced Till	2939 a	31.70 a	940 a
LSD (P=0.05)	ns	0.92	ns
OSL	0.5206	0.0241	0.2851
CV (%)	4.91	1.69	5.01

*Values are means of 4 replications; means in a column followed by the same letter are not different at P=0.05 according to the Student-Newman-Keuls significant difference test; LSD=least significant difference, OSL=observed significance level, and CV=coefficient of variation.