Reduced Tillage and Crop Residue Effects on Cotton Weed Control, Growth and Yield

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Abstract

The tillage operations conducted in a barley and cotton double-crop rotation were reduced by eliminating tillage prior to planting cotton, eliminating cultivations for weed control in cotton, and especially by eliminating tillage following cotton prior to planting barley. Data collected in 2002 and 2003 in Coolidge and Marana showed that a weed sensing, automatic spot-spray system reduced the amount of spray volume and herbicide used by 50 to 60%. Data from Maricopa in 2003 indicated that the savings can be much greater (e.g., in a treatment with thick Solum barley cover crop residues) or much less if volunteer grain germinates after grain harvest. Similar weed control was obtained with the weed sensing, automated spot-spray system compared to conventional continuous spray systems for most weed species. At Coolidge in 2002, the minimum tillage treatment with a barley cover crop produced 24% more lint than the conventional tillage system (1089 versus 880 lb/A) because more water was applied in that treatment. In 2003, the minimum tillage treatment yielded 24% less than the conventional tillage treatment (1178 versus 1539 lb/A) due to herbicide injury. There were no differences in cotton yields among the tillage systems at Goodyear in 2002 and 2003. In Marana (2002 and 2003) and Maricopa (2003), there were yield differences between treatments related to planting date, with late-planted cotton yielding less than early-planted cotton. At Marana, the cotton yields of the minimum-till and conventionally tilled treatments were not statistically different. At Maricopa, the early-planted minimum-till cotton yielded less than the early-planted conventionally tilled cotton (956 versus 1141 lb/A). The yield comparisons between conservation tillage and conventional tillage cotton production systems are not yet definitive and more research needs to be conducted. Economic comparisons between productions systems indicated an advantage for conservation/minimum tillage treatments if cotton yields were comparable.

Introduction

The goal of this project is to provide cotton growers in the southwestern United States with the necessary economic and agronomic information required to facilitate adoption of conservation tillage practices including using cover crops, double cropping small grains with cotton, and using weed sensing, automatic spot-spray technology. To achieve this goal, four research objectives were established: (1) evaluate the planting of cotton into cover-crop residues or into small grain crop stubble without preseason tillage; (2) evaluate weed sensing, automatic spot spray technology and weed control programs that use only postemergence herbicides 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; and (4) collect and compare operational, agronomic (i.e., plant growth), and cost data for minimum-till and conventional production systems. The results of field experiments conducted on commercial farms and University of Arizona experiment stations are presented in this report.

Materials and Methods

Field trails were established in October and November 2001 by planting barley and oat crops on three commercial farms (Fast Track farms, Coolidge; A Tumbling T Ranch, Goodyear; John Thude Farms Partnership's Paradise Ranch, Stanfield)) and at an experiment station (University of Arizona Marana Agricultural Center). The experiment at Coolidge was reconfigured and simplified to reduce the area of the experiment and the amount of water required in the fall of 2002. The experiment at Paradise Ranch encountered numerous difficulties including loss of the first cotton planting due to water management problems with the center-pivot irrigation system in 2002. A cotton seed-lot with poor cold germination was planted at this site in 2003 and the resulting crop failure precluded us from gathering data at this site in 2003. The treatments varied among the three remaining sites and were strongly influenced by what our farmer cooperators were able and willing to investigate. A Tumbling T Ranch in Goodyear was unable to support a straw management experiment despite the cooperator's interest due to the space and resource commitment. In addition, Arizona Public Service Company (APS) constructed their Southwest Valley 500 KV transmission line from the Palo Verde Nuclear Power Plant through the A Tumbling T Ranch destroying some plots and causing severe soil compaction in a portion of the field. Thus, the Goodyear experiment was reduced in scope, tillage was conducted to reclaim the field, and the experiment was restarted with the 2003 cotton season. Because of the difficulties we encountered at some of our original sites and to increase our educational outreach opportunities, we started additional experiments at the University of Arizona Maricopa Agricultural Center. The experiments conducted in the period following cotton harvest in 2002 to the end of the 2003 cotton season are discussed below; the treatments and procedures in earlier experiments were discussed in Adu-Tutu et al. (2003).

At Fast Track Farms (cooperator: Greg Wuertz, Coolidge), the tillage/cover crop treatments were: (1) winter fallow; conventional tillage cotton; (2) winter fallow; conventional tillage cotton with Telone nematicide soil injection; and (3) Solum barley cover crop; minimum tillage cotton planting. Treatments at A Tumbling T Ranch (cooperator: Ron Rayner, Goodyear) were: (1) fall minimum tillage/wheat grain crop, spring no-till cotton planting; and (2) fall minimum tillage/wheat grain crop, spring minimum tillage cotton planting. Treatments at the Marana and Maricopa Agricultural Centers were the same and were: (1) winter fallow, conventional tillage cotton planting in April (early planting); (2) winter fallow, conventional tillage cotton planting in late May (late planting); (3) Solum barley cover crop, no-till cotton planting in April (early planting); and (4) Solum barley grain crop, no-till cotton planting in May (late planting). Planting dates, cotton varieties, herbicide application, weed control rating, and harvest dates for 2003 are given in the data tables; see Adu-Tutu et al. (2003) for details of the 2002 experiments.

In addition, a straw management study was conducted at the Maricopa Ag. Center in 2002 to 2003 that included the following treatments: (1) winter fallow followed by conventional tillage cotton; (2) Beardless barley cover-crop followed by no-till cotton; (3) Cayuse oat cover-crop followed by no-till cotton; (4) Solum barley grain crop with straw baled followed by no-till cotton; (5) Solum barley grain crop harvested low (stem stubble 5 inches tall from bed top) followed by no-till cotton; (6) Solum barley grain crop harvested at medium height (stems 9 to 10 inches tall) followed by no-till cotton; and (7) Solum barley grain crop harvested high (stems 17 to 18 inches tall) followed by no-till cotton.

Results and Discussion

The small grain cover crops and grain crops were planted in the fall of 2002: 1) using a conventional grain drill following cotton stalk shredding, and one pass with a Sundance disk bedder/ripper at Coolidge; 2) using a conventional grain drill at Goodyear since the cotton roots were pulled and the entire field was disked following the 2002 cotton season; 3) using a conventional grain drill following disking, listing and bed shaping (new experiment) at Maricopa; and 4) using a John Deere 1560 no-till grain drill following cotton stalk shredding but without tillage at Marana. All cover crops were killed using 40 to 64 oz of Roundup UltraMax (glyphosate) plus ammonium sulfate. The amount of biomass produced by the cover crops ranged between 2,126 and 16,646 lb/A, varying considerably depending on location, number of irrigations, rainfall, year and when the cover crop was killed with a herbicide (Table 1). For example, the smallest amount of biomass, Coolidge in 2002, resulted from a single irrigation and an early termination whereas the greatest Solum barley biomass was produced with two irrigations plus rainfall and early termination at Marana in 2003 (5,642 lb/A), or with late termination at Maricopa in 2003 (16,646 lb/A). Solum barley was bred to maximize root development and tillering and is a low-input barley variety that can respond favorably to additional water in the form of rain or an additional irrigation (after the germinating irrigation following planting). The amount of Solum biomass at Maricopa in 2003 was prodigious resulting in a residue layer up to 4 inches thick on the soil surface that was a supreme challenge with respect to no-till cotton planting. The grain crops were harvested with conventional grain harvesters with the Solum barley yielding between 1,071 lb/A (Maricopa, 2003) to 2,599 lb/A (Marana, 2002) or 2,773 lb/A (Marana, 2003). The Orita wheat in Goodyear yielded 6,400 lb/A in 2003. A significant finding at Marana in 2002 was that the John Deere 1560 no-till grain drill was able to easily plant the fall barley crops despite the presence of shredded cotton stalks. The coulter/disk opener assemblies were able to slice through the stalks and place seed in the ground even when a grain drill seed-line coincided with an old cotton seed-line and shredded stalks.

The John Deere 1560 no-till grain drill was used to plant the fall 2003 barley cover-crops and grain crops into existing beds at Coolidge, Maricopa and Marana. Our 2003 observations confirm our experience at Marana in the fall of 2002. This type of grain drill can successfully plant on existing beds without tillage following cotton despite the presence of 6 to 10 inch tall cotton stalks. However, the uniformity of the barley population was not optimal in the bottom of the furrows at Marana compared to the other experimental sites. This appeared to be partly due to the use of a mower rather than a shredder to destroy the standing cotton stalks. The mower resulted in long sections of stem in the furrows that interfered with the disk openers rather than the small stem pieces produced by the shredder. This stem problem was exasperated by the fact that the disk openers of the planter units in the furrows did not penetrate the ground sufficiently to obtain an optimum and uniform grain planting depth despite using 2 inch spacers on these units. Larger spacers might solve this problem and will be tried in the fall of 2004.

Arizona has a "plow down" requirement following cotton harvest to facilitate pink bollworm control that has the effect of promoting tillage. The regulations require growers to disrupt cotton root-soil connections to kill the cotton plants which most growers accomplish by shredding stalks, pulling the roots loose from the soil with a root puller and disking at least twice. Alternatively, the regulations allow growers to plant a small-grain crop provided it is irrigated in December. This option is based on data showing that the combination of cold winter temperatures and irrigation in December results in a lack of pink bollworm emergence from the cotton stalks in the spring. With our successful planting demonstrations, several growers have expressed interest in no-till planting of grain crops following cotton in order to avoid significant tillage costs. Avoiding fall tillage after cotton also has the benefit reducing the production of PM10 dust which is a significant problem in the Phoenix, Arizona area. As a result of our work, we were able to put together funding from outside and within the University of Arizona to purchase a 10-foot wide John Deere 1590 no-till grain drill for research and demonstration purposes. Combined with the use of the Yetter 2960/2976 coulter/residue manager cotton planter attachments, we have demonstrated the successful use of no-till planting techniques for an annual barley-cotton double crop rotation.

Our experience irrigating the field at Marana in the fall of 2003 suggests that number of crop cycles that can be grown will depend on maintaining irrigation efficiency. At Marana after two annual barley-cotton cycles, the head end of the field (i.e., next to the irrigation ditch) was eroded to the point that it was lower than the rest of the field making irrigation difficult. Conversations with growers suggest that at this point they might finish the third barley planting as a grain crop (or plant wheat) and then use tillage and laser-level the field. However, to solve this irrigation problem we made a pass across the beds with a field disk at the top end of the field and rebuilt the beds for a short distance at the top of the field. The amount of slope in furrow-irrigated fields as a function of soil type required to maximize the number of grain-cotton double crop cycles needs to be further investigated. Increased slope in the presence of crop residues in the furrows could improve irrigation efficiency in coarse textured soils. In addition, more research is needed to verify that planting grain crops, particularly wheat, on beds with a no-till grain drill designed to operate on flat ground does not compromise grain yields.

Cotton was successfully planted directly into barley cover crop residues and grain crop stubble using standard John Deere MaxEmerge planters equipped with Yetter Farm Equipment 2960/2976 coulter/residue manager assemblies at Coolidge, Maricopa and Marana. The Yetter 2960/2976 coulter/residue managers did a good job of cutting a seed-line trench a fluted coulter and moving residue resulting in good seed placement in the dry beds at all locations despite the wide range in the amount of crop residues on the soil surface. At Marana and Maricopa, 200 lb or 100 lb per row unit, respectively, had to be added to the 4-row planters to achieve good soil penetration of the coulter and planter double disk openers. At Coolidge where there was a coarse textured soil, good soil penetration of the planter units was obtained without adding extra weight to the grower's 6-row JD MaxEmerge planter in 2002. The Goodyear site was planted with the grower's JD MaxEmerge cotton planter that was already adapted for no-till cotton planting into grain stubble. Overall the results from the Marana, Coolidge and Goodyear sites indicated that the no-till cotton planting methods did not negatively affect cotton seedling emergence compared to planting methods used in conventional tillage systems in either 2002 or 2003 (Table 2). A significant finding at Marana in 2003 was that the Yetter 2960/2967 coulter/residue manager attachments easily shattered and moved the old shredded cotton stalks remaining from the 2002 cotton season in addition to moving the barley residues.

Plant populations in the range of 31,000 to 49,000 plants/A (7.6 to 12 plants/meter of row on 1 m row spacing) and 25,000 to 59,000 plants/A (6.2 to 14.5 plants/meter of row) were obtained in 2002 and 2003, respectively (Table 2). At Marana in 2002, there was significantly less emergence in the conventional tillage, winter fallow, late-planted cotton treatment compared to the other treatments. This was caused by the high air and soil temperatures which dried out the pre-irrigated seed-bed before cotton germination and emergence were completed despite planting the seed into moisture. This problem was solved in 2003 by dry planting this treatment similar to the minimum tillage, late plant treatment and irrigating to germinate the cotton seed (Table 2). In 2003, the plant populations were relatively low at 25,000 to 28,000 plants/A (6.23 to 7.17 plants/m of row) at Coolidge (Table 2) and there were significant canopy gaps in the minimum tillage plots that contributed to reduce yield (Table 7). The small plant population was due to the grower's use of the Sundance ripper/bedder which produced poor quality, rough beds, and to planting without the Yetter attachments on the MaxEmerge planter.

Cotton growth was assessed in the various treatments by measuring plant height and counting the number of nodes per plant at various times during the cotton season in both conventional tillage treatments and reduced tillage treatments. In Coolidge, the cotton plants in the minimum tillage treatments were taller than the plants in the conventionally tilled treatment in 2002 (Table 3) probably because the minimum tillage treatment received more irrigation water than the conventional tillage treatments (76 versus 55.5 in/A). In 2003 when 62.6 and 50 in/A of irrigation water were applied to the minimum-till and conventional-till treatments, respectively, there were no differences in plant heights or height-to-node ratios (HNR) (Table 3). In Goodyear, the no-till cotton plants were also taller than the plants in the treatment that was disked prior to planting cotton in 2002 but there were no differences in plant heights or HNR in 2003 when the tillage operations were the same for both treatments (Table 4). In Marana, there were differences in plant height related to both planting date (later planted cotton was shorter) and tillage with taller plants in the no-tilled cotton treatment in both 2002 and 2003 (Table 5). At Maricopa in 2003, there were differences in plant heights related to planting date (later planted cotton was shorter) but there was no height difference between the conventional tillage treatments and the no-till cotton treatments (Table 6). Although there were inconsistencies between experiment sites with respect to plant heights, where significant differences occurred, the minimum or no-till cotton treatments had taller plants compared to the conventionally tilled cotton treatments.

Cotton growth was also assessed by harvesting the experiments and comparing cotton lint yields between treatments at Coolidge, Goodyear, Marana, and Maricopa (Tables 7 to 10). At Coolidge in 2002, the minimum tillage treatments 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, due to the greater amount of irrigation water used in these treatments (76 versus 55.5 in/A). The reverse was true in 2003 when the minimum tillage treatment yielded 24% less than the conventional tillage treatment yield of 1539 lb/A (Table 7) possibly due to herbicide injury. There were no differences in cotton yields among the tillage systems at Goodyear in 2002 and 2003 (Table 8). In Marana (2002 and 2003) and Maricopa (2003), there were yield differences between treatments related to planting date with the late-planted cotton yielding less than the early-planted cotton (Tables 9 and 10). At Marana, the no-till (i.e., minimum tillage) and conventional tillage cotton yields were not statistically different although there was a numerical trend of lower yield in the no-till cotton treatments (Table 9). At Maricopa, the early-planted no-till cotton yielded less than the early-planted conventionally tilled cotton (956 versus 1141 lb/A) and there was a similar but not statistically significant trend in the late-planted cotton treatments. A puzzling outcome of the experiments at Maricopa in 2003 was that the yields of the straw management study (Table 13) were almost double that of the late planted, minimum tillage treatment (Table 10). The late planted, minimum tillage treatment and the straw management study were planted on the same day with the same variety, irrigated and fertilized similarly (generally on the same day), and harvested on the same day. Thus, the straw management study appears to suggest that much greater yields can be achieved in the minimum tillage treatments. It appears that in some situations no-till cotton may yield less than conventionally tilled cotton although the yield comparisons are not yet definitive. More research is needed to determine if this trend is consistent but we think that there may be non-tillage related reasons for this apparent trend. Cotton petiole samples and the color of the cotton plants in the no-till cotton treatments suggest that plants in these treatments did not receive sufficient nitrogen possibly due the decomposition of organic matter in these treatments. There was also a severe water stress event in the Maricopa tillage systems experiment in mid-summer that might have reduced yields. In addition, at Coolidge and Marana, substantial injury symptoms from the Caparol layby herbicide applications (leaf burn and boll death) may have reduced yields. The herbicide injury may have occurred because plants in the no-till treatments had shallower root systems and absorbed more herbicide.

A study was conducted at the Maricopa Agricultural Center in 2003 to assess various straw management strategies during grain harvest prior to no-till cotton planting. The treatment list included a conventional tillage treatment (winter fallow), two cover crop treatments (beardless barley and Cayuse oats) and several Solum barley treatments all harvested for grain but cut at different heights (5 inches, 9 to 10 inches, and 17 to 18 inches) leaving different amounts of stubble in the field. The cereal biomass prior to harvest was determined in each cover crop or grain crop treatment along with grain yields; there were no significant differences between treatments in any of the measured parameters (Table 11). Because of the way the grain harvesters spread straw during harvest, it was not possible to accurately measure the amounts of barley residue following grain harvest. Cotton plant establishment after no-till planting, cotton plant height and HNR were similar in all of the treatments (Table 12). Cotton yields also did not differ between the straw management treatments (Table 13). These results indicate that the no-till planting methods we using were not very sensitive to differences in straw biomass or the height of the standing stubble following grain harvest. Although a second year study will provide more data, it appears the no-till planting method we used on beds is very robust and that growers do not have to pay particular attention to straw management.

A weed-sensing, automatic spot sprayer using WeedSeeker technology (NTech Industries, Inc.) and post-emergence herbicide weed control programs were evaluated in the minimum tillage cotton treatments in 2002 and 2003. An existing 6-row hooded sprayer equipped with Redball model 410 conservation spray-hoods was modified by obtaining two modified Redball 410 hoods and purchasing and installing three WeedSeeker automatic spot sprayer units (each with one spray nozzle) in each of the 28 in wide hoods. Thus, in a single pass through the field in no-till or minimum tillage plots, the weed-sensing, automatic spot spray system could be compared to conventional continuous spray technology in terms of the spray volume applied and weed control. Roundup Ready cotton varieties were planted at all experiment sites and weed control in all minimum tillage treatments was obtained using postemergence and layby (postemergence and preemergence) herbicide applications.

The data collected in 2002 and 2003 in Coolidge (Table 14), Marana (Table 18) and Maricopa (Table 21) found that the weed sensing, automatic spot spray system reduced the amount of spray volume and herbicide used between 4 and 99% depending on weed population densities and other conditions. Discarding the extremes, spray volume and herbicide use were reduced between 12 and 90% with most reductions falling between 50 to 75%. Little herbicide was saved by the WeedSeeker system at Coolidge in 2002 where cover-crop biomass was low (Table 1), the field had been fallow the previous 5 years, and the weed pressure was intense (i.e., high weed densities). The data from Maricopa in 2003 indicated the savings can be much greater as shown by a 99% reduction in herbicide use in the treatment with thick Solum cover crop residues that suppressed weed germination, or much less as shown by a 4% reduction in the late planted cotton in Maricopa if volunteer grain germinates after grain harvest (Table 21). Weed control was a significant challenge in the minimum tillage plots as shown by the lower weed control ratings for common purslane, horse purslane and pigweeds at Coolidge in 2002 (Table 15) and 2003 (Tables 16 and 17), by the poorer control of annual sowthistle in 2003 at Marana (Table 20), and by the poorer control of sprangletop, common purslane and horse purslane at Maricopa in 2003 (Table 23). Weed control ratings made after the layby herbicide applications at Coolidge (Table 17) or after mid-season and layby applications in Marana (Tables 19 and 20) and Maricopa (Tables 22 and 23) indicated that the weed control obtained with the weed sensing, automated spot-spray system was marginally acceptable for some weed species and good for other species.

Factors affecting the performance of the WeedSeeker automatic spot-spray system included setting of the sensitivity level of the computer controller, the size of the weeds sprayed (and therefore the timeliness of herbicide applications) and the presence of sparse barley cover crop residues. Another problem that was observed is that weeds partially obscured from herbicide sprays by crop residues were difficult to control and were relatively large at the time of the next herbicide application (and therefore more difficult to control). A larger calibration spray volume (GPA) and higher pressure may solve some of these problems by improving weed foliage spray coverage. The weed control data indicates that controlling weeds in conservation tillage systems remains a challenge and that additional research is needed to develop improved weed control strategies with the WeedSeeeker automatic spot-spray technology. The registrations of two new herbicides, trifloxysulfuron and flumioxazin for the 2004 cotton season may help in this regard.

References

Adu-Tutu KO, McCloskey WB, Husman SH, Clay P, Ottman M, Martin EC. 2003. Effects of reduced tillage and crop residues on cotton weed control, growth and yield. *In:* Silvertooth J, editor. Cotton. Tucson, AZ: College of Agriculture and Life Sciences, University of Arizona. Report nr P-134. p 235-250.

Tables and Figures

Table 1. Average biomass produced by barley cover crops in spring 2002 and 2003 in various experiments. Four sub-samples were collected in each plot in each treatment that included a cover crop.

Site	Year	Tillage/small grain system	Dry weight (lb/A)
Coolidge	2002	Minimum-till cotton, Solum barley cover-crop	2,126
	2003	Minimum-till cotton, Solum barley cover-crop	3,527
Maricopa	2003	No-till cotton, Solum barley cover-crop	16,646
Marana	2002	No-till cotton, Solum barley cover-crop	2,453
	2002	No-till cotton, Brittle stem barley cover-crop	2,767
	2003	No-till cotton, Solum barley cover crop	5,645

Table 2. Cotton emergence and establishment in the various tillage and barley cover/grain crop treatments at Coolidge, Goodyear, Marana and Maricopa. Stand counts were made in 10, 1-m long subplots in each plot; row spacing was approximately 40 inches. At Coolidge, the Yetter attachments were used on the grower's MaxEmerge planter in 2002 but not 2003. The grain crops at Goodyear were Poco barley harvested in 2002 and Orita wheat harvested in 2003. There were no operational differences between treatments at Goodyear in 2003 because the entire field was disked prior to planting grain in fall 2002 and was ripped, disked and laser-leveled prior to planting cotton in 2003.

Location	Grain/Tillage/Cotton System	Plants/meter of row	
		2002	2003
Coolidge	Solum barley cover crop, no-till cotton	9.7 a*	6.23 a
	Winter fallow/conventional tillage cotton	10.0 a	6.95 a
	Winter fallow/conventional tillage cotton with Telone	-	7.15 a
	LSD (P=0.05)	ns	ns
	CV (%)	10.5	13.32
Goodyear	Minimum-till grain crop, spring no-till cotton	12.0 a	12.6 a
	Minimum-till grain crop, spring minimum-till cotton	8.9 a	13.7 a
	LSD (P=0.05)	ns	ns
	CV (%)	10.0	10.1
Marana	Winter fallow, conventional tillage, early cotton planting	11.6 a	12.2 a
	Solum barley cover, no-till, early cotton planting	11.6 a	14.5 a
	Winter fallow, conventional tillage, late cotton planting	7.6 b	13.8 a
	Solum barley grain crop, no-till, late cotton planting	11.9 a	13.7 a
	LSD (P=0.05)	2.49	ns
	CV (%)	15.1	8.1
Maricopa	Winter fallow, conventional tillage early cotton planting	-	10.3 a
	Solum barley cover, no-till early cotton planting	-	9.6 a
	Winter fallow, conventional tillage late cotton planting	-	10.6 a
	Solum barley grain crop, no-till late cotton planting	-	10.3 a
	LSD (P=0.05)	-	ns
	CV (%)		6.19

*Values are means of 4 replications; means from the same location in the same 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 and CV=coefficient of variation.

Table 3. Average cotton plant heights and height-to-node ratios (H/N) measured in the cover-crop/cotton tillage systems at Coolidge in 2002 and 2003.

Tillage and cover-crop system	26 July 2002		21 August 2002		23 June 2003		25 July 2003	
	Height (in)*	H/N	Height (in)	H/N	Height (in)	H/N	Height (in)	H/N
Minimum-till, oats/barley cover	35.8 a	1.5 a	40.9 a	1.5 a	-	-	-	-
Minimum-till, barley cover-crop	36.2 a	1.6 a	42.3 a	1.6 a	23.6 a	1.3 a	41.4 a	1.6 a
Conventional tillage, winter fallow	31.6 b	1.4 a	35.6 b	1.4 b	23.7 a	1.3 a	40.5 a	1.6 a
Conventional tillage, Telone, winter fallow	-	-	-	-	24.8 a	1.3 a	37.9 a	1.5 a
LSD (0.05)	2.6	ns	3.3	0.1	Ns	ns	ns	ns
CV (%)	5.1	4.3	5.6	4.0	7.2	4.9	4.9	5.7

*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 and CV=coefficient of variation.

Table 4. Average cotton plant heights and height-to-node ratios (H/N) measured in the tillage systems at Goodyear in 2002 and 2003 in a cotton-small grain double crop rotation. Due to the ripping, disking, and laser leveling of the entire field in fall 2002 prior to planting the grain crops, there were no operational differences between treatments until the spring.

Tillage System	5 August 2002		10 September 2002		6 October 2003	
	Height (in)	H/N	Height (in)	H/N	Height (in)	H/N
Fall minimum-till, Spring no-till	37.6 a	1.7 a	43.9 a	1.7 a	37.1 a	1.3 a
Fall minimum-till, Spring minimum-till	34.3 b	1.5 b	41.4 b	1.5 b	38.7 a	1.3 a
LSD (P=0.05)	1.4	0.1	1.9	0.1	ns	ns
CV (%)	2.1	3.5	2.5	3.2	2.0	0.1

*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 and CV=coefficient of variation.

Table 5. Average cotton plant heights and height-to-node ratios (H/N) measured in the various Solum barley small grains, cotton/tillage double crop systems at the Marana Agricultural Center in 2002 and 2003. Cotton was planted into the barley cover-crop and grain stubble without preplant-tillage.

Grain/Tillage/Cotton System	22 July 2002		13 August 2002		11 July 2003		29 July 2003	
	Height (in)*	H/N	Height (in)	H/N	Height (in)	H/N	Height (in)	H/N
Conventional tillage, winter fallow, early cotton planting	37.6 b	1.6 a	39.9 a	1.6 a	28.3 b	1.46 b	30.0 b	1.4 c
Minimum-tillage, barley cover-crop, early cotton planting	40.7 a	1.7 a	42.4 a	1.6 a	31.6 a	1.5 ab	37.3 a	1.5 b
Conventional tillage, winter fallow, late cotton planting	30.8 b	1.5 a	40.8 a	1.6 a	24.0 c	1.6 a	33.5 b	1.7 a
Minimum-tillage, Barley grain crop, late cotton planting	30.1 b	1.4 a	40.1 a	1.6 a	21.7 d	1.5 ab	29.8 c	1.5 b
LSD (0.05)	3.3	ns	ns	ns	2.0	0.13	2.8	0.11
CV(%)	3.9	8.0	7.4	5.1	4.8	5.27	5.2	4.5

*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 and CV=coefficient of variation.

Table 6. Average cotton plant heights and height-to-node ratios (H/N) measured in the various Solum barley small grains, cotton/tillage double crop systems at the Maricopa Agricultural Center in 2003. Cotton was planted into the barley cover-crop and grain stubble without preplant-tillage.

Grain/Tillage/Cotton System	10 July 2003		24 July 2003	
	Height (in)	H/N	Height (in)	H/N
Conventional tillage, winter fallow, early cotton planting	28.1 a*	1.4 a	31.2 a	1.4 a
Minimum tillage, barley cover crop, early cotton planting	27.8 a	1.4 a	31.7 a	1.5 a
Conventional tillage, winter fallow, late cotton planting	22.3 b	1.4 a	29.7 b	1.5 a
Minimum tillage, barley grain crop, late cotton planting,	20.4 b	1.4 a	26.1 b	1.4 a
LSD (0.05)	1.9	ns	2.6	ns
CV(%)	4.8	5.6	5.4	1.4

*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 and CV=coefficient of variation.

Table 7. Cotton yields measured in different cotton-cover crop/tillage systems at Coolidge in 2002 and 2003. Cotton cultivar DeltaPine 422 BR was dry-planted at rate of 50,000 seed/A using a six-row, John Deere MaxEmerge II planter on 19 April 2002. Cotton variety DP 449 BR was planted at an 11 lb/A seeding rate with a six-row John Deere 7300 MaxEmerge II planter on 31 March 2003. Cotton was harvested on 28 October 2002 and 3 October 2003 with a John Deere 9976 six-row picker, and the seed-cotton was weighed in a Caldwell Boll Buggy (EL Caldwell and Sons, Inc.) equipped with a Weigh-Tronix scale (Model WI-152).

Tillage/Cover Crop System	Cotton Lint Yield (lb/A)	
	2002	2003
Minimum tillage, oats/volunteer barley cover crop	1007 a*	-
Minimum tillage, barley cover crop	1089 a	1178 b
Conventional tillage, winter fallow	880 b	1539 a
Conventional tillage with Telone, winter fallow	-	1622 a
LSD (0.05)	119	320
CV (%)	8.2	12.8

*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 and CV=coefficient of variation.

Table 8. Cotton yields measured in the various tillage systems at Goodyear in 2002 and 2003. Cotton variety DP451BR was planted on 20 May 2002 at 18 lb seed/A using a six-row John Deere 7300 MaxEmerge II planter and the same variety was planted on 13 June 2003 at 11.6 lb seed/A with the same planter. The treatments were harvested using equipment similar to that used in Coolidge in December 2002 and January 2004.

Tillage System	Cotton Lint Yield (lb/A)	
	2002	2003
Fall minimum tillage, spring no-till	971 a*	551 a
Fall minimum tillage, spring minimum tillage	940 a	485 a
LSD (0.05)	ns	ns
CV (%)	5.0	10.6

*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 yields measured in the various Solum barley, cotton and tillage double-crop systems at the Marana Agricultural Center in 2002 and 2003. Cotton variety DeltaPine 449 BR was dry-planted at a 10.8 lb/A seeding rate in early cotton planting treatments on 23 April 2003. DeltaPine 458 BR was planted at a 10.8 lb/A seeding rate in the late cotton planting treatments on 21 May 2003. Both conventional tillage early and late plant cotton treatments were planted with a standard John Deere 7100 MaxEmerge four-row planter. Yetter Farm Equipment 2960/2976 coulter/residue manager assemblies were bolted to each planter unit and 200-lb weights were added to each planter unit to no-till plant the cotton in the minimum tillage treatments. The experiment was harvested on 30 October 2003 using John Deere 9910 and 9930 2-row pickers. The seed-cotton was weighed in a Caldwell Boll Buggy (E.L. Caldwell and Sons, Inc.) equipped with a Weigh-Tronix scale (model WI-152).

Grain/Tillage/Cotton System	Cotton Lint Yield (lb/A)	
	2002	2003
Conventional tillage, winter fallow, early cotton planting	1140 a*	1129 a
Minimum tillage, barley cover crop, early cotton planting	1089 ab	946 a
Conventional tillage, winter fallow, late cotton planting	827 c	1080 a
Minimum tillage, barley grain crop, late cotton planting	927 bc	968 a
LSD (0.05)	163	ns
CV (%)	10.2	12.2

*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 and CV=coefficient of variation.

Table 10. Cotton yields in measured in the various Solum barley, cotton and tillage double-crop systems at the Maricopa Agricultural Center in 2003. Cotton variety DeltaPine 449 BR was planted in the early cotton planting treatments at 11.8 lb/A on 21 April 2003 and cotton variety DP 458 BR was planted in the late cotton planting treatments at 10.8 lb/A on 20 May 2003. The conventional tillage treatments were planted with a standard four-row John Deere 7100 MaxEmerge planter. Yetter Farm Equipment 2960/2976 coulter/residue manager assemblies and 200-lb weights were attached to the planter units to plant cotton in the minimum tillage treatments without tillage. The eight center rows of each plot were picked with a Case IH 2155 four-row picker on 22 October 2003 and the seed-cotton was weighed as in the Marana experiment.

Grain/Tillage/Cotton System	2003 Cotton Lint Yield (lb/A)
Conventional tillage, winter fallow, early cotton planting	1141 a*
Minimum tillage, barley cover-crop, early cotton planting	956 b
Conventional tillage, winter fallow, late cotton planting	856 bc
Minimum tillage, barley grain crop, late cotton planting	759 c
LSD (0.05)	163
CV (%)	9.2

*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 and CV=coefficient of variation.

Table 11. Cereal biomass measured in four locations per plot and Solum barley grain yields at Maricopa in 2003. Beardless barley and Cayuse oat cover crops were planted at a 100 lb/A seeding rate and the Solum barley grain crop was planted at a 25 lb/A seeding rate. Cover crop biomass was measured from 0.25 m^2 sub-samples per plot. The Beardless barley and Cayuse oat cover crop samples were green-chopped on 25 April 2003 and oven-dried at 150 F prior weighing. The Solum barley biomass samples were collected from four 1.24 m^2 sub-sample areas immediately prior to grain harvest on 21 May 2003 (the biomass was dry at time of sampling).

Cereal	Dry weight (kg/m^2)	Dry weight (kg/m^2)	Grain yield (lb/A)
Beardless barley cover crop*	5.83 a*	-	-
Cayuse oat cover crop*	6.22 a	-	-
Solum barley grain crop, straw baled, height of stubble 5 inches	-	0.35 a	1,344 a
Solum barley grain crop, cut low, height of stubble 5 inches	-	0.37 a	1,475 a
Solum barley grain crop, cut medium height, stubble 9 to 10 inches tall	-	0.30 a	1,324 a
Solum barley grain crop, cut high, stubble 17 to 18 inches tall	-	0.38 a	1,316 a
LSD (P=0.05)	ns	ns	ns
CV (%)	16.9	37.5	11.7

*Values in the same 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; CV = coefficient of variation.

Table 12. Cotton emergence and establishment, plant heights and height-to-node ratios (H/N) measured on 10 July 2003 in various cereal/tillage systems at Maricopa in 2003.

Cereal/tillage system	Plants/m of row	Plant height (in)	H/N
Winter fallow, conventional tillage cotton	11.0 a*	21.5 a	1.3 a
Beardless barley cover crop, no-till cotton	10.0 a	23.1 a	1.4 a
Cayuse oat cover crop, no-till cotton	9.6 a	23.0 a	1.4 a
Solum barley grain crop, straw baled, stubble 5 inches tall, no-till cotton	9.5 a	21.4 a	1.3 a
Solum barley grain crop, stubble 5 inches tall, no-till cotton	9.0 a	21.2 a	1.3 a
Solum barley grain crop, stubble 9 to 10 inches tall, no-till cotton	10.2 a	22.2 a	1.4 a
Solum barley grain crop, stubble 17 to 18 inches tall, no-till cotton	9.3 a	22.3 a	1.4 a
LSD (P=0.05)	ns	ns	ns
CV (%)	9.3	1.5	5.3

*Values are means of 10 observations; values in the same 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; CV = coefficient of variation.

Table 13. Cotton yields in the various cereal/tillage systems in the straw management study at Maricopa in 2003. Cotton variety DP458BR was planted at 10.8 lb/A using a four-row John Deere 7100 MaxEmerge planter on 20 May 2003 and harvested on 22 October 2003 (see Table 10 for details).

Cereal/tillage	Seed cotton (lb/A)	Lint (lb/A)
Winter fallow, conventional tillage cotton	3221 a*	1367 a
Beardless barley cover crop, no-till cotton	3416 a	1418 a
Cayuse oat cover crop, no-till cotton	3437 a	1452 a
Solum barley grain crop, straw baled, stubble 5 inches tall, no-till cotton	3280 a	1357 a
Solum barley grain crop, stubble 5 inches tall, no-till cotton	3306 a	1434 a
Solum barley grain crop, stubble 9 to 10 inches tall, no-till cotton	3471 a	1469 a
Solum barley grain crop, stubble 17 to 18 inches tall, no-till cotton	3236 a	1396 a
LSD (P=0.05)	ns	ns
CV (%)	8.4	8.7

*Values are means of four replications; means in the same 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; CV = coefficient of variation.

Table 14. Herbicide spray volumes in gallons per acre (GPA) applied by NTech Industries WeedSeeker weed-sensing, automatic spot spray technology versus conventional continuous flat fan spray nozzles at Coolidge in 2002 and 2003.

Tillage/cover crop system	Sprayer technology	Spray volume (GPA)			
		6/20/02	7/16/02	5/30/03	6/16/03
Minimum tillage, oat & 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	19.6 a	20.2 a
	Weed sensing	24.8 a	20.6 b	7.6 b	10.0 b
	LSD (P=0.05)	ns	1.4	2.8	3.6
	CV (%)	21.2	4.6	9.2	10.5

*Values are means of 5 replications (2002) or 4 replications (2003); 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 and CV=coefficient of variation.

Table 15. Percent control of horse purslane and common purslane in minimum-tillage and conventional tillage cotton treatments at Coolidge following application of a layby herbicides in 2002 and following an early-season topical herbicide in 2003.

Cover crop treatment	Percent weed control		
	7/30/02*	7/30/02*	5/07/03**
	Horse purslane	Common purslane	Common purslane
Minimum tillage, oat cover	73 b***	41 b	-
Minimum tillage, barley cover	77 b	37 b	79 b
Conventional tillage	87 a	79 a	92 a
Conventional tillage with Telone	-	-	91 a
LSD (P=0.05)	7	6.	8.8
CV (%)	7.5	11.4	5.8

* All herbicide treatments contained Roundup UltraMax @ 52 oz/A + AMS @ 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 24 oz/A + Prometryne 24oz/A was made in all treatments on 29 July 2002.

**Weed control following topical Roundup UltraMax (32 oz/A in the conventional tillage treatment and 40 oz/A plus AMS in the minimum tillage treatment) applied on 30 May. A pre-plant application of pendimethalin (Prowl 3.3 EC @ 48oz/A) was made in the conventional tillage treatments on 25 March 2003, and in the minimum tillage treatment on 31 March 2003. The minimum tillage plots were tilled with a Sundance disk/bedder on 31 March 2003 and again on 8 April 2003.

*** Means in a column 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 and CV=coefficient of variation.

Table 16. Percent weed control at Coolidge assessed on 13 June 2003 following herbicide applications on 30 May 2003 (see Table 14) with the Redball 410 Conservation tillage hoods equipped with either conventional continuous spray nozzles or weed sensing, automatic spot spray nozzles*. All data are from the Solum barley cover-crop, minimum tillage cotton treatment.

Spray system type	Common purslane	Horse purslane	Prostrate amaranth	Palmer amaranth	Puncture-vine
Continuous spray	88 a*	94 a	99 a	100 a	94 a
Weed-sensing spot sprayer	58 b	52 b	64 b	70 b	89 a
LSD (P=0.05)	26	14	11	23	ns
CV (%)	9.6	8.3	6.2	12.2	5.5

*In the minimum tillage plots, glyphosate (Roundup UltraMax @ 26 oz/A) + AMS @ 2% w/w was applied post-directed to the base of the cotton plants while simultaneously applying glyphosate (Roundup UltraMax @ 52 oz/A) + AMS @ 2% w/w under the hoods of the RedBall 410 Conservation Tillage hoods. The conventional tillage plots were treated with glyphosate (Roundup Ultramax @ 24 oz/A) + pyrithiobac sodium (Staple @ 1.9 oz/A) using the grower's RedBall 420 layby sprayer (weed control data not shown but see Table 17 below).

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

Table 17. Percent weed control at Coolidge assessed on 2 July 2003 and 16 July 2003 following herbicide applications on 16 June 2003 (see Table 14) with the Redball 410 Conservation tillage hoods equipped with either conventional continuous spray nozzles or weed sensing, automatic spot spray nozzles. Data are from both the conventional and minimum tillage treatments**.

Tillage/Cotton system	Spray system	Common purslane		Horse purslane		Pigweeds
		7/2/03	7/16/03	7/2/03	7/16/03	7/16/03
Winter fallow, conventional tillage	Continuous	100 a*	95 a	100 a	94 a	95 a
Winter fallow, Telone, conventional tillage	Continuous	100 a	96 a	100 a	96 a	98 a
Solum barley cover crop, minimum tillage	Continuous	99 a	95 a	99 a	94 a	100 a
Solum barley cover crop, minimum tillage	Weed sensing	86 b	74 b	91 b	70 b	88 b
LSD (P=0.05)		2.7	7.0	2.1	6.0	ns
CV (%)		1.7	4.9	1.3	4.2	8.9

*Glyphosate (Roundup UltraMax @ 52 oz/A) + carfentrazone ethyl (Aim @ 0.8 oz/A) + AMS @ 1% w/w was applied under Redball 410 conservation tillage hoods with or without weed-sensing units, while glyphosate (Roundup UltraMax @ 26 oz/A) + AMS @ 1% w/w was directed to the base of the cotton plants in the reduced tillage treatment on 16 June, 2003. The conventional tillage plots were treated with prometryn (Prometryne 4F @ 25 oz/A) + pendimethalin (Prowl 3.3 EC @ 32 oz/A) under Redball 420 hoods on 26 June, 2003. In addition to the herbicide treatments, the conventional tillage plots were cultivated twice in April and once in May.

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

Table 18. 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 in gallons per acre (GPA) at the Marana Agricultural Station in 2002 and 2003.

Tillage/grain/cotton treatment	Sprayer technology	Spray volume (GPA)		
		7/27/02	6/02/03	7/03/03
Minimum tillage, Solum barley cover crop, early cotton	Continuous	20.4 a*	20.3 a	25.0 a
	Weed sensing	4.3 b	10.7 b	11.8 b
Minimum tillage, brittle stem barley cover crop, early cotton	Continuous	19.9 a	-	-
	Weed Sensing	5.1 b	-	-
Minimum tillage, Solum grain crop, late cotton	Continuous	24.4 a	-	-
	Weed sensing	2.3 b	-	-
LSD (P=0.05)		4.0	5.9	2.0
CV (%)		20	17	4.8

*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 and CV=coefficient of variation.

Table 19. Percent weed control at the Marana Agricultural Center in 2003 following herbicide applications*.

Grain/tillage/cotton system	Ivyleaf morningglory		Annual sowthistle	
	6/19/03	9/03/03	6/19/03	9/03/03
Solum barley cover crop, minimum tillage, early cotton planting	68 b**	88 a	57 c	100 a
Solum barley grain crop, minimum tillage, late cotton planting	97 a	93 a	88 b	100 a
Winter fallow, conventional tillage, early cotton planting	95 a	76 a	100 a	100 a
Winter fallow, conventional tillage, late cotton planting	100 a	71 a	100 a	100 a
LSD (P=0.05)	9.8	ns	6.3	ns
CV (%)	6.8	12.5	4.6	0

*Weed control in the no-till treatments was obtained only with postemergence, glyphosate-based herbicide programs. However, in the conventional tillage treatments, a pre-plant application of pendimethalin (Prowl 3.3 EC @ 1.75 qt/A) + prometryn (Prometryne 4F @ 1.75 qt/A) was combined with postemergence glyphosate-based herbicide applications, hand-weeding in some plots and two cultivation operations to provide weed control. After missing the window to make the initial topical, broadcast application of glyphosate, we made a post-directed application on 2 June, 2003 in the early plant no-till treatment. It consisted of glyphosate (Roundup UltraMax @ 26 oz/A) + AMS @ 1% w/w directed to the base of the cotton plants and glyphosate (Roundup UltraMax @ 52 oz/A) + carfentrazone-ethyl (Aim @ 0.008 lb ai/A) + AMS @ 2% w/w applied under RedBall 410 Conservation Tillage spray hoods equipped with three 95 degree even flat fan nozzles. Two of the spray hoods were modified by installing three WeedSeeker weed-sensing intermittent spray units (NTech Industries, Inc.), each with a single even 6503 flat fan nozzle, in each hood to detect and automatically spot-treat weeds in the furrows. On 10 June 2003, a topical, broadcast application of glyphosate (Roundup UltraMax 2 40 oz/A) + AMS @ 2% w/w was made in the late planted cotton. On 3 July 2003, glyphosate (Touchdown @ 0.75 lb ai/A) + carfentrazone-ethyl (Aim @ 0.016 lb ai/A) + AMS @ 2% w/w was applied under the RedBall Conservation Tillage 410 hoods (as described above) and simultaneously glyphosate (Touchdown @ 0.75 lb ai/A) + prometryn (Prometryne 4F @ 0.5 lb ai/A) + AMS @ 2% w/w was sprayed at the base of the cotton plants in the early planted no-till treatment. A similar application was made in the no-till, late planted cotton treatment on 6 July 2003. A layby application of glyphosate (Touchdown @ 0.75 lb ai/A) + carfentrazone-ethyl (Aim @ 0.016 lb ai/A) + prometryn (Prometryne 4F @ 1.2 lb ai/A) + AMS @ 1% w/w + Herbimax @ 1% v/v was made on 5 August 2003 in all treatments, both early and late plant cotton, using a RedBall 420 layby sprayer.

**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 and CV=coefficient of variation.

Table 20. Percent weed control at Marana assessed on 17 July 2003 following herbicide applications on 3 and 6 July 2003 (see herbicide application details in table 19).

Cover or grain crop/cotton system/Spray technology	Sprangle-top	Morning-glory	Volunteer barley	Russian thistle	Sow-thistle
Cover or grain crop/cotton system (averaged across spray technology types)					
Solum barley cover crop, Minimum-till early plant cotton	100 a*	98 a	100 a	100 a	96 a
Solum barley grain crop, Minimum-till late plant cotton	84 b	94 a	88 b	79 b	85 b
LSD (P=0.05)	5.7	ns	4.4	11.4	3.2
CV (%)	5.5	4.9	4.2	11.2	3.1
Spray type (averaged across cover or grain crop treatments in no-till cotton systems)					
Continuous spray	94 a	98 a	95 a	90 a	94 a
Weed-sensing technology	89 a	95 a	93 a	89 a	88 b
LSD (P=0.05)	ns	ns	ns	ns	3.2
CV (%)	5.5	4.9	4.2	11.2	3.1

*Values are means of four replications; means in a column within the same cover or grain crop/cotton system or spray type section followed by the same letter are not different at P=0.05 according to the Ryan-Einot-Gabriel-Welsch Range test; LSD = least significance difference, CV = coefficient of variation.

Table 21. 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 Maricopa Agricultural Station, 2003.

Tillage/grain/cotton treatment	Sprayer technology	Spray volume (GPA)	
		6/11/03	7/08/03
Minimum tillage, Solum barley cover crop, early cotton planting	Continuous	27.0 a*	-
	Weed sensing	0.3 b	-
Minimum tillage, Solum grain crop, late cotton planting	Continuous	-	27.3 a
	Weed sensing	-	25.4 a
LSD (P=0.05)		7.3	ns
CV (%)		23.84	4.91

*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 22. Percent weed control at the Maricopa Agricultural Center in 2003*.

Grain/tillage/cotton system	9 June 2003		26 August 2003	
	Common purslane	Volunteer barley	Common purslane	Volunteer barley
Solum barley cover crop, minimum-till, early cotton planting	100 a**	74 b	100 a	100 a
Solum barley grain crop, minimum-till, late cotton planting	96 b	99 a	100 a	99 a
Winter fallow, conventional tillage, early cotton planting	-	-	96 a	99 a
Winter fallow, conventional tillage, late cotton planting	-	-	99 a	98 a
LSD (P=0.05)	2.8	ns	ns	ns
CV (%)	1.2	1.8	2.5	2.0

*Only postemergence, glyphosate-based herbicide applications were used for weed control in the no-till plots. In contrast, a pre-plant, incorporated application of Prowl 3.3 EC at 2 pt/A was made in addition to postemergence, glyphosate-based herbicide applications and three cultivations to provide weed control in the conventional tillage treatments. A topical, broadcast application of glyphosate (Roundup UltraMax @ 26 oz/A) + AMS @ 1% w/w was made in both early planted cotton treatments on 23 May 2003. A post-directed application of glyphosate (Touchdown @ 0.75 lb ai/A) + prometryn (Caparol @ 0.5 lb ai/A) + AMS @ 1% w/w was directed to the base of the cotton plants, and simultaneously, glyphosate (Touchdown @ 0.75 lb ai/A) + carfentrazone-ethyl (Aim @ 0.016 lb ai/A) + AMS @ 1% w/w was applied under RedBall 410 Conservation Tillage spray hoods (as in the Marana experiment) in the no-till, early planted cotton treatment on 11 June 2003. Also on 11 June 2003, glyphosate (Touchdown @ 0.75 lb ai/A) + prometryn (Caparol @ 0.5 lb ai/A) + AMS @ 1% w/w was post-directed to the base of the cotton plants in the conventional tillage, early planted cotton treatment. In addition, on 11 June 2003, a topical, broadcast application of glyphosate (Roundup UltraMax @ 40 oz/A) + AMS @ 1% w/w was made in both late planted cotton treatments. The post-directed and under the hood applications made in the early planted cotton treatments on 11 June 2003 were repeated in the late planteded cotton treatments on 8 July 2003. On 25 July 2003, a layby application of glyphosate (Touchdown @ 0.75 lb ai/A) + prometryn (Caparol @ 1.2 lb ai/A) + AMS @ 2% w/w was applied to base of the cotton plants and simultaneously glyphosate (Touchdown @ 0.75 lb ai/A) + carfentrazone-ethyl (Aim @ 0.016 lb ai/A) + prometryn (Caparol @ 1.2 lb ai/A) + AMS @ 2% w/w was applied under RedBall 410 Conservation Tillage spray hoods in the no-till, early planted cotton treatment. Glyphosate (Touchdown @ 0.75 lb ai/A) + prometryn (Caparol @ 1.2 lb ai/A) + AMS @ 2% w/w was applied to base of the cotton plants in the conventional tillage, early planted cotton treatments. The layby herbicide applications were repeated in both late planted cotton treatments on 7 August 2003.

**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 and CV=coefficient of variation.

Table 23. Percent weed control at Maricopa assessed on 21 July 2003 following the 11 June (early planted cotton) and 8 July 2003 (late planted cotton) post-directed/hooded herbicide spray applications (see Table 22 for herbicide application information).

Cover or grain crop/cotton system/Spray technology	Volunteer barley	Skeleton weed	Common purslane	Sprangletop	Horse purslane
Cover or grain crop/cotton system (average across spray technology types)					
Solum barley cover crop, minimum-till, early plant cotton	97 a*	99 a	96 a	95 a	98 a
Solum barley grain crop, minimum-till, late plant cotton	96 a	96 b	79 b	82 b	91 b
LSD (P=0.05)	ns	3.0	6.4	4.1	4.7
CV (%)	2.5	2.7	6.5	4.1	4.4
Spray type (averaged across cover or grain crop/cotton systems)					
Continuous spray	97 a	98 a	90 a	91 a	95 a
Weed-sensing unit	96 a	98 a	85 a	86 b	94 a
LSD (P=0.05)	ns	ns	ns	4.1	ns
CV (%)	2.5	2.7	6.5	4.1	4.4

*Values are means of four replications; means in a column within the same cover or grain crop/cotton system or spray type section followed by the same letter are not different at P=0.05 according to the Ryan-Einot-Gabriel-Welsch Range test; LSD = least significance difference, CV = coefficient of variation.