Weed Management and Agronomic Performance of a Cotton-Barley Double Crop Rotation

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Abstract

The tillage operations required to grow an annual barley and cotton 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. A light activated, weed sensing automatic spot-spray system reduced the amount of spray volume and herbicide used by 40% to 60% at Marana and 36% to 56% at Maricopa in 2004. At Maricopa, a large number of volunteer cotton plants in the furrows of early planted no-till cotton reduced the spray volume savings from using the weed sensing automatic spot-spray system. Weed control was similar with the weed sensing, automatic spot-spray system compared to the conventional continuous spray system for most weed species but weeds with narrow leaf, upright leaf canopies such as sprangletop, barley and skeleton weed were more difficult to detect and control. In both Marana and Maricopa, there were yield differences between treatments related to planting date, with late-planted cotton yielding less than early-planted cotton. At Marana, the early-planted conventional tillage cotton out-yielded the barley cover crop, early-planted no-till cotton treatment. At Maricopa, there were no yield differences between the two early planted cotton treatments; however, the late-planted conventionally tilled cotton yielded 28% more than the late-planted no-till cotton. Although the yield comparisons are not yet definitive, it appears that in some situations no-till cotton may yield less than conventionally tilled cotton. At Maricopa, the height of cereal crop stubble did not affect subsequent cotton establishment, field populations, plant height or lint production (2003 and 2004) and the position or node of the first fruiting branch and the first retained boll were similarly unaffected in 2004.

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). Cotton farmers, including Arizona farmers, have traditionally used many forms of mechanical soil disturbance and pre-emergence herbicides to prepare fields for cotton planting (Bryson and Keeley, 1992). 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 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. After cotton harvest, considerable tillage is conducted to comply with Arizona statutes related to pink bollworm (*Pectinophora gossipiella*, Sanders) but recent regulatory changes have allowed for a reduction in tillage when a small grain crop is planted following cotton and irrigated in December. Previous University of Arizona research found that the number of tillage passes across cotton fields can be significantly reduced using a cotton-barley double crop-permanent bed system and no-till planting equipment (Adu-Tutu et al., 2004) thereby saving money on fuel and labor without reducing economic returns to growers..

Postemergence herbicides are generally applied either broadcast or in bands to entire cotton fields regardless of whether or not weeds are uniformly present. 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. When steel (i.e., cultivation) was no longer used for weed control there was a greater reliance on herbicides in conservation tillage systems compared to conventional tillage 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 Roundup spray applied was reduced 63-85% by using weed-sensing, automatic spray technology in conventional cotton. 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.

This report presents the results of fall 2003 to fall 2004 research conducted at the Maricopa and Marana University of Arizona experiment stations to evaluate the use of conservation tillage practices in annual barley and cotton double-crop rotations and to evaluate the performance of a weed sensing, automatic spot sprayer in conservation tillage systems.

Materials and Methods

Two field experiments, one initiated in October 2001 at the University of Arizona Marana Agricultural Center and one initiated in December 2002 at the University of Arizona Maricopa Agricultural Center were continued through the 2004 cotton harvest. Treatments were the same at both experiment stations, and were: (1) winter fallow, conventionally tilled cotton planted in April (early planting); (2) winter fallow, conventionally tilled cotton planted in late May (late planting); (3) a Solum barley cover crop followed by no-till cotton planted in April (early planting); and (4) a Solum barley grain crop followed by no-till cotton planted in May (late planting). In addition, a straw management study, which was initiated at the Maricopa Agricultural Center in 2002, was continued in 2003-2004. Cotton was planted using no-till equipment into the various straw management treatments which included: (1) a Beardless barley cover crop; (2) a Cayuse oat cover crop (3) a Solum barley grain crop where the straw was baled, (4) a Solum barley grain crop that was cut low (stem stubble 5 inches tall from bed top) (5) a Solum barley grain crop cut at a medium height (stems 9 to 10 inches tall); and (6) a Solum barley grain crop cut high (stems 17 to 18 inches tall) cotton and these treatments were compared to a winter fallow, conventional tillage cotton treatment.

Marana Barley Cover and Grain Crops: After the stems of the previous cotton crop were shredded about 6 in above the ground, Solum barley was planted on the existing beds using a 10-ft wide John Deere 1560 no-till grain drill at a seeding rate of 51 lb/A on 9 December 2003 and irrigated to germinate the seed. The barley cover and grain crops received an additional irrigation on 11 December 2003 that included 50 lb of nitrogen/A (UAN32) and the grain crop received a final irrigation on 19 March 2004. The barley cover crop was killed by applying 1.17 lb ae glyphosate/A (40 oz of Roundup UltraMax/A) plus 2% w/w AMS (ammonium sulfate) on 26 March 2004 using a tractor mounted 20 ft. boom sprayer. The barley grain crop was harvested with a grain combine (Gleaners Baldwin Allis Chalmers) on 14 May 2004 and plot weights were measured in a weigh wagon equipped with load cells and a Weightronix electronic scale.

Marana Cotton Crop: The conventional tillage treatments were disked, ripped twice with a chisel plow, disked a second time, listed to form beds, and mechanically mulched before cotton was planted in the spring of 2004. The conventionally tilled early planted treatment was pre-irrigated before mulching the bed and planting cotton in contrast to the other treatments where cotton seed was planted in dry soil and irrigated to germinate the seed. Cotton cultivar DeltaPine 449 BR was planted at seeding rate of 14 lb/A in the early planted treatments on 16 April 2004 and cotton cultivar DeltaPine 451 BR was planted at seeding rate of 11 lb/A on 14 May 2004 in the late planted treatments. A 4-row, John Deere 7100 MaxEmerge planter was used in the conventional tillage plots for both early and late plantings. Yetter Farm Equipment 2960/2976 coulter-residue manager assemblies were bolted to each planter unit for planting in 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 coulter-residue manager-planter units into the dry stale beds. Thus, it was necessary to add 200 lb to each planter unit to accomplish satisfactory soil penetration and placement of the cotton seed. The cotton crop was grown using standard irrigation and fertilization practices. Plant populations were counted and plant height and number of mainstem nodes were determined periodically during the season. The treatments were harvested on 30 October 2004 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 Weightronix scale (model WI-152) and ginned with a 25-saw gin.

Marana Cotton Weed Control: Weed control in 2004 in all conventional tillage treatments was obtained using a preplant incorporated application of pendimethalin @ 1.44 lb ai/A (Prowl 3.3 EC @ 1.75 qt/A) + prometryn @ 1.75 lb ai/A (CottonPro 4F @ 1.75 pt/A) and post-emergence glyphosate-based herbicide applications. In the no-till treatments, only post-emergence glyphosate-based herbicide applications were used. A topical, broadcast application of glyphosate @ 1.125 lb ae/A (Roundup WeatherMax @ 32 oz/A) + AMS @ 1% w/w was made on 10 May 2004 in the early planted treatments. On 6 July 2004, a post-directed application of glyphosate @ 0.77 lb ae/A (Roundup WeatherMax @ 22 oz/A) + AMS @ 1% w/w was directed to the base of cotton plants in all four treatments using nozzles mounted on the outside, rear corners of RedBall 410 conservation tillage spray hoods. During the same spray operation, glyphosate @ 0.77 lb ae/A (Roundup WeatherMax @ 22 oz/A) + AMS @ 1% w/w was applied in the late-planted no-till cotton treatment under 28 inch and 20 inch RedBall 410 Conservation Tillage spray hoods equipped with three or two 95 degree even flat fan nozzles, respectively. Similarly, glyphosate @ 0.77 lb ae/A (Roundup WeatherMax @ 22 oz/A) + carfentrazone-ethyl @ 0.0156 lb ai/A (Aim @ 1 oz/A) + AMS @ 1% w/w was applied in the early-planted, no-till cotton treatment under the RedBall hoods. Two of the 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 detect and automatically spot-treat weeds in the furrows. Thus, in a single pass through the field in no-till plots, the weed-sensing, automatic spot spray system could be compared to conventional continuous spray technology. A layby application of carfentrazone-ethyl @ 0.03 lb ai/A (Aim @ 2 oz/A) + prometryn @ 1.75 lb ai/A (CottonPro 4F @ 1.75 pts/A) was made in all four treatments on 27 July 2004 using a Redball 420 layby sprayer.

Maricopa Barley Cover and Grain Crops: Solum barley was planted on 8 December 2004 into shredded cotton stalks at a seeding rate of 51 lb/A using the John Deere 1560 no-till grain drill and irrigated. The grain and cover crops were irrigated and fertilized with UAN-32 (53.18 lb nitrogen/A) on 19 February 2004. The barley cover crop was killed using 1.15 lb ae glyphosate/A (40 oz/A of Roundup UltraMax) plus 2% AMS applied on 15 March 2004 as described above. The barley grain crop received additional irrigations on 19 March 2004 and 9 April 2004 and was fertilized a second time with UAN-32 (53.18 lb nitrogen/A) during the April irrigation. The grain crop at Maricopa was harvested with a Case International Harvester 1440 on 3 May 2004 and weighed as described for the Marana experiment.

Maricopa Cotton Crop: Shredded cotton stalks in conventionally tilled plots were root-pulled and plots were disked twice; beds were listed, mulched, shaped and a cultipacker was run over the beds before planting cotton. Cotton cultivar DeltaPine 449 BR was planted in the early-planted conventional tillage (10.9 lb/A) and the early-planted no-till (14 lb/A) treatments on 9 April 2004. Cotton cultivar DP 449 BR was planted in the late-planted conventional tillage and the late-planted no-till cotton treatments at a 14 lb/A seeding rate on 4 May 2004. The conventional tillage treatments were planted with a standard John Deere 7100 4-row planter. Yetter Farm Equipment 2960/2976 coulter-residue manager assemblies and additional 100-lb weights were attached to the planter units to plant cotton in the no-till treatments. In all treatments, cotton seed was planted into dry soil and the plots were irrigated to germinate the seed. The cotton crop was grown using standard irrigation and fertilization practices. Plant populations were counted and plant height and number of mainstem nodes were determined periodically during the season. The experiment was harvested on 20 October 2004. The eight center rows of each plot were picked with a Case IH 2155 4-row cotton picker. The seed-cotton was weighed and ginned as described for the Marana experiment.

Maricopa Cotton Weed Control: A pre-plant application of pendimethalin @ 0.825 lb ai/A (Prowl 3.3 EC @ 2 pt/A), one post-emergence glyphosate herbicide application and one cultivation were used for weed control in the conventional tillage treatments. In contrast, only post-emergence, glyphosate applications were made in the no-till cotton plots. Glyphosate @ 0.77 lb ae/A (Roundup WeatherMax @ 22 oz/A) + 1% w/w AMS were applied topically in the early planted cotton treatments on 4 May 2004. On 24 June 2004, a post-directed application of glyphosate @ 0.77 lb ae/A (Roundup WeatherMax @ 22 oz/A) + 1% w/w AMS was directed to the base of cotton plants, and simultaneously glyphosate @ 1.125 lb ae/A (Roundup WeatherMax @ 32 oz/A) + 1% w/w AMS was sprayed under Redball 410 Conservation Tillage spray hoods in the early-planted no-till cotton treatment as described for Marana. On the same date, glyphosate @ 0.77 lb ae/A (Roundup WeatherMax @ 22 oz/A) + 1% w/w

AMS was directed to the base of cotton plants in the early-planted conventional tillage cotton treatment. On 25 May 2004, a topical, broadcast application of glyphosate @ 1.125 lb ae/A (Roundup WeatherMax @ 32 oz/A) + 1% w/w AMS was made in the late planted cotton treatments. Post-directed and hooded herbicide applications were made in the late-planted cotton treatments on 24 June 2004 as described for the early planted cotton treatments made on the same day. No layby herbicides were applied in this experiment in 2004.

Straw Management Experiment - Cover and Grain Crops: After shredding the previous cotton crop as described in the above experiments, Solum barley was planted at 51 lb/A seeding rate on 8 December 2003 using the John Deere 1560 no-till grain drill as described above. Beardless barley and Cayuse oat cover crops were planted at 108 lb/A using the same method as for Solum barley. Cover crop biomass samples were collected from four 0.25 m^2 sample areas in each plot on 15 March 2004 and were oven-dried at 150 F to measure dry weight. The cover crops were green-chopped on 19 March 2004. Solum barley grain crop biomass which was dry at harvest was sampled from four 1.24 m^2 areas immediately prior to grain harvest. The Solum barley grain crop treatments were harvested at the three desired straw heights on 3 May 2004.

Straw Management Experiment – Cotton Crop: In the conventional tillage treatment a Sundance root puller was used followed by two disking operations and then the plots were listed, the beds were mulch and shaped and a cultipacker was used before planting cotton, as described for the Maricopa experiment above. Cotton cultivar DP 449BR was planted in all treatments at a 14 lb/A seeding rate on 4 May 2004. The conventional tillage treatment was planted with a standard John Deere 7100 4-row planter. Yetter Farm Equipment 2960/2976 coulter-residue manager assemblies and 100-lb weights as described above were attached to the planter units to plant cotton in the no-till treatments. Glyphosate @ 0.77 lb ae/A (Roundup WeatherMax @ 22 oz/A) + 1% w/w AMS were applied topically on 4 May 2004 to kill beardless barley and Cayuse oat cover crop. Cotton stand counts, plant heights and height-to-node ratios were measured assessed as in the other experiments above and after defoliation the cotton mainstem node at which the first fruiting branch and the first retained boll occurred were also recorded.

Results and Discussion

Small grain cover crops and barley grain crops were planted in the fall of 2003 at the University of Arizona Marana and Maricopa Agricultural Centers. The amounts of biomass produced by the Solum barley cover crops were 3,567 lb/A and 3,716 lb/A at Marana and Maricopa, respectively, and the Solum barley grain yields were 2,231 lb/A and 3,260 lb/A at Marana and Maricopa, respectively. A significant finding was that the John Deere 1560 no-till grain drill was able to easily plant the fall barley crops despite the hard soil and the presence of shredded cotton stalks in the center of the beds. The disk opener assemblies were able to slice through the soil and stalks and place seed in the ground even when a grain drill seed-line coincided with an old cotton seed-line and shredded stalks due to the application of hydraulic force and the heavy weight of the drill. However, the grain yields were less than those obtained by growers using conventional tillage practices and planting in level basins. Assessment of barley plant populations found that the no-till grain drill which was designed to broadcast plant on relatively uniform surfaces (as opposed to on beds) was not planting the bottom of the furrows consistently resulting in low barley plant populations. In current experiments with a John Deere 1590 grain drill, only the drill lines on the beds were planted and not the drill lines in the furrows. Plant densities in the drill lines on the beds were increased so that plant populations were same as in commercial broadcast grain plantings.

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. The coulter-residue managers did a good job of moving residue and cutting a seed line with a fluted coulter resulting in good seed placement in the dry beds at all locations regardless of the amount of residues present 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 operation of the residue managers and soil penetration of the coulter and planter units. The no-till cotton planting methods did not negatively affect cotton seedling emergence compared to conventional tillage/planting methods and plant populations in the range of 40,000 to 50,000 plants/A (10 to 13 plants/meter of row on 1 m row spacing) were generally obtained (Table 1). The greater plant population in the no-till, early planted cotton compared to the conventionally tilled cotton treatment planted at the same time was due to the higher seeding rate in the reduced tillage treatment (Table 1). In addition, emergence of the late-planted cotton at Marana in 2004 was hampered by poor irrigation management which resulted in the water running over the top of the beds and sealing the soil before the cotton seedlings could emerge (Table 1).

Cotton growth was assessed by measuring plant height, the number of nodes per plant at various times during the cotton season, and yield at the end of the season in both conventional tillage and reduced tillage treatments. In Marana, at mid-season the late-planted cotton was shorter than the early-planted cotton but there were no differences in plant heights and the height-to-node ratios (HNR) at the end of the season (Table 2). At Maricopa, there was no particular trend in plant heights and HNR, with the early-planted no-till and the late-planted conventionally tilled cotton being taller and having greater HNR than cotton in the other treatments (Table 3). In both Marana and Maricopa, there were yield differences between treatments related to planting date with the late-planted cotton yielding less than the early-planted cotton (Table 4). At Marana, lint yield differences were also related to tillage. The early-planted, conventionally tilled cotton (1,693 lb/A) produced 23% more lint than the early-planted, reduced-tillage cotton (1,378 lb/A) and both of these treatments produced more lint than the late-planted cotton treatments. Clark and Carpenter (1998) and Silvertooth *et al.* (1998) also reported that cotton yields were reduced by planting late at Marana and Maricopa due to reduced heat unit accumulation after planting and because a greater portion of the primary fruiting cycle occurred during the hottest part of the summer. The poor performance of the late-planted, conventionally tilled cotton at Marana was also partly due to the low plant population (19,318 plants/A) that resulted from poor irrigation management. At Maricopa, there was no yield difference between the two early-planted cotton systems and these treatments produced more cotton than the late-planted, cotton systems. The late-planted, conventionally tilled cotton at Maricopa produced 28% more lint than the late-planted, reduced-tillage cotton. Although the yield comparisons are not yet definitive, it appears that in some situations no-till or reduced tillage cotton production practices may reduce cotton yields. More research is needed to determine if this trend is consistent and if it can be alleviated using strip tillage techniques. There may be non-tillage related reasons for this apparent trend such as insufficient nitrogen fertilizer in the reduced tillage treatments due to the decomposition of organic matter as occurred in 2003 (Adu-Tutu et al., 2004) although petiole nitrogen levels were used in 2004 to monitor fertility and adjust nitrogen applications.

A study was conducted at the Maricopa Agricultural Center 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 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 amount of cereal biomass was determined in each cover crop or grain crop treatment prior to harvest because the way grain harvesters spread the straw chafe makes it impossible to accurately measure the amounts of barley residue following grain harvest (Table 5). Grain yields were significantly lower when the grain crop was cut above the normal height of about 5 inches because the harvester did not collect heads of plants that had lodged lower than the pre-determined cutting heights (Table 5). There were no significant differences between treatments in any of the measured parameters. Cotton plant populations after no-till planting, cotton plant height and HNR were generally similar in all of the treatments, though the conventional tillage cotton was significantly taller than most of the no-till cotton that followed a grain crop (Table 6). The cotton mainstem nodes at which the first fruiting branch and the position of the first sustained boll occurred were also assessed. The height of the cereal stubble did not affect the position of the first fruiting branch or the first retained boll of cotton that was planted after the cereal crops (Table 7). Cotton yields also did not differ between the straw management treatments (Table 7). These results indicate that the methods we used for planting cotton without tillage are not very sensitive to differences in straw biomass or the height of the standing stubble following grain harvest. It appears the no-till planting method on beds is very robust and growers do not have to pay particular attention to straw management.

A light activated, weed-sensing, automatic spot sprayer (WeedSeeker; NTech, Industries, Inc.) and post-emergence herbicide weed control program were used in the conservation tillage cotton treatments and compared to the weed control obtained using both preemergence and postemergence herbicides and cultivation in the conventional tillage cotton treatments. WeedSeeker spray units under the Redball 410 hoods were compared to conventional continuous spray nozzles in other 410 spray hoods in terms of the spray volume applied and weed control achieved. The data from Marana (Table 8) and Maricopa (Table 9) indicated that the weed sensing automatic spot spray system could reduce the amount of spray volume and herbicide used by 36 to 63%. Data from Maricopa in 2003 indicated that the savings could be much greater (e.g., in the treatment with thick Solum cover crop residues) or much less if volunteer grain germinated after grain harvest (Adu-Tutu *et al*., 2004). At Maricopa in 2004, the presence of a large number of volunteer cotton plants when the herbicide was applied in the treatment with the Solum barley cover crop residue reduced the savings in spray volume and the amount of herbicide used relative to the savings in 2003. In general the weed control data comparing spray systems in Marana (Table 10) and Maricopa (Table 11) indicated that the weed control obtained with the weed sensing, automated spot-spray system was commercially acceptable comparable to that obtained with conventional continuous spray systems for most weed species. However, the data also indicated that for some weed species such as sprangletop and volunteer barley at Marana and skeletonweed at Maricopa, the automated system did not perform quite as well as conventional continuous spray technology with the postemergence herbicides that we applied. Factors affecting the performance of the WeedSeeker units include setting of the sensitivity level of the computer controller, the type of weed canopy (broadleaf versus grass), the size of the weeds sprayed and the presence of sparse barley cover crop residues. A larger calibration spray volume (GPA) and higher pressure may solve some of these problems by improving weed foliage spray coverage especially foliage partly obscured by barley residues. Cumulative weed control evaluations made later in the season at Marana (Table 12) and Maricopa (Table 13) after multiple herbicide applications suggest that it is possible to obtain commercially acceptable weed control in conservation or minimum tillage cotton production systems but controlling weeds in conservation tillage systems remains a challenge. Additional research is needed to develop improved weed control strategies. The development of Roundup Ready Flex cotton and the recent registrations of new herbicides, carfentrazone (Aim) trifloxysulfuron (Envoke) and flumioxazin (Chateau) provide new weed control tools that need to be integrated into improved weed control systems.

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Table 1. Cotton emergence and establishment in conventional tillage and reduced tillage (i.e., conservation tillage) cotton systems at the Marana and Maricopa Agricultural Centers in 2004.

Location	Cereal-Cotton-Tillage System	Plants/meter of row
Marana	Conventional tillage, winter fallow, early cotton	16.2 a*
	Reduced tillage, Solum barley cover crop, early cotton	14.6 a
	Conventional tillage, winter fallow, late cotton	4.8 c
	Reduced tillage, Solum barley grain crop, late cotton	7.0 b
	LSD (P=0.05)	2.2
	CV (%)	12.7
Maricopa	Conventional tillage, winter fallow, early cotton	10.2 b
	Reduced tillage, Solum barley cover crop, early cotton	13.4 a
	Conventional tillage, winter fallow, late cotton	12.2 ab
	Reduced tillage, Solum barley grain crop, late cotton	12.1 ab
	LSD (P=0.05)	1.7
	CV (%)	9.0

*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 2. Cotton plant heights and height-to-node ratios (HNR) measured in the various tillage-cotton systems at the Marana Agricultural Center in 2004.

	28 July 2004		26 October 2004	
Cereal-Cotton-Tillage System	Height (in)	HNR	Height (in)	HNR
Conventional tillage, winter fallow, early cotton	37.6 b*	1.6 a	39.9 a	1.6 a
Reduced tillage, Solum barley cover crop, early cotton	40.7 a	1.7 a	42.4 a	1.6 a
Conventional tillage, winter fallow, late cotton	30.8 b	1.5 a	40.8 a	1.6 a
Reduced tillage, Solum barley grain crop, late cotton	30.1 b	1.4 a	40.1 a	1.6 a
LSD (0.05)	3.3	ns	ns	ns
CV(%)	3.9	8.0	7.4	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 and CV=coefficient of variation.

Table 3. Cotton plant heights and height-to-node ratios (HNR) measured in the various tillage-cotton systems at the Maricopa Agricultural Center in 2004.

	23 July 2004		21 October 2004	
Cereal-Cotton-Tillage System	Height (in)	HNR	Height (in)	HNR
Conventional tillage, winter fallow, early cotton	37.1 b*	1.37 b	42.4 b	1.33 c
Reduced tillage, Solum barley cover crop, early cotton	42.9 a	1.64 a	47.6 a	1.61 a
Conventional tillage, winter fallow, late cotton	35.6 b	1.55 a	46.5 a	1.59 a
Reduced tillage, Solum barley grain crop, late cotton	25.5 c	1.25 b	42.3 b	1.44 b
LSD (0.05)	3.5	0.16	2.7	0.09
CV(%)	6.1	6.6	3.8	3.6

*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. Cotton yields in the various tillage-cotton systems at the Marana and Maricopa Agricultural Centers in 2004.

	Lint (lb/A)	
Cereal-Cotton-Tillage System	Marana	Maricopa
Conventional tillage, winter fallow, early cotton	1,693 a*	1,522 a
Reduced tillage, Solum barley cover crop, early cotton	1,378 b	1,546 a
Conventional tillage, winter fallow, late cotton	960 d	1,225 b
Reduced tillage, Solum barley grain crop, late cotton	1,247 c	958 c
LSD (0.05)	119	132
CV (%)	5.4	6.3

*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 5. Cereal biomass and Solum barley grain yields measured at the Maricopa Agricultural Center in 2004. The cover crops were killed using glyphosate herbicide. Except for the conventional tillage cotton treatment, cotton was planted after grain harvest without tillage using a John Deere MaxEmerge planter equipped with Yetter 2960/2976 coulter-residue manager assemblies. The Solum barley grain was harvested to leave various heights of standing stubble as indicated in the table.

Cereal Management Strategy	Dry weight (kg/m^2) 3/19/04	Dry weight (kg/m^2) 4/28/04	Grain yield (lb/A) 5/3/04
Winter fallow, conventional tillage cotton	-	-	-
Beardless barley cover crop	1.02 a*	-	-
Cayuse oat cover crop	1.28 a	-	-
Solum barley grain, straw baled, stubble 5 in.	-	0.96 a	2,575 a
Solum barley grain, stubble 5 in.	-	0.90 a	2,711 a
Solum barley grain, stubble 9 to 10 in.	-	0.91 a	2,030 b
Solum barley grain, stubble 17 to 18 in.	-	0.94 a	2,038 b
LSD (P=0.05)	ns	ns	330
CV (%)	40	12.1	8.8

*Values are means of 4 replications; 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 6. Cotton emergence and establishment, plant heights and height-to-node ratios (HNR) measured on 16 August 2004 in various cereal management systems at the Maricopa Agricultural Center in 2004. Except for the conventional tillage cotton treatment, cotton was planted after grain harvest without tillage using a John Deere MaxEmerge planter equipped with Yetter 2960/2976 coulter-residue manager assemblies. The Solum barley grain was harvested to leave various heights of standing stubble as indicated in the table.

Cereal Management Strategy	Plants/m of row	HNR
Winter fallow, conventional tillage cotton	11.60 a*	1.57 a
Beardless barley cover crop	12.30 a	1.60 a
Cayuse oat cover crop	11.95 a	1.58 a
Solum barley grain, straw baled, stubble 5 in.	12.70 a	1.47 a
Solum barley grain, stubble 5 in.	12.36 a	1.50 a
Solum barley grain, stubble 9 to 10 in.	12.54 a	1.54 a
Solum barley grain, stubble 17 to 18 in.	11.98 a	1.49 a
LSD (P=0.05)	ns	Ns
CV (%)	5.74	3.86

*Values are means of 10 observations; 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 7. Cotton mainstem node where the first fruiting branch and first retained boll occurred and cotton yield in various cereal management systems at the Maricopa Agricultural Center measured after defoliation in 2004. Except for the conventional tillage cotton treatment, cotton was planted after grain harvest without tillage using a John Deere MaxEmerge planter equipped with Yetter 2960/2976 coulter-residue manager assemblies. The Solum barley grain was harvested to leave various heights of standing stubble as indicated in the table.

Cereal Management Strategy	First fruiting branch	First boll position	Seed cotton (lb/A)	Lint (lb/A)
Winter fallow, conventional tillage cotton	7.1 a*	11.7 a*	4244 a*	1468 a*
Beardless barley cover crop	6.8 a	10.2 a	4166 a	1455 a
Cayuse oat cover crop	6.7 a	9.3 a	3955 a	1402 a
Solum barley grain, straw baled, stubble 5 in.	6.7 a	10.7 a	3361 a	1180 a
Solum barley grain, stubble 5 in.	7.1 a	11.1 a	3432 a	1235 a
Solum barley grain, stubble 9 to 10 in.	7.4 a	10.8 a	3573 a	1251 a
Solum barley grain, stubble 17 to 18 in.	7.1 a	10.1 a	3813 a	1362 a
LSD (P=0.05)	ns	ns	ns	ns
CV (%)	5.6	11.7	11.0	10.6

*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 8. Herbicide spray volumes in gallons per acre (GPA) applied by NTech Industries WeedSeeker weed-sensing, automatic spot sprayer compared to conventional continuous flat fan spray nozzles on at the Marana Agricultural Station in 2004.

Cereal-Cotton-Tillage System	6 July 2004	
	Sprayer technology	Spray volume (GPA)
Reduced tillage, Solum barley cover crop, early cotton	Continuous	14.4 a*
	Weed sensing	8.7 b
Reduced tillage, Solum barley grain crop, late cotton	Continuous	13.0 a
	Weed sensing	4.9 c
LSD (P=0.05)		1.5
CV (%)		9.5

*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 9. 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 in 2004.

Cereal-Cotton-Tillage System	6/24/04	
	Sprayer technology	Spray volume (GPA)
Reduced tillage, Solum barley cover crop, early cotton	Continuous	18.9 a
	Weed sensing	12.1 b
Reduced tillage, Solum grain crop, late cotton planting	Continuous	18.5 a
	Weed sensing	8.1 c
LSD (P=0.05)		0.8
CV (%)		3.36

*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 10. Percent weed control at the Marana Agricultural Center in the reduced tillage treatment as influenced by spray system (weed sensing or continuous spray) or Solum barley system (cover or grain crop) on 26 July 2004.

Crop and Spray System	Sprangletop	Ivyleaf Morningglory	Volunteer barley	Common purslane	Annual sowthistle
Cover or grain crop/cotton system (averaged across spray types)					
Cover crop, early cotton	97 a*	89 a	100 a	99 a	100 a
Grain crop, late cotton	94 a	78 b	85 b	97 a	89 b
Spray type (averaged across cover or grain crop/cotton systems)					
Continuous spray	98 a	84 a	95 a	99 a	95 a
Weed-sensing	92 b	82 a	91 b	98 a	94 a

*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 11. Percent weed control at Maricopa Agricultural Center in the reduced tillage treatments as influenced by spray system (weed sensing or continuous spray) or Solum barley system (cover or grain crop) on 8 July 2004.

Cereal and Spray System	Volunteer barley	Skeleton weed	Common purslane	Sprangle-top	Ground-cherry	Annual sowthistle	Jungle-rice
Cover or grain crop/cotton system (averaged across spray types)							
Cover crop, early cotton	100 a*	100 a	81 a	97 a	99 a	99 a	97 a
Grain crop, late cotton	89 b	86 b	98 b	98 a	99 a	99 a	98 a
Spray type (averaged across cover or grain crop/cotton systems)							
Continuous spray	95 a	96 a	89 a	99 a	100 a	99 a	98 a
Weed-sensing	93 a	91 b	89 a	96 a	98 a	99 a	98 a

*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 12. Percent weed control in the various cereal-cotton-tillage management systems at the Marana Agricultural Center in 2004.

Cereal-Cotton-Tillage System	Annual sowthistle	Russian thistle	Ivyleaf morningglory		
	5/27/04	5/27/04	5/27/04	6/07/04	8/30/04
Conventional tillage, winter fallow, early cotton	90 a*	92 a	94 a	100 a	76 b
Reduced tillage, Solum barley cover crop, early cotton	85 a	100 a	89 a	96 a	82 b
Conventional tillage, winter fallow, late cotton	-	-	-	-	88 b
Reduced tillage, Solum barley grain crop, late cotton	-	-	-	-	100 a
LSD (P=0.05)	ns	ns	ns	ns	ns
CV (%)	11.4	11.0	7.1	3.2	6.7

*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 13. Percent weed control in the various cereal-cotton-tillage management systems at the Maricopa Agricultural Center on 8 July 2004.

Cereal-Cotton-Tillage System	Volunteer barley	Sprangletop	Common purslane	Annual sowthistle	Junglerice	Russian thistle
Conventional tillage, winter fallow, early cotton	100 a*	100 a	100 a	100 a	100 a	100 a
Reduced tillage, Solum barley cover crop, early cotton	100 a	94 b	78 b	92 a	91 b	92 a
Conventional tillage, winter fallow, late cotton	100 a	100 a	100 a	100 a	100 a	100 a
Reduced tillage, Solum barley grain crop, late cotton	92 b	100 a	100 a	99 a	99 a	98 a
LSD (P=0.05)	2.3	2.6	2.3	ns	3.8	ns
CV (%)	1.5	1.7	1.5	4.8	2.4	8.4

*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.