THE USE OF SMALL GRAINS IN REDUCED TILLAGE COTTON SYSTEMS

ANNUAL/FINAL REPORT 2006

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INTRODUCTION

This study of reduced tillage, small grain-cotton rotational systems was funded jointly by the Arizona Grain Research and Promotion Council, the National Cotton Council, and the Arizona Cotton Growers Association during the 2004-2005 and 2005-2006 small grains-cotton production cycles with each organization contributing $5,000 per year/production cycle for a total funding level of $20,000 over a 2-year period. This project followed a 3-year research effort funded by the USDA Western Region Sustainable Agriculture and Research Education (SARE) grant program.

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 or more of the previous crop residue remains on the surface after planting (Bryson and Keeley, 1992). Conventional tillage practices after cotton harvest in Arizona typically include: 1) shred stalks, 2) disking (once or twice), 3) chisel plow (subsoil) if needed, and after winter fallow 4) disking again (once or more with second pass at an angle), 5) forming beds (lister), 6) condition or shape beds, 7) plant conventionally, and 8) cultivate for weed control and to maintain irrigation furrows. Additional tillage operations often required in irrigated fields are land planning and leveling. Less tillage is required to rotate to a small grain since these crops are usually drilled in level basins and flood irrigated. Bryson and Keely (1992) cite several sources and indicate that there are on average 13 or 14 tillage operations in conventional cotton per year although the frequency of tillage has decreased due to increases in fuel and labor costs. Due to sanitary measures required by law for pink bollworm control and other factors, some tillage will continue to be required or will continue to be advantageous (e.g., land leveling for irrigation).

Early research conducted in Arizona from 1954 to 1957 by Kaddah (1977) found that reduced-tillage cotton had higher yield and greater profits than conventional cotton indicating that not all of the tillage operations listed above are essential to cotton production. In a review of reduced tillage systems in cotton, Bryson and Keely (1992) found that 85% of the studies reported equal or higher yields under reduced-tillage and that cost reductions from the use of reduced- or no-till versus conventional tillage ranged from $37 to $135 per acre not including the additional profit from higher yield. More recent studies using Roundup Ready cotton varieties have obtained similar results (Smart and Bradford, 1999a; Smart et al., 1998). Other economic benefits of reduced tillage operations include: a) reduced cost for labor and equipment, b) reduced fuel usage, c) easier timing of operations since seedbed preparation is faster and simpler, and d) fewer tractors are required for a given farm size (Bryson and Keely, 1992). Recent research in Arizona on ultra-narrow row cotton production (i.e., no in-season tillage) also found that reduced-tillage practices could save money (Clay et. al., 2000; Husman et. al., 2000). From a practical standpoint, conservation or reduced tillage practices are not likely to be adopted locally unless there is an economic advantage over conventional tillage.

Previous research into the feasibility of double-cropping cotton and small grains, primarily barley showed that the double crop system resulted in later planting dates for cotton and significantly reduced yields compared to earlier planted cotton (Adu-Tutu et. al., 2004, 2005). In this reduced tillage system there was no tillage between the harvest of barley and the planting of cotton. Economic analysis showed that the lost income from cotton production could be compensated for by income gained from barley production and reduced numbers of tillage operations. Irrigation was impacted due to a decrease in advance times (i.e., increase in the time required for irrigation water to reach the bottom of the field) and an increase in water infiltration rates such that irrigation costs were greater in reduced tillage systems compared to conventional tillage systems (Martin et. al, 2004, 2005). At some long-term study sites, cotton yield was the same in no-till planted cotton plots as in conventionally tilled cotton plots planted on the same date. However, in some cases yield in the reduced tillage plots declined over a three year period such that yield in the reduced tillage treatments was less than that in the conventionally tilled plots planted on the same day. Possible reasons for this decline in cotton yields over time in the reduced tillage plots were thought to be related to the consolidated nature of the soil profile in plots without tillage which could restrict cotton root development. Two potential remedies for the observed yield declines were identified: strip tillage and the use of irrigation practices based on a shallower cotton rooting depth.

In 2005, a Bigham Brothers, Inc. (Lubbock, Texas) strip tillage implement was tested following grain harvest in dry soil prior to planting cotton. Our intention was to use this implement to rip the middle of the beds, reform the beds with a disk-lister, and mulch the bed with a soil conditioner (all these soil engaging tools are part of this machine). However, running the implement in dry soil completely destroyed the beds and resulted in cantaloupe to watermelon sized dirt clods. We then irrigated the plots in the hope that moisture in the soil would allow us to run this strip tillage implement without destroying the stale beds. However, additional test runs of the Bigham Brothers strip tillage implement after irrigation were not successful because the beds were destroyed regardless of the amount of soil moisture present (i.e., moist versus dry) and we were unable to find an optimum soil moisture level. Bed destruction was primarily caused by the ripping shanks which ran in the center of the beds at a depth of about 14 inches. Thus, it appears that strip tillage after barley harvest and before planting cotton in the barley-cotton double-crop rotation system may not be feasible in Arizona.

Alternatively, it is possible that bed-ripping is not necessary and that the yield decline noted at one site in the past was due to not adequately farming consolidated soil versus unconsolidated soil. In tilled soil cotton plants are able to extract significant amounts of water from the 2-3 ft and 3-4 ft depths of the soil profile (Moffett and McCloskey, 1998). It is possible that in consolidated, untilled soil, cotton plants may extract most of the water transpired from the top 2 feet of the soil profile. Thus, one objective in the 2006 experiments was to use soil moisture probes to compare water extraction by cotton from tilled and untilled treatments with the same planting date following barley harvest.

Part of the barley-cotton, double-crop system research focused on the transition from cotton to small grains since several tillage passes are required to obtain pink bollworm control as noted above. An alternative method for pink bollworm control and compliance with sanitary regulations is to plant a small grain crop and irrigate it in December. Initially we used a 10 ft wide John Deere 1590 no-till grain drill to plant into stale cotton beds after the cotton stalks were shredded. The JD 1590 no-till drill is designed to broadcast plant with a 7.5 in row spacing on nearly level ground. Our particular 1590 drill is towed behind a tractor on a pair of 13.5 inch wide, 15 inch diameter front castor wheels and a pair of similar sized rear wheels 100 inches apart (center to center). In the fall of 2003, we were not able to obtain uniform barley stands for two reasons: 1) the drill is designed to plant flat and the disk openers could not reach the bottom of the furrows, and 2) the drill's wide, rear wheels "wandered" in and out of furrows changing the placement of the drill rows. In the fall of 2004, we planted only the drill lines on the top and upper shoulders of stale cotton beds and did not plant the drill lines in the furrows. We increased the seed density in the planted drill lines to obtain plant populations similar to those in conventional broadcast planted fields. To make this strategy work we had to stop the drill from wandering behind the towing tractor. This was accomplished by replacing the 15 inch wide rear wheels with modified 20 inch diameter truck-trailer wheels. Thus, other objectives of the field experiments conducted as part of this project were to gain experience planting with the reconfigured drill and to demonstrate the value of a reduced tillage transition from cotton to small grain crops with farmer cooperators.

The 2005-2006 objectives were to:

1. Compare conservation (i.e., reduced) tillage practices in a barley/cotton double crop system with a conventional tillage cotton system using paired field comparisons with commercial farmers in central Arizona (if possible) and a replicated, large plot field study at the Maricopa Agricultural Center. The latter involves continuing for a second year to compare conventional tillage systems with flood-irrigated level basin and bedded conservation tillage systems in which Yetter 2960/2967 Combination Coulter/Residue Managers and a John Deere 1590 no-till drill are used to plant cotton and barley, respectively. This includes investigating the reason for yield declines in some reduced tillage treatments in our previous long-term experiments by measuring cotton water use in tilled and untilled plots using ESRI Moisture Point TDR probes in the large plot experiment at the Maricopa Agricultural Center.

2. Compare conservation tillage or no-till transitions from cotton to wheat or barley with conventional tillage preparation and planting of small grains on both beds and in level basins with commercial farmers.

3. Gather production data that will allow the development of conservation tillage crop budgets.

MATERIALS AND METHODS

Maricopa Agricultural Center

A randomized complete block experiment with four replications was planted in the fall of 2004 at MAC. Treatments were:

1) winter fallow followed by cotton planted in early April with conventional tillage,
2) winter oat (Cayuse) green chop crop followed by early April planted cotton,
3) winter barley (Poco) planted flat followed by no-till cotton planting in May, and
4) winter barley (Barcott) planted on beds followed by strip tillage and late May cotton planting.

In the fall of 2005, treatments 1 and 3 were maintained in the same plot locations as in fall 2004, and treatments 2 and 4 were changed as noted below:
1) winter fallow followed by cotton planted in early April with conventional tillage,
2) winter barley (Barcott) planted on beds followed by no-till cotton planted in May,
3) winter barley (Barcott) planted flat followed by no-till cotton planted in May, and
4) winter barley (Barcott) planted on beds, tillage after grain harvest, cotton late planted in May.

In all of the commercial cotton to small grain transitions, barley or wheat crops were planted directly into shredded cotton stubble and stalks without disrupting the soil. The standard 15 inch rear wheels on the 1590 grain drill were replaced with modified 20 inch wheels that changed the relationship between the hub and rim of the wheel. Narrow truck-trailer tires were mounted on the rims. In this configuration the rear wheels were 82 inches apart center to center and the drill consistently tracked behind the towing tractor. The 20 inch wheels had the added advantage of compensating for furrow depth so that the drill was approximately level with the smaller front wheels running on the bed tops and the larger rear wheels running in furrows. This assured normal seed flow and performance of the JD1590 drill. A new planting configuration was used where 3 or 4 drill seed-lines were planted on the top and shoulders of the stale beds but the drill lines in the furrows were closed (i.e., not planted). Thus, 10 of the 16 disk openers were used to plant seed. The seed density in the planted drill lines was increased to obtain plant populations similar to those in conventional broadcast planted grain fields. In all experiments on University of Arizona and commercial farms unless otherwise noted, nitrogen (e.g., 11-53-0) was applied during the planting operation with the drill (i.e., the dual seed and fertilizer hoppers allowed us to fertilize and plant in the same pass across the field) and additional nitrogen (e.g., UAN-32) was water run during the season.

<u>2004-2005 Barley, Maricopa Agricultural Center</u>

In treatment 1 (winter fallow) at the Maricopa Agricultural Center in both fall 2004 and 2005, the previous cotton crop was shredded, roots pulled (Sundance) and the plots disked twice to meet plow down requirements. In treatment 2 which also followed cotton was similarly treated and in 2004 oats were planted flat with the JD1590 in the normal wheel configuration (i.e., 13 in rear wheels). In 2004, Treatment 3 was similar to treatment 2 but was planted with Poco barley (131 lb/A) using the JD1590 drill. In treatment 4 which also followed cotton, the cotton stalks were shredded and Barcott barley (129 lb/A) was planted using the JD1590 in the custom wheel configuration that planting only the drill lines on the beds. The furrows were not planted with barley (see above). The small grains were planted on 29 November 2004 with 22 lb N/A, were grown using standard production practices (including water-running UAN-32) and harvested on 24 May 2005. The oats were green chopped 17 March 2004 and irrigated.

<u>2005-2006 Barley, Maricopa Agricultural Center</u>

In the fall of 2005, the experiment was reconfigured and several treatments were changed. After a root puller (Sundance) and shredder were used (October 12 to 14), the entire experimental area was disked three times. Treatments 1, 2 and 4 were listed using a Bigham Brothers, Inc. Paratill, and a disk-hipper was used to further build up the beds (November 8 to 14). Treatment 1 was fallow, treatments 2 and 4 were planted with Barcott barley (129 lb/A) using a 12 ft conventional John Deere grain drill. Treatment 3 was planted with Barcott barley (120 lb/A) using the John Deere 1590 grain drill. No fertilizer was used at planting on 5 December 2005 since fertilizer could not be applied by the conventional grain drill. The Barcott barley plots were grown using standard production practices including water-run UAN32 fertilizer. The grain plots were harvested on 8 and 9 May 2006 with a Case International 1440 Axial Flow Combine and plot weights were measured in a weigh wagon equipped with load cells and a Weigh-Tronix electronic scale. In late March 2006, a critical irrigation with UAN32 was missed during the boot stage which substantially reduced yields.

<u>2005 Cotton, Maricopa Agricultural Center</u>
In the 2005 cotton season, cotton (DeltaPine 449BR was dry planted on 14 April 2005 in the winter fallow, conventional tillage treatment using a 4-row Monosem planter and in the oat green chop treatment (treatment 2) using Yetter coulter/residue managers bolted onto a 4-row John Deere 7100 MaxEmerge planter. Additional weight (about 100 lb) was added to each row unit on the cotton planter to force the coulter and disk-openers to penetrate the hard, dry soil adequately for planting. Similarly, cotton (DP449BR) was planted into Poco barley grain crop residues following grain harvest using Yetter coulter/residue managers bolted onto a 4-row John Deere 7100 MaxEmerge planter on 25 May 2005 in treatment 3. Treatment 4 was not planted because the beds in these plots were destroyed by the Bigham Brother strip-till implement. The eight rows of each 12 row plot were picked with a 2-row Case IH 1822 cotton picker. 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).

<u>2006 Cotton, Maricopa Agricultural Center</u>
At the start of the 2006 cotton season, in the winter fallow, conventional tillage treatment (treatment 1), pendimethalin was applied at 0.83 lb ai/A (2 pt/A of Prowl 3.3 EC) and incorporated with a field cultivator on 17 April 2006. The plots were then listed, roto-mulched, bed-shaped. Stoneville 4357B2RF Bollguard 2, Roundup Ready Flex cotton was dry planted using a 4-row Monosem planter (11 lb/A) on 20 April 2006 and irrigated on 22 and 29 April 2006. After harvesting the Barcott barley, treatment 4 plots were roto-mulched, beds were formed using a disk hipper and bed-shaper and were planted using a 4-row Monosem planter (11 lb/A) on 11 May 2006. Treatments 2 and 3 were no-till planted with Stoneville (ST4357B2RF) cotton seed (14 lb/A) on 10 May 2006 using Yetter 2960/2967 combination coulter/residue managers bolted onto a 4-row John Deere 7100 MaxEmerge planter as described for 2005. Treatments 2, 3 and 4 were irrigated on 12 May 2006 and irrigated a second time to insure uniform germination on 19 May 2006. Glyphosate was applied topically at 1.55 lb ae/A (Roundup WeatherMAX at 44 oz/A) with 12 lb/100 gal of spray grade ammonium sulfate (AMS) on 18 May 2006 in treatment 1 and on 2 June 2006 in treatments 2, 3 and 4. A layby application of glyphosate (1.55 lb ae/A) plus flumioxazin at 0.064 lb ai/A (Chateau at 2 oz/A) was made in treatment 1 on 11 July 2006. A second topical glyphosate and AMS application at the same rate described above was made in treatments 2, 3, and 4 on 11 July 2006 followed by a layby application of glyphosate and AMS on 18 July 2006. Major weed species in the plots were annual sowthistle and prickly lettuce early especially in the no-till plots followed by Wright

groundcherry and junglerice in all plots mid- to late-season. Treatment 1 was cultivated and side-dressed with urea (46-0-0 at 133 lb/A) on 30 May, 13 June and 12 July 2006. Treatments 2, 3 and 4 were treated with UAN-32 in the irrigation water at 50 lb elemental N/A on 1 July, 13 July and 14 August and with 40 lb N/A on 13 September 2006. Late season insects were treated with Orthene 90S (acepahte) at 1 lb/A and Danitol (fenpropathrin) at 8 pt/A on 25 September 2006. The experiment was defoliated by spraying Ginstar (thidiazuron/diuron) at 12 oz/A on 9 October 2006. Six rows of each 12 row plot were picked with a 2-row Case IH 1822 cotton picker on 1 November 2006. The seed-cotton from each plot was weighed separately in a Caldwell Boll Buggy (E.L. Caldwell and Sons, Inc.) equipped with a Weigh-Tronix scale (model WI-152). Seed-cotton sub-samples were collected and ginned to determine turnout (31.33% lint).

2006 Soil Moisture Analysis, Maricopa Agricultural Center

The study was conducted on a soil classified as a Trix clay loam. The Trix soil is a deep, well drained very slowly permeable soil with upper horizons that were formed with fine textured particles that were recently deposited. The 0-12 inch surface horizon is a brown clay loam with the lower horizon (12-24 inches) a reddish brown clay loam with calcium carbonate content increasing with depth. Below this to a depth of 24 inches is a horizon enriched with calcium carbonate and that tends to develop into a sandy clay loam texture. Textural analysis showed that the top 24 inches of the soil was dominated by clay, with the clay content ranging from 40-55% and at lower depths the texture transitions to a sandy clay/sandy clay loam, with the clay content reducing to 25-35% at depths below 24 inches. The available soil water content in the top 24 inches of the soil is fairly uniform. Bulk density measurements ranged from 1.40 to 1.55 g/cm^3 and the volumetric moisture ranged from 0.29-0.42% at Field Capacity (upper limit) to 0.18-0.24% at the Permanent Wilting Point. Available water averaged about 1.32 to 2.2 inches per foot (Post et al., 1988).

Soil moisture measurements were taken prior to irrigations events during the season. The measurements were taken with a Time Domain Reflectometer (TDR). The TDR device sends a microwave pulse through wave guides installed in the soil. The pulse travels down along the wave guide until it reaches the end of the guide, at which time the pulse reflects back up the guide. The time it takes the pulse to travel down the guide and reflect back is a function of the soil moisture content. The wetter the soil, the longer it takes the pulse to travel. Two probes were installed in each plot at approximately 4/5 of the distance from the head end of the field (about 480 ft. down the field) in the seed-line with the cotton plants. One set of probes measured volumetric soil moisture from 0-6, 6-12, 12-18 and 18-24 inch depths. A second set of longer probes measured 0-6, 6-12, 12-24, 24-36 and 36-48 inch depths. It was hoped these longer probes would give some insight into water movement throughout the soil profile. Unfortunately, factors such as heavy clay content and salt content can interfere with TDR measurements. The soil in this study contained high calcium carbonate levels that mimicked salts and caused interference with TDR readings in the lower depths. Therefore, only the top 24 inches of soil moisture readings are reported here. However, given that the minimum tillage system used in this study would primarily affect the surface soil layers, analysis of the top 24 inches should adequately reflect any significant differences in soil moisture.

2005 Commercial Farms

The John Deere 1590 no-till grain drill was towed to 5 commercial farms in the fall and winter of 2004-2005. All of our cooperating farmers intended to plant a small grain crop on stale cotton beds after they shredded the cotton stalks. Four cooperators successfully used the drill to plant either barley (Tom Clark in Marana) or wheat (Paul Grasty in Casa Grande, Mike Urton in Coolidge and Bill Stanbaugh in Mammoth). They all used the custom 20” wheel configuration of the JD1590 drill discussed above and planted the drill lines on the beds but not the drill lines in the furrows. All of these cooperators applied nitrogen (e.g., 11-53-0) in the planting operation with the drill and water ran additional nitrogen (e.g., UAN-32). One cooperator tried to use the drill in moist soil conditions, was not successful, and decided not plant with the JD1590. Tom Clark was interested in following Solum barley with cotton but a cool spring, delays in custom harvesting and a potential cotton planting date after a May 15 cutoff date for crop insurance caused him to decide not to plant cotton.

<u>2006 Commercial Farms</u>

The John Deere 1590 no-till grain drill was towed to 3 commercial farms in the fall and winter of 2005-2006. The drill was successfully used to plant either barley or wheat on beds in Marana and Coolidge using the configuration described above for the Maricopa Agricultural Center. In Glendale, the drill was used in its standard configuration to broadcast plant level fields. All of the cooperators applied nitrogen (e.g., 11-53-0) in the planting operation with the drill and water ran additional nitrogen (e.g., UAN-32). The Marana cooperator (Tom Clark) planted Solum barley in two fields (seeding rates of 38 lb/A and 54 lb/A) and Kronos wheat in one field at two different seeding rates (138 and 155 lb/A) around Thanksgiving. There were no conventionally planted comparison wheat or barley fields in Marana. The Coolidge cooperator (Noah Hiscox) planted three fields of Crown wheat into stale cotton beds after shredding with the JD1590 at a seeding rate of 145 lb/A. Each field also had a comparison area where the grower shredded the cotton, spread granular fertilizer, ran a disk-lister and broadcast planted with a conventional grain drill at a seeding rate of 175 lb/A. A cooperator in Glendale (Larry Rovey and Alan Quame) planted two fields where cotton was grown in level basins. After the cotton stalks were shredded, a Nebula/Baretta barley seed mixture was planted at 123 lb/A in one pass across the field using either the John Deere 1590 or the growers conventional drill.

An additional experiment was conducted in Wellton, AZ where wheat was planted in 4 lines per 42 inch bed on 9 February 2006 following a lettuce crop. This experiment was conducted as a paired field comparison where no-till portions of the field were compared to portions that were disked twice and leveled (i.e., “floated”). Since a portion of the lettuce field was not harvested, a single pass was made over the portion of the field with beds with a cultipacker (i.e., ring-roller) to crush the un-harvested heads prior to planting the wheat. The modified configuration described above for planting barley on beds at the Maricopa Agricultural Center was used except that 12 of the 16 disk openers were used rather than 10 of 16 due to the larger bed size. Kronos wheat was planted at 179 lb/A and no fertilizer was drilled with the seed because nitrogen levels in the soil are typically high following a lettuce crop. A significant number of lettuce plants resprouted after the wheat was irrigated on 10 February 2006 and these volunteers along with broadleaf weeds were killed by spraying a tank-mixture of MCPA-Clarity on 3 March 2006. Wheat populations in the different portions of the field were counted on 29 March 2006. The field was harvested with a John Deere Titan II 8820 combine on 6 July 2006 and the grain was weighed in a grain weigh wagon equipped with load cells and a Weigh-Tronix electronic scale.

RESULTS AND DISCUSSION

Barley – Maricopa Agricultural Center

Of interest at MAC was the yield comparison between the Poco barley planted in level basins and the Barcott barley planted on stale cotton beds. The Poco barley on the flat significantly out yielded the Barcott barley on beds, 5,069 lb/A versus 4,176 lb/A, respectively. Both were respectable yields and greatly exceeded the yields we have obtained in the past with Solum barley. We do not know if the yield differences were due to the different planting configurations (on the flat versus on beds) or due to differences in the barley varieties. Both barley varieties produced enough biomass to completely cover the soil surface with residues after harvest which appears to be a prerequisite for successful cotton planting. In fall 2005 due to a change in some treatments, the experimental field was tilled before planting the Barcott barley. Thus, there were two equivalent treatments with Barcott barley on beds, treatments 2 and 4, which yielded 2401 and 3080 lb/A compared to a barley yield of 2411 lb/A in the level basin (treatment 3). With Coefficients of Variation that were about 50% of the means, it appeared there was no difference in the yield of barley grown on the flat versus on beds. The grain yields in 2006 were much worse than in 2005 due to a missed irrigation with fertilizer in late March during the boot stage of development that severely reduced yield potential. Also in contrast to 2005, not enough biomass was produced to cover the soil surface so that a substantial amount bare soil was exposed at the time of cotton planting similar to the oat residue amounts in treatment 2 in 2005.

Maricopa Agricultural Center 2005 Cotton

Cotton (DP449BR) was dry planted in treatments 1, 2 and 3 at MAC. In the conventionally planted cotton (treatment 1), the cotton was dry planted and irrigated to germinate the seed. Unfortunately, the field was irrigated at night and the irrigator allowed water to go over the tops of some beds reducing the cotton population in some parts of the plots. Sufficient plant populations were obtained in some 2 row strips so yield was measured in fall 2005. In the Cayuse oat green-chop treatment, the amount of oat residue on the soil surface was small, about 30 to 40% cover with covered areas having a shallow residue depth. After cotton planting in the level basins and flood irrigation, the soil surface rapidly dried and formed a crust. Thus, a poor cotton stand was obtained in most of the plot area that would have dramatically reduced cotton yields so treatment 2 was not irrigated again after the three germinating irrigations and the treatment was abandoned for the 2005 cotton season. The cotton planted into barley residues in the level basin system (Poco in treatment 3) successfully germinated due to the nearly complete residue cover on the soil and good cotton field populations were obtained. Over the past several years we have successfully planted cotton into barley residues on stale beds using the Yetter coulter/residue managers and it appears that this planting configuration and method works equally well in level fields provided sufficient residue is present. Cotton yields were measured in four 2-row strips (8 rows total) after defoliation and were 1434 lb seed-cotton/A in the Poco barley-cotton, level basin double crop treatment and 1,865 lb seed-cotton/A in the winter fallow, bedded, conventional tillage treatment. These yields were much lower than those obtained in past years in part to late planting (treatment 3), high temperatures and heat stress in June and July, and most importantly a critical missed irrigation during peak bloom resulting in severe water stress. Assuming a 32% turnout, treatments 1 and 3 yielded only 597 and 458 lb of lint/A, respectively; yields significantly lower than in most of our previous experiments (Adu-Tutu et. al., 2004, 2005).

Cotton was not planted in treatment 4 as intended because running the Bigham strip tillage implement in dry soil prior to planting cotton destroyed the beds. Our intention was to use this implement to rip the middle of the beds, reform the beds with a disk-lister, and mulch the bed with a soil conditioner (all these soil engaging tools are part of this machine). We hoped that some moisture in the soil would allow us to run this strip tillage implement without destroying the stale beds. However, test runs of the strip tillage implement after irrigation of treatment 4 were not successful because the beds were destroyed regardless of the amount of soil moisture present (i.e., moist versus dry) and we were unable to find an optimum soil moisture level. Bed destruction was primarily caused by the ripping shank which ran at a depth of about 14 in. Strip tillage after barley harvest and before planting cotton in the barley-cotton double-crop rotation treatments may not be feasible but perhaps a different or modified implement and more experimentation is needed to develop a successful strip-tillage implement.

Maricopa Agricultural Center 2006 Cotton

The amount of irrigation water applied and dates of irrigation for the various cotton treatments are listed in Tables 1 and 2. Due to the high costs of the ESRI probes and limited budget, no soil moisture measurements were recorded in the conventional tillage treatment (Treatment 1). The total amount of water applied in nine irrigation events to Treatment 1 during the 2006 season was just over 56 inches. Treatments 2, 3 and 4 were all irrigated on the same schedule and the amount of irrigation water applied in 10 irrigation events to treatments 2, 3 and 4 was just over 68 inches in 10 irrigation events. With an additional irrigation event and a longer season, it was expected that the cotton crop planted in May would require some additional irrigation water. However, it should be noted that the increase in irrigation amounts may be due to the slower advance times caused by the barley crop residues on the soil surface in the furrows as found in our previous studies (Martin et. al., 2004, 2005). The conventionally tilled treatment averaged 6.2 inches per irrigation event. The no-till/minimum till treatments averaged 6.8 inches per event - an additional 0.6 inches per irrigation. Even if all the treatments were irrigated 10 times, this would still correspond to a 6-inch increase in the amount of irrigation water applied. At a price of $42 per acre foot of water, this additional water cost $21 per acre which though not a large amount is certainly a factor to consider.

Cotton yields at Maricopa in 2006 were affected by planting date and the presence or absence of tillage (Table 3). Cotton yields in 2006 were much greater than in 2005 despite hotter temperatures and more level II heat stress due to better crop management, especially irrigation management that avoided drought stress. Comparison of treatment 1 planted in April with the other treatments planted in May shows the significant yield loss that resulted from delayed cotton planting in the spring (Table 3). Similar results were found in our previous studies (Adu-Tutu et. al., 2004, 2005). Note that treatment 1 produced more lint and used less water than the other treatments. Comparison of the treatments planted on 10 and 11 May, treatments 2 and 3 without tillage and treatment 1 with tillage, indicate that tillage increased cotton yield (Table 3) when the amount of irrigation water applied was the same (Tables 1 and 2). The implication of these results is that some use of tillage was required to maintain or enhance cotton yield possibly by breaking up compaction and consolidation zones in the soil thereby presumably enhancing cotton root growth and development.

Soil moisture measurements were taken prior to seven irrigation events as shown in Figures 1 to 4. Figure 1 shows the volumetric soil moisture for 0-24 inch cm depth. The three treatments have similar soil moisture contents throughout much of the season. However, it can be seen that treatment 3 has either the highest or second highest soil moisture content for six of the readings. Only on the 12 September reading, did treatment 3 have the lowest soil moisture content. The 0-18 inch moisture readings followed a similar pattern except that treatment 3 has the greatest moisture content on the first four measurement dates. On September 12, only the longer probes were read due to time constraints and therefore the 0-18-inch measurement were not made. The 12- and 6-inch readings (Figures 3 and 4) continued to show treatment 3 at or near the top in terms of volumetric soil moisture. This greater soil moisture in treatment 3 was likely due to patchy, low plant populations resulting in reduced water use causing an increase in soil moisture content relative to treatments 2 and 4. Overall, there did not appear to be a treatment that consistently had lower or higher soil moisture water content in the upper 24 inches of soil. In particular there were no consistent differences in volumetric soil moisture at 0-24 inches between the treatments where cotton was planted on beds following barley with tillage (treatment 4) and without tillage (treatment 2). This would appear to suggest that modifying irrigation regimes to irrigate no-till cotton more frequently than conventionally tilled cotton is not likely to make the two production systems yield similarly and that the effect of tillage is not related to irrigation.

<u>2005 Commercial Farms</u>

Our four grower cooperators were pleased with the results obtained with the John Deere 1590 no-till grain drill when used with the 20 inch rear wheel configuration that only planted the drill lines on the beds. Typically, a cotton field may be double disked, landplaned and planted flat or disked, listed, and then planted to grain. The numbers of field operations (not counting planting) were reduced from as many as 5 to 1 by our cooperators. Tom Clark (Marana) obtained Solum barley yields of 4,200 and 4,400 lb/A using seeding rates of 50 lb/A. These fields compared favorably with a nearby conventionally planted Solum barley field that yielded 3208 lb/A and with yields he has obtained from conventionally planted Solum barley in these fields in the past. We discussed the next crop to be planted and options for moving into that crop with the minimum number of field passes in spring 2005. This component of the project was quite fluid with the intent of working closely with cooperating farmers and tailoring system approaches to best suit their farm’s objectives and strategies. Unfortunately, a cool, wet spring (actually a more normal spring compared to our recent drought years) delayed the harvest of the barley crop and the cooperator (Tom Clark) could not plant cotton before the cutoff date for crop insurance.

Similar to the barley producer in Marana, Bill Stanbaugh obtained a Sky wheat yield of 4,767 lb/A in north half of a field planted with the JD1590 compared to 5,249 lb/A in the south half of a field planted with a conventional grain drill following a bed-mulching tillage pass. Bill’s field had a soil texture gradient with the soil becoming coarser (i.e., more sand and gravel) going from south to north towards Aravaipa Creek. Bill considered the yields essentially equivalent given the change in soil texture. Another wheat producer, Mike Urton planted Mohawk Durum wheat using the JD1590 on 9.45 acres of a field using the 20 inch wheel configuration and planted only the drill lines on the beds (minimum till) and compared this to the remaining 26.5 acres of the field planted with his conventional drill (conventional till). The minimum till wheat was planted 29 November 2005 following shredding of the cotton stalks on 4 November. This seed germinated and a complete (100%) stand was obtained following 0.85 inches of rain on 4 to 6 December 2005. This rain delayed disking of the conventional till portion of the field until 15 December 2005. After spreading fertilizer, disking a second time, listing with a disk lister, and using a cultipacker or ring roller on 16 to 18 December, the conventional till field was planted. Both sections of the fielding were irrigated on 21 to 24 December 2005 (Table 4). Mike noted "Timeliness of reduced tillage a benefit as no-till grain brought to a complete stand by early rain. Tillage of conventional grain delayed by same rain". He did not observe differences in the quantity of water applied in the first irrigation (about 10 inches/A) despite the cotton residues in the minimum till portion of the field. Mike further noted "Able to eliminate final irrigation, and one fertilizer application on minimum till. Yield and quality nearly identical. Significant savings in land preparation with minimum till".

<u>2006 Commercial Farms</u>
The John Deere 1590 no-till grain drill was successfully used to plant barley and wheat on beds in Marana and Coolidge using the configuration described above for the Maricopa Agricultural Center. In Glendale, the drill was used in its standard configuration to broadcast plant level fields. The Marana cooperator (Tom Clark) planted Solum barley in two fields (seeding rates of 38 lb/A and 54 lb/A) that yielded 4164 lb/A and 3,332 lb/A, respectively. These barley yields are similar to 2005 and comparable to historical yields for Solum barley in Marana, AZ. The Marana Kronos wheat field was split in half and planted at two different seeding rates, 138 and 155 lb/A, that yielded 7,202 and 6,888 lb/A, respectively, on 17 June 2006. There were no conventionally planted comparison wheat fields in Marana. The Coolidge cooperator (Noah Hiscox) planted three fields of Crown wheat into stale cotton beds after shredding with the JD1590 at a seeding rate of 145 lb/A but reliable harvest weights were measured on only one field due to miscommunication with the custom combine operator. The portion of the field planted using the JD1590 at a seeding rate of 145 lb/A with drill lines on only on the beds yielded 6,226 lb/A. In comparison, the portion of the field that was tilled with a disk-lister and broadcast planted with drill lines on the beds and in the furrows using the growers conventional grain drill and a seeding rate of 175 lb/A yield 5,820 lb/A. A cooperator in Glendale (Larry Rovey and Alan Quame) planted two fields where the cotton grown in level basins. After the cotton stalks were shredded the fields were split into two portions and a Nebula/Baretta barley seed mixture was broadcast planted at 123 lb/A in one pass across the field using either the John Deere 1590 or the growers conventional drill. In field 14 by the shop, the barley yields were 4,781 and 4,956 lb/A for the JD1590 and the conventional drill, respectively. In field 3 near the intersection of Grand and Olive, the barley yields were 5,933 and 5316 lb/A for the JD1590 and the conventional drill, respectively.

An additional experiment was conducted in 2006 in Wellton, AZ (Marlatte Brothers) in which the John Deere 1590 no-till grain drill was used to plant wheat on lettuce beds following lettuce harvest. A lettuce field was divided into four sections and in two of the sections a cultipacker was run over the lettuce beds (2 seed-lines per bed) to crush lettuce heads that were not harvested. The 1590 drill was used to plant Kronos wheat at 179 lb/A using 12 of the 16 disk openers (the disk openers in the furrows were not used) to plant 4 lines of wheat per 42 inch bed on 10 February 2006. No fertilizer was applied with the wheat seed because residual nitrogen levels were adequate. The other two sections were prepared using conventional tillage (two passes with a disk followed by a land-plane to level or "float" the field) resulting in two sections of level basins that were planted using the grower's grain drill and a similar planting rate. Wheat plant populations were similar in all parts of the field with the reduced-tillage sections containing 205 plants m^{-2} compared to 207 plants m^{-2} in the conventional-tillage sections on 29 March 2006. Wheat yields harvested with a John Deere Titan II combine on 6 July 2006 averaged 6,714 lb/A in the reduced-tillage sections and 6,699 lb/A in the conventional-tillage sections. An adjacent conventional-tillage field to the north yielded 7,395 lb/A of wheat. Thus, reduced tillage practices did not result in any loss of wheat yields following lettuce harvest.

Summary

This project documented the advantages of using a John Deere 1590 no-till grain drill or similar implement to plant barley or wheat on cotton beds after the cotton stalks were shredded. Similarly, wheat was successfully no-till planted on beds following lettuce harvest. By planting 3 or 4 drill lines per bed and not planting the drill rows in the furrows, small grain seeding rates could be reduced at least 25% while obtaining yields similar to broadcast, conventionally planted grain crops. Thus, considerable expense ($40 to $50/A) and time can be saved using a no-till planter to make the transition from cotton (and other crops such as lettuce and alfalfa) to a small grain crop. Future work using this reduced tillage planting method could focus on measuring grain yield at even lower grain seeding rates and measuring the yield of various wheat varieties produced using this planting/growing system. Additional work could also focus on the appropriate herbicide treatments in alfalfa to the kill the alfalfa in the fall in preparation for no-till planting of wheat or other small grains.

In contrast to the positive results obtained in the transition from cotton to a small grain crop, cotton production in a reduced tillage barley-cotton double crop presents numerous challenges. The Maricopa data above and past experiments indicate that cotton can be successfully planted into barley stubble on beds using Yetter 2960/2967 combination coulter/residue managers attached to a conventional cotton planter. However, there is a yield penalty associated with the late planting of cotton following barley harvest. The primary fruiting cycle of late-planted cotton will occur during the summer when the potential for level II heat stress will threaten yield potential. The data also indicated that tillage often has a positive impact on cotton growth and yield probably mediated by root growth at some locations during some production years. Although tillage costs are saved in the no-till double crop system, more water is used due to slower advance times and increased infiltration thus increasing costs. Thus, no-till planting of cotton with Yetter attachments either on beds or in level basins is associated with the risk of substantially reduced yield that cannot be alleviated by altered irrigation management. In some cases the loss of income from reduced cotton yields can not be compensated for by the income gained from barley production in a barley-cotton double-crop rotation. At best, the barley-cotton double crop system can match the economic returns of conventionally tilled cotton planted at the normal time but there is substantial risk that economic returns will be reduced with the double-crop system.

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TABLES AND FIGURES

Table 1. Amount of irrigation water applied in cotton in Treatment 1 (winter fallow followed by cotton planted in early April with conventional tillage) at Maricopa in 2006.

Irrigation Date	Water Applied (inches)
4/22	4.81
4/29	5.26
5/31	9.25
6/14	8.52
6/27	6.33
7/10	6.49
7/20	6.37
7/31	5.19
8/12	4.05
TOTAL	**56.27**

Table 2. Amount of irrigation water applied in cotton in Treatments 2, 3 and 4 at Maricopa in 2006. Treatment 2 was winter barley (Barcott) planted on beds followed by no-till cotton planted in May, Treatment 3 was winter barley (Barcott) planted in level basins followed by no-till cotton planted in May, and Treatment 4 was winter barley (Barcott) planted on beds, tillage after grain harvest, cotton late planted in May.

Irrigation Date	Water Applied (inches)
5/12	4.7
5/19	6.4
6/5	7.4
6/20	6.1
7/1	6.6
7/13	8.9
7/25	7.1
8/14	6.5
8/28	8.7
9/13	5.9
TOTAL	**68.3**

Table 3. Cotton lint yield at the Maricopa Agricultural Center in conservation tillage (i.e., reduced tillage) and conventional tillage treatments.

Year	Trt. #	Treatment Description	Yield (lint lb/A)
2005	1	Winter fallow followed by cotton planted in early April with conventional tillage	597
	3	Winter Poco barley planted flat followed by no-till cotton planted in May	458
2006	1	Winter fallow followed by cotton planted in early April with conventional tillage	1366 a*
	2	Winter Barcott barley planted on beds followed by no-till cotton planted in May	573 c
	3	Winter Barcott barley planted flat followed by no-till cotton planted in May	493 c
	4	Winter Barcott barley planted on beds, tillage after grain harvest, cotton late planted in May	956 b

*Means followed by the same letter are not significantly different at P=0.05%.

Table 4. Summary of Wheat Production on Urton Farms in 2005.

Mohawk Durum Wheat Production on Urton Farms, Coolidge, AZ.			
Crop Inputs		Minimum Till	Conventional Till
	Total Nitrogen	293 lb/A	307 lb/A
	Total P2O5	165 lb/A	67 lb/A
	Total Irrigation	31.8 acre-inches/A	36.9 acre-inches/A
Harvest Parameters			
	Grain Yield	3.94 tons/A	4.07 tons/A
	% Protein	13.1%	13.2%
	Bushel weight	64 lb	63.5 lb
	% Moisture	6.7%	7.6%

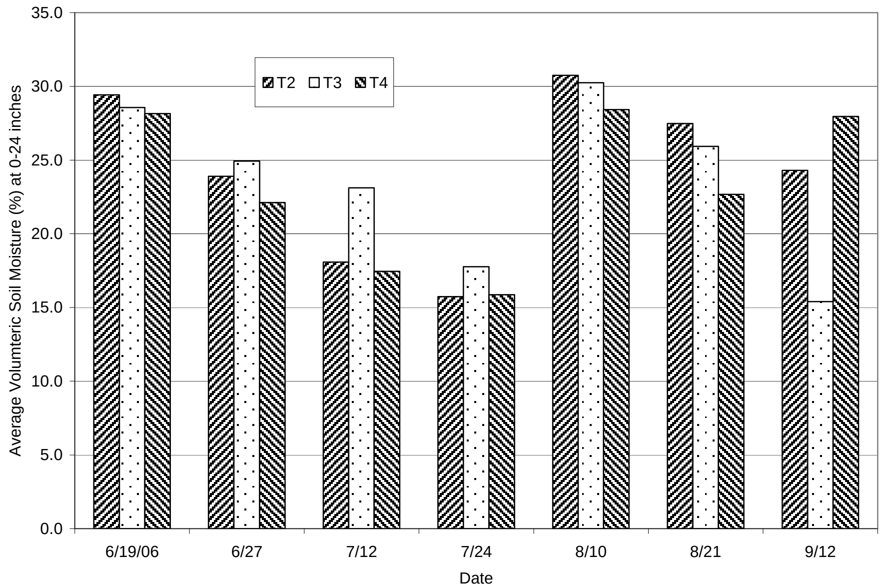

Figure 1. The average volumetric soil moisture in the top 24 inches of soil prior to several irrigation events at Maricopa in 2006. Treatment 2 was winter barley (Barcott) planted on beds followed by no-till cotton planted in May, Treatment 3 was winter barley (Barcott) planted in level basins followed by no-till cotton planted in May, and Treatment 4 was winter barley (Barcott) planted on beds, tillage after grain harvest, cotton late planted in May.

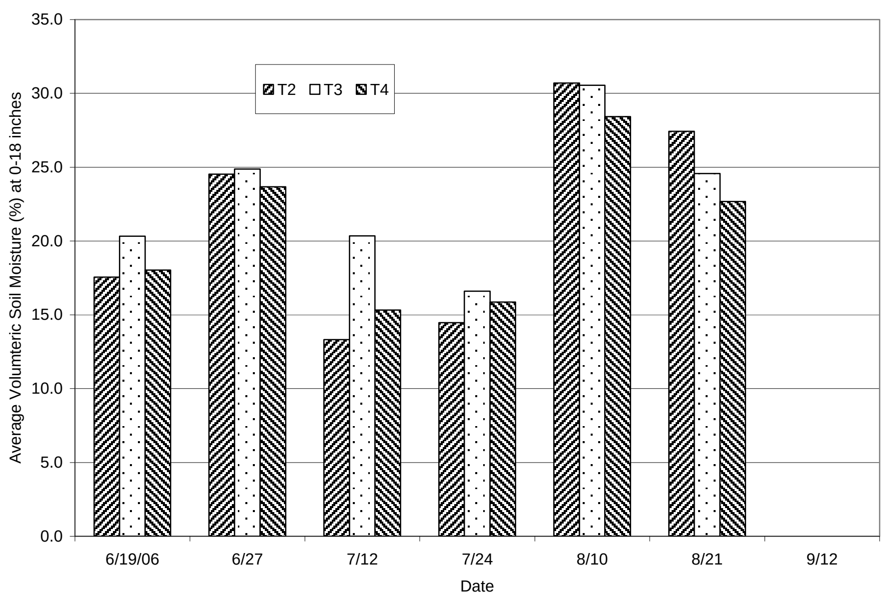

Figure 2. The average volumetric soil moisture in the top 18 inches of soil prior to several irrigation events at Maricopa in 2006 (see Figure 1 for description of treatments).

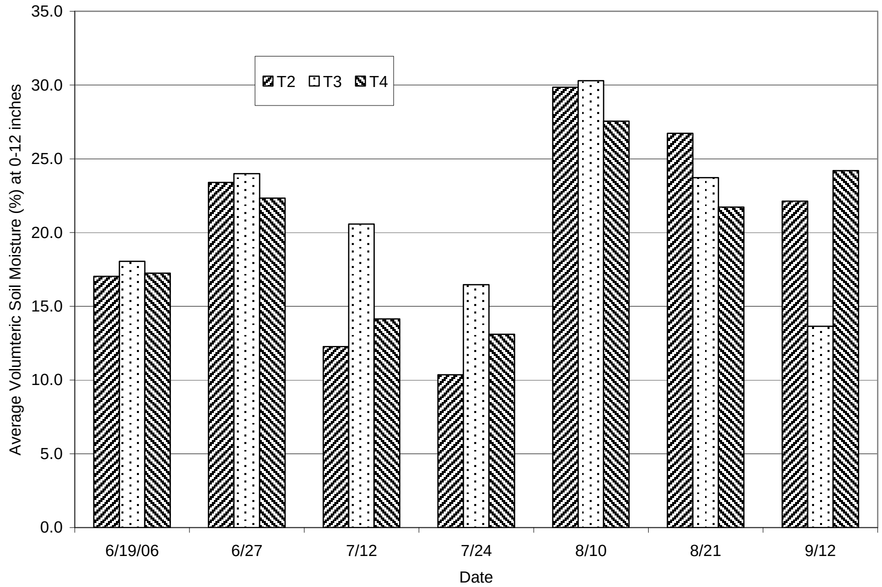

Figure 3. The average volumetric soil moisture in the top 12 inches of soil prior to several irrigation events at Maricopa in 2006. Treatment 2 was winter barley (Barcott) planted on beds followed by no-till cotton planted in May, Treatment 3 was winter barley (Barcott) planted in level basins followed by no-till cotton planted in May, and Treatment 4 was winter barley (Barcott) planted on beds, tillage after grain harvest, cotton late planted in May.

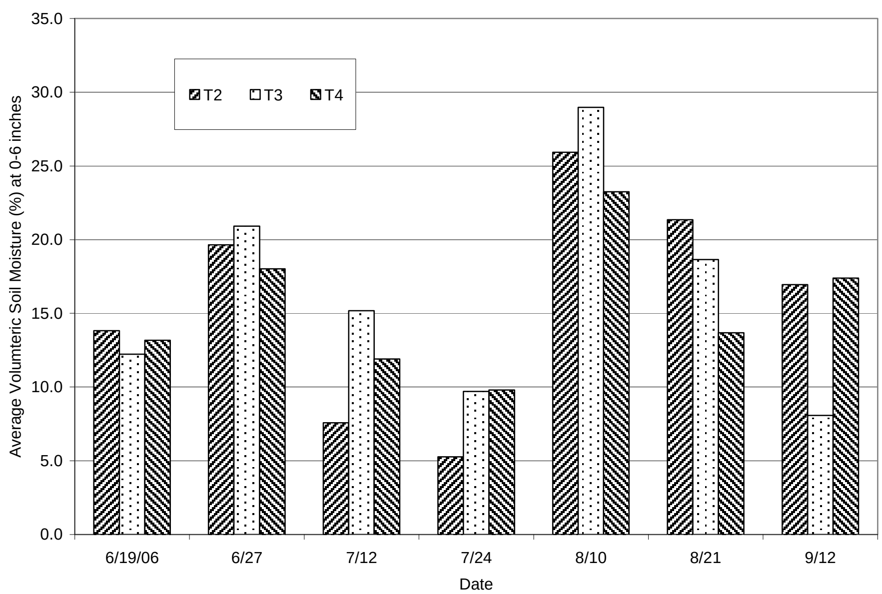

Figure 4. The average volumetric soil moisture in the top 6 inches of soil prior to several irrigation events at Maricopa in 2006 (see Figure 3 for description of treatments).