Conservation Tillage Systems for California Cotton: A Review of Recent Research Findings

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Introduction

Cotton production systems that have evolved over the past sixty years in California's San Joaquin Valley (SJV) rely heavily on tillage for seedbed preparation, weed control, and postharvest pest management. Intensive tillage practices that are used throughout the cotton production season contribute significantly to the crop's yield potential and help producers manage risk by providing uniform plant stands, weed control, as well as water and root penetration. These practices can also be costly (Table 1). Preplant tillage for conventional cotton production systems requires not only considerable labor and time, but also a number of specialized tillage implements and the corresponding tractor horsepower to pull them. Tillage or soil "preparation" costs for traditional SJV cotton production systems typically can easily exceed nine operations for ground preparation before the crop is even seeded (Mitchell et al., 2009).

Despite the recent availability of incentives programs such as the Farm Bill's USDA Natural Resources Conservation Services Environmental Quality Incentives Program (EQIP) encouraging tillage reduction as well as the increasing cost of intensive tillage, the majority of SJV cotton continues to be produced using traditional, heavy tillage practices (Mitchell et al., 2009). Cotton is today one of the most tillage-intensive agronomic crops produced in CA (Mitchell et al., 2007; Mitchell et al., 2009) and standard tillage management systems for SJV cotton in many areas have changed relatively little over the past 50 or more years. (Carter, 2007).

During the past decade, however, experience with a number of tillage system alternatives for cotton has increased and a variety of what are called "conservation tillage" (CT) approaches that reduce the frequency of tillage in cotton production systems have been evaluated and are now beginning to be used. The term "conservation tillage" as defined by the University of California Conservation Tillage and Cropping Systems Workgroup, refers to tillage management systems such as no-till (Photo 1), strip-till (Photo 2), ridge-till (Photo 3) or mulch-till that reduce tillage intensity and soil disturbance so as to maintain 30 or more percent of the soil covered by residues from previous crops after seeding, or that reduce the overall number of tillage passes across a field by 40 or more percent relative to what was conventionally done in 2000 (Mitchell et al., 2009) (See Sidebar 1). This latter type of conservation tillage systems is termed "minimum tillage

(Photo 4)." We report here a summary of findings resulting from two long-term studies that have evaluated a variety of sustained CT production systems for cotton in California's San Joaquin Valley to provide producers who may be interested in growing cotton using CT with information on the performance and initial challenges of these systems.

Long-term CT cotton study

To determine impacts of CT cotton systems over a number of years on productivity, profitability and soil properties, a study at the University of California West Side Research and Extension Center in Five Points, CA was established in 1999. An 8-acre field in a map unit of Panoche clay loam (fine-loamy, mixed, superactive, thermic Typic Haplocambids) (Arroues, 2000) was used for the study and a uniform barley (*Hordeum vulgare*) crop was grown over the entire field before beginning the treatments.   The field was divided into two halves; a tomato (*Lycopersicon esculentum*)-cotton (*Gossypium hirsutum* L.) rotation was used in one half, and a cotton-tomato rotation was pursued in the other half to allow tomato and cotton plantings and experiments to occur within each year. Management treatments of standard tillage without cover crop, STNO, standard tillage with cover crop, STCC, CTNO, and CTCC were replicated four times in a randomized complete block design on each half of the field. Treatment plots consisted of six beds, each measuring 30 x 270 ft. Six-bed buffer areas separated tillage treatments to enable the different tractor operations that were used in each system. All tractor and implement traffic was restricted to the furrows and planting beds were not moved or tilled, except for shallow weed cultivations during each tomato season and except in the ST treatments between crops. Cotton was seeded directly into tomato beds that were not disturbed following tomato harvest in the CT plots. A cover crop mix of Juan triticale (*Triticosecale* Wittm.), Merced ryegrain (*Secale cereale* L.) and common vetch (*Vicia sativa*) was planted at a rate of 125 lbs ac^{-1} (30% triticale, 30% ryegrain and 40% vetch by weight) in late October in the standard and conservation tillage plus cover crop plots and irrigated once in 1999 (Photo 5). In each of the subsequent years, no irrigation was applied to the cover crops, which were planted in advance of winter rains (Photo 6). The cover crops were chopped in mid-March of the following years using a Buffalo Rolling Stalk Chopper (Fleischer, NE). In the STCC system, the chopped cover crop was disked into the soil to a depth of about 8 inches and 5 ft-wide beds were reformed prior to tomato transplanting. The chopped cover crop in the CTCC was sprayed with a 2% solution of glyphosate after chopping and left on the surface as a mulch.

Conventional intercrop tillage practices that knock down and establish new beds following harvest were used in the ST systems (Table 2). The CT systems were managed from the general principle of trying to reduce primary, intercrop tillage to the greatest extent possible. Zone production practices that restrict tractor traffic to furrows were used in the CT systems and planting beds were not moved or destroyed in these systems during the entire study period.

The number of tractor trips across the field was reduced by about 50% for tomato and 40% for cotton in the CT systems relative to the ST approach (Table 2). This reduction occurred as a result of eliminating fall and spring tillage passes in the CT systems. CT cotton yields were lower than ST yields in the first four years of the study, but similar in subsequent years (Figure 1). From 2000 – 2007, a glyphosate-resistant (RR) transgenic Acala cotton variety, "*Riata*," was used, and in 2008 and 2009, an experimental RoundUp Ready-Flex Pima variety, Phy-8212 RF was grown. The Pima variety used represented a significant change in growth habit from the Acala variety, with a relatively aggressive growing, indeterminate growth habit. Pima with this growth habit can be more difficult to manage for high yields unless the right combination of plant growth regulator and deficit irrigation management are used, and this was seen to impact yield potential in the Pima part of the experiment (Figure 1). This variety of cotton was used to follow the Acala work to gain CT experience with Pima cotton.

The number of passes over the field in the CT plots compared to the ST plots was reduced from 23 to 15 for the CC systems and from 19 to 11 for the NO systems. The result of this was a reduction in fuel use by 26 gallons per acre and labor hours by two hours per acre (Table 3). The savings in fuel, labor, and repairs equaled $94 per acre in 2007 (Figure 2). The cover crop added three operations for the standard tillage treatment and two operations for the conservation tillage treatment for an increased cost of about $50 per acre per year. Consequently, the highest cost system was standard tillage with a cover crop followed by standard tillage without a cover crop. The two conservation tillage systems had the lowest costs with the cover crop system higher than without a cover crop (Figure 2).

However, looking at net income, the differences in yields and corresponding income were greater prior to 2005 than the differences in costs (Figure 3). In particular, the CTCC system showed the poorest yields in most years and also had the lowest accumulated net income despite the savings from reduced tillage (Figure 3). STNO had the highest yields in all years and the highest accumulated net income even though it had the second highest costs per acre. Adding a cover crop increased costs and decreased yields in both the ST and CT systems. CTCC showed the poorest economic performance with the lowest accumulated net income. CTNO showed a higher accumulated net return than STCC despite slightly lower yields in some years due to lower input costs. It should be mentioned that all systems were profitable in all years except the first year of the trial when yields were devastated by a mite infestation from a neighboring field.

The major improvements in the management of the CT cotton systems that enabled yield increases after the first four years of this work were primarily related to more successful planting operations that resulted in better early-season seedling vigor in the CT systems than were achieved early in the study. These improvements in plant populations and yields seen in later years of this long-term test stem from the recognition that because no soil “cap” is pulled over the seed in the CT systems to preserve soil moisture during germination and emergence, the timing of no-till seeding is critical and must correspond to the availability of adequate soil moisture conditions for emergence. Seeding into moist soil conditions is thus a critical requirement of successful no-till cotton production under SJV spring conditions.

The long-term nature of this tillage system comparison is unique in CA and has afforded opportunities to also evaluate impacts of tillage and cover cropping not only related to production economics, but also on a number of additional cropping system attributes (Table 3). The Soil Conditioning Index (SCI), for example, has been proposed by the USDA Natural Resources Conservation Service (NRCS) as a predictor of the consequences of management on soil organic carbon, or more specifically, on particulate organic matter, which is considered to be a labile precursor of more stable forms of soil carbon (Zobeck et al., 2007). The NRCS currently uses the SCI as one of its criteria for determining eligibility for Farm Bill conservation programs such as the Environmental Quality Incentives Program (EQIP). The computed SCI values in Table 3 seem to be closely associated with the field operations that were used in the tillage and cover crop systems. SCI values were negative for the two ST systems, suggesting a tendency for degrading soil carbon (C) stocks, and positive for the CT systems, indicating agrading C stocks. Fuel use was estimated to be reduced by about 72% in the CT systems relative to the ST systems. Long-term impacts of these tillage and CC systems on soil properties and information on the performance of tomatoes and cover crops in these systems is reported in other publications (Mitchell et al., Submitted; Mitchell et al., Submitted).

6-year CT cotton planting study

Other CT cotton planting options including ultra-narrow no-till drill seeding, twin-row no-till seeding, as well as single-row no-till, strip-till, and a minimum tillage "control" system into 60” tomato beds have also been evaluated through three cycles of a tomato – cotton rotation at the West Side Research Center near Five Points, CA. Treatment plots consisting of twelve 5-ft beds 270 ft long were replicated four times in a randomized complete block design in an 8-acre field with a similar deep, relatively uniform clay loam soil described above. Cotton was produced in 2003, 2005, and 2007 using these planting systems following uniform tomato crops in each preceding year. Two passes of a Wilcox “Performer” (Wilcox Agriproducts, Walnut Grove, CA) were used to provide a “control” treatment comparable to some of the minimum tillage systems that are increasingly being used in the San Joaquin Valley (Mitchell et al., 2009). Winter weed control was accomplished in all treatments by one spraying of a 2% solution of glyphosate applied in February or early March. The RoundUp Ready™ transgenic upland cotton (*Gossypium hirsutum*) variety, ‘*Riata*,” was used in all cotton systems in all years and was established using a John Deere (Moline, IL) 1730 No-till Planter for the minimum tillage, no-till and strip-till systems. A Monosem twin-row 30” seeder was used in the twin-row system and a 15 ft John Deere 1560 no-till drill with 7.5” between-row spacing was used to establish the ultra-narrow row system (Photo 7). An application of 125 lbs ac^{-1} of urea fertilizer per acre was made in each year in each system using a fertilizer shank fitted with an 18 inch coulter to cut residues about 10 inches to the side of plants and about 6 inches deep. All tractor traffic was restricted to the furrows between planting beds in the CT systems; no tillage was done in the CT plots following tomatoes and preceding the next cotton crop, and only two tractor passes were conducted following cotton and preceding each subsequent tomato crop. These operations included shredding and uprooting the cotton stalks in order to comply with “plowdown” regulations for pink bollworm (*Pectinophora* *gossypiella*) control in the region and a furrow sweep operation to clean out furrow bottoms to improve irrigation water movement down the furrows. Cotton lint yields were determined using seed cotton weights from the inner eight rows in each plot multiplied by gin turnout percentages determined on samples sent through the UC Shafter Research and Education Center research gin.

Very high plant populations exceeding 80,000 plants per acre were achieved with the ultra-narrow row no-till method. While this system provided a cheaper crop establishment option and although raw yields for this system were comparable to the highest yielding system in each year of the study, its gin turn-out percentages were consistently lower than other systems and thus final yields ended up being lower (Table 4). The ultra-narrow row no-till planting practice also requires stripper-head harvesters which are currently not widely available in the SJV (Photo 8). The minimum and twin-row no-till systems had highest yields in 2003 (Table 4) with the no-till and ultra-narrow no-till systems having about 100 lbs of lint productivity lower. Low yields of the strip-till system in 2003 seemed to result from the fact that the strip-till implement that was used destroyed the shoulders of the 60” planting beds and created low trough areas that were difficult to plant into. This issue was remedied in 2005 and 2007 by running the strip-tiller less aggressively and thereby preserving better planting bed conditions. As a result, strip-till yields were not significantly lower than the top yielding systems in either 2005 or 2007. As in the longer-term study described above, the relative yields of the CT systems improved as the study progressed. Because, however, early-year strip-till and ultra-narrow no-till yields tended to be lower than the min-till control, the 3-year average yields of these two systems were about 100 lbs of lint lower than yields of the other systems.

CT Postharvest Cotton Management

Effective control of pink bollworm (*Pectinophora gossypiella*), a pest that damages cotton bolls and has cost the US cotton industry billions of dollars over the years, has been a long-standing priority of SJV cotton producers. A major strategy for pink bollworm (PBW) control, which has been highly successful for more than 30 years in the SJV, is an IPM approach largely based on a pest-monitoring program and the controlled use of a biological control method (http://www.cdfa.ca.gov/phpps/ipc/pinkbollworm/pbw_hp.htm). Components of the system include a minimum “host-free” period in which no cotton plants are available as hosts to the pest. This minimum period is from mid-to late December (last date for cutting plant stems from the roots and incorporating plant residue) through March 10 (earlier allowed planting date in the SJV). Other parts of the pink bollworm control program include monitoring pink bollworm adults in pheromone-baited traps placed throughout California cotton fields, followed by the targeted release of sterile moths to disrupt normal mating.

The host-free period for cotton currently mandated by the California PBW Eradication Program does not allow all forms of CT in cotton-containing rotations. Cotton stalk shredding, some form of root undercutting or dislodging, and a mixing of residues with surface soil so as to guarantee that no living cotton plants remain in a field during the host-free period are all required for compliance with PBW Eradication Program compliance. To balance the mutually important goals that cotton producers have to both eliminate risks associated with the PBW while at the same time minimize production costs and dust and diesel emissions that have been mandated by the SJV Air Pollution Control District, a variety of postharvest management options are now being evaluated as part of sustained CT cotton production systems. In addition to the "pass combination" minimum tillage implement options that have been described above and that essentially result in field conditions similar to conventional tillage, other equipment such as various root puller or root cutting implements may provide desired outcomes to comply with management regulations while at the same time reducing overall tillage. Two such implements are the root cutter that relies on rotating horizontal disk blades that are shallowly pulled through the soil effectively shearing off and dislodging cotton roots and stalks with relatively less overall soil disturbance than is typically done using conventional stubble disking (Photo 9), and a root puller implement (Arizona Drip Systems, Coolidge, AZ) (Photo10) that also relies on angled disk blades that uproot and dislodge roots as the implement is drawn through a cotton field. The effectiveness of these CT approaches for cotton PBW management will continue to be under investigation in Five Points, CA in conjunction with the CDFA PBW Eradication Program. In two recent years of CDFA monitoring of the long-term Five Points, CA study field described above, no PBW's have been found.

Opportunities and Barriers for Further Adoption of Conservation Tillage for SJV Cotton

In the aggregate, recent experiences with CT cotton in the SJV and the far wider experience base from other parts of the US Cotton Belt have been encouraging enough to warrant further evaluation and refinement of CT systems here in CA. A wide range of innovative CT equipment has been introduced to the region and has been shown to function successfully in CA cotton production fields under a variety of conditions. Two critical components of possible CT cotton production systems, however, are particularly important for wider success and will largely determine whether such approaches expand following the early "proof of concept" evaluations that have been described in this report. These are the indispensable need to achieve vigorous crop stands and the absolute need to avoid unnecessary trafficking in what will eventually be crop growth zones within a CT rotation field.

Because the various no-till and strip-till seeding systems that have been used in the CT evaluations described above do not rely on "pulling a cap" of dry soil over the cotton seed line to preserve seed zone moisture during germination and early seedling growth, the risk of having uneven emergence and weakened seedlings is great using CT seeding approaches unless care is taken to avoid these problems. Inadequate plant populations and low seedling vigor have been the greatest problems associated with reduced yields in CT cotton to date. Placing seed into adequate soil moisture is thus a key to CT cotton planting. Careful and well-timed seeding techniques that account for both planting degree day forecasts and adequate soil moisture are required for successful crop establishment. Whether a planting field has been prepared with beds or is flat is also another key factor because there may be less of an opportunity to move soil so as to reach moisture in a flat field and because currently-available no-till seeders may actually work better under flat field conditions.

The second possible constraint to sustained CT management in cotton-containing rotations is compaction. To date, no rigorous determinations of subsurface compacted zones arising from tractor and implement trafficking have been conducted in any of the recent CT evaluations that have taken place in the SJV. The bulk of the work reported here has either been of short-enough duration, used minimum till equipment that has been successful in alleviating compaction, or relied on dedicated traffic and crop growth zone production approaches that themselves minimize compaction risks. To be eventually sustainable over the long-term, however, CT systems will likely need to employ some combination of very deliberate compaction avoidance with perhaps targeted zone or vertical tillage (Carter, 1996).

The cost savings and general resource conservation benefits that may be provided by CT cotton production systems and that have recently been demonstrated in a number of the studies reported here thus warrant further evaluation and development. Provided yield performance, or more importantly, bottom-line profitability is maintained, the CT systems or appropriate modifications of them may be increasingly attractive to producers and also eventually more common in SJV cotton growing areas. Cotton producers interested in these CT options might increase their chances for success at them by considering the following as they work to improve their tillage systems.

Keys to Successful Adoption of CT

There is a growing CT experience and knowledge base that includes farmers, University of California Advisors, private sector consultants, and NRCS Conservationists in the SJV and although much local CT system experience is currently more directly related to dairy silage crop production, good practical information and guidance from these successes may be available and useful to SJV cotton farmers. A network of these information sources can be found by contacting California's Conservation Tillage and Cropping Systems Workgroup at http://groups.ucanr.org/ucct/

Successful and sustainable adoption of CT practices requires long-term planning and a number of relatively major changes to a cropping system. Growers thus attempting to transition to this type of management would benefit from very deliberate and up-front consideration of a number of factors that will eventually determine success. Such considerations include: starting the transition to CT with uncompacted field subsoil layers that can initially be achieved by ripping plow pans before CT practices are instituted, restricting tractor, implement and harvest equipment traffic to the greatest extent possible, using GPS-enabled "zone" production trafficking, and very deliberately avoiding tractor work when the field is wet.

Converting SJV cotton production to no-till or strip-till seeding techniques is not a trivial endeavor and because such a conversion entails risk, producers would do well to initially start on a somewhat small scale before attempting wholesale, farm-scale transformations. In addition, while both of the studies described in this report were furrow irrigated, other irrigation systems such as solid-set subsurface drip or overhead center pivot, may ultimately be more compatible with CT. Studies are now underway in Five Points to evaluate the coupling of these irrigation systems for CT cotton. A number of incentive and risk management programs are currently available via the CT and Cropping Systems Workgroup to help with initial CT cotton efforts.

As critical as seeding and establishment practices are in conventional cotton production fields, because surface residues may be present and because extensive seedbed preparation operations are no longer performed using no-till or strip-till systems, they are even more critical for success with CT. Having proper planter equipment, knowing how to operate it, and dedicating the time required for careful planting are keys to successful CT adoption for cotton.

UC's Conservation Tillage and Cropping Systems Workgroup maintains a considerable data base and a variety of networking opportunities for SJV farmer who are interested in transitioning to CT. For additional information contact Workgroup members at http://groups.ucanr.org/ucct/

References

Arroues, K. 2000. Classification and correlation of the soils of Fresno County, western part. USDA-NRCS, Washington, DC.

Carter, L.M. 1996. Tillage. In Cotton Production Manual. University of California Division of Agriculture and Natural Resources Publication 3352. Pages. 175 – 186.

Carter, L. 2007. USDA and Cotton in Kern County, USDA, ARS. November 29, 2007 http://www.ars.usda.gov/8F673E08-829A-4B92-9E83-34630579A850/FinalDownload/DownloadId-95D38A52B4221650968A619C5A16D65B/8F673E08-829A-4B92-9E83-34630579A850/sp2UserFiles/Place/53030000/KernCot.pdf

Mitchell, J.P., G.S. Pettygrove, S. Upadhyaya, A. Shrestha, R. Fry, R. Roy, P. Hogan, R. Vargas, and K. Hembree. 2009. Classification of conservation tillage practices in California irrigated row crop systems. Publication 8364. http://anrcatalog.ucdavis.edu

Mitchell, J.P., K.M. Klonsky, E.M. Miyao, and K.J. Hembree. 2009. Conservation tillage tomato production in California's San Joaquin Valley. UC ANR Communication Services Publication 8330.

Mitchell, J.P., K.Klonsky, A. Shrestha, R. Fry, A. DuSault, J. Beyer, and R. Harben. 2007. Adoption of conservation tillage in California: Current status and future perspectives. Australian Journal of Experimental Agriculture, 47(12):1383-1388.

Mitchell, J.P., W.R. Horwath, R.J. Southard, N.M. Madden, D.S. Munk, T. Gohlke and R. Bickel. Submitted. Agron. J.

Mitchell, J.P., E.M. Miyao, K.Klonsky and R. DeMoura. Covercropping and conservation tillage in California processing tomato production systems. Submitted. ANR Communication Services.

Zobeck, T.M., J. Crownover, M. Dollar, R.S. Van Pelt, V. Acosta-Martinez, K.F. Bronson and D.R. Upchurch. 2007. Investigation of soil conditioning index values for Southern High Plains agroecosystems. Journal of Soil and Water Conservation. 62(6):433-442.

Table 1. Pre-plant tillage operations and operating costs for a cotton crop in the San Joaquin Valley estimated for 2010[1/]

		Costs per Acre		
Operation	Hours/acre	Labor	Fuel, lube & repairs	Total Cost
Stubble disk	.54	$9	$28	$37
Chisel	.24	4	14	18
Triplane	.15	2	7	9
List beds	.14	2	7	9
Dry mulch / Lilliston beds	.25	4	8	12
Total	1.32	$21	$64	$85

[1/] Operating costs do not include equipment ownership or depreciation.

Table 2. Comparison of standard tillage (ST) and conservation tillage (CT) operations with and without cover crops used in this study for cotton. (Each "X" indicates a separate instance of each operation.)

	With cover crop		Without cover crop	
Operation	ST	CT	ST	CT
Disk	XX		XX	
Chisel	X		X	
Level (Triplane)	X		X	
List beds	X		XX	
Spray Herbicide: Treflan	X		X	
Incorporate Treflan (Lilliston)	XX		XX	
Spray Herbicide: Roundup	XX	XXXX	X	XXX
Cultivate – Rolling Cultivator	XX		X	
Chain Beds	X	X		
Plant Cotton	X	X	X	X
Fertilize	X	X	X	X
Plant Cover Crop	X	X		
Mow Cover Crop	X	X		
Spray Insecticides/Growth Reg	XX	XX	XX	XX
Spray: Defoliate	X	X	X	X
Spray Insecticides	XX	XX	XX	XX
Harvest-Custom	X	X	X	X
Times Over Field	23	15	19	11

Table 3. Tillage and cover crop system soil condition index and estimates of diesel fuel use.

Cropping System*	**Soil conditioning index§**	**Diesel fuel use (gallons)**	**Fuel cost for entire simulation ($)**
STNO	-0.71	32	128.6
STCC	-0.96	40	160.6
CTNO	0.43	9.3	36.8
CTCC	0.52	11	43.27

*STNO = Standard tillage no cover crop, STCC = Standard tillage with cover crop, CTNO = Conservation tillage no cover crop CTCC = Conservation tillage with cover crop. § SCI = soil conditioning index value;

Table 4. Cotton lint yields for standard tillage, no-tillage, strip-tillage, twin-row no-tillage, and ultra-narrow row no-till drill seeding following tomato harvest, Five Points, CA

Tillage / planting system	**2003**	**2005**	**2007**	**Average over 3 yrs**
	(lbs/ac)	*(lbs/ac)*	*(lbs/ac)*	*(lbs/ac)*
Standard tillage	1,638 a	1,475 a	1,885 ns	1,666
No-tillage	1,538 b	1,464 a	1,929 ns	1,644
Strip-tillage	1,348 c	1,450 a	1,887 ns	1,562
Twin-row no-tillage	1,696 a	1,371 b	1,893 ns	1,653
Ultra-narrow row drill seeded no-tillage	1,540 b	1,280 b	1,821 ns	1,547

Figure 1. Cotton yield per acre

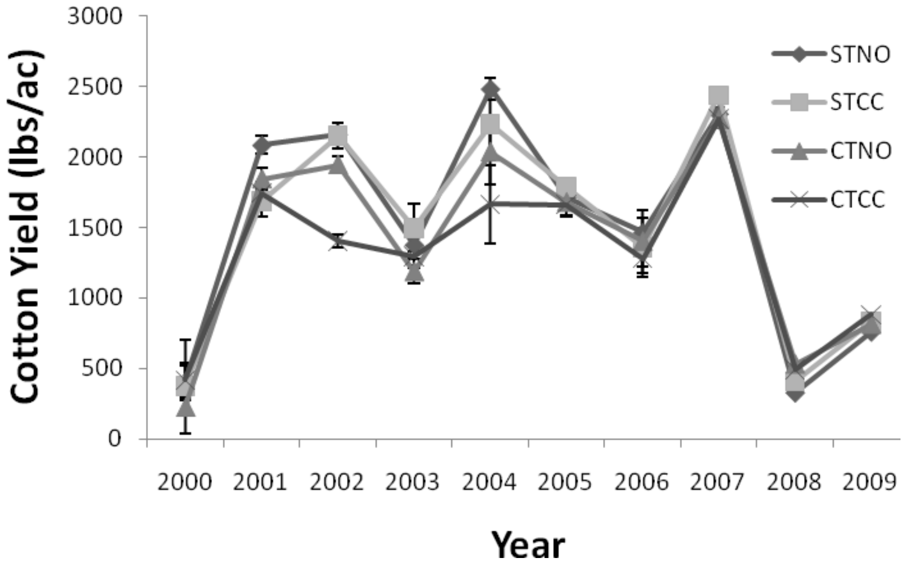

Figure 2. Cost of production per acre

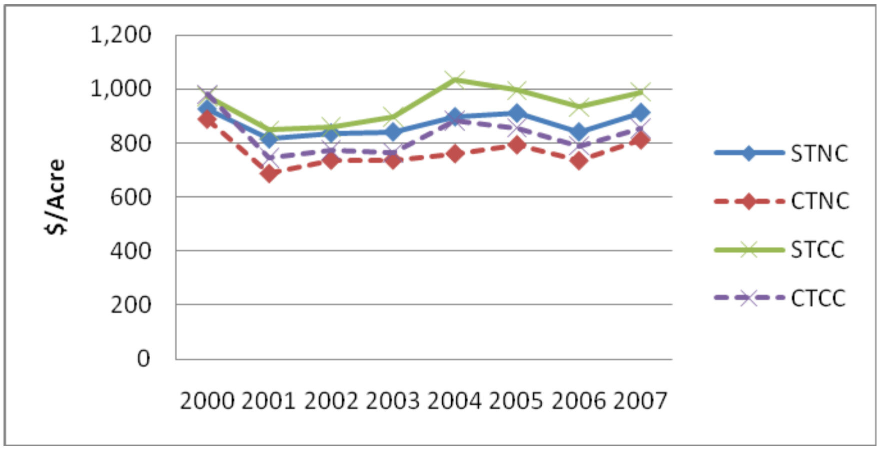

Figure 3. Net returns per acre

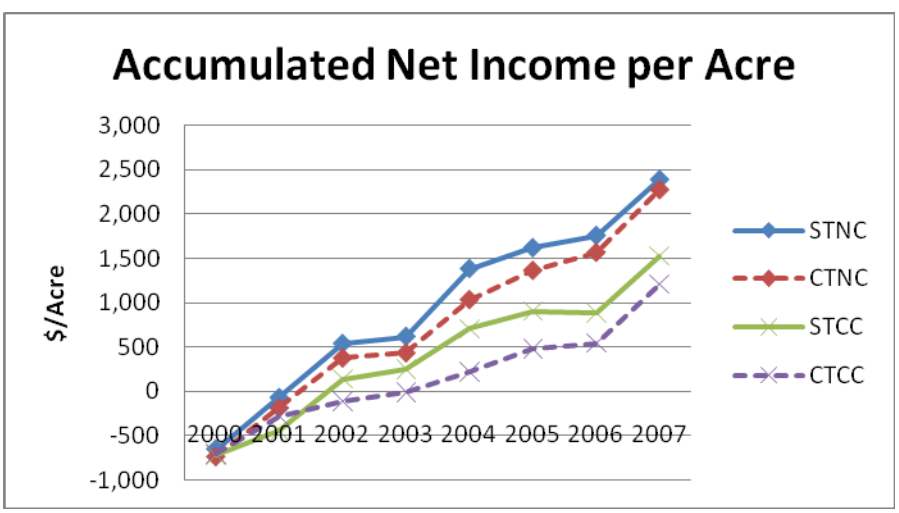

Photo1	No-till planting into wheat residue, Five Points, CA 2007
Photo 2	Strip-till seedbed preparation prior to cotton seeding, Borba Farms, Riverdale, CA 2003
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Photo 9 Horizontal disk blade toolbar used for cotton root shearing and dislodging following stalk shredding, Five Points, CA

Photo 10 Cotton residue following stalk shredding and root pulling with an Arizona Drip Systems (Coolidge, AZ) root puller

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Figure 1

Cotton yield (lbs lint/ac) for STNC (standard tillage no cover crop), STCC (standard tillage with cover crop), CTNC (conservation tillage no cover crop), and CTCC (conservation tillage with cover crop) for 2000 – 2007 at the University of California West Side Research and Extension Center, Five Points, CA study

Figure 2

Costs of cotton production ($/ac) for tillage and cover cropping systems evaluated at the University of California West Side Research and Extension Center, Five Points, CA. Symbols are identical to those in Figure 1.

Figure 3

Net returns ($/ac) for tillage and cover cropping systems evaluated at the University of California West Side Research and Extension Center, Five Points, CA. Symbols are identical to those in Figure 1.

Sidebar 1

Classification of tillage systems in California

no-tillage	soil is left undisturbed from harvest to planting except perhaps for injection of fertilizers
strip-tillage	seed row is tilled prior to planting to allow residue removal, soil drying and warming and in some cases subsoiling
ridge-tillage	soil is undisturbed from harvest to planting expect for fertilizer injection and crops are seeded and grown on ridges or shallow beds that have been formed or built during prior growing season
mulch-tillage	any CT systems other than no-till, strip-till, or ridge-till that preserves 30 percent or more surface residue
minimum tillage	systems that reduce tillage passes by at least 40% relative to what was conventionally done in 2000

typically by using tillage

implements that "combine passes"

1