CONSERVATION SYSTEMS FOR TOMATOES AND COTTON IN CALIFORNIA

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ABSTRACT

Labor shortages, rising diesel fuel costs, and regulations aimed at improving air quality are major factors impacting crop production systems in California's San Joaquin Valley. Since 1999, we have evaluated conservation tillage (CT) tomato and cotton production practices with and without winter cover crops as a means to address these factors. CT reduced tractor trips across the field by 50% for tomatoes and 40% for cotton compared to standard tillage. Yields have been generally maintained in the conservation tillage tomato systems, but 11 – 14% lower for the CT without cover crop system and 6 – 36% lower for the CT with cover crop cotton system. Fuel use was reduced by the CT systems, however, because only about 20% of operating costs for these crops are for preplant tillage operations, the cultural costs of production were reduced by only about 10 percent. Production problems with the cotton crops included difficulties with consistent and uniform stand establishment.

INTRODUCTION

Since the development of water resources in California's San Joaquin Valley (SJV) during the 1930's through the 1960's, this region has become a major production zone for a number of crops. Six SJV counties, Fresno, Tulare, Kern, Merced, Stanislaus and San Joaquin, are consistently among the nation's top ten producing counties in recent years (California Agricultural Resource Directory, 2005). Whereas conservation tillage practices have become common in other regions of the country, they are not widely used in the SJV (CTIC, 2002).

CT practices have been developed in other regions for several of the crops grown in the SJV including corn, wheat, cotton, and beans (CTIC, 2002). No-till techniques for growing tomatoes have also been described for other areas (Abdul-Baki and Teasdale, 1993), though their adoption has not been widespread (Abdul-Baki, Personal communication).

In the fall of 1999, we established a field comparison of conservation and standard tillage cotton and tomato rotations with and without winter cover crops at the University of California West Side Research and Extension Center in Five Points, CA. The objective of the study was to compare conservation tillage and conventional tillage practices in crop rotations common to the SJV in terms of productivity and profitability, key soil quality indicator properties, and the quantity of dust produced. We report here aspects of how the tillage systems generally performed during the first four years of this ongoing study.

MATERIALS AND METHODS

An 8 acre field in the map unit of Panoche clay loam (fine-loamy, mixed, supernatic, 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 enable comparisons of both tomatoes and cotton in each year. Management treatments of standard tillage without cover crop (STNO), standard tillage with cover crop (STCC), conservation tillage without cover crop (CTNO), and conservation tillage with cover crop (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. 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 100 lbs per acre (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. In each of the subsequent years, no irrigation was applied to the cover crops due to the advent of timely early winter rains. The cover crops were then 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 then disked into the soil to a depth of about 8 in. and 5 ft. wide beds were then 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 standard tillage (ST) systems. The conservation tillage 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 four years.

Tomatoes (‘*8892*’) were then transplanted in the center of beds at an in-row spacing of 12 in. during the first week of April in each year using a modified three-row commercial transplanter fitted with a large (20 in.) coulter ahead of each transplanter shoe. All systems were fertilized the same. Dry fertilizer (11-52-0 NPK) was applied preplant at 100 lbs per acre. Additional N was sidedress applied at 125 lbs. per acre. The *RoundUp Ready*™ cotton (*Gosypium hirsutum*) variety, ‘*Riata*,’ was used each year in all cotton systems and was established using a John Deere (Moline, IL) 1730 No-till Planter. 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 pinkboll worm control in the region and a furrow sweep operation to clean out furrow bottoms to allow irrigation water to move readily down the furrows. Crop yields were determined in each year using field weighing gondola trailers following the commercial machine harvest of each entire plot.

During the four years of this study, the number of tractor trips across the field was reduced by about 50% for tomato (Table 1) and 40% for cotton (Table 2) in the CT systems relative to the ST approaches. Differences in the tillage intensity between systems were due primarily to

Table 1. Comparison of standard and conservation tillage system operations with and without cover crops for tomato.

	With cover crop		Without cover crop	
Operation	Standard	Conserve	Standard	Conserve
Shred cotton	X		X	
Undercut Cotton	X		X	
Disc	XXXX		XX	
Chisel	X		X	
Level (Triplane)	X		X	
List beds	XX		X	
Incorporate/Shape beds	X		X	
Clean Furrows		X		X
Shred Bed		X		X
Spray Herbicide: Treflan	X		X	
Incorporate Treflan (Lilliston)	X		X	
Spray Herbicide: Roundup			X	X
Spray Herbicide: Shadeout	X	X	X	X
Cultivate – Sled Cultivator	XXX		XXX	
Cultivate – High Residue Cultivator		XXX		XXX
Roll Beds				
Plant Tomatoes	X	X	X	X
Fertilize	XX	XX	XX	XX
Plant Cover Crop	X	X		
Mow Cover Crop	X	X		
Harvest-Custom	X	X	X	X
Times Over Field	23	12	19	11

reductions in those soil disturbing operations commonly associated with postharvest "land preparation," including disking, chiseling, leveling and relisting beds, - operations that are typically performed in the fall. The operations listed in Tables 3 and 4 represent average sequences for all years; slight differences occurred in certain years. For instance, we originally performed two operations following cotton harvest in the CT systems, - a one-pass Shredder-Bedder (Interstate Mfg., Bakersfield, CA) to shred and undercut the cotton plant, and a furrow sweeping operation using a Buffalo 6000 High Residue Cultivator (Fleischer Mfg., Columbus, NE) modified and fitted with only furrow implements. However, in 2003, we fitted our no-till tomato transplanter with furrow "ridging wings" and thereby cleared out residues from furrow bottoms at the time of transplanting.

The general CT approach pursued in this study was to more severely restrict tillage operations than is customarily done today. As a result of this, more residues accumulated on the soil surface, particularly in the CTCC systems and this at least partly explains the lower numbers of cotton plants that were established in this system in each year relative to the STNO system (data not shown).

Table 2. Comparison of standard and conservation tillage operations with and without cover crops for cotton.

	With cover crop		Without cover crop	
Operation	Standard	Conserve	Standard	Conserve
Disk	XX		XXXX	
Chisel	X		X	
Level (Triplane)				
List beds	X		XX	
Incorporate/Shape beds				
Clean Furrows				
Compact Furrows				
Spray Herbicide: Treflan	X		X	
Incorporate Treflan (Lilliston)	XX		XX	
Spray Herbicide: Roundup	XX	XXXX	X	XXX
Cultivate – Rolling Cultivator	XX		X	
Cultivate – Sled Cultivator				
Open/close Ditch for Irrigation				
Chain Beds	X	X		
Plant Cotton	XX		X	X
Fertilize (Water Run)				
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
Custom Defoliate				
Custom Spray Insecticides				
Spray Insecticides	X	X	X	X
Harvest-Custom	X	X	X	X
Times Over Field	19	12	22	13

In addition, we were initially concerned that residues would interfere with the action of the "over-the-top" tomato herbicide *ShadeOut*, which can be sprayed after transplanting and sprinkled in to activate. By 2003, however, we used it in all systems with observed benefits. Though we did not consistently monitor weed populations during this study, we did generally observe more weeds under CT for both tomato and cotton. For CT cotton, we relied solely on 1 or 2 in-season applications of *RoundUp*; no cultivation was done in these systems. For tomatoes, we typically cultivated 2 to 3 times, but this did not achieve a comparable level of weed control in the CT systems as in the ST systems in all years and this is one aspect of the approach taken here that needs to be improved.

It is important to point out that while the CT systems we employed in this study dramatically reduced overall tillage and soil disturbance relative to today's norms for the SJV, they by no means constitute what is customarily considered "no-till" production. In classic no-till, or "direct seeding" systems, crops are planted directly into residues and no additional soil disturbance is generally done prior to harvest. We employed the intermediate or incremental tillage reduction strategy described here in part because of California Department of Food and Agriculture mandates for pink bollworm control that require considerable soil disturbance, and because of the need to maintain somewhat clear channels for irrigation water movement down furrows.

RESULTS AND DISCUSSION

Yield results during the first four years of this study show that tomato yields were maintained in the CT system relative to the ST system in each year (Table 3). Processing tomato yields in 2000 were slightly lower in each of the cover cropped systems relative to both the standard can conservation tillage systems without cover crops. This occurrence may have been caused in part by the slower early season tomato growth that was observed in each of the cover cropped systems and this growth reduction may have resulted from nitrogen immobilization following cover crop termination in each spring, and, in the case of the CTCC system, lower soil and near-surface air temperatures. Additional testing is now underway to evaluate each of these hypotheses. Data from the 2001 tomato harvest indicate that yields in the CT both with and without cover crops were similar to those in the standard till plots, with an elimination of several tillage operations following the preceding year's cotton crop in the CT plots relative to the standard till systems. In both 2002 and 2003, the highest yielding system was the conservation tillage system without a cover crop. Using a cover crop meant lower yields for the conservation tillage system in all years. Interestingly, for the standard tillage system, a cover crop increased yields in 2001 and again in 2003. Using the average of 2001 – 2003, conservation tillage without a cover crop resulted in 8.7 tons per acre more than the standard tillage, while with a cover crop the average yield was .8 tons lower.

Cotton yields were low in all systems in 2000 due to a devastating infestation of mites in the field that persisted all season and were exacerbated by pesticide resistance that developed presumably because the same miticide was sprayed repeatedly in the field during the same season (Table 4). 2001 cotton yields were lower in both conservation tillage crop systems relative to the standard tillage control system. In 2001 and 2003, yields were comparable, but higher for the standard tillage systems than the conservation tillage systems both with and without cover crops. A cover crop increased yields only in 2003. Average yields for 2001 – 2003 were higher for standard tillage with and without cover crops (277 and 207 pounds per acre, respectively). Reasons for the reduced yields in the CT systems as well as in the STCC system in 2001, we believe, relate largely to difficulties we experienced establishing the crops in these systems. Further work to refine and improve our planting and establishment of cotton in these contexts is underway.

Although conservation tillage reduced the number of operations in half, the cultural cost of tomato production was reduced by only about 10 per cent. This is explained by realizing that 41 percent of costs are for harvest and 14 percent are for seed. Only 20 percent of operating costs are for preplant tillage operations. The value of the savings from reducing labor and fuel use will increase as labor rates and fuel costs per gallon increase. For example, conservation tillage reduced fuel use by 16 gallons per acre. At a price of $1 per gallon the savings is $16 but at a price of $3 per gallon the savings is $39 per acre.

The summary findings presented here indicate short-term outcomes and issues associated with a conversion to CT production in an irrigated region such as California's Central Valley.

Table 3. Processing tomato yields (tons/acre) for standard and conservation tillage systems with and without cover crops in Five Points, CA.

	2000	2001	2002	2003
Standard tillage no cover crop	58 a	61 b	46 b	42 c
Standard tillage cover crop	53 b	63 a	43 b	45 b
Conservation tillage no cover crop	56 a	64 a	56 a	54 a
Conservation tillage cover crop	51 b	61 b	43 b	52 a

Different letters within columns indicate statistical significance at P = 0.05.

Table 4. Cotton yields (lbs lint/acre for standard and conservation tillage systems with and without cover crops in Five Points, CA.

	2000	2001	2002	2003
Standard tillage no cover crop	360 a	1784	1930 a	1228 ab
Standard tillage cover crop	360 a	1405	1921 a	1336 a
Conservation tillage no cover crop	200 a	1579	1736 b	1058 b
Conservation tillage cover crop	372 a	1454	1252 c	1157 ab

Different letters within columns indicate statistical significance at P = 0.05.

These preliminary results suggest that establishing and harvesting processing tomatoes and cotton with conservation tillage systems is possible given some equipment modification and that yields may be maintained for tomato, but were reduced in the case of cotton, relative to standard tillage in CT crop residue environments. A number of possible constraints to the adoption of these high residue production systems were observed during this "transition" period and these require further investigation (Table 5). First, the continued, long-term accumulation of surface residues may eventually present problems in terms of planting, cultivating and harvesting of both tomatoes and cotton. Transplanting and cultivating tomatoes took more time in the CTCC plots relative to the standard till systems. Second, although we did not attempt to quantify the actual amount of residue that gets picked up by harvesting equipment, there would seem to be at least the possibility that high surface residue systems may eventually result in greater "material other than tomatoes" being harvested, which will ultimately require increased cleaning effort and perhaps expense at harvest. Third, although "zone production" theory might suggest that soil compaction constraints may, to a large extent, be avoided by keeping tractor traffic away from "crop growth zones," (Rechel *et al.*, 1987), longer-term studies that investigate implications of reduced till regimes on compaction are needed.

This study is the first of its kind in California to systematically compare tillage system alternatives through a crop rotation. The extent to which such alternatives are adopted in this region will ultimately depend on their profitability, whether or not weed, insect and disease pests can be adequately managed over time, and possibly, whether processors and ultimately consumers find sufficient value in these types of production approaches to provide cost offsets to support their adoption.

Table 5. Major difficulties with CT cotton and tomato production systems and possible solutions

Cotton	
Problems	*Possible solutions that are being pursued in subsequent evaluations*
Erratic, weak and delayed stand establishment	Plant into adequate moisture (earlier than for traditional "cap planted" systems
Soil moisture dries up at seeding time	Plant earlier or closer to time of "pre-irrigation" than with traditional "cap planted" systems
In-season weed control is weaker in CT systems that only received one application of glyphosate	Apply diverse IPM weed management interventions including cultivation
Tomato	
Problems	*Possible solutions that are being pursued in subsequent evaluations*
Early season tomato growth is delayed in heavy cover crop residues	Consider strip-tilling residues in the transplant line
	Develop improved early season fertility program for CT tomatoes
Season-long weed control	Use both "over-the-top" transplant line herbicides at transplanting and season-long cultivations

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