CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE
FERTILIZER RESEARCH AND EDUCTION PROGRAM
**Annual Report**
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**Project Title:** **Fertilization Technologies for Conservation Tillage Production Systems in California**
CDFA Contract # 01 - 0123

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**Statement of Objectives:**

The objectives of this research are:

1) to evaluate the effectiveness of various fertilization practices in conservation tillage tomato, corn and cotton production systems

2) to determine the fertilizer use efficiency in conservation tillage production systems transitioning to CT

**3) to compare crop tissue nitrogen status in standard (ST) and conservation tillage** (CT) production **systems, and**

4) to extend information developed by the project widely to Central Valley row crop producers via field days, equipment demonstrations and written project outcome summaries

Executive Summary:

Replicated large-scale field experiments have been established in Davis and Five Points to determine the fertilizer use efficiencies of conservation tillage and standard tillage cotton / tomato and corn / tomato crop rotations. At the Davis site, four experimental treatments (standard tillage no cover crop, STNO, standard tillage with incorporated cover crop, STCC, conservation tillage with no cover crop, CTNO, and conservation tillage with cover crop, CTCC) were established in the fall of 2002 in nine- bed (60" each) field plots that are replicated 4 times in a randomized complete block design. In 2001, a uniform field corn crop was produced across the entire field. Following corn harvest in September 2001, common vetch cover crops were seeded in each of the CC plots. Forty 15N microplots (4.57m wide and 3m long) were then established during the 2001 - 2002 winter to track the amount of 15N-labelled fertilizer and vetch cover crop that is taken up by each of the main summer crops during the course of the study. The 2001 corn crop began a five-year, ongoing corn-tomato rotation with winter vetch cover crops grown in the STCC and CTCC systems each year. Considerably different tillage and organic matter management has thus been done in these plots. The Five Points study is evaluating fertilizer use efficiencies of standard and conservation tillage tomato / cotton systems also with and without winter cover crops. Both sites have been important in terms of our developing initial data on how CT systems perform and in terms of adjustments in management hat might be required as production systems scale back tillage intensity. To date, we have seen somewhat variable results with respect to crop yields. In Davis, CT tomato yields have been equal to or slightly lower

than ST yields, but CT corn yields in 2003 were reduced by 20% or more relative to the ST systems. At the Five Points site, CT tomato yields have equaled or exceeded those of ST, however, CT production of cotton was reduced between 8 - 15% in comparison to standard till. At this point, we speculate that these yield reductions for the CT systems relate to both difficulties establishing adequate plant populations and suboptimal N fertility. Preliminary 15N uptake data indicate that more N is taken up under ST than CT, however, there may be factors that complicate this simple interpretation. These two CDFA/FREP-sponsored studies have become key sites in terms of efforts of California's Conservation Tillage Workgroup to develop information related to reduced tillage alternatives. Information based on the background, objectives and preliminary findings of these studies has been presented to more than 100 audiences during the course of the project.

**Description** of Work **Accomplished:**

**Task 1** . *Establish **experimental** plots at UCD and WSREC sites*

This project is being conducted in a 5 acre field at the Vegetable Crops and Weed Science Field Headquarters on the UC Davis campus and in an 8 acre field study at the UC West Side Research and Extension Center in Five Points, CA. A corn/tomato/corn/tomato/corn rotation is being pursued at the UC Davis site, and a tomato/cotton/tomato/cotton rotation is used in Five Points

In Davis, four experimental treatments (standard tillage no cover crop, STNO, standard tillage with incorporated cover crop, STCC, conservation tillage no cover crop, CTNO, and conservation tillage with cover crop, CTCC) were established in the fall of 2000 in nine-bed (60"each) field plots that are replicated 4 times in a randomized complete block design. In 2001, a uniform field corn crop was produced across the entire field. Following corn harvest in September 2001, common vetch cover crops were seeded in each of the CC plots. Forty 15N microplots (4.57m wide band 3m long) were established at the Davis site during the 2001 - 2002 winter as indicated below.

| STNO | STCC | CTNO | CTCC |
|---|---|---|---|
| Zero N | Zero N | Zero N | Zero N |
| Labeled fertilizer | Labeled fertilizer + | Labeled fertilizer | Labeled fertilizer + |
| | vetch | | vetch |
| | Labeled vetch + | | Labeled vetch + |
| | fertilizer | | fertilizer |

These microplots are being used to track the amount of 15N-labelled fertilizer and vetch cover crop that is taken up by each of the main summer crops during the course of the study.

A summary of the generalized tillage operations for each system is provided below for tomato and corn. Similar overall reductions in tillage were achieved in the CT systems in Five Points.

**Tomato**

| STNO | STCC | CTNO | CTCC |
|---|---|---|---|
| • Flail mow / chop corn residue<br>• Stubble disk | • Flail mow / chop corn residue<br>• Stubble disk | • Flail mow / chop corn residue<br>• Winter | • Flail mow / chop corn residue<br>• Plant cover |

| | | | |
|---|---|---|---|
| (2X)<br>• Finishing disk<br>• Moldboard plow<br>• **Rip / subsoil**<br>• Landplane<br>• List beds<br>• Winter herbicide **application**<br>• **Bed** cultivator<br>• Herbicide **application** and bed **mulching**<br>• **Roll beds flat** | **(2X)**<br>• **Finishing disk**<br>• **Moldboard plow**<br>• **Rip / subsoil**<br>• Landplane<br>• List beds<br>• **Plant cover crop**<br>• **Flail chop cover crop**<br>• **Bed disk** (2X)<br>• **Herbicide application and bed mulching**<br>• **Roll beds flat** | **herbicide applicatoin** | **crop**<br>• **Chop cover crop**<br>• **Herbicide application** |

**Corn**

| STNO | STCC | CTNO | CTCC |
|---|---|---|---|
| • **Stubble disk** (2X)<br>• Landplane<br>• List beds<br>• Winter **herbicide application**<br>• **Bed cultivator** | • Stubble disk (2X)<br>• Landplane<br>• List beds<br>• **Plant cover crop**<br>• **Disk cover crop**<br>• **List beds** | • Winter herbicide **application** | • Winter herbicide **application** |

**Task 2** ***Conduct baseline soil sampling at each site***

**Initial soil sampling was done at the Davis site in the spring of 2001 prior to that** year' **s uniform** field **corn crop**. **These samples were submitted** to the UC DANR Analytical Lab, **and have been** analyzed. **$^{15}$N soil and plant tissue sampling has also been done.**

Soil sampling has also been done at the Five Points location in the spring and fall of each year. These samples were processed, submitted to the UC DANR Analytical Lab, and analyzed.

**Task 3**: *Manage and monitor crops at each site*

***Davis Site***

In Davis, the 2001 "uniform" field crop that was planted across the entire field was harvested in late September 2001 using a Geringhof header fillet to a John Deere grain harvester. Use of this header permitted the corn crop residue to be uniformly spread out behind the harvester and did not leave "windrows" as is done with most typical harvesters. Surface residue biomass and % ground cover were quantified in October 2001 and March 2002 and periodically thereafter.

Common vetch cover crops were planted in the CC plots and in a cover crop nursery in which 15N labelling was done in early November 2001. Within this nursery, a 160 m2 area was marked out and on February 28, 2002, the first application of15N was made from a solution of 32g ammonium sulfate 54.2 atom % 15N plus 278g ammonium sulfate 49.2 atom% 15N in 2 liters of water. 13.3 ml of this solution were then pipeted into a metal watering can and 2 – 3 liters of water were added to the mix. This was sprinkled in several back and forth motions over each square meter. A second labeling was applied on March 21. The purpose of labeling vetch in this nursery was to produce 15N-labelled vetch that would later be applied to specific microplots in the main experimental area in which the vetch had been removed so as to have a representative amount of tracer material that will subsequently be tracked in succeeding tomato and corn crops. Weed growth in both the vetch nursery and in the CC experimental plots was a problem during the 2001 – 2002 winter and efforts were subsequently successful during the following winter season to provide less weedy cover crops.

The 2002 and 2004 tomato crops were successfully transplanted into both the previous year's corn residues and the corn residue / cover crop mulch. Fertilization was done using a rig fitted with 20" coulters ahead of standard fertilizer shanks. Corn in 2003 was seeded using a John Deere 1730 No-Till planter. We encountered difficulties establishing a uniform crop in this year due to uneven soil moisture conditions and thus were forced to furrow irrigate about a week following planting. We have improved our planting systems for the upcoming 2005 corn crop.

*Five* ***Points Site***

**The Five Points site was initiated in the fall of 2001 as part of an ongoing 8 acre field comparison of standard and conservation tillage production. 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.**

**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 ReadyTM* **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.**

**Task 4**: *Harvest and 15Nplant and* ***soil sampling***

Forty 15N microplots (4.57m wide band 3m long) were established at the Davis site during the 2001 - 2002 winter as indicated below

| STNO | STCC | CTNO | CTCC |
|---|---|---|---|
| Zero N | Zero N | Zero N | Zero N |
| Labeled fertilizer | Labeled fertilizer + vetch<br>Labeled vetch + fertilizer | Labeled fertilizer | Labeled fertilizer + vetch<br>Labeled vetch + fertilizer |

These microplots are being used to track the amount of 15N-labelled fertilizer and vetch cover crop that is taken up by each of the main summer crops during the course of the study. GPS coordinates of the center of each microplot were recorded so that the microplots might be relocated at any time in the future. Soil samples were taken annually in each plot. Three random cores from 30 - 60 and 60 - 90 cm, and 15 - 20 cores form 0 - 15 and 15 - 30 cm were taken throughout each plot. Composited samples were homogenized by passing them through a 4 mm sieve. A subsample of each core was air dried for total carbon and nitrogen content, another subsample was taken for moisture content, and a third subsample was extracted for determination of nitrate.

The main plots and microplots were fertilized each year following planting at a rate of 125 lb N / acre for tomatoes and 150 lb N / acre for corn. The main fertilizer applicator was shut off when passing through microplots, but the shank line remained in the soil. In the microplots, these shank bands (2 per bed) were opened with a shovel to 3 - 4" so that fertilizer could be applied close to where the normal application was.

Yields in each year were determined by machine harvesting the main plots and by hand harvesting and weighing fruit and vegetative biomass in each microplot. 15N in crop tissue and in the surface soil were determined.

Task 5: *Report preparation and outreach*

**Periodic progress reports have been submitted** to CDFA FREP **and two in-person** summary presentations have been made at FREP annual conferences. These two CDFA/FREP-sponsored studies have been key sites in terms of efforts of California's Conservation Tillage Workgroup to develop information related to reduced tillage alternatives. Information based on the background, objectives and preliminary findings of these studies has been presented to more than 100 audiences during the course of the project.

**Results, Discussion and Conclusions:**

An average of 1010 g / m2 of corn residue (+ 286 std dev) was left on the soil surface in each CT plot following the 2001 corn harvest. This corresponded to nearly 100% of the soil surface being covered by corn residue in the fall of 2001. An average of about 2800 kg / ha of vetch dry matter was produced from November 2001 - April 2, 2002 in the CC plots.

Crop yields for 2002, 2003 and 2004 are presented below. On average, both for tomato and corn, the ST systems performed better than both of the CT systems. The CTCC tomato system provided the lowest tomato yields of the four systems for both 2002 and 2004, due, we believe, to difficulties transplanting the crop into the heavy crop and cover crop residue and reduced early season growth and vigor. Corn yields were reduced 30% and 18 % by CTNO and CTCC.

UCD FREP Corn / Tomato Study
Yields
(2002 - 2004)

| | 2002 Tomato (tons/ac) | 2003 Corn (tons/ac) | 2004 Tomato (tons/ac) |
|---|---|---|---|
| ST no cover crop | 51.8 a | 5.7 ± 0.3 | 39.0+2.4 |
| ST cover crop | 51.7 a | 6.2+0.3 | 40.5+2.4 |
| CT no cover crop | 50.3 a | 4.0+0.2 | 33.5+2.9 |
| CT cover crop | 38.5 b | 4.7+0.2 | 30.8+2.8 |

We have seen better CT performance in Five Points with both tomatoes and cotton (See two tables below). Therefore, the fact that the Davis site has considerably "heavier" soils with higher clay content, might be a contributing factor to the differences in crop productivity that we are seeing.

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 | 58 | 46 | 42 |
| Standard tillage cover crop | 53 | 63 | 45 | 45 |
| Conservation tillage no cover crop | 56 | 62 | 56 | 54 |
| Conservation tillage no cover crop | 51 | 61 | 43 | 52 |

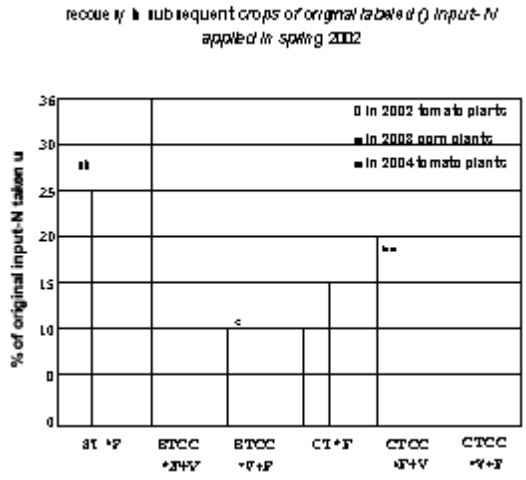
Different letters within columns indicate statistical significance at P = 0.05.

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

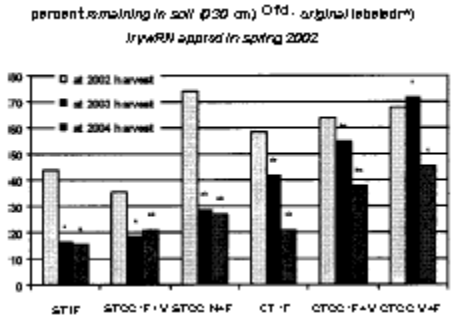
| | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|
| Standard tillage no cover crop | 360 a | 1784 | 1930 a | 1228 ab |
| Standard tillage cover crop | 360 a | 1405 | 1921 a | 1336 a |
| Conservation tillage no cover crop | 200 a | 1579 | 1736 b | **1058 b** |
| Conservation tillage cover crop | 372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

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

The figure below presents the recovery of original labeled 15N to tomato, corn and tomato crops in 2002, 2003 and 2004, respectively. These data suggest higher N uptake in the first year under ST than CT, and much lower levels in the following years. In this figure, the "*" refers to whether either fertilizer (F), or vetch (V) were labeled.

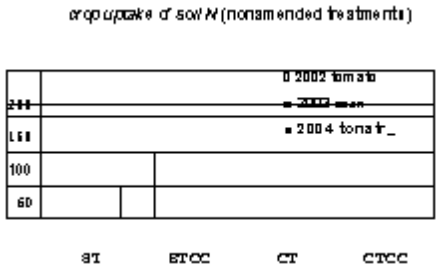


Less 15N was taken up by CT crops compared to ST and there was a correspondingly greater amount of N remaining in the soil under CT. (See figure below).



This may be due to a number of factors including the possibility that the fertilizer N somehow was more mobile in the ST systems because of greater overall soil disturbance in these systems or perhaps the fact that the ST soils did not appear to "consolidate" and harden as much as the CT soils. This is merely speculation, however, and will be monitored as these and other related studies proceed.

Finally, evidence of this last observation may perhaps be seen in the figure below in which total N uptake in the unamended plots is presented. This graph presents a trend toward higher N input from the zero N plots under ST in both of the first two years.




These preliminary findings point to a number of tentative considerations. First, from a productivity perspective, considerable improvements in CT production techniques are needed in order for yields to match those of ST systems, - particularly for the Davis site and its soil conditions. Nitrogen availability may be a yield-limiting factor in the CT systems as we've implemented them here. There are also other management issues affecting CT crop performance: general lack of soil mixing, problems of stand establishment and cloddy weed cultivation conditions.

**Extension of information**

While it is somewhat difficult to separate this project from other ongoing CT studies that we have underway, aspects of these Davis and Five Points projects have been presented at a very wide variety of venues during the course of this project in addition to the two formal presentations that PI Mitchell made at Annual FREP conferences. Several of these outreach activities are listed below.

October 5, 2003. Expansion of conservation tillage production practices in California's Central Valley. Poster presentation. ASHS Centennial Conference. Providence, RI.

**October 6, 2003. Transitioning tomato and cotton production to conservation tillage in California's San Joaquin Valley. Oral presentation. ASHS Centennial Conference. Providence, RI.**

October 7, 2003. **Introduction to CT2003. Oral welcome and introduction to Conservation Tillage 2003: The California Experience. CT Workgroup Annual Conference, Tulare, CA. 80 participants.**

October 7, 2003. Reduced tillage cotton and tomato rotation study in Five Points, CA: An evaluation after four years. CT Workgroup Annual Conference, Tulare, CA. 80 participants.

October 8, 2003. Introduction to CT2003. Oral welcome and introduction to Conservation Tillage 2003: The California Experience. CT Workgroup Annual Conference, Five Points, CA. 90 participants.

October 8, 2003. Reduced tillage cotton and tomato rotation study in Five Points, CA: An evaluation after four years. CT Workgroup Annual Conference, Five Points, CA. 90 participants.

October 9, 2003. Introduction to CT2003. Oral welcome and introduction to Conservation Tillage 2003: The California Experience. CT Workgroup Annual Conference, Davis, CA. 60 participants.

October 9, 2003. Reduced tillage cotton and tomato rotation study in Five Points, CA: An evaluation after four years. CT Workgroup Annual Conference, Davis, CA. 60 participants.

November 3, 2003. California's Conservation Tillage Workgroup: Research, Demonstrations and Extension Education. Poster presentation at the 2003 Annual Meetings of the American Society of Agronomy, Crop Science Society of America and the Soil Science Society of America. Changing Sciences for a Changing World: Building a Broader Vision. Denver, CO.

November 5, 2003. Reduced tillage cotton production systems in California's San Joaquin Valley. Poster presentation at the 2003 Annual Meetings of the American Society of Agronomy, Crop Science Society of America and the Soil Science Society of America. Changing Sciences for a Changing World: Building a Broader Vision. Denver, CO.

November 6, 2003. Productivity and profitability of reduced tillage cotton and processing tomato production systems in California's San Joaquin Valley. Oral presentation at the 2003 Annual Meetings of the American Society of Agronomy, Crop Science Society of America and the Soil Science Society of America. Changing Sciences for a Changing World: Building a Broader Vision. Denver, CO.

January 9, 2003. Reduced tillage cotton and tomato production systems evaluations in California. JPM prepared 38-slide Powerpoint presentation for Dan Munk to present). 2004 Beltwide Cotton Conferences. Marriott River Center, San Antonio, TX.

January 8, 2004. Conservation tillage and environmental protection. Invited presentation. 96th Tomato Day. University of California, Davis. Buehler Alumni Center. 70 participants.

January 21, 2004. What is **conservation tillage and** why might **it be an important means** for improving **San Joaquin** Valley air quality **? Invited presentation** to USDA Natural **Resources** Conservation **Service San Joaquin** Valley Air Quality Coordinators. **Fresno** County **Farm Bureau**. Fresno, CA.

February 4, 2004. Sustainable tomato production in California. Introductory discussion for Liz Mann, Australian Tomato Commission and Chuck Rivara, California Tomato Research Institute. Walnut Grove, CA.

February 4, 2004. Conservation **tillage corn production**. CT Corn Production **Meeting.**
Western Farm Service. Wimpy's **Restaurant**. Walnut Grove, CA. 60 **participants.**

February 18, 2004. Annual Address. CT Workgroup Annual Meeting, Davis, CA. 45 participants.

April 2004. Conservation tillage. Oral presentation to USDA NRCS, Western Farm Service in NRCS office, Sacramento County. Invited by Christian Davis.

April 21, 2004. Presentation and tour for Steve Werblow. Writer for *California Farmer* and *The Furrow.*

May 27, 2004. Research and extension education related to conservation tillage in Califonria. Field tour and oral presentation to 19 students of Denmark agricultural science university. Five Points, CA.

June 15, 2004. Conservation tillage in intensive California agriculture. Invited presentation at the USDA Natural Resources Conservation Service National Agronomists' Conference. Lied Conference Center. Nebraska City, NE. 45 particpants.

**July 1, 2004. Conservation tillage in California: An overview. Presentation for Intern of USDA Associate Director, Mack** Gray, **John Beyer and Johnnie Siliznoff. Five Points,** CA.

July 14, 2004. Reduced tillage tomato production. 2004 Warm season vegetable field day. UC West Side Research and Extension Center. Five Points, CA. 150 participants.

July 17, 2004. **Farm research** networks **to create new conservation tillage systems.** Invited **oral presentation** in ASHS Workshop **"Serving organic growers** through **innovative outreach and on-farm research**. Austin, TX.

**September 8 and 9, 2004. Conservation tillage in California. Oral plenary session presentation at CT2004: Western States Conservation Tillage Conference. Five Points,** CA. 270 **participants.**

**Plan for Project Continuation**

This project has set upon a very important set of research objectives that are being met. Due to the nature of the production systems that are being investigated and their relative novelty in California, however, there has been a definite "learning curve" associated with the actual studies. We are, for instance, currently seeking means and technologies for improving crop stand uniformity and early season growth and vigor for all crops: tomatoes, corn and cotton. This is something we intend to fully

explore during our proposed "2005 continuation" year and as well, into the future. We are also quite keen on preserving both the UCD and the Five Points experimental sites because they now represent valuable "long-term" studies of important reduced tillage alternatives. All three crops, tomatoes, corn and cotton will be grown during the coming 2005 season.

Recently, we have also come across both additional literature as well as CT experience from other regions of the US that we believe may bear heavily on particularly the fertility or nutritional aspects of our development of CT systems in the coming years.

With this new understanding and these new approaches, we hope to propose a “second **generation**" of CT fertility **studies** to CDFA FREP in the coming proposal cycle.

A PowerPoint slide set is provided with this report.