ORGANIC FARMING RESEARCH FOUNDATION

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Organic farming research project report submitted to the Organic Farming Research Foundation:

Project Title:

Conservation tillage and cover crop systems for organic processing tomato production (Year 2)

FINAL PROJECT REPORT (Year 2)

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Project Summary

The production of organic processing tomatoes requires large inputs of organic sources of nitrogen. Besides the addition of compost, manure, and other organic amendments, leguminous cover crops, grown during the winter, are important sources of nitrogen for a subsequent tomato crop. Present management of cover crops for tomato production generally requires significant amounts of tillage that may retard the improvement of physical and chemical properties of the soil. This project investigated management strategies that combine conservation tillage and cover cropping practices for organic tomato production that could potentially reduce costs and improve long term fertility of organic fields. A 2-year field trial was conducted in an organic processing tomato field near Meridian, CA. Treatments compared 2 cover crop systems (legume mixture, legume/grain mixture) and 4 tillage practices (no-till, reduced tillage, strip tillage, conventional tillage). Results of the field experiment showed that weed pressure in the minimum tillage treatments and competition from regrowth of the cover crop reduced marketable fruit yields during the first season. Mineral nitrogen levels in the soil were also suppressed during the first growing season, which may have limited yields. In contrast, reduced tillage treatments had no effect on fruit yield in the subsequent year, presumably because the cover crop had more biomass, no regrowth and was terminated under moist soil conditions. Consequently soil mineral nitrogen levels were higher in all treatments during the second season. The grain/legume cover crop mixture provided the most surface residue in the reduced tillage treatments. However, the residue level was not sufficient to suppress weed growth. The results indicated that using the cover crops as a temporary mulch to suppress early weed growth and then incorporating the mulch to boost soil nitrogen levels as well as cultivate weeds, may be an economical management option for growers. Using the cover crop as a temporary mulch would also improve the timeliness of transplanting the tomato crop since most of the tillage needed to incorporate the cover crop before transplanting would be eliminated.

Introduction to Topic

The production of organic processing tomatoes requires large inputs of organic sources of nitrogen. Besides the addition of compost, manure, and other organic amendments, leguminous cover crops, grown during the winter, are important sources of nitrogen for a subsequent tomato crop. While cover crops are grown primarily for the nitrogen benefits, they also can improve soil physical properties by increasing soil organic matter content and contributing root exudates that aggregate soil particles thereby increasing macropore structure. In addition, cover crops improve long-term fertility of the soil by boosting microbial populations.

Conservation tillage, popular in Midwestern agriculture, has been shown to reduce production costs and increase soil organic matter by minimizing the rate of decomposition of organic material in the soil. Also, reducing the disturbance of soil using minimum tillage practices can improve physical and chemical properties, including macropore structure, aggregate stability, diversity of microbial populations, and availability of nutrients. Improving soil structure promotes root growth, which may also help the crop explore a larger volume of soil and use nutrients and water more efficiently.

Present management of cover crops for tomato production generally requires significant amounts of tillage that may retard the improvement of physical and chemical properties of the soil. For example, to maximize nitrogen mineralization, the cover crop is usually incorporated into the soil by discing and rototilling, several weeks before planting the tomato crop. Furthermore, mechanical cultivation is necessary to control weeds until the canopy of the tomato crop covers the bed. Intensive tillage, including subsoiling, discing, chiseling, triplaning, and rototilling is also used to prepare beds during the fall, which can cost between $75 and $100 per acre.

Identifying management strategies that combine conservation tillage and cover cropping practices for organic tomato production could potentially reduce costs and improve long term fertility of organic fields. This project will examine the benefits of using conservation tillage with legume and legume/grass cover crop mixtures for organic processing tomato production.

Objectives Statement

The objective of this project was to identify strategies to combine conservation tillage and cover crop practices into organic processing tomato production. Specific objectives are to:

- **A.** Quantify weed control under different tillage/cover-crop systems.
- **B.** Monitor nitrogen mineralization under various tillage and cover crop treatments.
- **C.** Measure the effect of cover crops on moisture status of the soil profile.
- **D.** Identify the best cover-crop/tillage system for optimizing tomato fruit quality and yield.

Materials and Methods

On-farm experimentation

Experiments were conducted in the same commercial, organic field in 2000 and 2001 near Meridian, Calif. on a Nueva loam. The field was certified organic in 1998 and, since 1997, cover crops and compost at 4.5 ton/acre have been incorporated into its soil every year. Treatments compared 2 cover crop systems (legume mixture, legume/grain mixture) and 4 tillage practices (no-till, reduced tillage, strip tillage, conventional tillage) described in Table 1. Plots measured 120 ft × 3 beds (15 ft) and treatments were replicated 5 times.

Cover crops were sown on 25 Nov. 1999 and 12 Oct. 2000 on the top of pre-shaped 5 ft wide beds. Cover crops were killed on 5 Apr. 2000 and 22 Mar. 2001 using a rolling stalk chopper (Buffalo Manufacturing Company, Fleischer, Nebr.) and then incorporated on 7 Apr. 2000 and 27 Mar. 2001 only in the conventional (incorporated at planting) treatments. Other tillage operations done at this time included incorporation of the winter weeds in the fallow treatment and a single pass with the Unverferth Ripper-Stripper Subsoiler in the strip till treatment. Delayed incorporation of the cover crop occurred 17 days after planting in 2000 and 19 days after planting in 2001. Processing tomato (‘BOS 3155’ in 2000, ‘CDX 179’ in 2001) seedlings were planted on 12 Apr. 2000 and 13 Apr. 2001. A Sub Surface Tillage Transplanter was used to transplant in a single row at 1 ft distance between plants. Fish emulsions containing 3% N at a rate of 40 gal/acre were applied during transplanting in 2001.

All data were collected from the center bed of the plots. Biomass, total nitrogen, and carbon content of cover crops were evaluated before incorporation and mulching. Soil moisture was monitored in cover cropped and fallow treatments using gravimetric and neutron probe methods. Soil was sampled to a 3-foot depth and analyzed for mineralized nitrogen (nitrate-N, ammonium-N) before and after incorporation or mulching of the cover crops. Subsequent soil-samples were taken at 2-week intervals to monitor nitrogen mineralization (nitrate-N, ammonium-N). Soil temperature of mulch, strip till, and fallow treatments were compared using dataloggers equipped with temperature probes. Weed density was monitored during the growth of the tomato crop. Fruit yield and quality data were determined from the center bed of each plot. Fruit quality data included color, ° Brix, and percentage of red, pink, and green, and cull fruit. Data was statistically analyzed using SAS software to determine statistically significant differences among treatments.

Table 1. Cover crop and tillage practices compared in replicated trial.

Treatment #	Cover Crop	Tillage Practice
1	*Vetch, Pea, Bell bean, Rye, Triticale Mixture	Incorporate at Planting
2	**Vetch, Pea, Bell bean Mixture	Incorporate at Planting
3	Vetch, Pea, Bell bean, Rye, Triticale Mixture	Mulch, Incorporate at 4 wks after planting
4	Vetch, Pea, Bell bean Mixture	Mulch, Incorporate at 4 wks after planting
5	Vetch, Pea, Bell bean, Rye, Triticale Mixture	No-Till
6	Vetch, Pea, Bell bean Mixture	No-Till
7	Vetch, Pea, Bell bean, Rye, Triticale Mixture	Strip-Till without incorporation
8	Fallow	Conventional Tillage

*30 lb:30lb:30 lb vetch, Magnus pea, Bell Bean + 25 lb triticale + 25 lb grain rye/acre
**30 lb:30lb:30 lb vetch, Magnus pea, Bell Bean /acre

Project Results

Soil nitrogen dynamics

Nitrogen mineralization under the various tillage and cover crop treatments was monitored during the growing season, beginning before transplanting and ending during fruit ripening. Figure 1 illustrates how soil mineral nitrogen ($NH_4 + NO_3$) levels changed at the 1 ft depth for each treatment during the season. The data indicated that in the 2000 season:

- Incorporation of the legume cover crop raised soil nitrogen levels above the levels observed in the fallow, incorporated treatment.
- Soil mineral nitrogen levels were very low in all treatments in early April when soil moisture levels were also very low.
- Incorporating or mulching of the grain/legume cover crop immobilized nitrogen until the end of the season.
- Tillage treatments appeared to have much less influence on soil mineral nitrogen levels than did the cover crop mixture treatments.

During the 2001 season the data indicated that:

- Soil mineral nitrogen levels were higher in all treatments (7 to 15 ppm) compared with levels in the 2000 season (2-10 ppm).
- Soil mineral nitrogen levels were similar among grain/legume and legume mixture cover crops
- Unlike the 2000 season, incorporating or mulching of the grain/legume cover crop did not seem to immobilize nitrogen during the 2001 season.

2000 **2001**

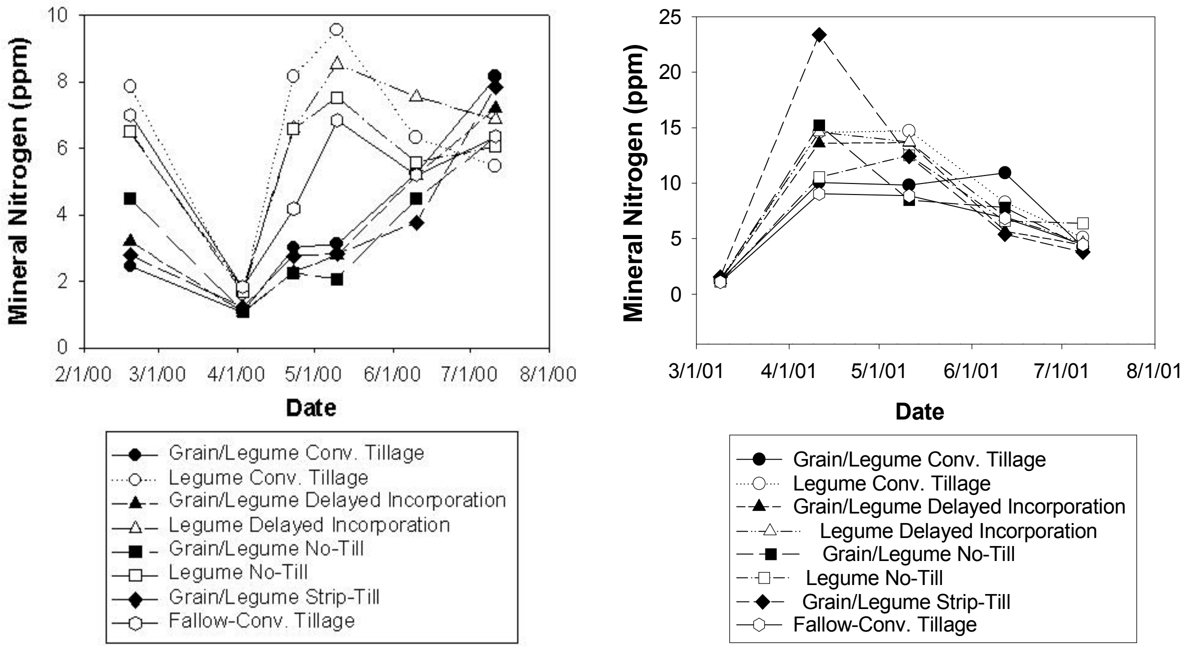


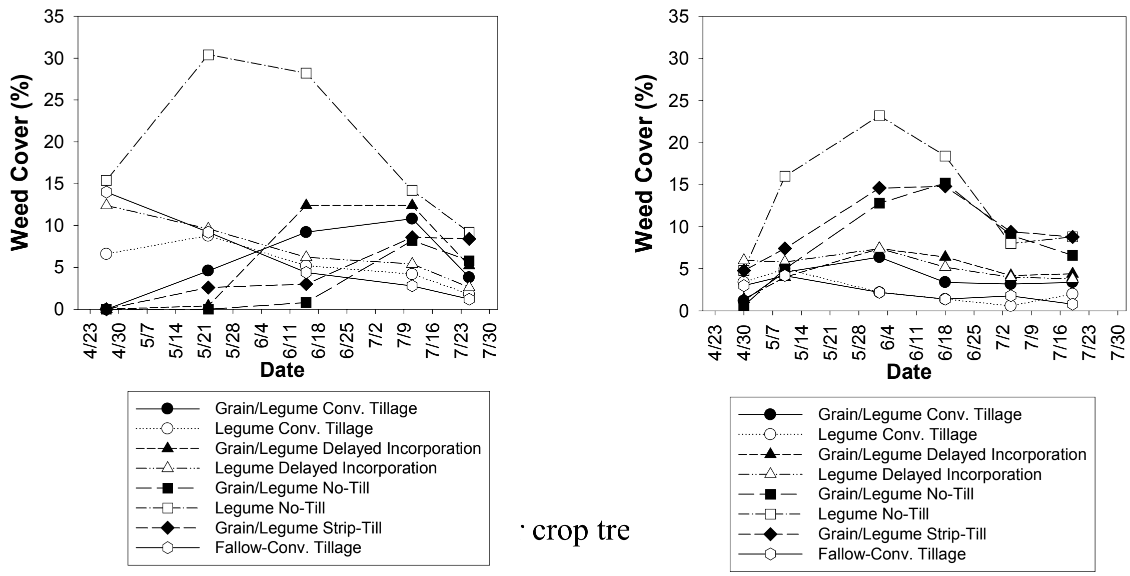
Figure 1. Soil mineral nitrogen at the 1-foot depth during the 2000 and 2001 seasons.

Weed and surface residue

Visual weed and surface residue evaluations were made before every cultivation operation to quantify weed control under the different tillage/cover crop systems. Since mechanical cultivation is important for weed control in organic systems, it was essential to assess whether adequate weed control could be obtained using a surface mulch in the no-till treatments. Figures 2 and 3 show the differences in weed and residue cover for each treatment at different times during the year. The data collected during the 2000 and 2001 seasons showed that:

- The no-till and strip till treatments had the highest weed pressure in 2001.
- The delayed incorporation tillage treatment had similar weed control as the incorporated at planting treatment.
- Legume residue broke down faster than grass residue.
- Grain/legume cover crop residues persisted longer in 2001 than in 2000.
- Tillage provided better weed control than a surface mulch

2000 **2001**



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2000 **2001**

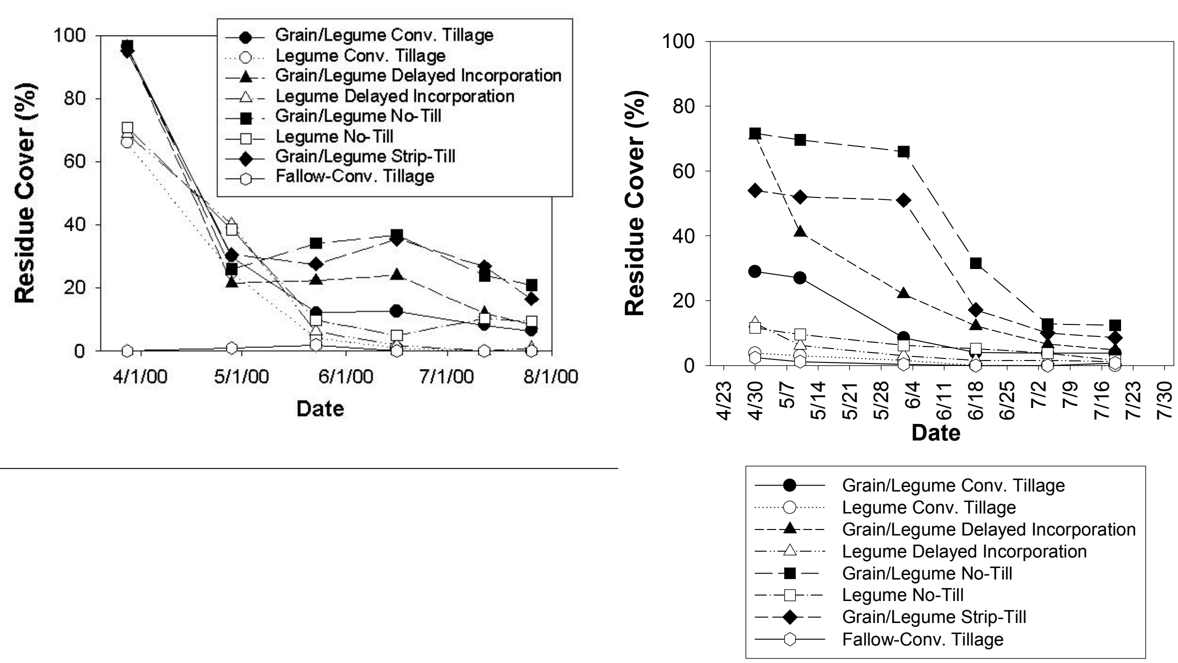


Figure 3. Residue cover of tillage/cover crop treatments during the 2000 and 2001 seasons

Soil moisture under winter cover crops

Figure 4 shows that soil moisture levels increased at a higher rate under cover crop treatments than under fallow winter weeds during rain events in February 200. This result may indicate that infiltration rates were highest in plots under cover crops. However, after winter rains ended mid-March, the soil profile dried down the most in plots with cover crops. The dry soil conditions impeded the incorporation of the cover crops and the transplanting of tomatoes. The dry soil conditions may have also contributed to lower nitrogen mineralization rates in early April 2000.

In contrast, soil moisture levels were nearly at field capacity in late March 2001, the time that the cover cop was terminated. Soil moisture levels were similar among cover crop/tillage treatments. The higher soil moisture levels in 2001 aided transplanting and may have helped increase the rate of mineralization of the cover crop.

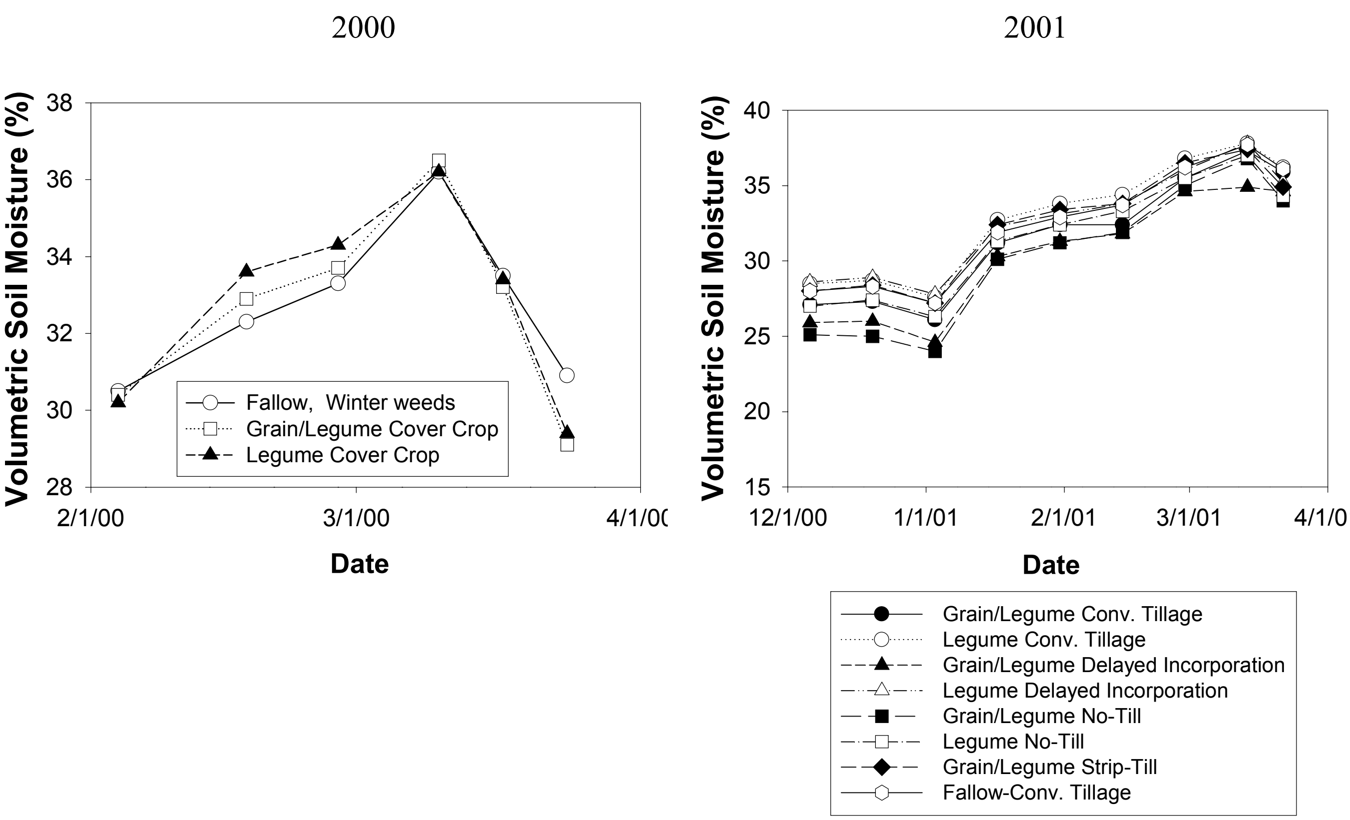
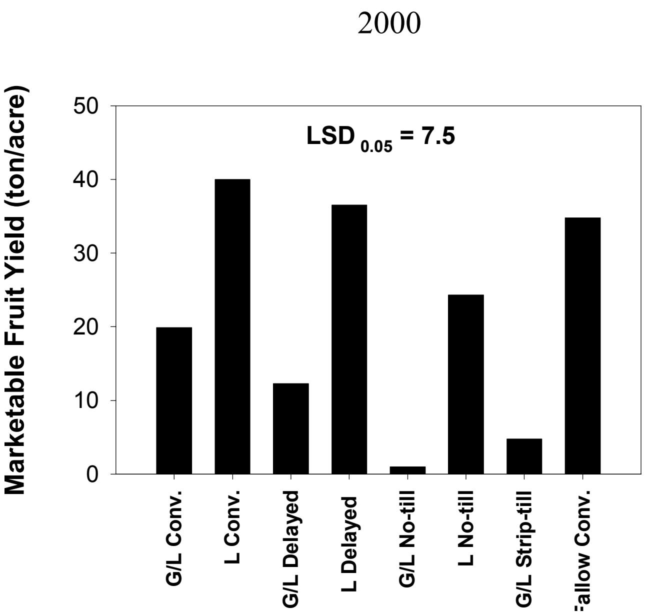


Figure 4. Average moisture content of soil profile (0-48 inches) under fallow and cover crop treatments during the 2000 and 2001 rainy seasons.

Marketable fruit yields

Figure 5 shows that tomato fruit yields ranged from no yield (grass/legume no-till treatment) to almost 40 tons per acre (legume, conventional tillage) during the 2000 season. Both tillage and the cover crop treatments affected fruit yield. Yields were reduced as tillage was reduced and the grain legume mixture caused significantly lower fruit yields compared to the legume cover crop mixture. The grain/legume mixture may have immobilized nitrogen to the point that the crop growth was inhibited. Also, regrowth of rye in the grain/legume mixture may have immobilized nitrogen and competed with the tomato crop. Tillage impacted yields by reducing weed pressure/cover crop regrowth in the incorporated at planting and delayed incorporation treatments. A regression analysis between total % weed cover (weeds + cover crop regrowth) and total % tomato cover was described by a linear model (r^2=0.61, $P \leq 0.05$) (data not shown). Consequently, because of better weed control and less cover crop regrowth in 2001, there were no treatment differences in yields (Figure 6).



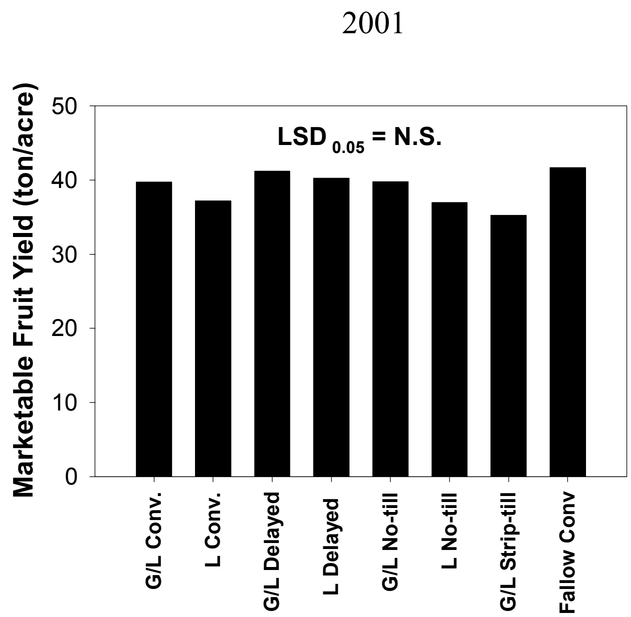


Figure 5. Marketable fruit yields of cover crop/tillage treatments for the 2000 and 2001 seasons.

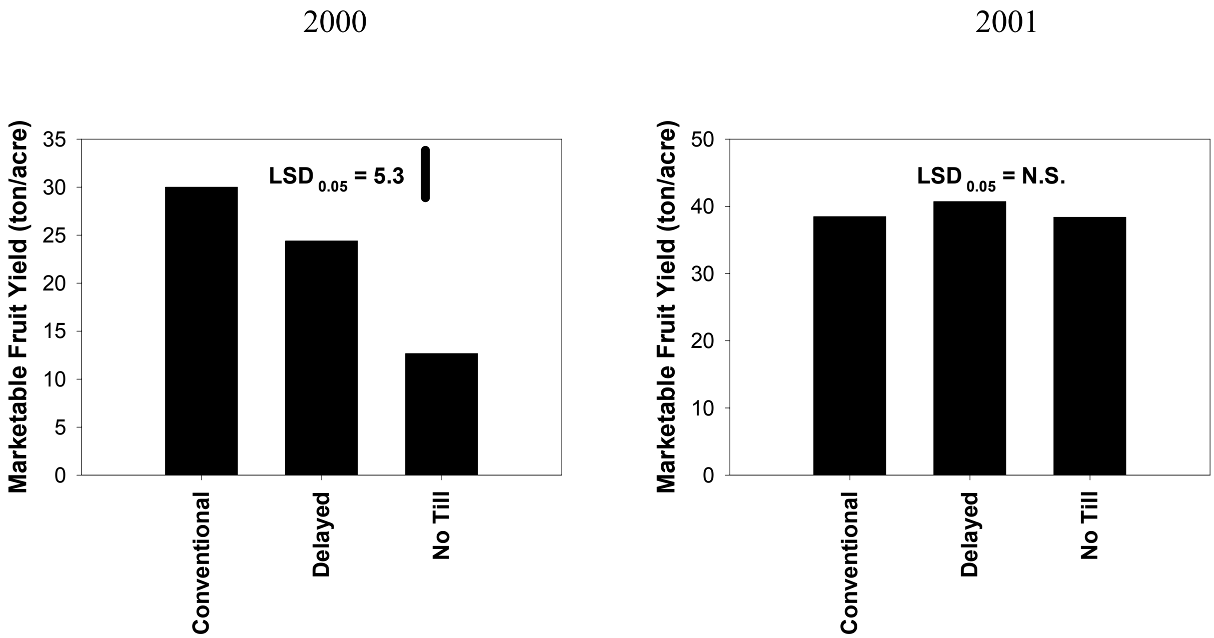


Figure 6. Marketable fruit yields of tillage treatments for the 2000 and 2001 seasons.

Conclusions and Discussion

The use of cover crops under reduced tillage systems for the production of organic processing tomatoes significantly reduced yields during the 2000 season but did not affect yields during the 2001 season. The most important difference between the 2 growing seasons was the management of the winter cover crop. The cover crops were established earlier and had more biomass in 2001 than in the 2000. The cover crops were also terminated when soil moisture levels were high and ideal for mineralizing nitrogen and for transplanting the tomato crop in 2001. Although the cover crop residue was highest during the 2001 season, in both seasons, the residue of the no-till and strip-till treatments was inadequate to control weeds. Some tillage was needed to control weeds in organic processing tomatoes. Delaying incorporation of the cover crop saved 1 to 2 passes with a cultivator by providing weed control after transplanting without affecting the mineral nitrogen levels in the top foot of soil. The delayed incorporation treatment also provided flexibility in using the cover crop for the production of processing tomatoes. Using the cover crop as a temporary mulch improved the timeliness of transplanting the tomato crop since tillage needed to incorporate the cover crop before transplanting was be eliminated. The use of the no-till transplanter allowed us to transplant under high residue conditions.

Outreach

Results of the project were presented at 4 grower meetings and in a trade journal article**:**

J. Mitchell, N. Madden, E. V. Herrero, M. D. Cahn, D. May. 2002. Reducing tillage in tomato rotation: A progress report, CA Tomato Grower Magazine, Feb/March 02, Vol. 45, No 2, pp. 20-21.

Outreach presentations

Date	Meeting name	Presentation topic	Location	Attendance
1/2001	Ecological Farming Conference	Comparison of conservation tillage systems for organic processing tomato	Pacific Grove, CA	--
6/26/2001	CT2001: Conservation Tillage Equipment and Technology Demonstration Conference	Comparison of conservation tillage systems for organic processing tomato	Five Points, CA	110
6/28/2001	CT2001: Conservation Tillage Equipment and Technology Demonstration Conference	Comparison of conservation tillage systems for organic processing tomato	Davis, CA	65
1/8/2002	Sacramento Valley Processing Tomato Production Meeting	Conservation tillage, a local evaluation for tomato growers	Woodland, CA	230

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Abdul-Baki, A.A. J.R. Stommel and J.R. Teasdale. 1995. Vetch mulch fetches more veggies. Agric. Res. May.

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Stirzaker, R.J. J.B. Passioura, B.G. Sutton and N. Collis-George. 1993. Soil management for irrigated vegetable production. II. Possible causes for slow vegetative growth of lettuce associated with zero tillage. Aust. J. Agric. Res. 44:831-844.

Stirzaker, R.J. B.G. Sutton and N. Collis-George. 1992. Soil management for irrigated vegetable production. I. The growth of processing tomatoes following soil preparation by cultivation, zero-tillage and in-situ grown mulch. Aust. J. Agric. Res. 44:817-829.

Addenda

Photos of the conservation tillage field trial from the 2001 season

Photo 1. Conventional Tillage-No Cover Crop (2001)

Photo 3. No-till, Grain/legume cover crop (2001)

Photo 2. Delayed incorporation, grain/legume cover crop (2001)

Photo 4. No-till, Legume cover crop (2001)