

Pest Management Grants Final Report

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Project Title: **Evaluation of reflective and cover crop mulches for insect, disease and weed control in fresh market tomato production systems**

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Abstract

We compared the effectiveness of silver reflective plastic and triticale/ryegrain/vetch cover crop mulches for pest and disease control as well as productivity relative to a standard bare ground fresh market tomato mulch system in Parlier, California in 1999 and 2000. The cover crop mix was planted in mid-October of each year preceding the tomato crops, and then chopped and sprayed with glyphosate in the following March in each study. Shady Lady tomato transplants were then set out in mid-April. Drip irrigation and fertigation was used for each system. Yields of marketable fruit were increased in the silver plastic mulch plots relative to the standard system by 1.6 and 1.1 in 1998 and 1999, respectively. Tomato yields over the cover crop mulch were 1.14 and 0.91 those of the standard system in the two years of the study. Both the silver reflective plastic and the cover crop surface mulch systems thus, provide the possibility to sustain productivity relative to current standard off-season fallow systems. The two alternative production systems will require different management, equipment and scheduling considerations in order to be successfully adopted. Detailed records of all operations required for each system were maintained and are currently being analyzed along with other, similar studies to determine the potential economic benefits of the two alternative systems.

Executive Summary

The objectives of this research have been

1. to evaluate the effectiveness of reflective and cover crop mulches for pest and disease control in fresh market tomato production systems, and
2. to determine the potential economic benefits of using mulches for tomato production

Both “early” and “late” season field experiments were conducted in 1999 and 2000 at the University of California Kearney Agriculture Center in Parlier, CA and in a grower’s field in Le Grand, CA in 2000. The following major preliminary findings have resulted from this California Department of Pesticide Regulation / California Tomato Commission jointly - sponsored research to date:

- Both the silver reflective plastic and the cover crop surface mulch alternative systems seem to provide the possibility to sustain productivity relative to current standard off-season fallow systems. In the case of the silver reflective plastic, productivity may, in fact, be increased.
- The two alternative production systems will require different management, equipment and scheduling considerations in order to be successfully adopted.
- Integrated pest management of the two production alternatives will also differ from the current standard.

- Overall economic evaluations of the alternative systems are currently being completed.

Report

Introduction:

Aphid transmitted virus diseases cause significant economic losses to California's multimillion vegetable crop industries annually. Over the past few years, production of fall melons (cantaloupe, honeydew and mixed melons), squash (zucchini, crookneck and hard winter squash), peppers (bell and chili) and tomatoes (fresh market and processing) has been virtually impossible in the San Joaquin Valley (SJV) due to extensive virus epidemics. Spring crops, while affected to a lesser extent, have also suffered significant losses due to aphid transmitted viruses. In 1994, over 1,200 acres of fall melons were lost due to virus infection (D. May, Fresno UCCE, Personal communication) and in 1995, more than 600 acres of cantaloupe were lost due to virus diseases (D. Mehling, Silver Creek Packing Co., Personal communication). Losses to fresh market tomatoes were substantial in both 1994 and 1995 (E. Beckman, California Tomato Commission, Personal communication).

Several plant viruses are responsible for these epidemics and most are capable of infecting all of the crops mentioned above. Among the most important viruses are cucumber mosaic virus (CMV), zucchini yellows mosaic virus (ZYMV), potato virus Y (PVY) and tomato ring spot virus (ToRSV). These viruses are all transmitted by aphids in a stylet-borne, nonpersistent manner. They can be both acquired and transmitted in as few as 15 seconds. They are all transmitted by a large number of aphid species (Kennedy and Estop, 1962), all of which are abundant throughout California (Summers, unpublished data, Pike *et al.*, 1992). Due to the rapidity with which the viruses can be acquired and transmitted, insecticides are of little value in preventing virus spread and under some circumstances, may actually increase the rate of virus transmission and spread (Broadbent, 1994, Gibson and Rice, 1989). This has not, however, dissuaded a large number of growers and PCA's from attempting to control the spread of these viruses with the use of insecticides. One large (over 200 acres) fresh market tomato grower in California's SJV applied insecticides on a weekly basis beginning in March 1995 and continuing until harvest with the result of 100% of the plants infected with two or more viruses at harvest (Summers, Personal communication). These fields had no less virus than did those left untreated. In a trial conducted at the Kearney Agricultural Center in 1995, tomato plots receiving five applications of *Admire* had the same incidence of virus infection (approximately 50%) as plots receiving no insecticides (Summers and Stapleton, unpublished data).

Reflective mulches have been used successfully to reduce the incidence of aphid-borne virus diseases in squash and other crops (Brown *et al.*, 1993, Summers *et al.*, 1995), Stapleton and Summers, 1995, and Summers and Stapleton, 1995). Brown *et al.* (1993) found silver plastic mulch superior to white, yellow or black with yellow edges in

repelling aphids in yellow crookneck summer squash. Plants grown on silver mulch produced significantly higher yields of marketable fruit than did those grown on bare soil. Other materials and colors used to successfully reduce virus incidence in various crops include: aluminum foil (Dickson and Laird, 1989), white plastic (Harpaz, 1982), aluminum powder sprayed on the soil (Harpaz, 1982) and aluminum silver spray mulch and two silver polyethylene film mulches, applied to the planting beds before seeding, were effective in repelling alate aphids and delaying the onset of several virus diseases in spring and fall-planted zucchini squash in California's SJV. Disease symptoms in plants growing over these mulches appeared 7 - 10 days later than in plants growing on unmulched beds. In spring seeded squash, approximately 30% of the plants on unmulched beds were infected with one or more viruses by the first harvest while only 10 - 15% of those grown over the silver mulches showed virus symptoms. In fall-planted trials, 100% of the plants grown on unmulched beds, with and without insecticide applications, were virus-infected by the first harvest. Silver-pigmented mulches were generally more effective in repelling aphids and delaying virus onset than were white-pigmented mulches. Marketable fruit yields in the spring planting were approximately 70% higher in plots mulched with silver than the unmulched control, either with or without an insecticide application. Although plants grown over the silver mulched plots eventually became infected, they continued to produce a significantly higher percentage of marketable fruit throughout the season than did the unmulched controls. Stapleton and Summers (1994) also showed that cantaloupe grown over reflective mulches yielded over 500 cartons of marketable fruit per acre compared to less than 50 cartons per acre from plants grown on bare soil. An earlier and higher rate of infection with CMV in plants delayed the onset of virus infection by four to six weeks thus allowing the plants time to mature and set a good crop of melon fruit before becoming infected. Even though the plants eventually became infected, the delay in infection permitted the harvest of a highly profitable crop. Summers and Stapleton (unpublished data) have shown that tomatoes grown over reflective mulches averaged approximately 7% infection with two or more viruses while plants grown over bare soil averaged in excess of 50% infection with the same viruses. This approach is currently the only viable means of managing virus disease.

There is currently very little information available on the use of surface organic mulches derived from off-season grown cover crops for insect and virus control. The winter annual legume hairy vetch has been used successfully as both a cover crop and as a mulch in fresh market tomato production systems in the East Coast. As a cover crop, the vetch fixes N, recycles nutrients, reduces soil erosion and adds organic matter to the soil. When mowed and converted to a mulch, the vetch reduces weed emergence, lowers soil temperature during the hot summer months, reduces water loss from the soil and acts as a slow-release fertilizer (Abdul-Baki and Teasdale, 1994). This system that Abdul-Baki and Teasdale have developed eliminates tillage, reduces the need for applying synthetic fertilizers and herbicides, and is, according to these workers, adaptable to both large and small-scale tomato production in a low-input, no-tillage system (Abdul-Baki and Teasdale, 1993). Preliminary work in California has been initiated by Mitchell to develop information about optimal cover crop mulch species, mulch management and potential weed suppressiveness and water conservation that may result from cover crop

mulches. This recent work is not, however, currently evaluating possible insect and disease implications of this mulch production system. It is critically important for California producers and researchers to evaluate these types of alternative production systems because they may provide options that may become increasingly attractive from both economic and environmental perspectives in the future. Recent similar work in Florida by Chellemi et al. (1999) has shown that although a cover crop surface residue mulch production system had lower fresh market tomato yields relative to the standard black polyethylene plastic system, the overall profitability of the alternative system was actually higher. Furthermore, if reduced tillage alternatives such as the cover crop mulch system, can be integrated into conservation tillage cropping systems, it may be possible to reduce production costs relative to today's tillage-intensive standard systems. The work reported here that has been supported by the California Tomato Commission with augmented funding by the national Pesticide Environmental Stewardship Program has initiated such investigations.

Objectives:

The objectives of this research have been

1. to evaluate the effectiveness of reflective and cover crop mulches for pest and disease control in fresh market tomato production systems, and
2. to determine the potential economic benefits of using mulches for tomato production

Results

Effectiveness of Reflective and Cover Crop Mulches for Pest and Disease Control in Fresh Market Tomato Production Systems: (Objective 1)

Cultural practices

Four field experiments have been carried out in 1999 and 2000 at the University of California Kearney Research and Extension Center (KREC) in Parlier, CA and two on-farm demonstrations were conducted in 2000 at Live Oak Farms in Le Grand, CA. Two "early season" and two "late season" studies were done in each year at the KREC. California Department of Pesticide Regulation (DPR) support of our 2000 work was critical in enabling us to gain not only more experience, but also more much-needed data on the alternative systems.

In the "early" trials, we evaluated the winter cover crop mixture of triticale / ryegrain / common vetch in comparison with silver reflective plastic and the standard bare ground fallow system. Land preparation that consisted of disking, listing and shaping 60' beds was done in October of each year prior to our summer studies. The cover crop mixture was planted in mid-October of each year at a rate of about 110 lbs per acre and sprinkle irrigated. Each plot consisted of six 60' beds that were each 60 feet long. Two "buffer"

or guard rows separated plots from each other. All experiments were replicated six times in a randomized complete block experimental design. Mid-winter weed control was accomplished in the fallow and plastic mulch plots by spraying *RoundUp*. In March of 1999 and 2000, the cover crops were chopped using a Buffalo Rolling Stalk Chopper and sprayed with a 2% solution of *RoundUp* about one week after being chopped. Beds for the fallow and silver reflective plastic mulch systems were fertilized at 500 lbs per acre of 6-20-20 and cultimulched using a power incorporator. Preplant-incorporated *Tillam* herbicide was also applied to the fallow and silver reflective plastic mulch plots.

Shady Lady tomato transplants were set out at about 16" spacing in the silver reflective mulch and 14" spacing in the fallow and cover crop mulch plots in mid-April 1999 and 2000. Hand weeding was done in all plots and weed aboveground biomass dried and weighed in each year of the study. Fertigation via surface drip tape was used to apply about 20 lbs N weekly to all plots and an amount of N-P-K to the cover crop plots to equal the amount applied to the other two systems.

An April-planted sorghum-sudan hybrid cover crop was used as the cover crop mulch in the "late season" study in 1999. This cover crop was planted at a rate of about 40 lbs per acre on April 19, chopped and then sprayed with *RoundUp* in June. In 2000, owing to problems associated with the sorghum-sudan mulch in 1999, (See Results section of our 1999 report to the CTC), wheat straw was used as the cover crop mulch in the late-season study. "Bonus" wheat straw was spread by hand over the tops of tomato beds in the cover crop system plots at a rate of about 9,000 lbs dry matter per acre to simulate the amount of aboveground biomass that might be expected to be produced from a winter wheat cover crop. Preplant herbicide and fertilizer were applied and power incorporated as in the early season trials in the fallow and silver plastic mulch systems. *Shady Lady* tomato seedlings were transplanted on July 19, 1999 and in July 2000. Weed biomass samples from the two center rows of each 6 row plot were collected, dried at 106F for one week and weighed. Fertigation was done as in each "early season" experiment.

Tomato plant growth was determined during each experiment by harvesting one plant from either the second or fifth rows of each plot weekly. The plants were then separated into vegetative and reproductive components, dried in an oven at 106F to constant weight and weighed.

Soil temperature was measured with HOBO XT Temperature Loggers (Onset Computer Corp. Pocasset, MA). Probes were placed 8 cm deep in either of the two middle rows of every other treatment replication, halfway between tomato plants and the edge of the bed. Temperature loggers were launched in July of each year for thirty days and were programmed to record soil temperatures at 30 minute intervals.

Insect Sampling

Yellow water pan traps were placed in one of the two middle rows of each 6-bed plot at the start of each treatment. These traps were serviced weekly and the following principal insect groups found were identified: green peach aphid, cotton/melon aphid,

potato/tomato aphid, bean aphid, cowpea aphid, and other species deemed appropriate. The traps were also examined for thrips, whiteflies, and leafhoppers, all species known to be attracted to yellow and for which yellow pan traps have been shown to be an appropriate sampling device. D-vac samples were taken from rows 2 and 5 in each plot weekly.

Disease monitoring

Visual observations of every plant in each data row were made on an approximately weekly schedule. Location of symptomatic plants within plots was recorded and virus was determined on symptomology. ELISA materials for certain virus diseases were available for testing, if and when the appropriate symptomatic plants would be observed.

Yield determinations

All marketable tomatoes were harvested from the entire length of the two center rows in each plot for each experiment and weighed. In 1999, a single harvest was done in each plot at the time the majority of fruit were at a commercially harvestable stage. Based on our experiences in this first year and the recognition that fruit maturity might have been differentially impacted by surface mulch treatments, we harvested each plot three times in 2000 to provide more in-depth productivity data.

From each treatment, three hundred fruit were randomly selected from the total volume harvested and marked. Two hundred fruit were then randomly selected from these three hundred. The two hundred fruit were divided into ripe and green fruit and weighed separately. From the green sample, one hundred fruit were randomly selected and sized. Four sizing categories matching commercial standards, small (5.5 – 6 cm diameter), medium (6 – 6.5 cm diameter), large (6.5 – 7 cm diameter), and x-large (7 cm and larger diameter) were used. Tomatoes from each size category were then counted and weighed.

One hundred rotten fruit were randomly selected from each treatment's harvest of culls. The rotten fruit were sorted and divided into six categories: sunburn, worm damage, catface, blossom end rot, other rot and other defects. Fruit in each category were counted and weighed.

2000 On-Farm Demonstrations at Live Oak Farms, Le Grand, CA:

Demonstration Plot Procedures

Two on-farm demonstrations were conducted in 2000 at Live Oak Farms in Le Grand, CA to provide opportunities for additional evaluations and refinement of the silver reflective and cover crop residue mulch production approaches. These demonstrations were coordinated through California Tomato Commission Research Liaison, John LeBoeuf, with Bob Giampaoli and Mike Marchini, Live Oak Farms Manager and

Agronomist, respectively. In one of the on-farm demonstrations, a cover crop of wheat was grown over the 1999 – 2000 winter, chopped in late March using a Buffalo Stalk Chopper, sprayed with RoundUp and left on the bed surface to serve as a mulch. A three-row Unverferth Ripper Stripper was then used to till the middle 6 inches of each bed so as to provide an incorporated area into which tomato transplants were set out using a commercial transplanter in April. Twelve 60” beds, each of which measured about 1200 ft in length, were prepared using this surface residue/strip till approach, and these were to be compared with a “green manure” / incorporated cover crop system, which is a standard practice at Live Oak Farms. In-season cultivation was accomplished in the surface mulch system using a Buffalo High Residue Cultivator. No additional herbicide was used in this system. Fertilization was done using standard injector shanks used by Live Oak Farms.

In a second and separate demonstration at Live Oak Farms, replicated plots were established to compare silver reflective mulch tomato production with the farm’s standard fallow system. The plastic mulch was installed in 6-bed plots using a standard plastic layer. Weekly determinations of tomato plant growth were made by harvesting, drying and weighing one representative plant from each plot. Visual observations of every plant in each of the two middle rows of each plot were made on an approximately weekly schedule. If symptoms of disease were observed, notes would be made and plant material taken for laboratory diagnosis. The plots were harvested on September 11, 2000. Yield data were taken from 10-foot-long sections of the two central rows within each plot. Care was taken to select areas without visual evidence of large numbers of missing plants. Total fruit fresh weight was taken and 200 fruit (if available) were randomly selected, divided into green and red, counted and weighed separately. Finally, 100 mature green fruit from each plot were randomly selected and graded for size.

Determining the Potential Economic Benefits of Using Mulches for Tomato Production: (Objective 2)

We maintained quite detailed records of each operation that was required or performed to each production system during the course of each of the studies we have conducted. These records include inputs, tractor operations, labor and time required. These data are currently being compiled so as to present a generalized description of how each of these factors might vary between systems under consideration. We are conducting one final “late season” trial in 2001 which will complete our data set of production inputs and operations. Following completion of this trial, all data will be analyzed and presented so as to present an aggregate comparison of the three systems we have examined.

Results of 2000 Experiments:

To date, we have conducted two “Early Season” and two “Late Season” evaluations of three production systems: standard bare ground, silver reflective plastic and cover crop surface mulch. In 1999 and 2000, we evaluated the winter cover crop mixture of triticale / rye / vetch in our “early season” comparison, and an April-planted sorghum-sudan cover crop in our “late season” study, in comparison to silver reflective plastic mulch and

the standard bare ground fallow system. Results of these 1999 studies were presented in our 1999 Annual Report to the California Tomato Commission.

2000 “Early Season” Planting Experiment

Figure 1 shows whole tomato plant growth during the 2000 season. Plants growing over the silver reflective plastic grew faster and to a larger size at harvest than those of either the cover crop mulch or bare ground.

Yield results of the 2000 “early season” trial are provided in Table 1.

Yields from our 1999 work were significantly higher in the silver reflective plastic mulch, but similar in both the standard bare ground fallow and cover crop surface mulch systems.

These findings are now being analyzed in terms of production costs and inputs. Our 2001 “late season” experiment will be planted June 20, and once data collection and analysis for this study are complete, full cost/benefit accounting will be done based on the bulk of our recent studies.

2000 “Late Season” Planting Experiment

In our 2000 “late season” study, we evaluated these similar systems, however, we used wheat straw as the cover crop. This cover crop was actually “artificially” hand applied to the soil surface to the cover crop surface mulch plots, owing to the fact that the original cover crop species we had hope to evaluate, cow peas, did not produce significant biomass during the late April – mid June window in which it was growing. 1999 results for this “late season” trial indicated that the warm season grass, sorghum-sudan, severely inhibited the growth of tomato planted into it. Sorghum-sudan is thus, not at all a cover crop prospect to be used in this surface mulch context, - at least not immediately or soon after the cover crop is turned into a surface mulch. Yield results of our 2000 “late season” trial are provided in Table 2.

In this trial, which we will repeat in 2001, there were no significant differences in tomato yields between the systems. We are currently in the process of analyzing production costs and other, more detailed pest data from this 2000 study.

Insect and Disease Monitoring in 2000 Experiments

Statistical analyses have been made and these analyses are now being prepared for presentation. From these initial summary efforts, the following may be said. Aphid populations that were determined by yellow pan traps, leaf turns and leaf counts, were, in every case, highest in the fallow plots, followed by the cover crop plots, and then the reflective mulch plots. The same can be said of both thrips and leafhopper populations.

Data on observations of fruit scarring are still being analyzed. Results from tomato plant disease determinations in 2000 were very similar to those obtained in the two experiments conducted in 1999. No symptoms of virus disease were observed in any plants in the 2000 “Early Season” experiment. In the 2000 “Late Season” experiment, symptoms typical of those of curly top virus, vectored by the beet leafhopper, were observed (Table 3). Symptoms developed in certain plants between September 1 and September 21. After September 21, no additional plants showed development of virus symptoms. Although the incidence was low, the following means were obtained:

Analysis of variance showed that the 82% lower incidence in virus-infected plants in the mulched (either biological straw or reflective plastic) treatments was significantly different from the nontreated control treatment.

On-Farm Demonstration Plot Results

Yields from the on-farm comparison of the cover crop surface mulch with Live Oak Farm’s conventional “green manure” cover crop were not determined because the field was harvested before we were able to secure harvest data.

In the comparison between the silver reflective plastic mulch and the standard fallow system, apart from some plants being killed shortly after transplanting in the plastic, no symptoms of disease were observed in any plants during the course of the experiment. Crop yields were relatively inconclusive and confounded by conditions of unexpected experimental error. These conditions were caused first by logistical constraints that resulted in the reflective mulch plots being transplanted several days after the conventional or control plots in June. In order to minimize differences in plant growth and yield due to the difference in transplanting date, the plastic mulch plots were transplanted during a heat wave by a crew inexperienced in plastic mulch tomato culture. The plants were planted too shallowly, resulting in “leggy” transplants which bent over during transplant shock and came in contact with the plastic surface. These conditions resulted in significant transplant mortality in the mulched plots. While the demonstration field was observed to be free of discernable plant disease problems throughout the growing season, yield data from this effort must be considered inconclusive owing to the procedural irregularities that were encountered.

Exploration of opportunities for extension of these trials to be conducted in Southern California:

We recently initiated phone discussions with two farmers in Southern California concerning opportunities to begin small-scale, on-farm studies that follow up on the work we have conducted during the past two years for CTC and for DPR in 2000. It seems reasonable that possible benefits of the cover crop alternative system might have greatest relevance and import in tomato production systems in which repeated harvests are employed. We fully intend to pursue in-person discussions with these key growers in the very near future to see if together we might engage in appropriate research in this critical production region.

Importance of DPR funding in terms of our ability to “leverage” additional research support:

It is significant to consider that this embryonic CTC/DPR-sponsored work has led to significant additional opportunities for us to further explore possible benefits of these alternative production systems. The initiative of CTC Research Liaison, John LeBoeuf, is particularly noteworthy and appreciated in this regard. John enabled us to access research and extension education augmentation support for 2000 which tremendously enabled us to pursue this work and to conduct on-farm trials and a very successful field day in Le Grand, CA with CTC member Bob Giampaoli and his farm manager, Mike Marchini.

In a broader respect, CTC/DPR support of this early work has also enabled us to evaluate and develop reduced till alternatives that might have relevance within cropping systems that include tomatoes as part of their rotation scheme. In this sense, this work on fresh market has greatly contributed to our ongoing work with processing tomatoes, and likewise, our processing tomato work has benefited fresh market tomato alternatives.

A full cost accounting of the two alternative production systems relative to current commercial standard practices is underway

Discussion

In a very preliminary sense, these data point to the possibility of each of the alternative systems in terms of sustaining, and in the case of the silver reflective mulch, perhaps increasing productivity. A more complete picture of the implications of these alternatives will be presented in articles that will be submitted for peer-reviewed publication at the close of our 2001 “late season” study. In order for either of the two alternative production systems to be adopted at a large scale, however, it is likely that more successful demonstrations or grower trials will need to be undertaken for producers to become more familiar with the various management subtleties that each might require. For example, while plasticulture is well established in many vegetable production regions, many Central Valley producers are not familiar with its use. It will thus require more familiarity by growers in order for this system to become more widespread. In the case of the cover crop mulch system, this again will require a greater investment in terms of “learning the system” by growers before it might move ahead. It is likely that either of the mulch alternative systems may become more attractive to producers if and when a dedicated commitment to “zone traffic” production becomes more common. This would mean that producers consciously preserve beds and furrows, or plant growth zones and tractor zones in the field. This type of conservation tillage approach is, according to our UC Division of Agriculture and Natural Resources Conservation Tillage Workgroup, receiving considerable interest among farmers throughout the Central Valley and this DPR-sponsored work has helped demonstrate that such reduced till systems might be possible, at least on a short-term basis.

The LeGrand, CA field day enabled us to showcase this work and to interact with growers and PCA's regarding the preliminary findings of this work. The several popular press publications that have highlighted in part this work are also helping to disseminate the results of this project.

Summary and Conclusions

DPR partial sponsorship of our 2000 work has enabled us to demonstrate that both the silver reflective plastic and the cover crop-derived mulches may provide alternatives to current production practices for fresh market tomatoes. Both the silver reflective plastic and the cover crop surface mulch alternative systems seem to provide the possibility to sustain productivity relative to current standard off-season fallow systems. In the case of the silver reflective plastic, productivity may, in fact, be increased. The two alternative production systems will require different management, equipment and scheduling considerations in order to be successfully adopted. Integrated pest management of the two production alternatives will also differ from the current standard. This single-year work is now being added to our larger body of systems comparisons so as to determine the potential relative economic benefits of the systems we have compared. These comparisons are now underway. By merging our production cost data from 2000 with other, related studies, we hope to have a better, more robust economic analysis available for producers to consider in 2001. Our 2000 work has been in a very important sense, a demonstration of the fact that these alternatives can, in fact, be used to produce tomatoes consistent with current standards in California's San Joaquin Valley. The reflective plastic, in both of the early season studies reported here, had the highest yields of the three systems. This work will need to be carried to more on-farm implementation studies in the near future in order for management details of the alternative systems to be refined and for farmers to become familiar with each set of required practices.

Work conducted in 2000 constitutes an important component of our ongoing efforts to develop and evaluate alternative pest, crop, and soil management systems for major crops in California's Central Valley. This work has provided examples of alternative management approaches that equal or exceed the current standard production systems in terms of productivity. It has also provided visible examples of the management mechanics for each system and has yielded a considerable data base for insect, disease and weed pests of each system. While this progress and these outcomes are important, it is necessary to bear in mind that they are really only part of a broader research program that is considering the eventual integration of such single-season practices into crop rotations in which the potential full benefits of dedicated zone production systems and reduced tillage are evaluated. Our economic analysis, which will be summarized following our 2001 late season study, will be useful to producers who may be considering various aspects of the two alternative systems we have demonstrated here. We believe that this economic analysis will be strengthened by considering a number of studies we have recently conducted together. This component of our objective 2 will be available in 2001 and will appear in an amended final report to DPR.

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Appendices

Figure 1. Tomato plant growth (grams per plant)

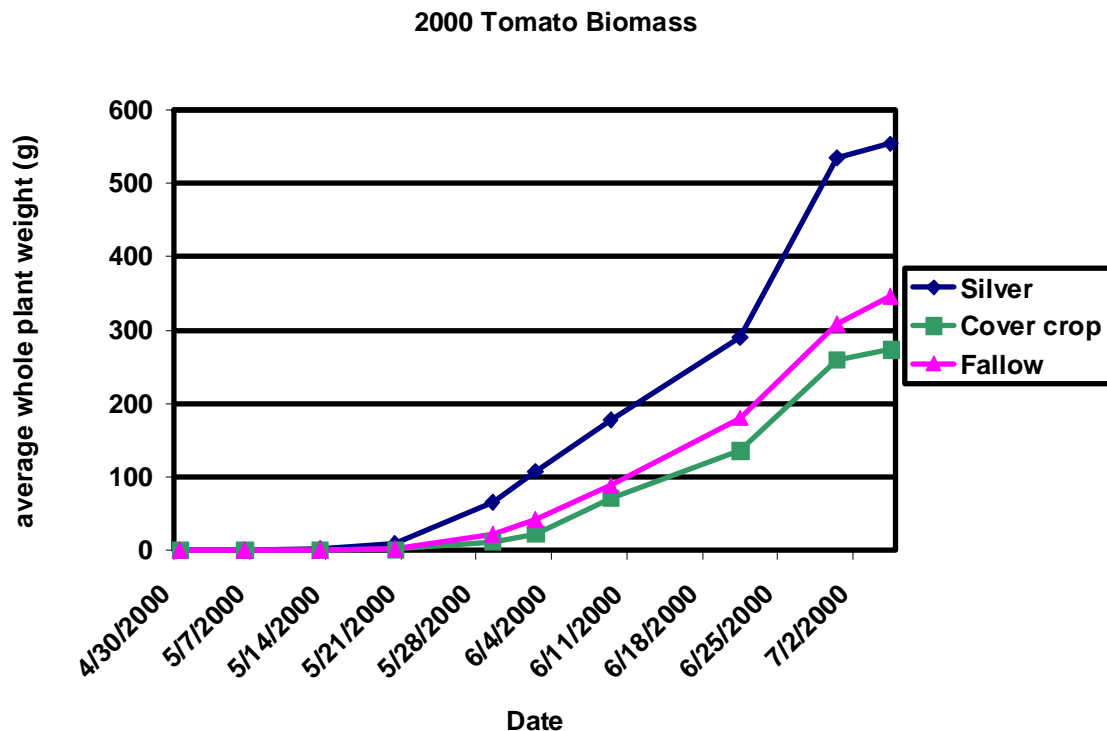


Table 1. Yields (kilos of marketable tomatoes per hectare)

Standard bare ground winter fallow system	74,820 ab
Silver reflective plastic mulch	83,008 a
Cover crop surface mulch	67,818 b

(Systems with similar letters following yield numbers are not considered significantly different from each other.)

Table 2. Yields (kilos of marketable tomatoes per hectare)

Standard bare ground winter fallow system	24,571 a
Silver reflective plastic mulch	29,480 a
Cover crop surface mulch	28,616 a

(Systems with similar letters following yield numbers are not considered significantly different from each other.)

Table 3. Virus symptoms in 2000 “Late Season” Planting Experiment

Standard bare ground fallow system	3.8 plants/plot
Silver reflective plastic mulch	0.7 plants/plot
Cover crop surface mulch	0.7 plants/plot

Dissemination of Results:

The objectives and preliminary findings of these CTC/DPR-sponsored studies have been conveyed to growers and Commission members through publications in both popular and scientific literature, field days and industry meetings as well as a variety of “general concept” presentations that we have made during the last two years of the components of the alternative systems that have been under study. A summary of a number of these extension education outlet efforts that we have accomplished follows. DPR-sponsorship of this work was credited in these presentations.

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