Pest Management Grants Final Report

Contract #98-0261
Project Title: Evaluation of cultivars for yield in organic strawberry production in the presence or absence of mycorrhizal inoculum.

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Acknowledgements:
Partial funding for this research was received from UC-SAREP

Growers: Christine Coke, Phil Foster, Jim Leap, Dick Tamagni, and Paul Kohatsu

This report was submitted in fulfillment of (contract number) under the partial sponsorship of the California Department of Pesticide Regulation. Work was completed as of December 1, 2000

Table of Contents

ABSTRACT

This project provides organic farmers and transitional farmers with basic information about the performance of strawberry cultivars produced on organically managed farmers. In the first side-by-side comparisons of commercially available cultivars under organic management, the cultivars Aromas, Pacific, and Seascape were consistently the top performing of those tested. Cultivars Diamante, Douglas, Hecker, Pajaro, Selva, Sequoia, Capitola, Camarosa, Carlsbad, Cartuno, Irvine, and Gaviota were also evaluated. The data indicated that significant differences yield occur among cultivars grown under organically managed conditions.

A commercially available mycorrhizal inoculant provided no benefit to organic strawberry production. Although transplants were initially sparsely colonized, inoculation with a commercial inoculant did not increase the percent of the roots colonized when plants were grown in organic fields. Likewise there was no increase in yield due to the mycorrhizal inoculant. The failure may be due to the presence of adequate mycorrhizal inoculum in the organic production fields.

In these evaluations organic strawberry production in these fields was not limited by lethal plant diseases such as Verticillium wilt. Other yield limiting diseases were not detected in high levels at any of the locations or on any of the cultivars.

EXECUTIVE SUMMARY

The organic strawberry farmers realize the need for scientific research in order to develop optimal production systems. Conventional farmers are now interested in the organic production of strawberry, but find little scientific basis for making important choices about production. The cultivar evaluations and experiments with mycorrhizae were conducted during the 1999-2000 strawberry growing season. After a July meeting with growers to choose cultivars to be evaluated, plots were established in October and November of 1999. An extension of the grant was requested to complete the field season in October of 2000. Data analysis was completed on December 1, 2000. A final lunch meeting will be held for growers in January 2001 and the results of the work with be reported in The Cultivator and Farmer-to-Farmer during the winter of 2001.

This was the first evaluation of strawberry cultivar performance under organic management conditions. We successfully provide farmers and agricultural professionals (over 350) with data about the performance of these cultivars and the influence of cultivar choice on yield. Aromas, Pacific, and Seascape were consistently the top performing of those tested. In a second year of evaluations some cultivars will be excluded and growers have added other cultivars to be tested.

Preliminary evidence indicated that a commercial inoculant could increase plant yield by 25%. In contrast, in these rigorous experiments presented in this report, no benefit in yield or colonization by mycorrhizae was detected after inoculation with one product. This year seven commercial inoculants will be evaluated for their effect on strawberry yield and colonization.

Little plant disease was detected in the demonstration and research plots. A detailed comparison between the presence of disease and pathogens in organic and conventional fields is needed in order to determine if plant disease influences yield in organic production.

INTRODUCTION

Strawberries rank as the 11th most important crops in California. Preplant fumigation with a mixture of methyl bromide and chloropicrin (MBC) is an important tool in obtaining high strawberry yields due to its ability to control soilborne pests and weeds. However, methyl bromide is a class I ozone depleter, and as such is scheduled for a 50% and 100% use reduction in 2001 and 2005, respectively. In addition to the loss of methyl bromide, strawberry growers face the loss of other pesticides due to FQPA restrictions. The approach taken by the vast majority of scientists in the search for alternatives to MBC is to test chemical or biological alternatives as one-for-one replacements. Studies taking a systems approach to producing strawberries in biologically integrated systems are almost non-existent.

A small amount of California's strawberry acreage is grown organically. In 1997, 1 % of California strawberries were organically produced on approximately 0.2% of the land. In the years since then strawberry acreage has steadily increased. According to CCOF (California Certified Organic Farmers, the leading California organic certification agency) the number of CCOF certified strawberry growers has increased from 18 to 34 (CCOF 1993, 1999), with a similar increase in total acreage in California.
Although organic production is the state-of-the-art production method in the absence of MBC fumigation, there is little research aimed at optimizing this alternative. An added benefit of optimizing this system is that it does not depend on FQPA targeted chemicals. The success that organic growers have experienced has been with a virtual absence of scientific research and extension. The overall goal of this research is to provide farmers with research conducted in an explicitly organic setting so that they can make informed choices about cultivar selection, microbial treatments, and disease management issues. High yielding cultivars used in California were evaluated and selected for their yield and fruit quality in conventional agricultural systems. In organic fields, plants are presented very different environments from those in which they were selected. Under conventional conditions, cultivars did not rank in the same order if they were grown in fumigated verses non-fumigated soil (Frank Martin, personal communication). Therefore it is likely that the cultivars that perform best under standard conventional conditions are not the optimum cultivars for organic production. Although choice of variety is very important for success, a study to determine how strawberry cultivars perform in organic production fields is non-existent and farmers are left to extrapolate from conventional systems. Our first objective was to demonstrate the relative performance of standard California cultivars grown under organic management.

Though microbial inoculants can be used in organic production and they have been shown to mitigate plant disease or promote plant growth in conventional cropping systems, little is known about the potential of microbial inoculants in organic systems. Arbuscular mycorrhizae (AM) have been shown to increase plant growth and reduce the impact of disease in some cropping systems. In a preliminary study, application of one commercial inoculant resulted in increased yield in organic strawberry production (Bull unpublished data). The benefit of AM to strawberries is cultivar dependant. AM will be

beneficial to some cultivars and detrimental to others (Khanizadeh et al., 1995). The second objective of this work was to determine if a commercial AM inoculant could provide benefit to the cultivars being tested in the first objective.

It is unknown what factors limit yield in organic strawberry production. Plant disease or abiotic factors may play a role in decreasing yields in non-fumigated soils. Our third objective was to evaluate major plant pathogens in organic strawberry production.

RESULTS

All objectives outlined for this project have been met. A second grant 99-0261 has been awarded to repeat and expand the experiments presented here.

1. Demonstration of cultivar performance.

Cultivar performance was successfully evaluated at four certified organic locations during the 1999-2000 growing season. The sites were located in Monterey, Santa Cruz and San Benito Counties. At three of the locations yield was measured on each cultivar in replicated experiments. There were four replications of each cultivar and the plots were established and evaluated as a randomized complete block. Yield was evaluated on 20 plants for each replication. At an additional site, a demonstration of several cultivars was conducted in larger blocks with no replication. Cooperating growers are listed in Table 1.

The cultivars used at each location are listed in Table 2. Cultivars, Aromas, Diamante, Douglas, Hecker, Pacific, Pajaro, Seascape, Selva and Sequoia were used at all three of the sites in which the evaluation was conducted as replicated experiments. Capitola, Camarosa, Carlsbad, Cartuno, Irvine, and Gaviota were used at some but not all of the sites. The cultivars were chosen by growers at a lunch meeting attended by local organic strawberry growers.

Aroma, Pacific, and Seascape consistently performed the best in the field trials evaluated (Table 3). Aromas ranked as one of the top three cultivars in all experiments. Pacific ranked as one of the top 4 cultivars in all experiments and Seascape ranked in the top 5 in all experiments. Selva also ranked in the top 5 in all three experiments but never ranked in the top two positions while Seascape did. Diamante ranked first in one experiment but ranked 5 and 8 in the two additional experiments. According to the average of the rankings across all experiments, Aromas, Pacific, and Seascape were the best performers in organic production fields.

Market and Total yield were evaluated for all experiments. Market yield is more meaningful to many growers because of the high value of fresh market fruit. Data is presented for both market and total yields. We have also presented weekly yields at some growers meetings so the growers can evaluate market trends with production patterns.

Here we present two types of data. Weight of berries (gm/plot) was calculated without regard to loss of plants. The second manor in which data was expressed was crates/acre.

This value is a weighted value because it was calculated from gm/plant taking in to consideration missing plants. However, as is explained under section 3, plant loss due to disease or other causes was minimal so analysis of the unweighted data (gm/plot) is similar to the analysis of the weighted data (creates/acre).

At location 1 Diamante performed best followed by Aromas, Selva, Pacific, and Seascape (Figure 1). The grower at this location was reluctantly experimenting with a small amount of organic production acreage. Of the three sites at which replicated experiments were conducted, this site had the least amount of time in organic production, and the farmer with the least experience with organic production. Diamante is the cultivar that this grower uses primarily in his conventional operation and his growing methods may be adapted for success with this cultivar. There was no significant difference in yield among cultivars Diamante, Aromas, Selva, Pacific, and Seascape in this experiment.

The grower at location 2 is one of the premier organic strawberry producers in California. This grower has been producing organic strawberries for over 10 years. At this location Seascape performed the best followed by Pacific and Aromas (Figure 2). Market and total yield for Seascape was significantly higher than the market and total yield for Diamante. The yields for Aromas Pacific, Seascape and Selva did not differ significantly.

At location three, Aromas ranked first with Pacific closely behind (Figure 3). These two cultivars had significantly greater market and total yields than Selva and Diamante. In addition yields of Diamante were significantly lower than Selva. Market and total yields did not differ to the extent that they differed at the other two locations. This is because this organic grower sells directly to his customers on the same day that the berries are harvested. This allows this grower to sell many berries that the other growers would not be able to due to their shipping and marketing plans. This location has been managed organically for 10 years and the grower used a broccoli rotation prior to planting strawberries for the biofumigation effect.

In summary Aromas, Pacific, and Seascape performed the best under organic production conditions. Selva and Diamante also performed well. The growers and the pickers prefer the taste of Seascape to the other varieties. They also expressed an interest in seeing Camerosa evaluated next year. The yield of the cultivars was not measured in the second year because none of the growers were keeping their plots for a second year.

2. Influence of inoculation with mycorrihzae.

In addition to evaluating standard cultivars for production under organic conditions we also evaluated the effect of a commercial inoculant on the strawberry yield. A commercial inoculant containing 7 species of mycorrhizae was used to inoculate plots with each of the 10 cultivars tested (BioBlend RD, Soil Technology). The experiments were established and evaluated as a Split Plot experiment with each cultivar serving as a plot. The treatments were replicated 4 times at each of three locations.

Transplants were evaluated for mycorrhizal colonization prior to planting using standard methods (Kormanik and McGraw1982). All transplants were from conventionally managed nurseries. These are currently the only plants available to organic growers. Speedling has contacted us because of a field day associated with this work and we are currently beginning a project with them to produce organic transplants. There was a very low level of colonization by mycorrhizae on the transplants at the time of planting (Table 4). Many of the cultivars were not colonized. This low level of colonization is to be expected because the nurseries fumigate the soil in which these plants were grown.

There were differences in colonization by mycorrhizae at the different locations. At the first two sampling times, colonization of plants was higher at locations 1 and 3. Colonization at location 2 was significantly lower. Because we did not carefully evaluate the soil chemistry at these locations, we can only speculate why there is a difference in colonization. If the phosphorus level was high at location 2, formation of mycorrhizae would be inhibited.

Inoculation with the commercial inoculant did not increase colonization detected on roots at any location (Figures 4-7). Organic production fields are not fumigated and have natural occurring inoculum in the fields. This inoculum apparently colonized the uninoculated strawberry roots. We are currently conducting greenhouse experiments to determine how well the inoculant colonizes strawberry roots under controlled conditions without a natural source of inoculum.

Strawberry yield was not influenced by inoculation with the commercial inoculant tested (Figure 8). None of the cultivars responded to inoculation with the mycorrhizal inoculant at any of the locations. The lack of influence on yield may be due to the equal colonization of inoculated and uninoculated plants. This year we are evaluating additional inoculants.

3. Evaluate diseases in organic strawberry production.

The incidence of soilborne pathogens were monitored by soil sampling at the beginning of the season and by evaluation of dead or dying plants during the season. There was a very low incidence of fruit and foliar diseases at all locations so these were not monitored. Location 3 did have a short and inconsequential outbreak of powdery mildew late in the season. No abiotic disorders were detected in these fields during the season.

The presence of *Verticillium dahliae* was evaluated by plating soil from each location on a selective medium. The pathogen was not detected at any of the sites. In general, 3 propagules of *Verticillium dahliae* per gram of soil will cause large losses and growers may want to biofumigate prior to planting at that location. Each location had either had a long rotation between the last time strawberries were planted or had used broccoli to biofumigate prior to planting this season. For one grower a broccoli rotation prior to strawberries is standard practice.

During the season there was no plant loss due to disease in these fields. At most two plants were lost in a given plot. However, there was no trend in which plots had the plant loss. *Verticillium dahliae* was not isolated from these dying or dead plants. Many of the plants that were lost were lost at the beginning of the season and the loss was primarily due to original transplant conditions and gophers. Each plot had between 18-20 plants throughout the season.

In summary, organic strawberry production in these fields did not appear to be limited by lethal plant diseases such as Verticillium wilt. Other yield limiting diseases such as Botrytis fruit rot were not detected in high levels at any of the locations or on any of the cultivars. More detailed analysis of the non-lethal fungal pathogens is needed in organic production, in order to determine if plant disease influences yield in organic production.

DISCUSSION

We have had an effective outreach program that has made most strawberry farmers in the central coast area familiar with our work. Through the CAFF Lighthouse Farm Network, postcards, direct phone calls and announcements in Farmer-to-Farmer (formerly The Foghorn published by CAFF) growers have been invited to meetings. Over 350 farmers and agricultural professionals attended meetings where the DPR funded research described here was discussed.

We have extended the impact of the DPR funded research by leveraging the UC-SAREP funded program BASIS/OASIS. This program has helped to advertise the DPR funded research to an extent that could otherwise not been done.

It is difficult to measure what effect this research has had on the switch of conventional farmers to organic production of strawberries. According to CCOF (California Certified Organic Farmers, the leading California organic certification agency) the number of CCOF certified strawberry growers has increased from 18 to 34 (CCOF 1993, 1999), with a similar increase in total acreage in California. Organic farmers have little technically sound information for their management-decision making process. Conventional farmers now interested in the organic production, but find little scientific basis for choosing among the many organic. Prior to these experiments, virtually no research had been conducted on organic strawberry production. Here we have provided growers with replicated cultivar trials. These are the first publicly funded cultivar trials conducted under organic management. Because the field trials ended just as the new plantings for this year were being planned, numerous growers called to ask our final results on some of the cultivars tested. Several growers are planting more Seascape and Aromas this year because of the results of these experiments. We are including Camerosa in the next evaluations because many growers wanted to see the comparisons. These results helped them to make cultivar choices for the 2000-2001 field season. We are not finished presenting the results of this work and will present the final results from this year at a lunch meeting in 2001.

In a first year of study, commercial inoculants did not improve colonization or yield of organically grown strawberries. However, several growers contacted us this fall to ask if they should try a mycorrhizal inoculant. We provided free material to 4 growers not involved in the study to try it under their conditions. We told them that we had no success with the product tested, but they wanted to see the results under their conditions. We also provided information that helped the mycorrhizal provider receive OMRI registration for their mycorrhizal product.

Finally, because of our reports at one of the field days, a representative from Speedling approached us about testing organically produced plug transplants in organic production. These would be the first organically produced transplants available to organic strawberry growers. We will provide information to this company to help optimize their product.

Summary and Conclusions

The major accomplishment of this project was to provide growers with data about commercially available cultivars that will help them make scientifically based choices in cultivar use. Organic farmers have little technically sound information for their management-decision making process. Here we provide the first side-by-side comparisons of commercially available cultivars under organic management. The cultivars Aromas, Pacific, and Seascape were consistently the top performing of those tested under organic management. The data indicate that significant differences yield occur among cultivars grown under organically managed conditions. Optimization of organic strawberry production may require selection of cultivars in an organic system because other cultivars ranked highest in conventional and conventional but non-fumigated trials (Frank Martin personal communication).

Transplants from conventionally managed nurseries had low levels of colonization by mycorrhizae. This low level of colonization is to be expected because the nurseries fumigate the soil in which these plants were grown.

Early in the season there were differences in colonization by mycorrhizae at the different locations. Although growers are interested in using commercial inoculants, inoculation with one commercial inoculant tested did not increase colonization by mycorrhizae at any location.

Strawberry yield was not influenced by inoculation with the commercial inoculant tested. None of the cultivars responded to inoculation with the mycorrhizal inoculant at any of the locations. The lack of influence on yield may be due to the equal colonization of inoculated and uninoculated plants. In a second year of research additional commercially available mycorrhizal inoculants are being evaluated.

Strawberry production in these fields was not limited by lethal plant diseases such as Verticillium wilt. Other yield limiting diseases were not detected in high levels at any of

the locations or on any of the cultivars. A detailed comparison of pathogens and diseases between conventionally and organically produced strawberries is needed to determine what role plant diseases have in the reduced yields in organic production.

Literature cited

Khanizadeh, S., Hamel, C., Kianmehr, H., Buszard, D., and Smith, D. L. 1995. Effect of three vesicular-arbuscular mycorrhizae species and phosphorus on reproductive and vegetative growth of three strawberry cultivars. J. Plant Nutrition 18:1073-1079.

Kormanik, P. P., and McGraw, A. -C. (1982). Quantification of vesicular-arbuscular mycorrhizae in plant roots. In: N. C. Schenck (Editor), Methods and Principles of Mycorrhizal Research. APS Press, St. Paul, MN, 37-45.

Table 1. Growers and locations of experiments and demonstrations.

Location	Farm	Grower
San Juan Bautista	Coke Farm	Christine Coke
San Juan Bautista	Phil Foster Ranch	Phil Foster
Santa Cruz	UCSC organic farm	Jim Leap
Salinas	Spence Organic Field	Paul Kohatsu

Table 2. Cultivars evaluated in these experiments.

	Location			
Cultivar	1	2	D	E
Aromas	X	X	X	X
Captiola	X	X		
Carlsbad			X	
Cartuno				X
Diamante	X	X	X	X
Douglas	X	X	X	
Gaviota				X
Hecker	X	X	X	
Pacific	X	X	X	
Pajaro	X	X	X	
Seascape	X	X	X	
Selva	X	X	X	
Sequoia	X	X	X	

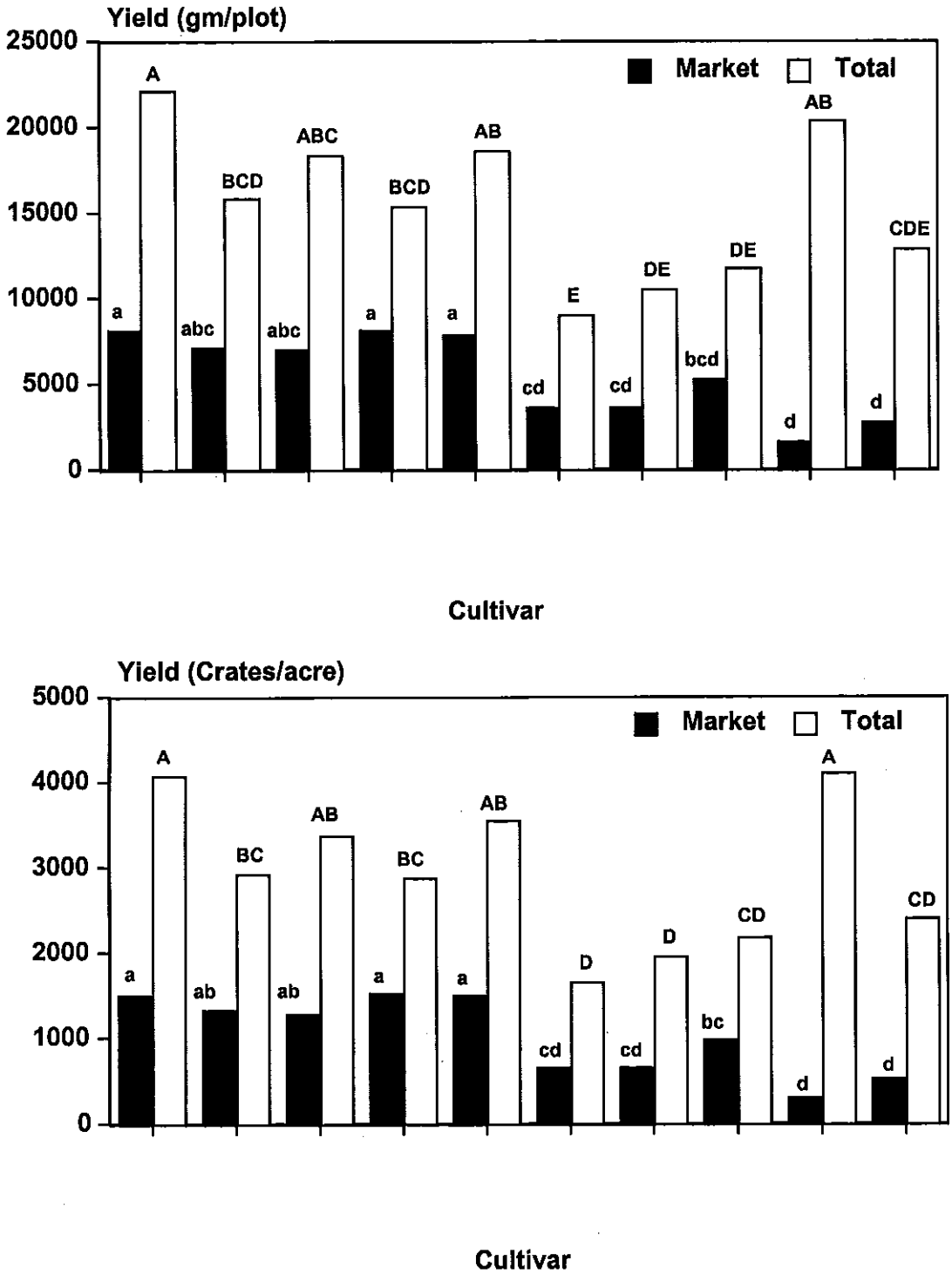
X, indicates locations at which cultivars were grown.

Table 3. Ranking of top five cultivars in organic production.

	Location 1	Location 2	Location 3	**Total of rankings**
Aromas	2	3	1	**6**
Pacific	4	2	2	**8**
Seascape	5	1	3	**9**
Irvine	NT	NT	4	**NT**
Selva	3	4	5	**12**
Diamante	1	5	8	**14**

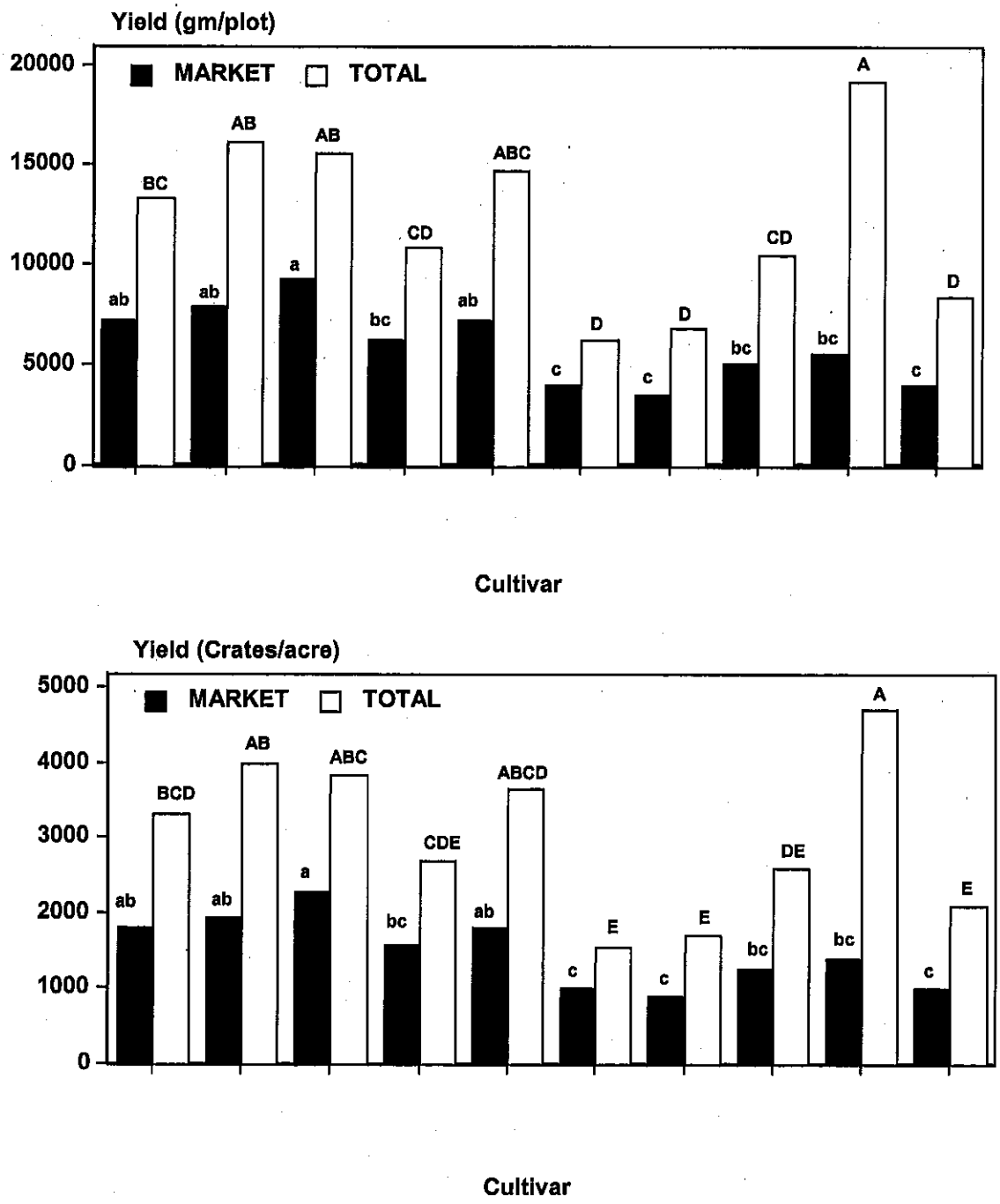
A rank of 1 indicates the highest yielding cultivar.
NT = Not tested
Cultivars with the lowest total rankings performed best under organic production conditions.

Figure 1. Yield of strawberry cultivars grown under organic management at location 1.



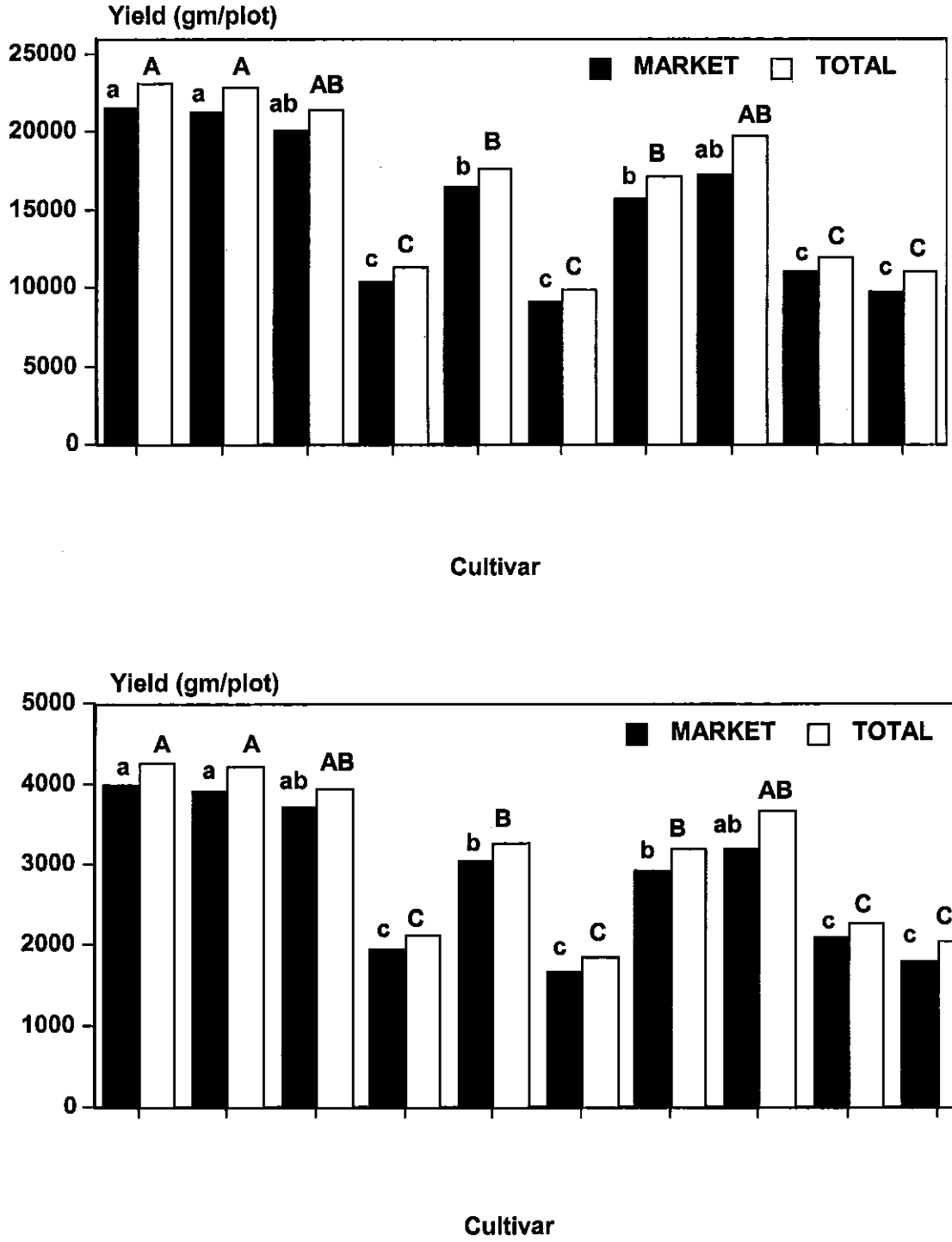
Market and total yields were analyzed separately.
Means having the same letters were not significantly different at the P=0.05 level according to Tukey-Kramer HSD.

Figure 2. Yield of strawberry cultivars grown under organic management at location 2



Market and total yields were analyzed separately.
Means having the same letters were not significantly different at the P=0.05 level according to Tukey-Kramer HSD.

Figure 3. Yield of strawberry cultivars grown under organic management at location 3



Market and total yields were analyzed separately.
Means having the same letters were not significantly different at the P=0.05 level according to Tukey-Kramer HSD.

Table 4. Mycorrhizal status of strawberry transplants from conventional nurseries.

Cultivar	Mycorrhizal colonization (% colonized)
Aromas	1.7 ± 0.6 A
Camerosa	0.0 ± 0.0 A
Capitola	0.5 ± 0.5 A
Diamante	0.5 ± 0.9 A
Douglas	0.2 ± 0.3 A
Hecker	0.3 ± 0.3 A
Pacific	0.7 ± 0.3 A
Pajaro	1.3 ± 1.1 A
Seascape	1.5 ± 1.5 A
Selva	0.0 ± 0.0 A
Sequoia	0.2 ± 0.3 A

No significant differences were detected at the P=0.05 level.

Figure 4. Mycorrhizal colonization of strawberries planted in organically managed soils.

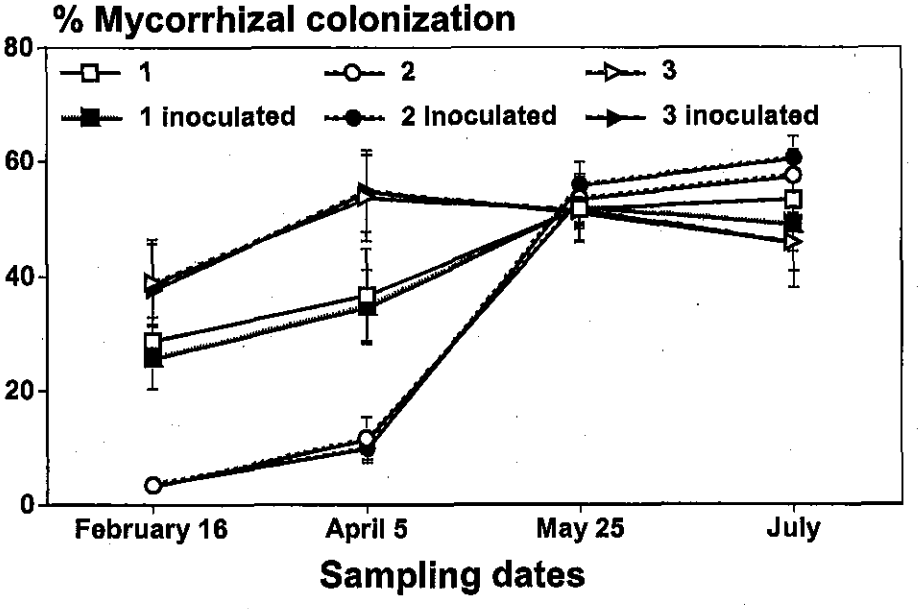
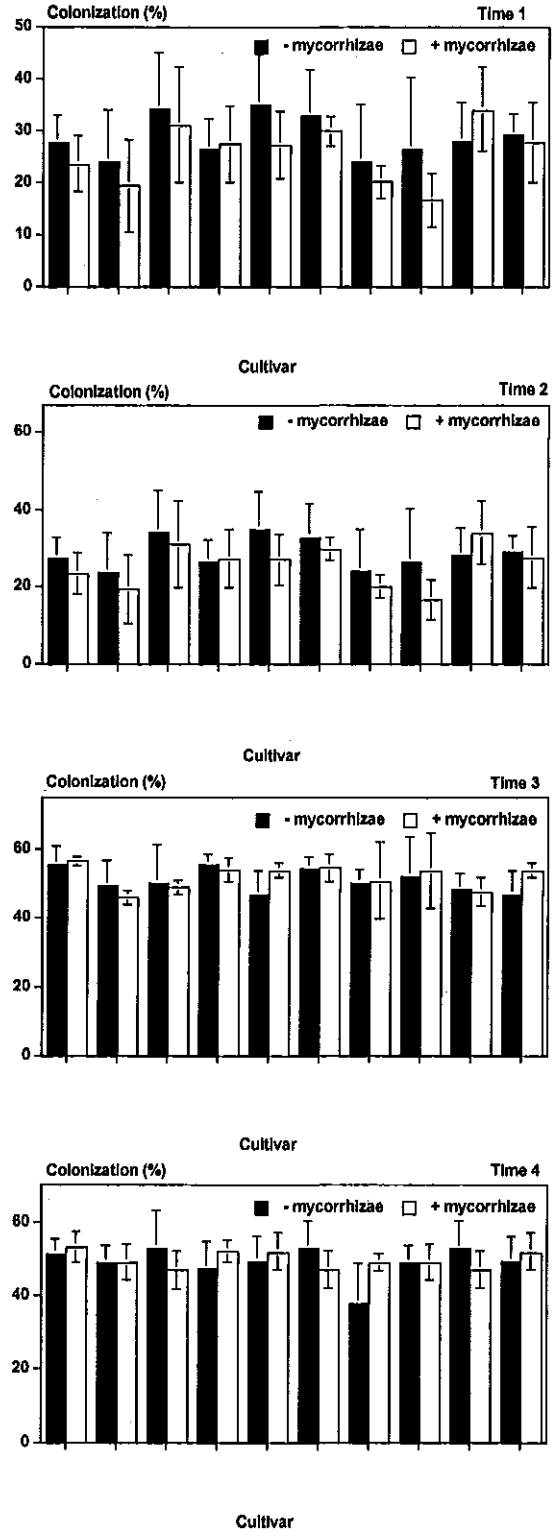
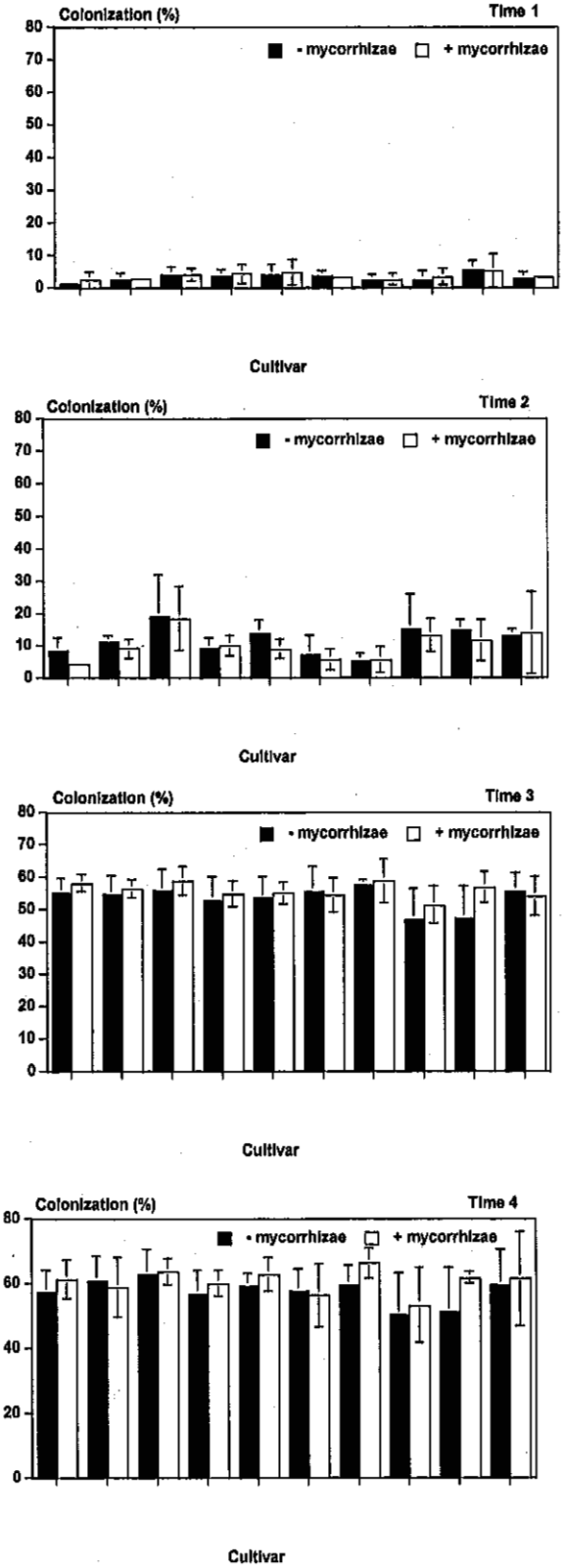


Figure 5. Mycorrhizal colonization at location 1.



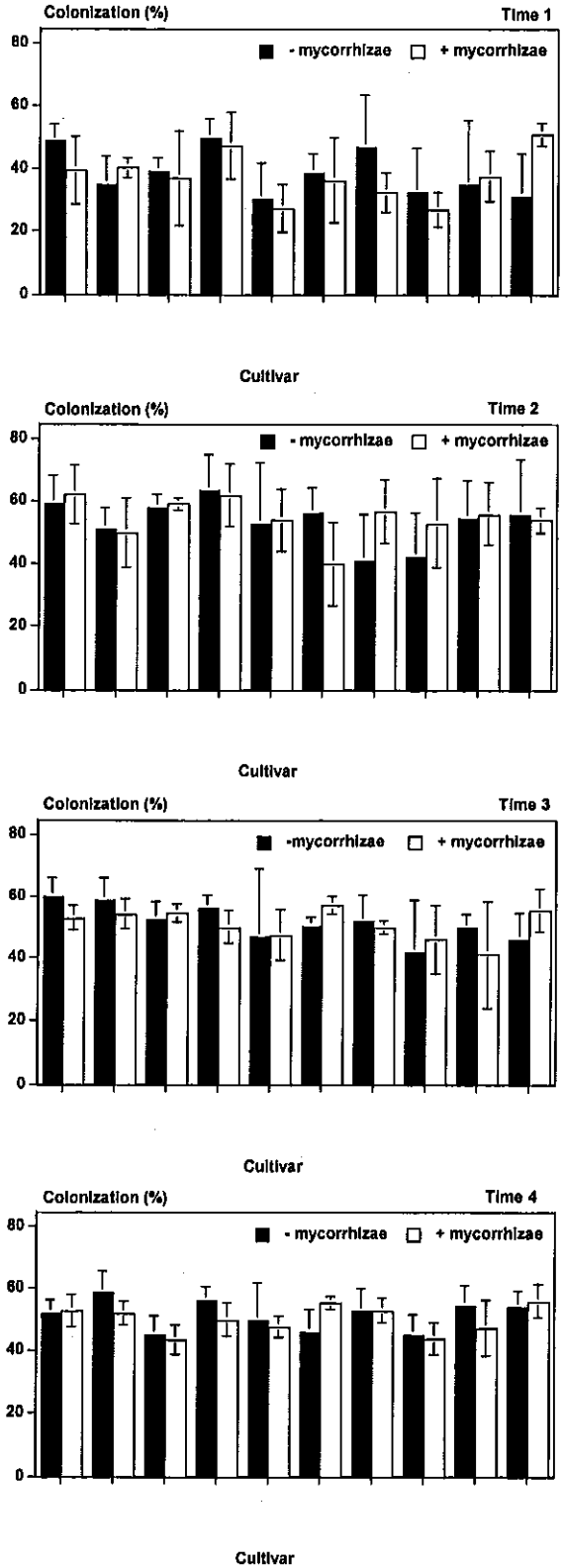
No significant differences were detected between inoculated and uninoculated controls at the P=0.05 level.
Time 1 = February, Time 2 = April, Time 3 = May, Time 4 = July

Figure 6. Colonization of mycorrhizae, location 2.



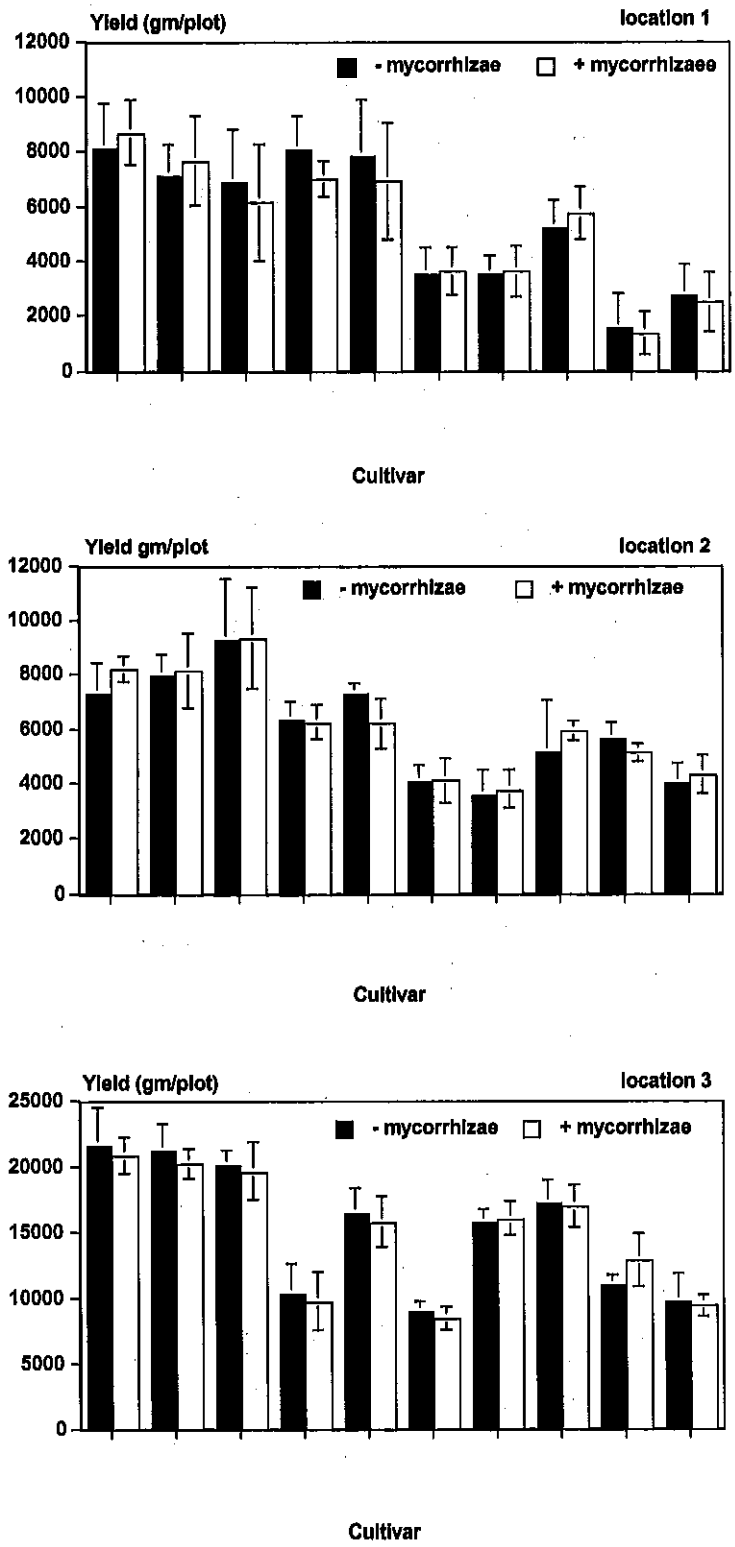
No significant differences were detected between inoculated and uninoculated controls at the P=0.05 level.
Time 1 = February, Time 2 = April, Time 3 = May, Time 4 = July

Figure 7. Colonization of mycorrhizae, location 3.



No significant differences were detected between inoculated and uninoculated controls at the P=0.05 level.
Time 1 = February, Time 2 = April, Time 3 = May, Time 4 = July

Figure 8. Yield of strawberries with and without mycorrhizal inoculant at three organic locations.



No significant differences were detected between inoculated and uninoculated controls at the P=0.05 level. See figures 1-3 for statistical differences among cultivars.

APPENDIX A. TECHNICAL TRANSFER

Grower meetings

June 8, 1999. Update on Strawberry Varieties, Old & New; What works for Organic production. Hosted by CAFF. Growers helped us to decide what varieties should be used in the variety trials.

October 23, 1999. Strawberry research and production" Presented by Carolee Bull during the Salinas to the Sea tour of agricultural projects for philanthropists.

December 14, 1999. Salinas, CA. Carolee Bull, Sean Swezey, and Steve Gliessman presented "Update on current strawberry research and Biological Agricultural Systems in Strawberries (BASIS)." Carolee Bull reported on the cultivar and inoculant trials funded by DPR

April 2000. Organic production methods meeting. CAFF hosted a meeting to develop a template for organic production. Many of the participants in the DPR project attended and worked on the project. An organic consultant, an organic grower and two PCAs participated in an open discussion of pest and beneficial monitoring activities, action thresholds, and treatment methods or response. The goal is to produce in-house guidelines as a reference for future research and management activities for organic growers.

April 4, 2000 Field day with BASIS-OASIS program. Carolee Bull talked about the DPR funded cultivar trials on organic managed land.

June 27, 2000. UCCE Annual Strawberry Field day. Approximately 200 growers and agriculture professionals attended. Fundamentals of organic production and the DPR funded research projects were discussed. A poster of the DPR research was available for growers.

June 28, 2000. USDA/ARS Annual Field day. CAFF provided outreach by making calls to 50 growers and PCAs the day before the meeting. Approximately 100 growers and agriculture professionals attended. Fundamentals of organic production and the DPR funded research projects were discussed. A poster of the DPR research was available for growers. Sandra Fischbin of Speedling Corp. let me know that because of the DPR work we reported on at this meeting she has started a program to develop organic plug plants for strawberry growers. We will work with her in the future to help growers learn to use them.

Publication of results in growers and outreach journals:
The Foghorn July 1999 "Update on Strawberry Varieties Old and New, and What Works for Organic Production" Written by Foghorn staff to report on June 8, 1999 Lunch time meeting.

Farmer to Farmer (formerly the Foghorn) May 2000. Write up on April 4 field day.

The Cultivator Winter/Spring 2000. "Variety Trials Play key Role in Organic Farming" Discusses importance of DPR funded variety trials. Written by Dr. Carole Shennan Director of The Center for Agroecology and Sustainable Food Systems.

Scientific publications and presentations from this work

Bull, C. T., 1999. Factors Influencing integrated methods for control of soilborne diseases of strawberry. Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, San Diego, CA. (abs).

F. N. Martin, and **C. T. Bull**. 2000. Biological approaches for control of some root pathogens of strawberry. Phytopathology 90:S102. Paper will be published from this symposium in Phytopathology in 2001.

C. T. Bull 1999. BIOS, BIFS, BASIS-OASIS: acronyms for success in agricultural research partnerships. Proceedings of the 2nd National Small Farms Conference, November 1999

C. T. Bull. 2000. Participatory Research for the Dynamic California Strawberry Industry. Proceedings of the Western Region SARE conference. Portland, OR, March 2000.

C. T. Bull, Joel Stryker, Steven T. Koike, and Carol Shennan. 2000. Use of mycorrhizal inoculants in organic production of strawberries. IFOAM 2000. Basel Switzerland. August 2000.

C. T. Bull, 2000. Research Models for Maximizing the Impact of Organic Research Conducted with Limited Resources. IFOAM 2000. Basel Switzerland. August 2000.

C. T. Bull, 2000. Organic Research in the USDA/ARS. Poster presented at the USDA/ARS National Program Meeting (600 farmers and scientists) San Diego, CA, October28-November 2, 2000.