# Crop Rotations Can Increase Net Returns in Organic Strawberry and Vegetable Production Systems

Aleksandr Michuda, Rachael Goodhue, Joji Muramoto, and Carol Shennan

**Crop rotations aimed at suppressing verticillium wilt disease in organic strawberries pose a dynamic tradeoff to growers. Using broccoli (a non-host crop) and other crops in the rotation, reduces current revenues but increases future strawberry yield and revenues. Trial results suggest that crop rotations can be sufficiently effective at reducing the strawberry yield penalty due to verticillium wilt for commercially viable organic production systems.**

Providing adequate plant nutrients and building effective system-based pest management strategies are critical challenges in organic strawberry and vegetable cropping systems on California's Central Coast. Growers must achieve economic sustainability while meeting these challenges. Long-term economic sustainability of organic production systems requires the development of integrated fertility and pest management strategies that also seek to reduce negative impacts of agriculture on nearby natural ecosystems and environmental quality.

Organic strawberries obtain a premium in fresh markets. Figure 1 plots organic and conventional strawberry prices at the Salinas-Watsonville shipping point over the last 10 years reported by the U.S. Agricultural Marketing Service. On average, organic strawberries sold for $0.68 more per pound, approximately a 25% premium over conventional prices. Despite this, organic strawberry growers do not realize higher net returns, due to higher costs of cultivation and lower yields, so there is a need to enhance the commercial viability of these systems in the presence of disease.

The work reported here was conducted as part of the California Collaborative Research and Extension program, which has the goal of building a research and outreach network for producers of organic strawberries and vegetables on California's Central Coast. The centerpiece of the project is a replicated rotation study conducted at the University of California, Santa Cruz, Center for Agroecology and Sustainable Food Systems farm. The trial was conducted from November 2011 to November 2015 at a site that has been under organic management for 40 years.

The main purpose of this trial was to design a rotation to suppress verticillium wilt. This piece will discuss the results and their implications regarding economic sustainability. Verticillium wilt (in this case, caused principally by *Verticillium dahliae*) is a soil disease that can cause major damage to strawberry yields, and strawberries are very susceptible to it. The pre-plant soil fumigation used for the suppression of verticillium wilt in conventional cropping systems cannot be used in organic ones. Suppressive crop rotations are a potential alternative permitted under the rules governing organic production.

The rotations included in the trial were of different lengths, and included different combinations of crops with varying revenue potential and susceptibility to wilt. Two-year rotations were repeated twice during the four-year trial. Strawberries were planted in the final year of each rotation: years 2 and 4 for the two-year rotations and year 4 for the four-year rotations. The trial used a "split-split-plot" experimental design.

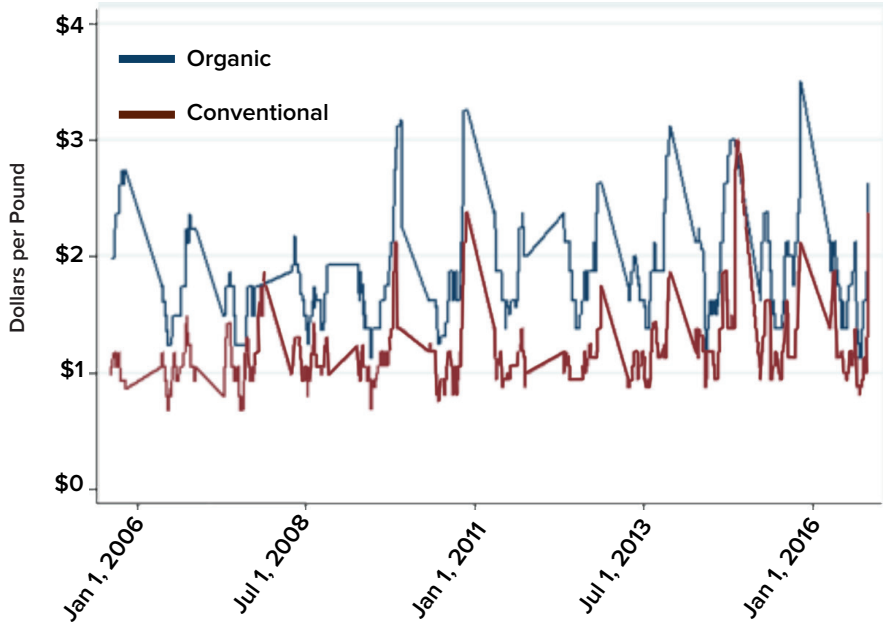


**Figure 1.** Daily Organic and Conventional Fresh Strawberry Prices at the Salinas-Watsonville Shipping Point: January 2006–December 2016

Source: Agricultural Marketing Service. https://marketnews.usda.gov/

**Table 1.** Crop Rotations Included in Trial

| | ----------Year 1---------- | | ----------Year 2---------- | | | ----------Year 3---------- | | ----Year 4---- |
|---|---|---|---|---|---|---|---|---|
| | Fall/Winter | Crop | Fall/Winter | Crop 1 | Crop 2 | Fall/Winter | Crop | Crop |
| **Four-year rotations** | | | | | | | | |
| 1a | CC* | Broccoli | CC | Lettuce | Cauliflower | CC | Broccoli | ASD/Strawberry |
| 2a | CC +C +F** | Broccoli | CC+C+F | Lettuce | Cauliflower | CC+C+F | Broccoli | ASD/Strawberry |
| 3a | Cereal CC+MSM*** | Broccoli | Cereal CC+MSM | Lettuce | Cauliflower | Cereal CC+ MSM | Broccoli | Strawberry |
| 4a | Fallow | Broccoli | Fallow | Lettuce | Cauliflower | Fallow | Broccoli | Strawberry |
| 5a | CC | Lettuce | CC | Lettuce | Broccoli | CC | Lettuce | ASD/Strawberry |
| 6a | CC +C +F | Lettuce | CC | Lettuce | Broccoli | CC | Lettuce | ASD/Strawberry |
| 7a | Cereal CC + MSM | Lettuce | Cereal CC + MSM | Lettuce | Broccoli | Cereal CC+ MSM | Lettuce | Strawberry |
| 8a | Fallow | Lettuce | Fallow | Lettuce | Broccoli | Fallow | Lettuce | Strawberry |
| **Two-year rotations** | | | | | | | | |
| 1b | CC | Broccoli | ASD****----------Strawberry---------- | | | CC | Broccoli | ASD/Strawberry |
| 2b | CC+C+F | Broccoli | ASD----------Strawberry---------- | | | CC+C+F | Broccoli | ASD/Strawberry |
| 3b | Cereal CC+MSM | Broccoli | ----------Strawberry---------- | | | Cereal CC+ MSM | Broccoli | Strawberry |
| 4b | Fallow | Broccoli | ----------Strawberry---------- | | | Fallow | Broccoli | ASD/Strawberry |
| 5b | CC | Lettuce | ASD----------Strawberry---------- | | | CC | Lettuce | ASD/Strawberry |
| 6b | CC+C+F | Lettuce | ASD----------Strawberry---------- | | | CC+C+F | Lettuce | Strawberry |
| 7b | Cereal CC + MSM | Lettuce | ----------Strawberry---------- | | | Cereal CC+ MSM | Lettuce | Strawberry |
| 8b | Fallow | Lettuce | ----------Strawberry---------- | | | Fallow | Lettuce | Strawberry |

*: Cereal/legume cover crop

**: Cereal/legume cover crop plus compost and supplemental organic fertilizer based on soil tests prior to vegetable crops

***: Mustard Seed Meal

****: Anaerobic soil disinfestation prior to planting strawberry

The site was divided into four blocks of sixteen plots each. Within a block, these sixteen plots were divided into two-year and four-year rotations. Within rotations of each length, half of the plots grew a revenue-generating cash crop, such as lettuce or cauliflower, which was more susceptible to wilt. The remaining plots grew a non-host crop, broccoli, which suppresses verticillium wilt, thus increasing future strawberry yields.

Each of the four—within a cash crop treatment—was then assigned a different fertility cover crop treatment: mustard-seed meal, a low-nitrogen cover crop mix, a high-nitrogen cover crop mix, or fallowing. The soil fertility treatments were used in the first and third years. In total, there were 16 treatments, each with four replicates. Due to the small number of replicates, pairwise statistical comparisons were not feasible. Table 1 summarizes the rotations studied.

## Two- vs. Four-Year Rotations: Second Year Strawberry Net Returns

Rotations can reduce pest and disease pressure, but also reduce net revenues. In this cropping system, strawberries are a very high-value crop on a per-acre basis, so rotating with other crops reduces net revenues significantly—all else equal. Using the yields per acre for organic strawberries and organic broccoli in the UC Cooperative Extension Cost and Return Studies, revenues per acre were around $61,000 for strawberries in the fourth year and around $10,000 for broccoli, a difference of roughly 83%. However, a reduction in the pathogens causing verticillium wilt can increase future strawberry yields and offset this reduction in net revenues.

Trial results found that the greater reduction of pest and disease pressure in the four-year rotations outweighed the reduced revenue from only one year of strawberry production. Comparing strawberry yields for two- and four-year rotations with the same cash crop choices, year 2 yields were much lower than year 4 yields. However, this comes with the caveat that a new bed shaper was used in the fourth year to create more favorable conditions for strawberry plants, after second-year

yields were reduced due to poor drainage and lower than normal bed heights. In year 2, strawberry net revenues were negative for all two-year rotations due to low yields. These lower returns were due to a higher incidence of verticillium wilt in the soil.

Net revenues for all treatments are summarized in Figure 2. From this figure, we can see the relationship between cash crop choice and year 4 strawberry revenues. The years in which a given rotation grew lettuce or cauliflower saw large current revenues compared to broccoli, which realized small or even negative returns. But, rotations with broccoli saw substantively larger strawberry revenues at the end of the rotation then those that did not. This highlights the tradeoff between using crops that generate more revenues per acre, lettuce or cauliflower, and non-host crops like broccoli. This tradeoff exists for both two-year and four-year rotations, independent of the difficulties with year 2 strawberry production noted earlier.

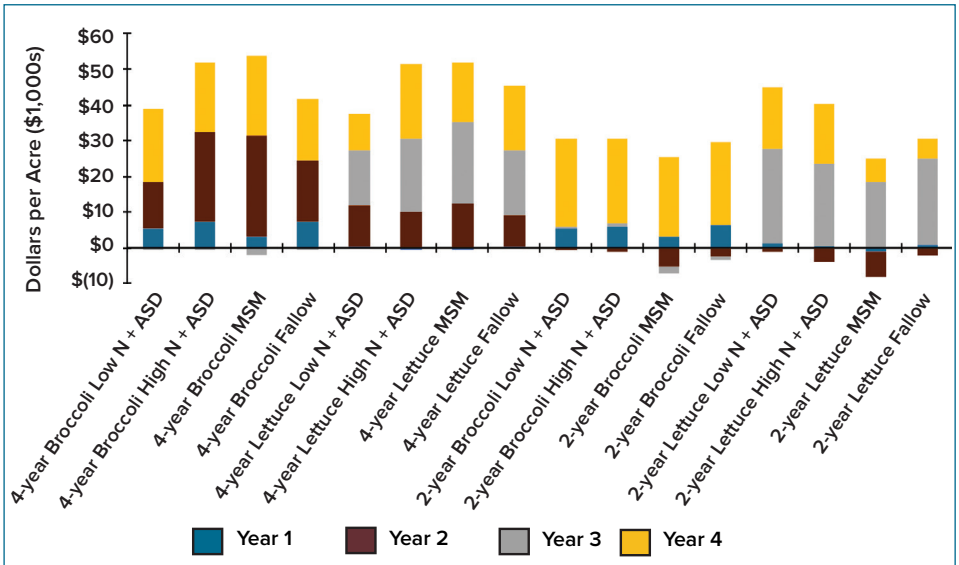


**Figure 2.** Present Discounted Value of Average Annual Net Revenues

Source: Authors' calculations

## Rotation Costs

Differences in costs affected net returns. Each crop had different costs associated with buying seed, installing irrigation, shaping and cultivating beds, and harvest. Harvest costs accounted for the majority of the costs for all crops. Strawberry harvest was by far the most expensive, often by three to seven times the harvest costs for broccoli or lettuce, due to the extensive use of hand labor.

## Crop Prices

Variation in crop prices was also important in determining net returns, especially for lettuce and broccoli. One reason why Figure 2 shows a large discrepancy between net returns from rotations including broccoli and lettuce is due to the differences in their prices. In commercial production, growers must make these decisions before planting—taking into account anticipated market conditions as well as technical factors. Such choices are not addressed in the trial. Instead, fixed rotations were tested. This affected the relative economic performance of the treatments.

Lettuce and broccoli net returns are very sensitive to price differences. To illustrate this, notice that in the third year, broccoli was unprofitable. In July 2014, lettuce had a relatively high harvest price, causing positive returns for the third year of the trial in all four-year treatments planting lettuce in year 3.

We assessed the extent to which unusually high and low prices during the trial drove the relative performance of the various rotations by using average historical prices for each crop. Running an analysis of variance (ANOVA) with average harvest month prices for the four-year trial period, we saw no statistically significant difference between them and the net returns in the primary analysis— suggesting that they are relatively robust to changes in prices. Figure 3 plots net returns by rotation, with primary results and net returns using average prices side by side.

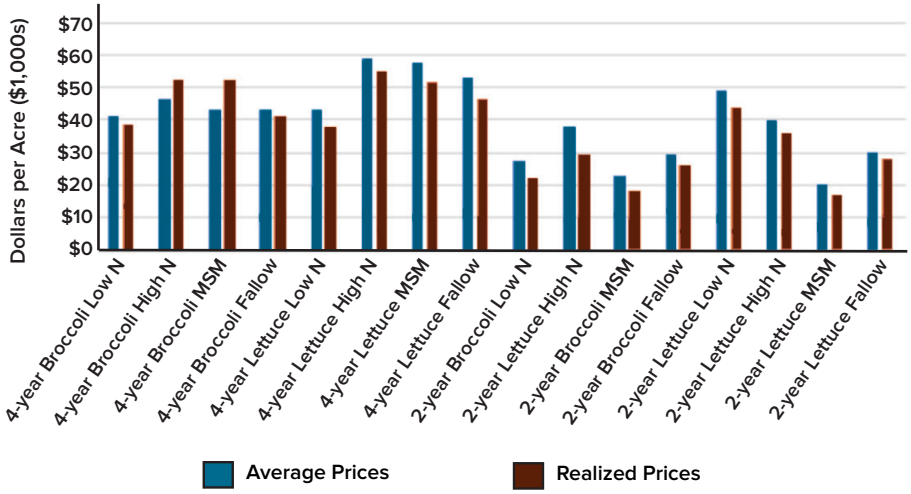


**Figure 3.** Present Discounted Value of Average Annual Net Revenues

Source: Authors' calculations

## Conclusion

Devising economically sustainable methods for growing organic strawberries is necessary for the industry's continued growth. The trial examined here considered organic crop rotations designed to be environmentally sustainable while suppressing verticillium wilt. The trial results illustrate the tradeoffs involved in such crop rotations, including the choice of higher net revenue per acre vs. the suppressive benefits of a non-host crop, the increased harvest costs associated with higher yields for strawberries, the highest-value crop, and price variability.

*Trial results found that the greater reduction of pest and disease pressure in the four-year rotations outweighed the reduced revenue from only one year of strawberry production.*

Returns for strawberries in two-year rotations were relatively low due to net outcome of the tradeoff outlined above. Shorter intervals with non-host crops led to higher incidence of verticillium wilt and lower strawberry yields. When comparing rotations of a given length within the trial, it was difficult to reach firm conclusions regarding the relative profitability of different crop combinations. While broccoli tended to increase future strawberry yields, current revenues from lettuce were higher.

Although more time is needed to evaluate how these crop rotations affect the incidence of disease over multiple repetitions, the Mother Trial demonstrated that crop rotations in organic production systems can be commercially viable. If these crop rotations are bundled with the prospect of some sort of insurance that can help them smooth their returns over time, the commercial viability of the rotations could be enhanced.


### AUTHORS' BIOS

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### For additional information, the authors recommend:


Shennan, C., Muramoto, J., Baird, G., Zavatta, M., Toyama, L., Nieto, D., & Klonsky, K. (2015, June). CAL-collaborative organic research and extension network: on-farm research to improve strawberry/vegetable rotation systems in coastal California. In *International Symposium on Innovation in Integrated and Organic Horticulture* (INNOHORT) 1137 (pp. 283-290). https://portal.nifa.usda.gov/web/crisprojectpages/0226309-a-collaborative-research-and-extension-network-for-sustainable-organic-production-systems-in-coastal-california.html

Bolda, M., Tourte, L., Klonsky, K., De Moura, R.L., Tumber, K.P., 2014. "Sample costs to produce organic strawberries: Central Coast, Santa Cruz, Monterey, and San Benito Counties." University of California Cooperative Extension. https://coststudyfiles.ucdavis.edu/uploads/cs_public/94/4b/944b5aad-6660-4dcd-a449-d26361afcae2/strawberry-cc-organic-2014.pdf