Cross-Disciplinary Analysis of the On-Farm Transition from Conventional to Organic Vegetable Production

Jackson, L.[1] , Smukler, S.[2], Murphree, L.[3], Yokota, R.[4], Koike, S.T.[5], & Smith, R.F.[6]

Key words: Soil, cropping systems, organic transition, regression trees, canonical correspondence analysis

Abstract

This farm-scale analysis of the three-year transition to organic from conventional vegetable production tracked the changes in crop, soil, pest and management on two ranches (40 and 47 ha) in the Salinas Valley, California. Many small plantings of a diverse set of cash crop and cover crop species were used, as compared to only a few species in large monocultures in conventional production. The general trends with time were: increase in soil biological indicators, low soil nitrate pools, adequate crop nutrients, minor disease and weed problems, and sporadic mild insect damage. Some crops and cultivars consistently produced higher yields than others, relative to the maximum yield for a given crop. Differences in insect and disease damage were also observed. These results support the value of initially using a biodiverse set of taxa to reduce risk, then later choosing the best-suited varieties for optimal production. The grower used some principles of organic farming (e.g., crop diversity, crop rotation, and organic matter management), but also relied on substitution-based management, such as fertigation with soluble nutrients, initially heavy applications of organic pesticides, and use of inputs derived from off-farm sources. The organic transition was conducive to both production goals and environmental quality.

Introduction

In California, large scale vegetable producers are starting to adopt organic practices to meet the growing market demand (Giles, 2004; Klonsky, 2004), and are now distributing produce to national and international marketplaces. Research on the transition to organic production by conventional, large scale growers requires methodology that represents decision making options at the whole-farm scale. Agricultural transition periods require adaptive management to meet production goals in an environmentally-sound fashion. Frequent and repeated sampling is needed to capture changes in management, yields, and other biophysical responses, and as a result, organic transition periods have rarely been studied under the conditions of

[1] Dept. of Land, Air and Water Resources, University of California, Davis, One Shields Ave., Davis, CA 95616, USA, E-Mail lejackson@ucdavis.edu, Internet http://groups.ucanr.org/jacksonlab/

[2] Dept. of Land, Air and Water Resources, University of California, Davis, One Shields Ave., Davis, CA 95616, USA, E-Mail smsmukler@ucdavis.edu

[3] Santa Catalina School, 1500 Mark Thomas Dr., Monterey, CA 93940, USA

[4] Tanimura and Antle, Inc., P.O. Box 4070, Salinas, CA 93912, USA

[5] University of California Cooperative Extension, 1432 Abbott St., Salinas, CA 93901 USA, E-Mail stkoike@ucdavis.edu

[6] University of California Cooperative Extension, 1432 Abbott St., Salinas, CA 93901 USA, E-Mail rifsmith@ucdavis.edu

dynamic decision-making on the scale of actual farms. Using indicator variables in large-scale studies, e.g., yield, nutrient content, pest damage indices, and soil properties, along with multivariate statistics, can show the linkages between management factors, environmental conditions, and crop performance. The outcomes of multi-year, multidisciplinary studies can generate hypotheses regarding factors that optimize the success of the transition to organic production.

An instructive organic transition occurred in the Salinas Valley, California, where one of the USA's largest cool-season vegetable production companies converted two ranches according to the California Certified Organic Farmer guidelines (Smukler et al., ms. submitted). Our cooperative research partnership jointly designed a project to monitor the temporal and spatial progress of the organic transition across the ranches. Each ranch was surrounded by conventional vegetable production that typically uses more than 150 kg of synthetic nitrogen (N) fertilizer per crop, frequent application of pesticides, and intensive hand labor for weeding, thinning, and harvesting.

On the two ranches, a network of 81 points was sampled at nearly every crop and cover crop harvest for a set of indicators for crop productivity, pest pressure, and soil status for 2.75 years. The design provided a large data set and a variety of different conditions that were conducive to analysis by multivariate methods, i.e., Classification and Regression Trees (CART) and Canonical Correspondence Analysis (CCA) to describe ecological relationships but also suggest pathways for management improvement (McCune and Grace, 2002).

Materials and methods

The project began in June, 2000, at the onset of the three-year period required for organic transition by the California Organic Food Act and National Organics Program on two ranches owned by Tanimura and Antle, Inc. Sampling ended in March, 2003, at a common end point prior to planting the crops for the spring season. The ranches had been divided into management blocks many years before. Three transects were established across 9 of these blocks (6 at Storm Ranch and three at Daugherty Ranch), for 27 permanent transects. The soil type is mainly Salinas clay loam.

The grower recorded all management operations, e.g., Intensive tillage, direct seeding of vegetables, and drip irrigation. Cover crops were usually planted once every year. Compost (C:N=18) was applied at least once per year. Pelleted chicken manure fertilizer (2.5-2-2.5) was applied prior to plantings (1100 kg ha^{-1} supplying 28 kg N ha^{-1}). Then a soluble fertilizer (6.0–0.4– 0.2) was applied multiple times through the drip tape during each crop growth cycle. Total application rates ranged from 25 kg N ha^{-1} for baby greens to 244 kg N ha^{-1} for celery. Several organically certified pesticides were used during the transition. Weather data were from a nearby station.

Along each transect, three sampling plots were evenly placed at least 35 m apart, for 81 plots in total on the 27 transects (54 at Storm Ranch and 27 at Daugherty Ranch). Soil samples were taken in June, 2000, and again in March, 2003, before organic certification. This composes the soil properties data set. In addition, throughout the transition, crops and soils were sampled within one week of harvest of each transect. This composes the crop and soil monitoring data set. At each sampling, soil cores, aboveground biomass and harvestable yield, and weeds were sampled, and presence/absence of damage by insects or disease was noted. For analytical procedures, see Cavagnaro et al. (2005) and Smukler et al. (ms submitted).

Analysis of variance (ANOVA) tested for year to year changes in relative yield, and soil biological activity, as well as by growing season during the transition period. Log linear models tested for differences in the categorical data for presence/absence of shoot damage by insects or disease, or for root disease. Recursive regression trees (CART) explored the relationship between management and relative yield, and damage to crops from insects, and disease for all crop taxa excluding cover crops. CCA examined how soil properties changed in the different transects.

Results

Crop performance increased over the three-year period based on relative yields, (observed yield of each crop divided by the observed maximum yield ever measured for that crop during the three year period, expressed as a percentage). During the most intensively cropped season, which was the summer, there was a significant increase in relative yields from 45% in the first year to 62% in year three. CART regression trees showed that: 1) Most of the variation in relative yield was explained by crop selection. The red leaf and green leaf lettuces had higher relative yields than romaine. 2) Different cultivars also showed different levels of performance, e.g., for baby greens, cilantro, frisee, and parsley. 3) Some management blocks were prone to lower relative yields, suggesting specialized needs for improving inputs.

Insect damage, measured by presence/absence, increased from an average of 3% during the summer of the first year, to 66% in the second summer, but then decreased in the summer of the third year to 28%, reflecting general trends in outbreaks in the region. Similarly, fall and spring damage increased from year one to year two, decreasing in year three. The crops that were most damaged were broccoli, endive, frisee, green leaf, radicchio, and romaine, while the least damaged crops were cilantro, escarole, baby greens and parsley. The lettuce aphid was the most important pest, especially in year two on romaine, and high applications of Bt and other organic pesticides were relatively ineffective. CART regression trees showed that: 1) Higher dew point (>13°C) and thus higher relative humidity, was a factor that contributed to insect damage. 2) Under these moister conditions, the most enclosed blocks were more likely to experience severe insect damage, compared to edge blocks near conventional production or paved roads. 3) High solar radiation and higher drip irrigation were also associated with higher pest damage especially for certain taxa.

There was an increase in leaf disease symptoms from the summer of year one, where 3% of the samples were infected, to the summer of year two, where 27% of the samples, followed in the summer of year three by a decrease to 7%. Red leaf and romaine lettuces had more incidences of leaf diseases than any of the other crops. The most important foliar disease was downy mildew of lettuce, forcing in year two, three romaine plantings to be disced before harvesting.

An indicator of weed pressure was the percentage of sampled plots containing weeds. For the Storm Ranch, in 2000, 2001, and 2002, respectively, 27, 39 and 16% of the plots contained weeds. For Daugherty Ranch, this was 4, 11, and 18%, respectively.

Over the three year transition period there was a trend towards greater soil biological activity. Soil microbial biomass carbon (C) at 0-15 cm depth increased ~25% during the most biologically active times of the year, which is the mild wet fall and spring, over the three-year period. Arbuscular mycorrhizal colonization was only 2.8% of the root length, but more than doubled to 6.8% by year three. By the second year, soil nitrate pools were very low, yet when N contents of each crop were compared with reported stringent critical deficiency values most were well above the critical value.

While mean values of soil C or N for the ranches did not change between the onset and the end of the transition period, there were significant changes in other soil parameters particularly between individual management blocks. Mean Olsen P, soluble K, and EC decreased, while pH increased. CCA analysis showed that changes in pH and EC were driven largely by higher silt, and amounts of Biolizer fertilizer and drip irrigation. Higher soil K was associated with higher amounts of chicken manure pellets. Thus, management blocks responded differently to the organic transition due to both soil characteristics and inputs.

Discussion

The transition from conventional to organic production was successful at a large scale even in a region dominated by conventional agriculture. Tanimura and Antle Inc. showed a distinct learning curve in relation to both nutrients, i.e., increased soluble fertilizer additions, and pest management, i.e., decreased use of organic pesticides. Overall, their management resulted in improved soil biological indicators, generally adequate plant available N with reduced soil nitrate, and a gradual increase in relative yields with time. The continued organic production at this site, and the expansion to other sites, suggests that it is economically viable.

Many organic growers manipulate plant species richness and evenness within the constraints of managing supply for market demand, as one of the main sets of allowable tools for farm management (Zehnder et al., 2007). This study shows that this may have benefits for mitigating risks associated with low yields and insect damage, and is best addressed through adaptive management.

Conclusions

These results demonstrate that some of the strategies that were developed by small-scale organic producers can be applied to larger-scale production to achieve a more sustainable agricultural intensification, which has far reaching implications as the demand for organic production increases.

References

Cavagnaro, T.R., F.A. Smith, S.E. Smith, and I. Jakobsen. 2005. Functional diversity in arbuscular mycorrhizas: exploitation of soil patches with different phosphate enrichment differs among fungal species. Plant Cell and Environment 28:642-650.

Giles, J. 2004. Organic FAQs. Nature (London) 428:796-798.

Klonsky, K. 2004. Organic Agricultural Production in California, *In* J. Siebert, ed. California Agriculture: Dimensions and Issues. Giannini Foundation, Berkeley.

McCune, B., and J. Grace. 2002. Analysis of ecological communities MjM Software Design, Gleneden Beach, Oregon

Smukler, S., L. Jackson, L. Murphee, R. Yokota, S. Koike, and R. Smith. ms submitted. Transition to large-scale organic vegetable production in the Salinas Valley. Agriculture Ecosystems & Environment.

Zehnder, G., G.M. Gurr, S. Kuhne, M.R. Wade, S.D. Wratten, and E. Wyss. 2007. Arthropod pest management in organic crops. Annual Review of Entomology 52:57-80.