

MAINTAINING AGROECOSYSTEM HEALTH IN THE CONVERSION TO ORGANIC

J. MURAMOTO¹, S. R. GLIESSMAN¹, B. FULFROST¹, S. T. KOIKE¹
 UNIV. OF CALIFORNIA-SANTA CRUZ¹, UNIV. OF CALIFORNIA-COOPERATIVE EXTENSION

ABSTRACT

Demand for organic produce has increased dramatically in the last five years. To limit soil-borne plant diseases without chemical fumigation, organic strawberries must be rotated off the land for several years. This inhibits the ability of most growers who specialize in this crop to increase their production. A team of organic growers, multidisciplinary researchers, and the landowner has worked together to design an organic strawberry/vegetable rotation system on the central coast of California. In 2001, we initiated a five-year rotation trial with five treatments (s-s-s-s, s-v-s-v-s, v-s-v-v-s, s-v-v-v-s, v-v-v-v-s. s: strawberries + broccoli biofumigation; v: vegetables (spinach + broccoli) + cover crops. year 1-2-3-4-5) to demonstrate shorter strawberry rotations that integrate multiple ecological practices. Soil health indicators (*Verticillium dahliae* propagule number, mycorrhizal colonization, microbial community and biomass, and physicochemical indicators) and agroecosystem health indicators (yield, disease incidence, nutrient budget, energy flows and production costs) will be monitored in the trial over five years. Initial results from the first year will be presented.



GOALS

- To demonstrate shorter strawberry rotation systems that integrate multiple ecological practices.
- To demonstrate indicators for soil health and agroecosystem health in an organic strawberry/vegetable rotation system.

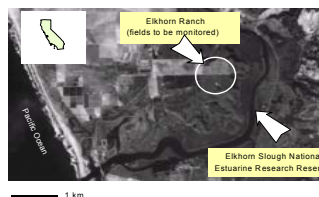
INTRODUCTION

The conversion to ecologically-based agroecosystem management results in an array of ecological changes in the system. Measuring and monitoring these changes helps the farmer evaluate the success of the conversion process, and provides a framework for determining the requirements for and indicators of sustainability. This approach is especially important for crops that are of high economic value and high environmental impact, such as strawberries on the central coast of California.

Organic strawberry growers use such practices as compost application, integrated pest management, black plastic mulch, hand weeding, the rotation of strawberries off the land after 3 or 4 years of production, and long-term fallow (Gliessman et al., 1996). But the need to fallow or rotate their land out of strawberries greatly inhibits many growers' ability to increase production. There is an urgent need to find effective ways to shorten the rotation or fallow periods and ensure that the soil ecosystem is kept in a healthy state, as well as develop indicators of that health.

In 1999, an organic strawberry grower and the land owner requested our assistance to establish an organic strawberry/vegetable rotation system at the Elkhorn ranch. A team of multidisciplinary researchers conducted soil characterization and began monitoring soil health indicators in Oct. 1999.

ELKHORN RANCH (MOSS LANDING, CA)



APPROACH

1. On-Farm Rotation Experiment

Upon completion of the three-year transitional period in 2001, an organic rotation experiment that integrated multiple ecological practices such as biofumigation with broccoli residues (Subbarao et al., 1999), mixed cover crops including mustards, compost application, strawberry variety selections, and choosing vegetables that do not host *Verticillium dahliae* was initiated.

ROTATION TREATMENTS

Treatment	2000	2001	2002	2003	2004	2005	2006
A (0 yr.*+ br.res.)	-cv- -cv- -vg-	st	st	st	st	st	st
B (1 yr.*)	-cv- -cv- -vg-	st	cv-sp-br-st	cv-sp-br-st	cv-sp-br-st	cv-sp-br-st	cv-sp-br-st
C (2 yrs.*)	-cv- -cv- -vg-	cv-sp-br-st	cv-sp-br-st	cv-sp-br-st	cv-sp-br-st	cv-sp-br-st	cv-sp-br-st
D (3 yrs.*)	-cv- -cv- -vg-	st	cv-sp-br-cv-sp-br-cv-sp-br-st	cv-sp-br-cv-sp-br-cv-sp-br-st	cv-sp-br-cv-sp-br-cv-sp-br-st	cv-sp-br-cv-sp-br-cv-sp-br-st	cv-sp-br-cv-sp-br-cv-sp-br-st
E (Control)	-cv- -cv- -vg-	cv-sp-br-cv-sp-br-cv-sp-br-cv-sp-br-st	cv-sp-br-cv-sp-br-cv-sp-br-cv-sp-br-st	cv-sp-br-cv-sp-br-cv-sp-br-cv-sp-br-st	cv-sp-br-cv-sp-br-cv-sp-br-cv-sp-br-st	cv-sp-br-cv-sp-br-cv-sp-br-cv-sp-br-st	cv-sp-br-cv-sp-br-cv-sp-br-cv-sp-br-st

* Period between strawberry plantings.
 br.res.: applying broccoli residues before planting strawberries. cv: cover crops.
 st: strawberries (2 different cultivars). sp: spinach. vg: vegetables other than broccoli and spinach (i.e. lettuce).

When strawberries are planted, one plot is divided into two-sub plots, where different cultivars (2001-2002 season: Aromas and Diamante) are planted. Split-plot design with 4 replicates. Plot size: 91.3 m² x 20 plots. Total area of ~1acre was donated by the land owner for the experiment.

2. Monitoring Soil Health and Agroecosystem Health Indicators

Throughout the experiment, we will monitor soil health indicators (*Verticillium dahliae* propagule number, Phytophthora population, mycorrhizal colonization, microbial community and biomass, available nutrient levels and other physicochemical indicators) and agroecosystem health indicators (yield, disease incidence, nutrient and energy flow analysis, and production costs).

In this poster, we report the initial results from the first year, including crop yields, *Verticillium dahliae* and Phytophthora tests, soil nitrate monitoring, and nitrogen flow analysis. Data from treatment A (for strawberries) and treatment E (cover crops and vegetables) are presented as representative plots.

1. Major Field Practices

Strawberries			Cover Crops and Vegetables		
DATE	D.A.P.*	PRACTICE	DATE	D.A.P.*	PRACTICE
10/2/01	-48	Compost application	10/2/01	-48	Compost application
10/13/01	-37	Broccoli residues application	10/13/01	-37	Broccoli residues application
10/22/01	-28	Listing beds and applying organic fertilizers	10/22/01	-28	Listing beds and applying organic fertilizers
11/19/01	0	Strawberry planting	11/19/01	0	Cover crops (Mustards, Vetches, Bell Beans, and Oats) planting
1/8/02	50	Plastic mulch application			
5/2/02	164	Strawberry fruit harvest began	3/1/02	102	Cover crop incorporation
10/1/02	316	Strawberry fruit harvest ended	6/19/02	212	Spinach planting
10/5/02	320	Strawberry incorporation	7/25/02	248	Spinach harvest
			8/2/02	256	Broccoli transplanting
			10/5/02	320	Broccoli incorporation

2. Weather

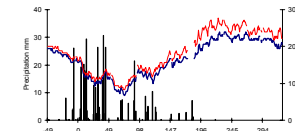


Fig. 1 Precipitation and soil temperature.



3. Crop Yield and Biomass

Crop	Yield (fresh weight tons/ha)
Strawberries (Aromas)*	39.9 (3.5)
Strawberries (Diamante)*	31.4 (3.2)
Cover crops (Mustards)**	14.9 (2.5)
Spinach	13.3 (0.9)
Broccoli**	30.0 (2.8)

Mean (SEM). * Marketable fruit yield.
 ** Though we planted mixed cover crops, mustards dominated over the others.
 *** Total fresh biomass. No floret was harvested due to a short growth period.



4. *Verticillium dahliae* and Phytophthora Tests

Soils were collected from experimental blocks and assayed for two important soilborne pathogens of strawberry: *Verticillium dahliae* and Phytophthora species. Soils used for *V. dahliae* quantitative tests were air dried for six weeks and then plated onto *V. dahliae* semi-selective medium (NP-10) using the Anderson Sampler dry sieve technique. Soils used for Phytophthora qualitative tests were tested immediately after collecting. Soils were placed in plastic containers, flooded with distilled water, then baited with firm, green, unwounded pears. After three to four days incubation at 18-20 degrees C, lesions that developed on the fruit were analyzed for Oomycete fungi by plating pieces of the lesions onto PARP semi-selective medium.

The quantitative *Verticillium* resulted in generally low counts (less than 3 micrococci/gram of soil). This indicates that a low, modest baseline population of *V. dahliae* was probably present in the experimental blocks. For the qualitative Phytophthora tests, the most commonly observed Oomycetes were various Pythium species. Only occasional Phytophthora isolates were recovered from the pear fruit baits. This again indicates that perhaps a low baseline population of Phytophthora was resident in the soils. We expect to find changes in both *Verticillium* and Phytophthora populations as a result of subsequent treatment effects over several years time.

5. Soil Nitrate M

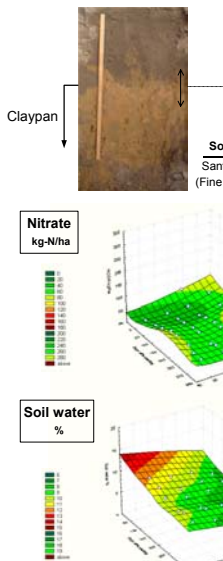


Fig. 3 Ter

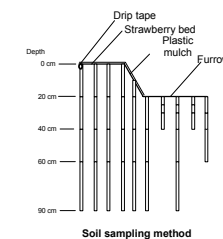


Fig. 4 Nitrate and water content and furrow profile. For both higher the contents. The images were sampled on 9/5/02 (DAP

ORGANIC MANAGEMENT OF A STRAWBERRY/VEGETABLE ROTATION SYSTEM

T. KOIKE², D. SCHMIDA³, J. R. HITCHCOCK⁴, AND R. STEPHENS⁵

UNIVERSITY OF CALIFORNIA, SAN DIEGO¹, UNIVERSITY OF CALIFORNIA, BERKELEY², SANDPIPER FARMS³, MISSION RANCHES⁴, ELKHORN RANCH⁵

RESULTS

5. Soil Nitrate Monitoring

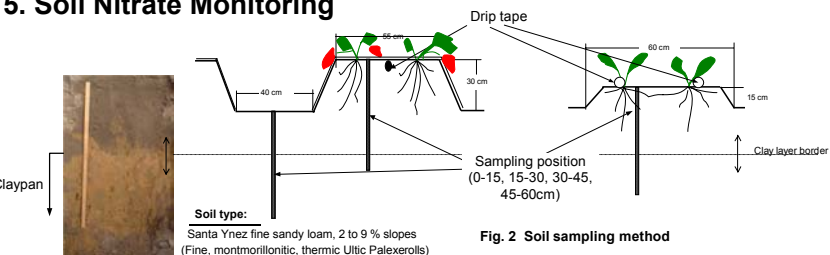


Fig. 2 Soil sampling method

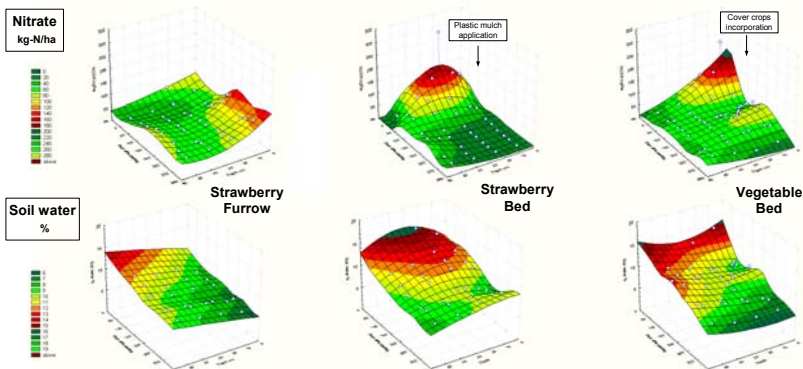


Fig. 3 Temporal changes in nitrate (top) and water (bottom) contents in 0-60 cm soil depth.

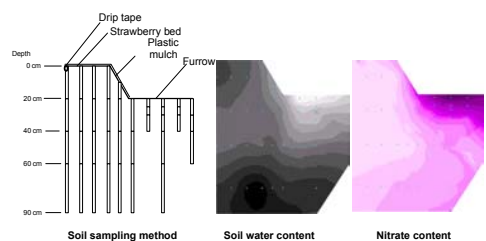


Fig. 4 Nitrate and water content distributions across a strawberry bed and furrow profile. For both soil water and nitrate, the darker the color, the higher the contents. The images were made using Kriging method. Soils were sampled on 9/5/02 (DAP 290).

Throughout the growth period, soils were sampled ~once a month from 4 depths (0-15, 15-30, 30-45, 45-60 cm) of strawberry bed, strawberry furrow, and vegetable bed (Fig. 2). Soil nitrate was extracted by 2M KCl and determined by FIA method.

About 300 kg/ha of NO₃-N was lost from both strawberry and cover crop beds during Nov. 2001 and Feb. 2002 (DAP 0-80. Fig 3) with more than 300 mm of rain (Fig. 1). The leaching below the strawberry beds was slow due to the thick claypan ~50cm deep (Fig. 2 picture) and does not account for all loss. Denitrification and run off are suspected as means of NO₃-N loss during this period. After March (DAP 100), NO₃-N concentration of furrow soils had gradually increased at all depths, especially at the top (0-15 cm. Fig. 3 top). A temporal change (Fig. 3 bottom) and a distribution pattern (Fig. 4) of soil water contents suggests the nitrate was transferred from the beds to the furrows as soil water evaporates from the furrow surface.

6. Nitrogen Flow Analysis

Nitrogen flows and cycling in strawberry plot and vegetable plot were analyzed using the standardized two-pool soil-plant model (Muramoto et al., 2001. Fig. 5). Data (plants, weeds, seeds, irrigation water, fertilizers, and N losses from soils) were mostly obtained by direct measurements except precipitation (NADP/NTN seasonal data in California). Finn's Cycling Index (C.I. varies from 0 [no cycling] to 1 [all material is cycled], Finn, 1976) and Total System Throughflow (TST: an indicator of system activity) were also calculated. To conduct a statistically reliable analysis, we used an observation uncertainty analysis system (Ellis et al., 2000) and results were presented as means and 90% credible intervals from 10,000 Monte Carlo simulation iterations (CIN: Morgan and Henrion, 1990). Both plots received the same amount of soil inputs (360 kg-N/ha) and had similar losses (~270 kg-N/ha. Fig. 6). Late planting of cover crop made it less effective at reducing N loss in vegetable plot during rainy season. Vegetable plot had a higher C.I. than strawberry plot because the greater amount of crop residues including cover crops were returned to the vegetable plot.

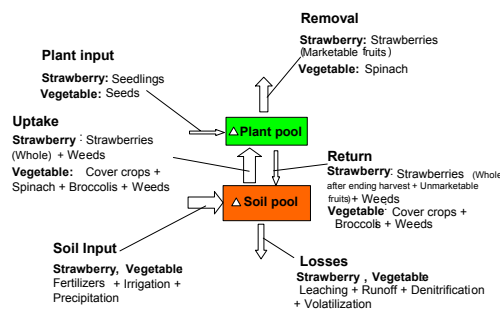


Fig. 5 Standardized two-pool soil plant model and components of nitrogen flows.

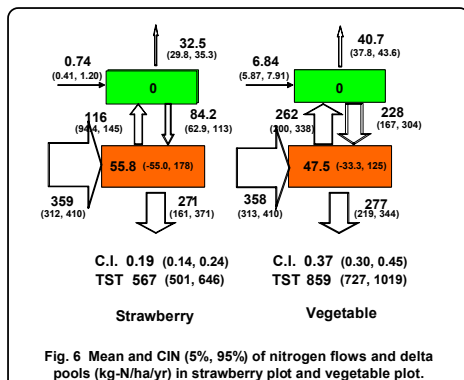


Fig. 6 Mean and CIN (5%, 95%) of nitrogen flows and delta pools (kg-N/ha/yr) in strawberry plot and vegetable plot.

SUMMARY

In the first year of the rotation experiment, the organic strawberries and vegetables had fair yields (except broccoli), and did not show any major disease problems. Based on the results of the soil nitrate monitoring, the grower decided to reduce the rate of basal N fertilizers for the next season. We will continue monitoring soil nitrate dynamics to develop more efficient nutrient management system for organic strawberries and vegetables.

Analysis of other indicators including mycorrhizal colonization of strawberry roots, flow analysis of potassium and phosphorus, soil microbial community analysis, energy analysis, and production cost analysis are underway or being planned for the near future.

SELECTED REFERENCES

- Ellis, E. C., Rong Gang Li, et al. (2000). "Long-Term Changes in Village-Scale Ecosystems in China Using Landscape and Statistical Methods." *Ecological Applications*, 10(4), 1057-1073.
- Finn, J. T. (1976). "Measures of Ecosystem Structure and Function derived from Analysis of Flow." *J. Theoretical Biol.*, 56, 363-380.
- Gliessman, S. R., M. R. Werner, et al. (1996). "Conversion to Organic Strawberry Management Changes Ecological Processes." *California Agriculture* 50(1): 24-31.
- Muramoto, J., Ellis, E. C. et al. (2001). Field-Scale Nutrient Cycling and Sustainability: Comparing Natural and Agricultural Ecosystems. Gliessman, S. R. eds., *Agroecosystem Sustainability: Developing Practical Strategies*, pp.121-134, CRC press, Boca Raton, FL.
- Subbarao, K. V., J. C. Hubbard, et al. (1999). "Evaluation of Broccoli Residue Incorporation into Field Soil for Verticillium Wilt Control in Cauliflower." *Plant Disease* 83(2): 124-129.

ACKNOWLEDGEMENT

This project was partially funded by the **North American Strawberry Growers Association (NASGA)** research grant 2001 and the **Alfred Heller Chair in Agroecology**.

FOR MORE INFORMATION

Joji Muramoto
Center for Agroecology
University of California
Santa Cruz, CA 95064
<joji@ucsc.edu>

on the web @:
<http://www.agroecology.org/joji.htm>