Indicators of Soil Health in an Organic Strawberry-Vegetable Rotation System

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Abstract

Organic strawberry production has been practiced by growers on the Central Coast of California since the mid-1980s. To limit soil borne diseases, strawberries must be rotated off the land for up to 3 to 5 years of alternate crops, or put in long-term fallow, which inhibits most growers' ability to remain in production. A collaborative grower/land owner/researcher team is investigating an organic strawberry-vegetable rotation system with a goal of shortening the rotation period for strawberries and developing soil health indicators in the system at Elkhorn Ranch, Moss Landing, California. Since 1999 we have been monitoring soil for nitrate, Olsen-P, and *Verticillium dahliae* propagules as key soil health indicators in three cultivated fields (transitional since 1998 - 20 acres each) and a restoration field (fallow since 1994 - 10 acres). To monitor responses of soil health indicators, disease levels, and crop yields for different crop rotations and soil amendment applications, we have established an on-farm field experiment this year. The experimental field design and initial monitoring results will be presented.

Introduction

The conversion to ecologically-based agroecosystem management results in an array of ecological changes in the system. As the use of synthetic agrochemicals is replaced, reduced or eliminated, and farming practices altered to promote more nutrient and biomass maintenance within the system, agroecosystem structure and function change as well. A range of processes and relationships are transformed, beginning with aspects of basic soil structure, organic matter content, and diversity and activity of soil biota. Eventually major changes also occur in the activity and relationships of weed, insect, and disease populations, and in the balance between beneficial and pest organisms. Ultimately, nutrient dynamics and cycling, energy use efficiency, and overall system productivity are impacted. 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 production does not have the option of the methyl bromide fumigation that allows the continual production of conventional systems. Organic 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 remain in 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.

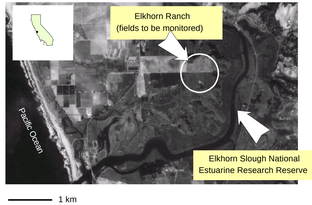
Background/Goals

In 1999, a local organic strawberry grower, Ed Ortega, and the land owner of Elkhorn Ranch, Robert Stephens, asked our help to:

- Develop soil health indicators to assess the effects of changing agricultural practices on the soils of the fields.
- Establish an organic strawberry-vegetable rotation system for sustainable organic production on the ranch.

--------- Grower/Land Owner Proposed Project

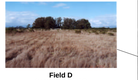
Elkhorn Ranch
(Moss Landing, CA)



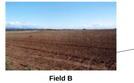
Elkhorn Slough

Fields

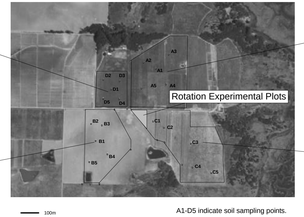
- Cultivated fields: A, B, C (~20 acres each)
  - before 1987: Conventional lettuce and Brussels sprouts
  - 1987-1995: Fallowed
  - 1995-1998: Conventional strawberries and lettuce
  - 1998-2001: Transition (Cover crops [winter] & fallowed [summer])
  - Oct.2001- : Organic production
- Restoration field: D (~10 acres)
  - before 1994: Conventional production
  - 1994- : Native grasses and perennials

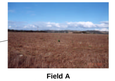


Field D
(restoration field)

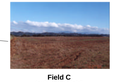


Field B
(cultivated field)





Field A
(cultivated field)



Field C
(cultivated field)

A1-D5 indicate soil sampling points.

Soil Characterization

Soil Sampling Methods:

Sampling Date: Oct. 1999, 2000, and 2001

- 5 points per field (See map of "Field" Section)
- GPS data at each point
  --- for long-term monitoring
- Top (0-15cm) and sub (15-30cm) soils per point *--- total 40 soil samples*

Soil type:

Santa Ynez fine sandy loam, 2 to 9 % slopes
(Fine, montmorillonitic, thermic Ultic Palexeralls)

- Suitable for alfalfa, artichokes, **broccoli,** cauliflower, lettuce, and **strawberries**
- Not suitable for carrots, potatoes, tomatoes, and sugar beets (USDA, 1978)

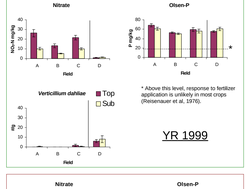
Soil Chemical Characteristics of the Elkhorn Ranch Fields
(YR 2000. Topsoils: 0-15 cm deep)

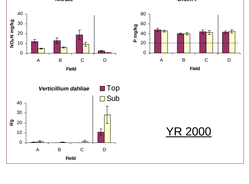
Field	Organic Matter %	T-C %	T-N %	CEC cmol(+)/kg	pH 1:1	EC 1:1 dS/m
A	1.04 ± 0.05	0.71 ± 0.03	0.09 ± 0.00	4.0 ± 0.1	6.7 ± 0.1	0.4 ± 0.0
B	0.87 ± 0.03	0.61 ± 0.06	0.09 ± 0.00	4.7 ± 0.3	6.6 ± 0.1	0.5 ± 0.1
C	1.09 ± 0.05	0.75 ± 0.03	0.09 ± 0.00	4.1 ± 0.3	6.5 ± 0.1	0.4 ± 0.1
D	1.06± 0.04	0.75 ± 0.05	0.09 ± 0.01	4.2 ± 0.1	6.3 ± 0.1	0.2 ± 0.0
Ref. value	–	–	–	–	5.0 – 6.5[1]	< 0.8[2]

Field	ex. K mg/kg	Fe mg/kg	Mn mg/kg	Zn mg/kg	Cu mg/kg	B mg/kg
A	72.0 ± 2.7	72.5 ± 9.3	30.6 ± 1.6	1.7 ± 0.1	1.3 ± 0.1	0.5 ± 0.1
B	63.7 ± 3.2	83.0 ± 8.2	33.9 ± 2.9	1.6 ± 0.1	1.2 ± 0.0	0.5 ± 0.0
C	67.8 ± 6.9	82.6 ± 10.5	36.4 ± 2.3	2.2 ± 0.2	1.3 ± 0.1	0.4 ± 0.0
D	78.4 ± 10.6	88.6 ± 3.0	29.5 ± 2.1	2.1± 0.2	1.2 ± 0.1	0.3 ± 0.0
Ref. value	> 70–80[3]	> 5.0[4]	> 1.0[4]	> 0.5[4]	> 0.2[4]	< 0.5[3]

Values show mean (n=5) ± SEM.
[1] Suitable range for strawberries (Whittaker et al. 1959).
[2] Acceptable range for general crop growth (USDA 1999).
[3] Range that response to fertilizer applications is unlikely in most crops (Reisenauer et al. 1976).
[4] Nondeficient range of California soils (Brown and De Boer 1976).
[5] Satisfactory range for all crops (Branson 1976).

Soil Health Indicators





Indicators Proposed by the Grower:

- Soil Nitrate
- Soil available phosphorus
- *Verticillium dahliae* propagule number in soil

In Summary:

- No significant chemical problems exist in the soil of the cultivated fields.
- Relatively high soil fertility
- Very low *Verticillium dahliae* propagules in cultivated field soils.
  -----probably due to residual effect of chemical fumigation in the past.

Other Indicators To Be Monitored:

- Soil microbiodiversity analysis (Phospholipid-fatty acid profiles)
- Soil nitrate (deep sampling, esp. before and after rainy seasons)
- Phythopthora and other disease and pest levels
- Mycorrhizal colonization level
- Nutrient budget (N, P, K)

Rotation Experiment

Questions:

- How can we shorten the rotation cycle of organic strawberries?
- How and how long can we keep a pathologically "clean" field "clean" with organic management practices?

Approach:

A combination of broccoli residue incorporation, mixed cover crops including mustard, compost application, strawberry variety selections, and choosing vegetables that do not host *Verticillium dahliae*.

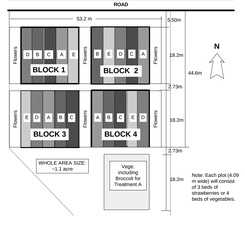
Biofumigation Using Broccoli Residues:

- Biofumigation --- Suppression of soil-borne pests and pathogens by biocidal compounds, mainly isothiocyanates (ITCs), released by brassicas when glucosinolates in their tissues are hydrolyzed (Sarwar and Kirkegaard, 1998).
- Demonstrated to be effective as an alternative for reducing Verticillium wilt severity in strawberry (Shetty, et al., 1999) and cauliflower (Subbarao et al., 1999) in California under moderate disease pressure.
- Economically feasible and environmentally sound (Koike and Subbarao, 2000).

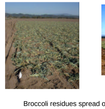
ROTATION TREATMENTS

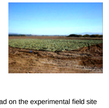
Treatment	2000	2001	2002	2003	2004	2005	2006
A (0 yr.*+ br.res.)	-cv- - - -cv - -vg-	---	**-st**	--------	**-st**	----------	**-st**	---------	**-st**	------
B (1 yr.*)	-cv- - - -cv - -vg-	---	**-st**	--------	cv--sp-br-	**-st**	----------	cv--sp-br-	**-st**	------
C (2 yrs.*)	-cv- - - -cv - -vg-	---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

* 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).
In Oct. 2001, compost (chicken manure base. 5 tons/acre) was applied to all plots.



Plot Arrangement





Broccoli residues spread on the experimental field site

Verticillium wilt of strawberry plant caused by *Verticillium dahliae*

Collaborators

- Organic Strawberry Growers: Dan Schmida and Ed Ortega (Sandpiper Farms)
- Organic Vegetable Grower: John Hitchcock (Mission Ranches)
- Land Owner: Robert Stephens (Elkhorn Ranch)
- Researchers: Stephen Gliessman (Agroecology), Joji Muramoto (Soil fertility & Nutrient management), Carolee Bull (Plant pathology & Soil microbiology), Steven Koike (Plant pathology), Jason Scorse (Economics), Carol Shennan (Agroecology) and more!!

Selected References

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Field C (Cover crops)

For more information

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