Sustainable Agriculture Farming Systems Project

University of California , Davis

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Introduction to the SAFS Project

In 1988, a group of farmers and UC researchers met at UC Davis and planned a large, interdisciplinary project with three main objectives. The primary objective of the Sustainable Agriculture Farming Systems (SAFS) research project is to compare conventional, low-input, and organic farming systems with respect to the following factors: the abundance and diversity of weed, pathogen, arthropod, and nematode populations; differences in soil biology, physical and chemical properties and water relations; crop growth, yield and quality; and economic viability. The disciplines that the project includes are: agronomy, agricultural economics, entomology, water science, nematology, plant pathology, soil microbiology, crop nutrition, and weed science

The SAFS project compares four different farming systems which include conventional 2-year and 4-year, low-input, and organic. The conventional systems utilize practices typical of Sacramento Valley growers, including mineral fertilizers and synthetic pesticides. The low-input system utilizes practices typical of both conventional and organic growers; cover crops are grown for fertility, yet mineral fertilizer is used to supplement when deemed biologically necessary and economically feasible. Pesticides are also used as necessary and efforts are made to reduce system dependency on nonrenewable inputs. The organic system is farmed according to standards outlined by California Certified Organic Farmers, and includes use of manures and cover crops for fertility, and mechanical control for weeds. No mineral fertilizers or synthetic pesticides are used in this system.

Although some features of this research are similar to work already reported, or in progress in others parts of the United states and internationally, several aspects of the SAFS project make this effort unique. The project's 20 acre experimental design combines a Mediterranean climate with a relatively long (4-year, five crop) rotation with three complete rotation cycles over a total of twelve years. The project is currently in its eighth year almost completing the second rotation cycle and preparing to enter the third. The conventional 4-year, organic, and low-input systems include: processing tomatoes, safflower, corn and wheat, (a mixture of oats and vetch is substituted for wheat in the low-input and organic systems), followed by beans. In addition to the five cash crops, the low-input and organic systems utilize nitrogen-fixing legume cover crops during the winter-spring season, preceding tomatoes, safflower and corn. The conventional 2-year rotation alternates processing tomatoes and wheat.

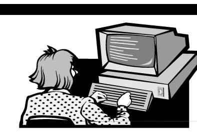
Unique Features of Project

- **Integration of Farmers and Farm Advisors**
- **Interdisciplinary**
- **Systems- Oriented**
- **Shared Leadership - Consensual Decision Process**
- **Four Year, Five Crop Rotation**
- **Use of "Best Farmer" Management Practices**

The study attempts to combine the best features of both on-farm and experiment station research; it is established under controlled conditions on a research farm, yet employs commercial farming practices that must be economically justifiable and that are regularly evaluated by farmer cooperators. Farmers and farm advisors participate in all decisions about planning, execution, and interpretation of all disciplinary facets of the project. Management of each system is accomplished using best farmer practices and the 1/3 acre plots allow for mechanized crop production practices.

The secondary objective of the project is to evaluate known and novel farming practices that show potential to reduce dependence on nonrenewable resources. The final objective is to distribute information generated by the project in an effort to facilitate a dialog about the adoption of more sustainable farming practices. This is

Visit the SAFS WWW Site at :



http://agronomy.ucdavis.edu/safs/home.htm

The Original World Wide Web

The Quest for Carbon

The maintenance of adequate soil fertility is an ongoing challenge for the SAFS project. A large fraction of nutrients supplied to the soil, whether as mineral fertilizers or in organic form, will cycle through the soil food web. The energy driving the food web originates from living plants, organic material and detritus. These are primary sources of carbon and other elements. As bacteria and fungi ingest carbon and nitrogen for growth, some nitrogen is released in its mineral forms; however, a considerable amount of nitrogen is retained in their bodies. That pool of nitrogen is later released by nematodes, protozoa and other microbial grazers as they feed and produce wastes. These organisms are in turn consumed by their own predators and additional nitrogen is released. As any organism dies, its body is returned to the detrital pool. Though our focus in agriculture is often on nitrogen, it is actually carbon that drives the food web and ultimately determines soil fertility.

The Soil Food Web

Mineral and nutrient cycling in the soil results from the activities of many different types of soil organisms. The community of organisms that lives in the soil is critical to the functioning of agricultural ecosystems. Every organism in the soil is part of a complex food web. The organisms range in complexity and size and are all uniquely adapted to life in the soil. The community consists of bacteria, actinomycetes, fungi (including mycorrhizal fungi), protozoa, nematodes, earthworms, arthropods, and other organisms which create a network of interdependency for food and energy. The organisms function collectively to exchange materials vital to the maintenance of the system. Although certain species are harmful to crops, most are beneficial and even essential for the well-being of plants. Their value lies in the roles they play in the decomposition of organic matter, as a living reservoir of nutrients, the active cycling of nutrients in the soil, and improvement of soil structure. The understanding of their contribution to soil fertility requires understanding of the structure and functional dynamics of their food web.

Food Web Dynamics

Every organism in the soil is the source of food for other organisms. Bacteria, fungi and root herbivores most actively utilize plant materials as available sources of food, and they provide food for other organisms within the soil food web. Protozoa and nematodes feed on bacteria; nematodes, collembola and mites feed on fungi; bacteria, protozoa, fungi, nematodes, tardigrades, mites and collembola feed on nematodes; bacteria, nematodes and tardigrades feed on protozoa; and so the complexity of interactions and interdependencies persists throughout the web and contributes to the decomposition of organic material and the supply of mineral nitrogen to the soil solution.

Ecological Functions of the Soil Food Web

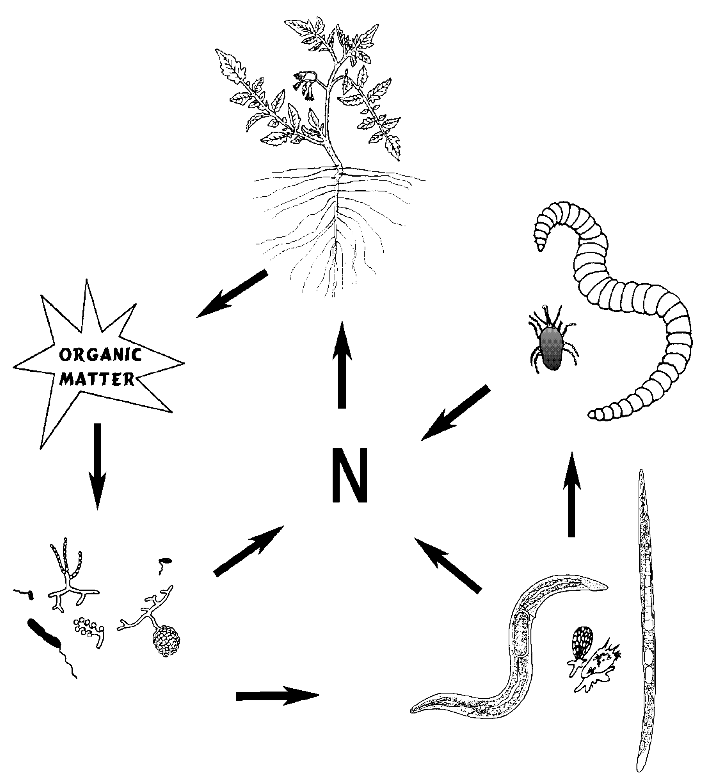
Many agriculturally-important functions are carried out by soil organisms, which include decomposition, mineralization and nutrient cycling.

Decomposition

Nutrient cycling and energy flow in soil ecosystems is tied to the decomposition of organic matter. Decomposition is the breakdown of complex organic compounds from plant exudates, crop residue, cover crops and dead bodies of organisms to simpler organic compounds. Plant roots exude compounds such as amino acids, simple sugars, and organic acids that provide a continuous energy supply to microorganisms living in the root zone, which is known as the rhizosphere. As the compounds are broken down through the metabolic activities of bacteria, fungi, and actinomycetes, the organisms derive and become pools of elemental components which serve as nutrients. In addition, Collembola, mites, earthworms, and arthropods also play important roles in decomposition and the overall function of the soil ecosystem.

Mineralization and Nutrient Cycling

Mineralization is the conversion of organic compounds to inorganic molecules including ammonium, nitrate, and phosphate. At each exchange within the food web, nitrogen is mineralized, excreted and made available to plants. Some of the important groups in the food web include the nitrifying bacteria (*Nitrococcus, Nitrobacter*, *Nitrosomonas*), which convert ammo-



nium to the nitrate form of nitrogen.

Nitrogen-fixing bacteria, such as the symbiont *Rhizobium*, and the free-living *Azotobacter* and *Azospirillum*, convert gaseous forms of nitrogen in the atmosphere to forms which can be readily used by crops. *Rhizobium* living in symbiosis with legumes permit growth of these crops without input of external sources of nitrogen. Microbial reactions can also result in the conversion of iron, sulfur, manganese, and some trace metals into forms that are more or less available to crops. Mycorrhizal fungi make phosphorus more accessible to plants, either by converting complex phosphorus-containing substances to simple forms or by extending the surface area of plant roots. Another important group of organisms is the nematode. Although the plant parasitic species receive more attention for their destructive activities on crops, nematodes that prey on bacteria, fungi and other nematodes make up the bulk of the total nematodes present in soil.

Environmental Modification by Soil Organisms

Other functions of soil organisms affect soil physical properties, and they can improve the tilth and structure of soil. Their transformation of plant material into the more stable forms of organic compounds that make up the humus is important to the maintenance of the organic fraction of soil. Many organisms promote the arrangement of primary soil particles (sand, silt, clay, organic matter), into soil aggregates. The growth of fungal hyphae in the soil causes soil particles and small aggregates to come together in larger units called macroaggregates, which improve soil structure. A well structured soil has low bulk density, is well aerated, absorbs rainfall and irrigation well, and is easily penetrated by plant roots and soil animals.

Maintenance of the Soil Community

As a general rule, soil with vegetation supports higher populations of soil organisms than does soil that is fallow. The majority of organisms found in soil are associated with plant roots which provide them with sources of carbon and other nutrients; therefore, it is important to maintain root growth and plant cover. Long periods of bare fallow may disrupt the community structure and result in reductions in the numbers and activity of soil organisms. Because these organisms are often limited by available carbon in agricultural soils, fresh organic material added to soil stimulates biological activity. The foundation of a healthy and thriving soil community is, just as is true for human beings, good nutrition and protection from major stresses.

SAFS Results

One aspect of the SAFS study compares the effect of four farming systems on microbial and nematode populations in tomato and corn plots. Each system is managed with different fertilization regimes, as discussed on page 1. At the beginning of the study, the size of the microbial biomass was similar in each of the farming systems. Only immediately after cover crop incorporation was the biomass greater in organic and low-input than in conventional tomatoes. By the third year of the study, however, microbial populations in the tomato plots have been consistently greater in the organic and low input systems than in the conventional systems.

Bacterial-feeding nematodes are believed to play major roles in the fertility of farming systems relying on soil biological processes to provide soil fertility. In response to greater food availability, bacterial-feeding nematodes are more abundant in organic than conventional soils (plant-parasitic nematodes are at lower numbers in organic than conventional systems). In these plots, at least 10 different species of bacterial-feeding nematodes have been identified; however, only a few of these nematode species exploit the increase in bacteria following incorporation of organic matter. As a result, one or two species tend to dominate the organic and low-input systems.

The dynamics of these nematodes are closely related to microbial population dynamics, both of which are influenced by seasonal changes. Microbial populations respond rapidly to the addition of organic material, steadily increasing until the mid growing season. Small increases in ammonium and nitrate concentrations are usually associated with these increases. As carbon and nitrogen become limited, as temperatures rise, and as soils dry in late summer, microbial biomass declines. The population of bacterial-feeding nematodes also begins to decline in response to changes in their food supply. The nematode species that most successfully capitalize on microbial food sources in the field plots also prove to be most important in stimulating nitrogen mineralization in laboratory studies. At this time, we do not know how other members of the food web react to changes in microbial or nematode populations in the SAFS plots.

Enhanced biological activity in the organic and low-input plots may have prevented the degradation of soil structure and reduction in water infiltration rates observed in the conventional soils. Cover crop amendments, and the subsequent higher microbial activity associated with these inputs, are directly related to the formation of significantly more water-stable soil aggregates in organic compared to conventional soils. Aggregation of soil particles across farming systems decreases in the following order: organic, low-input, conventional-4, conventional - 2.

It is interesting to note that microbial biomass is inversely correlated with soil nitrate levels, which are significantly lower in organic than conventional tomato plots. However, in the organic and low-input systems, high microbial biomass, high numbers of bacterial-feeding nematodes, and, in general, enhanced flow of carbon and nitrogen throughout the soil food web, may provide sufficient nitrogen to crops without excessive accumulation of nitrate in soil.

These observations have stimulated new ideas on the management of the soil food web. Perhaps the abundance and activity of soil organisms is too low in the spring when seedlings demand nitrogen. Can rates of nitrogen mineralization be enhanced by stimulating biological activity in the fall when soils are dry and biologically dormant? SAFS experiments are currently underway to answer these questions.

Summary

It is important to recognize that agricultural ecosystems have biological communities living below as well as above the ground. These communities exist in both conventionally and organically farmed soils. Because soil communities strongly regulate the

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