SUSTAINABLE
AGRICULTURE FARMING
SYSTEMS PROJECT
University of California, Davis
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Spring focus: Cover crops, tillage

Welcome to the Spring 2004 Sustainable Agriculture Farming Systems (SAFS) newsletter. The SAFS project began in 1988 at the main UC Davis campus and moved to a permanent site at the Long-Term Research in Agricultural Systems experiment fields provided by the UC Davis College of Agricultural and Environmental Sciences in 2003. Located at the Russell Ranch west of campus, both programs are part of the College's emerging sustainable agriculture and natural resource program. We are also pleased to be working with the statewide UC Sustainable Agriculture Research and Education Program on outreach, including our newsletter, Web site and other products.

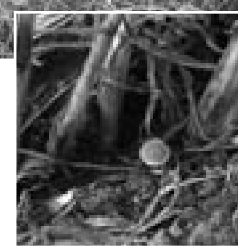
In this issue of our newsletter, we address operations and adoption of conservation tillage practices and their effect on the soil food web. In the next issue, we will address how conservation tillage and cover cropping affect the amount and quality of water from winter runoff and summer irrigation return. The articles continue our efforts to develop economic and ecologically sustainable research and management practices to help California growers farm at their best.

Please join us for our **June 24 field day** for further updates on our research (details back page).

—Will Horwath

Cover crops, tillage & soil food webs

by Louise E. Jackson, Howard Ferris, Steven R. Temple, Kaden B. Koffler, Hideomi Minoshima



photos by Louise Jackson

Soil sampling after Sudan grass cover crop at SAFS companion plots.

Cover crops are increasingly used in California as a means to improve soil and water quality. This occurs by nitrogen (N) capture during winter rains so that it is stored in the soil for subsequent crops and is not lost to leaching below the root zone, by decreasing erosion due to plant cover and lower soil moisture, and by reducing surface runoff of water and nutrients due to changes in soil physical properties and infiltration rates. In addition, cover cropping can affect the soil food web including microbes, nematodes, microarthropods, and their activity in sequestering and supplying nutrients to crops. By cover cropping, farmers "feed the soil to feed the plant," yet scientists are only now beginning to understand how the soil food web regulates the transformations of carbon (C) and nutrients from plant litter, and how this results in increased soil quality and nutrient availability for crops.

Carbon and energy from plants and soil organic matter are used by organisms in the soil food web for growth, reproduction and respiration. The rates at which C enters the food web and is lost from the soil through organisms' respiration limits the amount available to successive groups of predators, all of which are interdependent as sources of food. A diversity of soil organisms in the food web is generally considered beneficial. When organisms perform ecological functions that are important in agriculture, including mineralization of nutrients and regulation of pest species, redundancy in the number of species performing the function may compensate for seasonal dynamics of the species and differential effects of environmental conditions on their abundance.

Achieving the ideal of a well-functioning food web will require that food resources for soil organisms are continuously replenished. Further, reduction of environmental disturbance may be important for survival and activity of food web organisms. In food webs where C and energy are not provided by cover crops and green manures, a major source of C for the food web system may come through the activities of root-feeding species that are usually harmful to crop growth. We believe that management of the soil food web to regulate populations of soil herbivores below pest levels will require rotation of crop species, use of resistant cultivars and the conservation of predator activity. Consequently, to conserve and enhance soil communities, we are experimenting with the effects of rotations that use continuous plant cover, including frequent cover crops, coupled with conservation tillage.

Innovative tillage methods may increase the feasibility of cover cropping for some farmers by decreasing the time, labor and

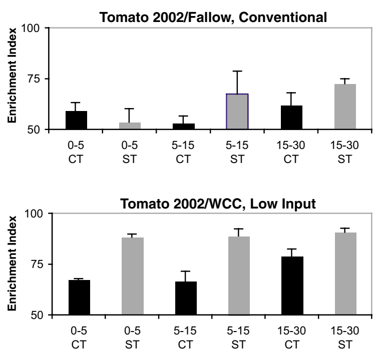


Fig. 1. *Enrichment index at three depths (cm) for representative examples of the SAFS main plots in May 2003.*

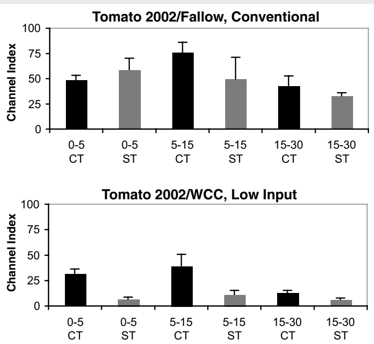


Fig. 2. *Channel index at three depths (cm) for representative examples of the SAFS main plots in May 2003.*

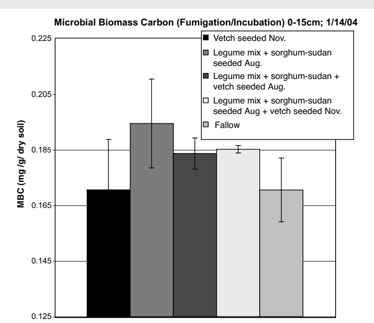


Fig. 3. *Soil microbial biomass in January 2004 in plots sown with various cover crop mixtures in August or November 2003.*

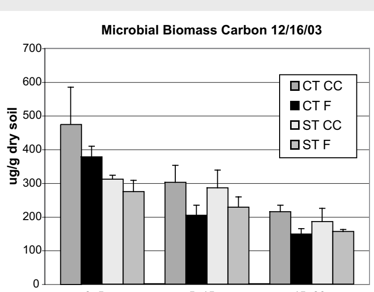


Fig. 4. *Microbial biomass at three depths (cm) in plots with (CC) or without (F) a fall cover crop and subjected to conservation tillage (CT) or standard tillage (ST).*

costs for preparing the field before planting the cover crop and for incorporating the cover crop residue. In fact, one of the disadvantages to cover cropping in the Central Valley is that planting schedules for cash crops can be delayed when a series of tillage operations is needed during a rainy spring season. Reducing tillage by less intensive operations, and fewer passes, may improve this situation.

Our research group is exploring the use of reduced tillage for cover crop incorporation from several perspectives: equipment and ease of residue management (see *Tillage system comparisons at SAFS*, page 3 of this newsletter), runoff (featured in next issue of SAFS newsletter, *Vol. 5, No. 1*), nutrient availability (work in progress) and effects on the soil food web (below). During the past year at the SAFS project, our comparisons of the soil food web and its activity have been between standard tillage (ripping, disking, bed-shaping, and cultivation) vs. conservation tillage. Conservation tillage involves minimal disturbance to open a slot in the planting line while leaving the plant litter on the soil surface.

Our preliminary results indicate that cover crops and conservation tillage alter the complex relationships that exist between the structure of the soil food web and the associated changes in decomposition processes, transformations of organic matter, and soil C dynamics. Fungi and bacteria biochemically degrade litter, and soil fauna further condition it by exposing litter surfaces to microbes, moving byproducts and fragments in the soil, altering C compounds and changing soil structure. Our goal is to understand how the composition of the soil food web regulates these processes and, in turn, how crop production is affected.

On-going research at main plots, companion plots

In the main plots of the SAFS experiment, we conducted a complete analysis of the nematode fauna (e.g., bacterial- and fungal-feeding nematodes) after the initial tillage operations in the spring of 2003. Those analyses allow us to compute several indices that reveal the structure and activity of the soil food web.

The biomass of opportunistic bacterial- and fungal-feeding nematodes that respond rapidly to increases in their food resources is indicated by the Enrichment Index, developed by Howard Ferris and colleagues in 2001. As an example (Fig. 1), the Enrichment Index of the plots coming out of tomatoes in 2002 and planted to corn in 2003 had greater soil organic resource enrichment where a winter cover crop was grown (low-input) than where mineral fertilizers were used (conventional). In the winter cover-cropped plots (WCC), the enrichment was greater where the cover crop was incorporated throughout the soil profile by standard tillage (ST) than where it was laid on the soil surface in conservation tillage (CT). Clearly, the biological machinery for incorporating the organic material through the soil profile is not yet in place in those plots. Will it ever be as efficient as the delivery of resources to the soil food web by ST? What about the offsetting disruptive effects of ST to the soil food web? Is there a middle ground where the benefits of both systems can be optimized? Time will tell as this long-term experiment progresses.

Organic matter decomposition in moist environments is mediated by bacteria when the material is relatively simple in structure. More complex organic structures tend to be degraded by fungi, which may also be active in drier conditions. We use the nematode faunal analyses to compute a Channel Index (CI) (Fig. 2). The CI is calculated from the proportional representation of fungal- and bacterial-feeding nematodes among the enrichment indicator species; a low CI suggests that bacterial decomposition predominates; a high CI suggests fungal decomposition. For the same main plots used for the Enrichment Index calculations, decomposition of organic matter is more bacterial in low-input situations, particularly where fresh cover crop material has been incorporated through the soil profile. The decomposition machinery of the conventional plots, fueled primarily by aged residue from the previous year's crop, is much more fungal.

In the companion area to the SAFS experiment, new technologies are explored and developed before being integrated into the main experiment. One such study is testing the relative utility of late-summer cover crops rather than winter cover crops in a tomato-corn CT rotation. We hypothesize that without tillage, winter cover crops may not be mineralized quickly enough for their N to be available for the following cash crop. In that case, summer cover cropping may be a better system for N management in low-input systems. The summer cover crop was sown in mid-August and the winter cover crop in mid-November. By mid-January, without incorporation of either cover crop, the soil microbial biomass was greater in summer than the in winter cover crop plots (Fig. 3). Soil analyses in the spring and the growth of the 2004 summer crop will provide further information on the utility of the two strategies.

In another companion area experiment, we are comparing two legume-vegetable rotations to examine the effects of year-round crop production and conservation tillage on the structure and activity of the soil food web, the fate of C in the soil, as well as on crop yields. Year-round inputs of plant-derived C and N, combined with CT, are expected to result in more complex food webs, greater activity at higher trophic levels, and more stabilized soil C fractions. We expect that to result from the continuous C supply, lack of disruption by tillage, and greater processing, turnover, and protection of C. The year-round, winter-legume rotation will utilize tomato, garbanzo, and bean as well as a cover crop and a hay crop. The winter-fallow rotation will use only two crops (tomato and garbanzo). Seasonal changes in microbial biomass, activity, CO_2 emissions, nematodes and earthworms will be measured at three depths in the soil.

Thus far, the Sudan grass cover crop tends to increase microbial biomass C, lower nitrate, and result in a higher nematode CI compared to the plots that were fallow in the fall. The CT vs. ST comparison, however, showed few differences except that ergosterol, an indicator of fungal activity, was greater in the CT plots. Perhaps the winter decomposition of the litter occurs slowly in both tillage types due to cool temperatures. In that case, the soil food web would not show pronounced differences in relation to placement of litter and tillage regime. As we have seen in the main plots, depth is a major determinant of activity and structure of the soil food web in plots subjected to CT. Most activities are elevated at the soil surface (Fig. 4). Time will tell whether integration of the organic matter through the soil profile by the activity of organisms will offset the effects of tillage. ■

Tillage system comparisons at SAFS

by Jeff Mitchell

Tillage practices in Central Valley row crop systems are constantly evolving due to various economic, equipment and resource conservation considerations. The growing interest in reduced or conservation tillage (CT) production systems in this region is driven by the desire to decrease diesel fuel use and dust emissions, while improving soil quality through increasing carbon sequestration, and reducing surface water runoff by having more crop residues in place during winter rainfall. Developing optimal production systems that achieve these goals over the long term are critical challenges to research and farm innovation.

At the SAFS site, we are evaluating CT systems for corn and tomatoes and directly comparing them with today's standard tillage approaches in 1) winter fallow, 2) winter legume cover cropped, and 3) organic production systems. Management principles governing the CT systems have been developed through a series of discussions with our project's farmer consultants and production team and include extensively reducing intercrop or primary tillage while attempting to remain productive and profitable.

CT systems at SAFS currently differ from standard till systems primarily in fall tillage intensity. Standard systems include a series of disking, chiseling and bed forming operations in the fall following corn or tomato harvest. In contrast, these first tillage passes are not being implemented in the CT systems. Winter legume cover crops are planted directly into crop residues using a no-till drill in each of the cover cropped systems, and no fall tillage is performed in the CT winter fallow systems.

In the spring, corn is no-till planted into existing beds in the CT winter fallow systems; tomatoes are transplanted directly into residues using a transplanter modified with a coulter in front of the transplanter shoe, paired disk residue managers in front of the transplanter furrow sleds, and heavy down-pressure closing wheels to seal-in soil moisture around the transplants. We recognize the need to incorporate the winter legume cover crops (WLCC) in both the WLCC and the organic systems at a shallow depth to provide cover crop-derived nitrogen to crops in these systems and to create a soil mulch layer that may aid tomato harvester efficiency. Therefore, we use a Hahn bed disk to mix the flail-mowed cover crop with soil, followed with a ring-roller to roughly shape the bed, reduce clod size and seal-in moisture in the WLCC and organic systems before corn planting and tomato transplanting

In-season cultivation is done in the WLCC and organic CT systems and in the winter fallow tomato system using standard equipment and specially developed high-residue cultivators, and as needed in the winter fallow CT corn system, which also takes advantage of Roundup tolerant seed that enables weed control without tillage.

Tractor wheel traffic is restricted to furrows. Beds are maintained in the CT systems with a Beeline global positioning tractor guidance system. In this way, we intend to preserve relatively undisturbed crop growth zones in bed areas during the course of this study.

The CT systems at the SAFS site differ in fundamental ways from today's standard till systems. Our management plan currently projects at least a 40 percent reduction in overall tillage passes in the CT systems compared to the conventional system. The relative costs and benefits of these changes are being evaluated in terms of productivity, profitability and resource conservation, and will be featured in future newsletter updates. ■

photo by Dennis Bryant

Hahn bed disk incorporating winter legume cover crop.

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Conservation tillage field day, Thursday, June 24

Join us for field tours, demonstrations and a panel discussion at the new SAFS site June 24.

LOCATION: Russell Ranch, 7 miles west of UC Davis on Russell Blvd., ½ mile west of County Road 95.
SIGN-IN/REGISTRATION: 7:30 a.m.
PROGRAM: 8 a.m.- 2:30 p.m.
PRE-REGISTER BY: June 18; $10 general/$5 students (includes lunch).

Registration at the SAFS Web site http://safs.ucdavis.edu/ or contact Sam Prentice, (530) 752-2023, seprentice@ucdavis.edu.

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

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