The LTRAS Century

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College of Agricultural and Environmental Sciences, University of California, Davis

Help keep LTRAS sustainable!

Core operations at LTRAS have been supported mainly by the UC Davis College of Agricultural and Natural Sciences **(CAES)** and the UC Division of Agriculture and Natural Resources **(DANR)**. Recently, we learned that DANR will no longer be providing this support. We thank DANR, the Sustainable Agriculture Research and Education Program **(SAREP)**, the UC Davis **Department of Agronomy and Range Science**, and the **USDA/NRI** Agricultural Systems program, for their early support.

Deans **Neal Van Alfen**, **Michael Parrella**, and **Tom Kaiser** met with **Ford Denison** and **Dennis Bryant** on June 8, and agreed to replace the DANR funding, without which a drastic reduction in LTRAS operations would have been needed. But they pointed out that relying on annual appropriations is a risky strategy for a 100-year project, and requested that LTRAS seek other reliable sources of long-term funding.

Therefore, we plan to establish an endowment to help keep LTRAS sustainable! The goal of the endowment will be to ensure that LTRAS lasts long enough to reveal the sorts of gradual but important trends discussed in previous issues. The endowment also will a support a funding program for undergraduate and graduate students doing research at LTRAS.

There are many options for giving. All offer tax or estate planning advantages that may be attractive to donors. Options include:

- Cash
- Securities
- Real estate
- Personal property or equipment
- Bequests
- Life income arrangements

More information is available from Rick Swantz, Director of Development for the College of Agricultural & Environmental Sciences at 530-752-7961 or raswantz@ucdavis.edu.

More information is also available from: **http://www-development.ucdavis.edu/develop**

LTRAS Live on the Web (soon)!

LTRAS is a popular destination for field trips and for visitors from around the world. Many learn about us from our web site, recently simplified to **LTRAS.ucdavis.edu**. Soon, students and others will have access to some of our data, within minutes of when it is collected, right on our web site.

Our data will be used in classes at UC Davis within the next year. Eventually, we hope to develop this system as a web-based resource for K-12 classes.

A grant from the Instructional Use of Computers program to **Greg Pasternak** and others is funding a network of environmental sensors at several locations. LTRAS, and the adjacent **Putah Creek Reserve**, will be the first locations in this network. Connecting the LTRAS weather station, soil moisture sensors, and sensors for measuring winter runoff are in progress or planned. Advances in sensors may soon allow measurements of crop growth, soil nitrate, etc.

Inside this issue…

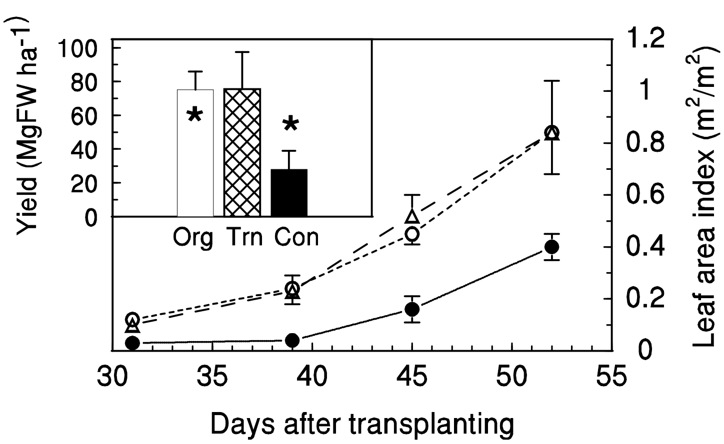
Is the "Organic Transition" Real?

Recent research at LTRAS challenges two beliefs which are widely held (not always by the same people!), namely that:

1) organic yields are lower than conventional
2) increases in yields of organic systems over years are due to increasing "soil quality."

Farmers who switch to organic methods often report lower yields in the first few years, frequently followed by yield increases. This "organic transition effect" has been attributed to hypothesized, lingering negative effects of conventional methods on "soil quality," and gradual improvements in soil quality with organic methods. Although there have been many reports of differences in soil properties between organic and conventional systems, previous reports supporting soil quality changes as the principal cause of yield trends during the early years of organic farming have all been confounded by a second factor – increasing grower experience. No previous study has been designed to measure the relative contributions of soil quality trends versus grower experience.

LTRAS is now conducting the needed research, with a grant from the **Kearney Foundation of Soil Science**. Three replicate, one-acre plots, which are not part of the main, 100-year experiment, were managed conventionally since LTRAS began in 1993. But since November 1998 these plots have been managed identically to our organic system, which has been managed organically since 1993. This is the first, replicated comparison of plots differing only in the duration of organic management.

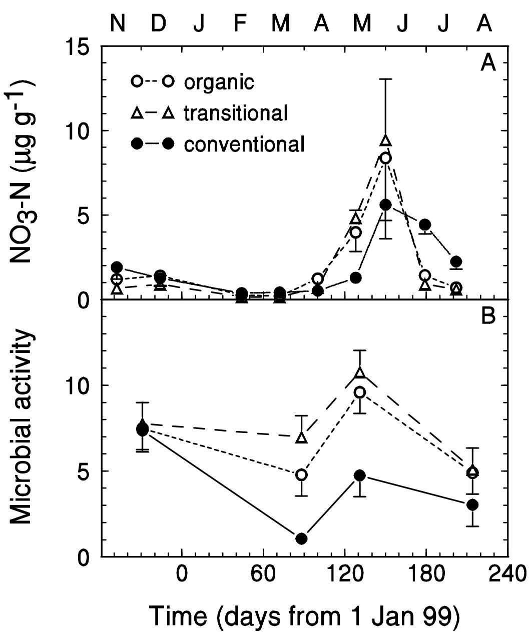


Under the prevailing, "organic transition" hypothesis, we would expect yields in the first-year "organic transitional" plots to be lower than those in either the "established organic" plots (farmed organically since 1993) or the comparable "conventional" plots. Neither prediction proved true, however. Instead, first year yields of tomatoes in the transitional organic plots were much *higher* than in the most directly comparable conventional system, but no different than in the established organic system. Graduate student **Elizabeth Martini** also found faster plant growth in the two organic systems, relative to their conventional counterpart, even early in the growing season (see graph below left). All three systems are two-year rotations of tomatoes and corn.

> **Y**ields of tomatoes in the transitional organic plots were much *higher* than in the most directly comparable conventional system, but no different than in the established organic system.

A possible explanation for the growth and yield differences between conventional and organic systems may come from the observation that a second conventional system, not shown, had higher yield even than the organic system. In the conventional wheat/tomato rotation, most field preparation can be completed in the late summer, after wheat harvest, when the soil is dry. But, because corn is harvested later, more work is often done in the spring, when the soil may be wet, as in the spring of 1999. Working wet soil can cause compaction, but the two organic systems appeared to be relatively immune to this problem, either because of the organic matter added by compost and winter legume cover crops, or because the cover crop itself used enough water to dry the soil. Further research may support or refute this hypothesis.

Another popular idea about the organic transition was also not supported by our data. Microbial communities in the transitional system were at least as effective in nutrient cycling (specifically, release of N from the compost and the leguminous "green manure") as those in the established organic system. Furthermore, USDA microbial ecologist **Jeff Buyer** found that overall microbial activity in the transitional system was not intermediate between the organic and conventional systems, as had been expected. Instead, the established organic systems were intermediate (see graph).



Our results are inconsistent with the hypothesis that there is a steady improvement in yield-limiting soil quality parameters during the organic transition. In wet years, there do seem to be some soil quality benefits of organic farming methods, as indicated by higher tomato yields. But it appears that these benefits can occur quite rapidly. The faster early growth of tomato plants in the transitional system, relative to its conventional counterpart, were seen less than 6 months into the transition period.

We do have very limited data suggesting that some other aspects of system performance may be more consistent with the "transition hypothesis." A limited comparison of winter runoff after one year of organic management gave results that seem to be intermediate between the conventional and organic systems. (The conventional system, which does not have a cover crop in the winter, had higher runoff.)

In collaboration with **Diane Barrett**, of Food Science and Nutrition, we found more vitamin C in organic tomatoes in an unreplicated comparison in 1999, but this was not confirmed in a replicated comparison in 2000.

Another result may interest some farmers who do not seek organic certification but are interested in farming more sustainably. Tomato yields of a system that includes a winter legume cover crop in alternate years (but is otherwise conventional) were intermediate between the organic and conventional systems. This result is particularly interesting because the cover crop preceded the corn year, rather than the tomato year. Thus, it appears that the benefits of a cover crop can persist for more than a year.

We are currently in the second year of this study, comparing second- with seventh-year organic systems. This year, corn (which can usually be planted earlier in systems without a legume cover crop) follows tomato in the rotation, so the two organic systems can only be compared, directly, with each other.

Principal investigators for the organic transition study are **R. Ford Denison**, of Agronomy and Range Science, and **Tim Hartz** of the Vegetable Crops department. Thanks also to LTRAS Associate Director **Dennis Bryant,** and to **Israel Herrera,** and **Sean Eldridge.**

Effect of plants on soil N cycling

Martin Burger, a PhD student with **Louise Jackson**, in the Vegetable Crops Department, is continuing his research on soil N cycling. For the 1999 growing season, the focus of their research was on NH_4^+ production and consumption in the organic and conventional tomato systems. Gross mineralization and gross nitrification rates were determined, using stable isotope techniques. Nitrification rates corresponded with gross mineralization rates. In both systems, microbes immobilized more NO_3^- than NH_4^+, a result suggesting prolific nitrifier populations.

Fertilizer NH_4^+ was nitrified within two weeks of its application. In the organic system, NH_4^+ production was roughly twice as high as in the conventional system throughout the growing season. This year's experiments are designed to answer the question of how much of this freshly produced NH_4^+ is taken up by tomato plants, or in other words, how much NH_4^+ is intercepted by roots before nitrifiers get it. Estimates of the proportion of crop N derived from NH_4^+ *vs.* NO_3^- could be useful to evaluate different farming systems with respect to their potential for NO_3^- leaching or N trace gas emissions.

LTRAS will be the new home of the UCD campus long-term climate station.

The weeds are coming!

Weed scientist **Robert Norris** reports that differences in weed populations among the ten different cropping systems at LTRAS are increasingly apparent each year. Such differences could be obscured by transfer of weed seeds among systems, so **Sean Eldridge**, **Nick and Israel Herrera** (not related), and Associate Director **Dennis Bryant**, make sure that soil is always cleaned from field equipment moving from one system to another. Summer weed counts in conventional systems have generally decreased over years, and dodder, which was once common, has nearly been eliminated by consistent removal of infected plants. But winter weeds have increased in some systems. Some weeds that were rarely found during the first five years have since become abundant in some systems, sometimes displacing previously common species.

For example, the nitrogen-fixing leguminous weed, yellow sweetclover (*Melilotus officinalis*) was not recorded in the initial weed survey in 1993. It was quite common in some plots in the spring of 2000 -- even visible in one aerial photo --, but only in unfertilized controls, without either fertilizer or legume cover crop.

Wheat rotations with winter legume cover crops in the fallow year have apparently maintained high enough soil N that sweetclover's ability to use atmospheric N provides little competitive advantage. But these plots have seen up to 100-fold increases in other weeds, such as annual bluegrass, common chickweed (*Stellaria media*) and miners lettuce (*Montia perfoliata*) when compared with herbicide-treated fallow systems.

Grasses were not common at the initiation of the LTRAS experiment in 1992-93. Annual bluegrass (*Poa annua*) was present in low numbers (1 or 2 plants/m^2 in a few plots), and one annual ryegrass (*Lolium multiflorum*) plant was recorded in two out of 300 quadrats evaluated. Canarygrass (*Phalaris canariensis*) and wild oats (*Avena fatua*) were not recorded in the initial sampling. But by the spring of 2000, canarygrass was present in every system in which wheat is part of the rotation. The overall canarygrass density in most systems is about 0.2 to 0.3 heads/m^2. Although the canarygrass density varies between plots it is clear that the two systems with supplemental irrigation and receiving fertilizer nitrogen have populations between 10 and 15-fold higher than the other systems. Wild oats are now present in many plots, but still at low density. Annual ryegrass is present in five plots. It thus appears that grass weeds are increasing under these 2-year rotations. The use of grass-specific herbicides in these systems was approved by the LTRAS General Committee last year. Unfortunately, wet soil conditions kept us out of the plots during the period that the weeds would have been susceptible this year.

Changes in soil aggregate stability

In recent years, we have noticed that irrigation water soaks into the soil more quickly in the organic plots at LTRAS. Recent research by **M.J. Singer** and **Valentina Prikhodko** may explain this result.

They are analyzing surface soil samples

were taken in fall 1992 prior to establishment of cropping treatments, and again in fall 1999, to determine if the cropping systems produced significant changes in these properties. Of particular interest was the fraction of water stable aggregates. Aggregates are associations of sand, silt and clay size particles that are bound together by soil humus, clay, carbonate and iron oxides. In the LTRAS soils, humus is probably the most important binding agent. Aggregates are important because they determine the pore size distribution of the surface soil material and they help to control the rate at which water enters the soil. The structure of a soil with water stable aggregates maintains the water entry rate at desirable levels while soils with a smaller percentage of water stable aggregates tend to seal and crust, greatly slowing water entry. This produces runoff and erosion on sloping ground and reduces irrigation efficiency on flat ground.

The analyses that have been completed so far show that, in two plots in the organic corn/tomato rotation, water stable aggregates increased from 86 to 94% and from 68 to 93% between 1992 and 1999. Meanwhile, two plots in the conventional wheat/tomato rotation changed less, from 92% to 90% and from 87% to 92%.

Differences in the *change* in % aggregate stability (+8 or +25% vs. -2 or +5%) are more obvious than differences in the current aggregate stability values (93-94% vs. 90-92%). This shows the value of a long-term approach. Without the "time zero" data that Prof. Singer and colleagues collected in 1992, before the treatments began, we might assume that all of the plots started with the same aggregate stability, which would lead us to underestimate the improvements in the organic system.

They also found small increases in total organic carbon over the seven-year interval studied. Will this organic matter continue to increase and will the increased organic matter content continue to improve the soil physical condition in the plots grown under organic management? Only time will tell.

Fingerprinting soil organic matter

Teresa Fan, of the Department of Land, Air and Water Resources (LAWR) and **Rick Higashi,** of Crocker Nuclear Lab**,** have started a series of experiments examining the effect of aging of different sources of soil organic matter (e.g., green and farmyard manures) on N and metal availability to crop plants and other soil biota. They will be focusing on fingerprinting the chemical properties of organic matter during the aging process so that a mechanistic understanding of how transformation of organic matter leads to N and metal release can be obtained.

Cover crop effects on soil capacity to store and supply nitrogen

Graduate student **Chris Hartley,** working with **Chris van Kessel**, of Agronomy and Range Science, and **Willi Horwath**, of LAWR, are using isotopically-labeled N fertilizer to determine the “inherent N supply power of soil.” This research has focussed on the flow of nitrogen in the wheat-fallow and wheat-cover crop rotations. From initial results it appears that the use of cover crops significantly decreases short-term nitrogen losses. Over the coming months, they will be working to improve our understanding of the underlying soil physical processes that are responsible for the differences in nitrogen recovery that were observed. From a management perspective, the results may be useful in determining fertilizer application rates and in improving the nutrient use efficiency of cropping systems.

Recently-accepted papers

- Timm, L., Pearson, D., and Jaffee, B. Nematode-trapping fungi in conventionally- and organically-managed agriculture: Early data from the LTRAS project. *Mycologia*.
- Hasegawa, H., D.C. Bryant, and R.F. Denison. Evaluation of CERES models for predicting N dynamics during crop growing periods following legume cover crop incorporation. *Field Crops Research*.

Overview of LTRAS

LTRAS is now in the eighth cropping year of what is planned as a 100-year experiment. Long-term experiments are important, as results from other sites around the world show that short-term trends can be misleading. Some important soil parameters (e.g., organic matter) change over decades rather than years, so up to 100 years may be needed to be certain which of our ten cropping systems are sustainable.

Researchers at LTRAS want to understand the relationship between sustainability and external inputs, especially irrigation water and nitrogen fertilizer. The ten cropping systems in the main LTRAS experiment differ in crops, N source, and use of irrigation. Sustainability will be determined from long-term trends in yield, efficiency in use of limited resources (such as water), profitability, and environmental impact (such as leaching of nitrate or pesticides). We are monitoring trends in key soil properties, such as organic matter, weed seeds, pH, and salinity to see if any of these are good predictors for long-term sustainability.

Research at LTRAS supports efforts to design more sustainable cropping systems, including both environmental and economic considerations. We also expect to make important short-term contributions to agricultural science. Methods first developed at LTRAS are already used in on-farm research. LTRAS is primarily a research facility, but we also host class trips, field days, undergraduate research, and visitors from around the world.

LTRAS Staff Directory

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- Israel Herrera; Agric. Tech.; igherrera...
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Executive Committee

- Ted Hsiao; Land, Air & Water Resources.
- Robert Norris; Weed Science.
- Richard Plant; Agronomy & Range Science.
- Louise Jackson; Vegetable Crops.
- Chris van Kessel, Agronomy & Range Science

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Cropping System	First Year	Alternate Year
Rainfed wheat control (RWC)	unfertilized rainfed wheat	fallow
Rainfed wheat/legume (RWL)	unfertilized rainfed wheat	rainfed legume cover crop
Rainfed wheat/fallow (RWF)	fertilized rainfed wheat	fallow
Irrigated wheat control (IWC)	unfertilized irrigated wheat	fallow
Irrigated wheat/legume (IWL)	unfertilized irrigated wheat	rainfed legume cover crop
Irrigated wheat/fallow (IWF)	fertilized irrigated wheat	fallow
Conventional wheat/tomato (CWT)	fertilized irrigated wheat	fertilized irrigated tomato
Conventional corn/tomato (CCT)	fertilized irrigated corn	fertilized irrigated tomato
Legume/corn/tomato (LCT)	winter legume then irrigated corn	fertilized irrigated tomato
Organic corn/tomato (OCT)	winter legume then irrigated corn with compost and no pesticides	winter legume then irrigated tomato with compost and no pesticides

The ten cropping systems (2-yr rotations) in the main LTRAS experiment.