Issue 2 University of California, Davis July, 1994

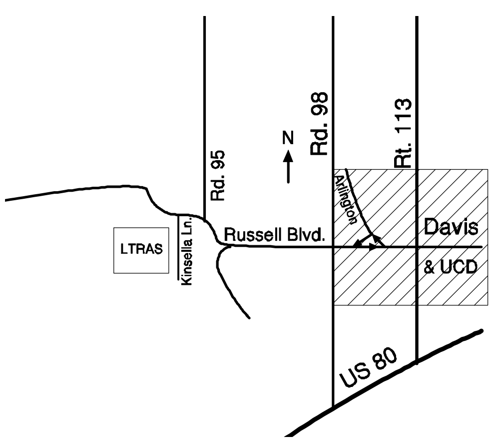
The LTRAS Century

First LTRAS Field Day Scheduled for July 20

You may have missed this year's Sustainable Agriculture Farming Systems field day (our sister project), but it's not too late to plan to attend the first annual Long Term Research on Agricultural Systems (LTRAS) field day, the morning of July 20. Refreshments will be available starting at 8:30. A formal presentation at 9:00 will be followed by field tours and poster presentations.

Please join us for an introduction to the program and research facility. Several LTRAS collaborators plan to be on hand for informal discussions of preliminary data or research plans. We expect presentations or demonstrations related to weeds, crop and soil water relations, agricultural dust production, and the use of LTRAS in undergraduate teaching.

LTRAS also welcomes visitors throughout the year. Feel free to stop by whenever the gate is open. To minimize problems with dust, soil compaction, crop damage, transfer of weed seeds, etc., please leave your vehicle at the field headquarters and walk only on the main field roads.



LTRAS is located on Kinsella Lane, off Russell Blvd., about 6 miles west of Rt. 113.

"That's Not Fair!"

Laboratory scientists and members of the public are sometimes bothered by the fact that cropping systems at LTRAS often differ by more than a single factor. The planting date for corn receiving synthetic nitrogen (N) fertilizer was significantly earlier than that for corn following a winter legume cover crop (WLCC). Different wheat cultivars were used in the rainfed and irrigated systems. There are numerous differences between our organic and conventional tomato/corn systems. Do these multiple differences make comparisons among systems "unfair," or just complex?

Within the context of each individual cropping system, these choices of planting date, cultivar, etc., make sense. Accumulation of N by the WLCC (much of it presumably from biological N_2 fixation) increases substantially during the spring (Fig. 2). Premature incorporation of the cover crop to allow early planting of corn could therefore lead to N deficiency in the corn. Reliance on a winter legume as the N source for corn (the defining characteristic of this cropping system) implies a late planting date. Late planting may actually have little effect on corn yield in this system, because a longer growing season wouldn't benefit corn if the crop ran out of N halfway through the season. Late planting may turn out to decrease seasonal water use efficiency (WUE: yield divided by water use) of the corn crop, but the effect on WUE of a crop failure due to N deficiency would be even more severe.

The LTRAS Farming Committee and our field staff attempt to consider these sorts of tradeoffs and to optimize each of our ten cropping systems within the particular constraints of that system. Trying to make one system follow the constraints of another would underestimate its true potential. For example, using a wheat cultivar adapted to irrigation in our rainfed wheat/fallow system (or *vice versa*) might result in lower yield or WUE than a more appropriate cultivar.

Similarly, our "organic" tomato/corn system is not just a mirror image of our "conventional" tomato/ corn system with one-for-one substitutions of organic for

Second Printing, February 1995

synthetic inputs. Our organic tomatoes also follow cover crop incorporation, so constraints on timing are similar to those for corn. However, the price premium for organic tomatoes makes transplanting tomatoes economically realistic. Transplanting compensates to some extent for late planting, but the decision to transplant was made within the context of the organic system, not in an attempt to make comparisons with other systems more "fair."

We consider optimizing each system within its own constraints the best way to fairly compare different cropping systems. (These comparisons will include resource-use efficiency, profitability, and environmental impact, not just yield.) Moreover, such systems comparisons are only a step towards our ultimate goal. Eventually, we hope that information from research at LTRAS will be used to design cropping systems (possibly including features from two or more of our ten experimental systems) that outperform any in existence today. To do that, we need to discover and refine the scientific principles that determine the long term productivity, efficiency, and environmental impact of cropping systems. But that goal raises a troubling question: doesn't this systems approach make it difficult to determine which of several differences among our experimental cropping systems contribute most to differences in system performance? (To be continued...)

Justus We Expected

LTRAS was planned from the start as a long-term experiment, but that was not true of the experiments at the Rothamsted (England) Experimental Station, which celebrated their 150th anniversary last year. The Rothamsted experiments would probably have been discontinued after only a few years had it not been for a bitter dispute between John Lawes, founder of Rothamsted, and Justus von Liebig, the father of agricultural chemistry. Liebig made many important scientific contributions, but at least one serious error. He insisted that crop plants in general could extract ammonia from the atmosphere, and therefore did not need an additional nitrogen supply from the soil. The Rothamsted experiments, including the Broadbalk wheat plots, clearly showed that Leibig was wrong. However, Liebig was so influential that Lawes felt it necessary to continue the experiment until, late in life, Liebig was finally convinced. Today, researchers from Rothamsted and the Liebig institute frequently collaborate.

Our first wheat yield data, from the winter of 1993-1994 (Fig. 1), confirm the importance of soil N, at least for wheat. Vetch, of course, *is* able to extract nitrogen from the air, but uses N_2, not ammonia. We have therefore included rainfed and irrigated wheat/vetch rotations (see p.4) as possible alternatives to use of synthetic N fertilizers. Our vetch crop accumulated about 180 lb of nitrogen per acre by the end of March (Fig. 2), more than the 100 or 150 lbN/acre we applied as fertilizer to the wheat crops. Some of the biologically fixed N will presumably be available to next year's wheat crop, but whether this source of N will completely satisfy the wheat's N requirements remains to be seen. We will begin to answer that question when we harvest wheat next summer from plots seeded to vetch this past winter. However, the long term benefits (or costs!) of including vetch in rotation with wheat may not be apparent for some years.

Long term trends in the other wheat based systems are also of interest. Although the yield of unfertilized wheat was only a fraction of that for fertilized wheat, the estimated N content of the grain removed from the unfertilized system is not insignificant. Assuming that wheat grain contains 2% N, a yield of 3000 lb/acre would contain 60 lb N/acre. Where did this N come from? No N fertilizer was applied to the sudangrass hay crops harvested in 1992 and 1993, but soil organic matter can represent a considerable reservoir of N. Ongoing inputs of N include rainfall or irrigation, dry deposition, and free-living N-fixing soil bacteria. Eventually, N removal in grain (plus any other N losses, e.g., leaching or denitrification) should come into balance with these inputs, but we don't know how long this process will take. The sustainability of systems relying on synthetic fertilizer as the main N input for wheat will also be evaluated. Will yields and quality be maintained over decades? Will more nitrate leach from wheat/fallow system with synthetic fertilizer, or from the wheat/vetch rotation? Stay tuned.

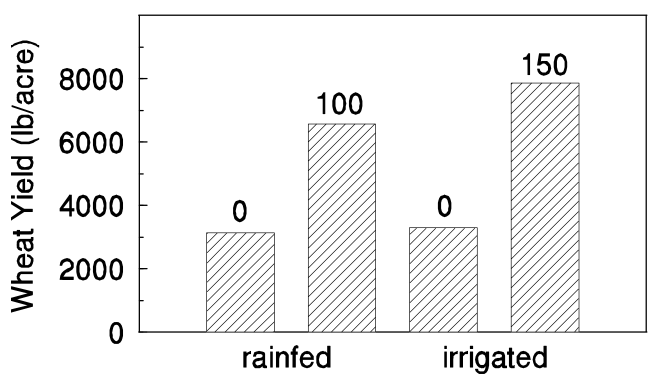


Figure 1. Yield of wheat grain, with and without irrigation, with N fertilizer amount (lbN/acre) as specified above each bar.

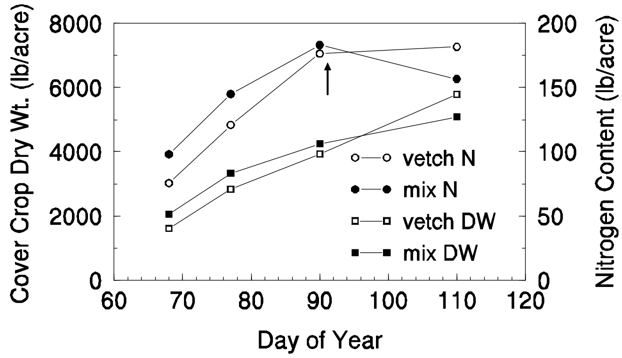


Figure 2. Accumulation of N and total dry matter in two test plots managed identically to the winter legume cover crop plots in the main experiment. Date of cover crop incorporation prior to planting corn or tomato is indicated by the

All We Are Saying, Is...

We gave peas a chance and they blew it. After considerable discussion, the LTRAS Farming Committee agreed on a mixture of Lana woolypod vetch (40 lb/acre) and Austrian winter peas (80 lb/acre) as our first winter legume cover crop. After seeding on 8 November 1993, the peas got off to a good start, but were soon overgrown by the vetch.

Two unassigned plots (see map in issue #1 of *The LTRAS Century*) were used to develop growth and N accumulation curves for the vetch/pea mix and a reference crop seeded with 50 lb/acre of vetch alone. The results (Fig. 2) do not show any benefit from including the peas with the vetch. Given the high cost of pea seed, and the difficulty of seeding a mixture of seeds differing in size, we may use vetch alone next year. (The LTRAS Farming Committee has not yet discussed these data.)

These results are based on unreplicated plots, (although vetch was observed to overgrow peas in all of our cover crop plots) for only one year and one location, so they may not be widely applicable. A mixture, or peas alone, might do better in other years. UC Publication #21471, *Cover Crops for California Agriculture*, by P.R. Miller, W.A. Williams, and B.A. Madson, reported accumulation of 6,700 lb dry matter and 247 lb N per acre of Lana vetch grown at Davis, vs. 5,600 lb/acre and 206 lbN/acre for Austrian winter peas.

Vetch also appeared to be highly competitive with winter weeds. On the other hand, the presence of the vetch precludes the use of cultivation or herbicides for weed control. Differences in weed populations between the wheat/fallow and wheat/vetch systems are expected to develop within a few years. We may eventually see evolution of distinct ecotypes adapted to each system, although transfer of seeds and pollen between cropping systems could slow this process.

A major reason for monitoring cover crop dry matter and N accumulation over time was to provide information relative to tradeoffs between maximum N accumulation and the earliest feasible seeding date for corn and tomatoes. It appears that the date of incorporation for the cover crop preceding corn and tomato corresponded to maximum N accumulation, as intended. Total dry matter continued to increase at least until the last date in Figure 2, which was the incorporation date for the wheat based systems. Increased incorporated organic matter could improve soil water holding capacity. However, the cover crop may also have consumed enough water during this period to affect water carryover to next year's wheat crop. Plans are currently underway to measure soil water storage for all plots in wheat based rotations.

Thanks for the Support

LTRAS continues to be supported primarily by appropriations from the **UC Davis College of Agriculture and Environmental Sciences**, the **California Division of Agriculture and Natural Resources**, the **Russell Ranch Management Committee**, and the **UC Sustainable Agriculture Research and Education Program**. We interpret this funding, in a time of very tight budgets, as indicating a continuing commitment to field research in support of a profitable and sustainable California agriculture.

We have also recently received generous donations of materials or services from the following: **Circle G Farms, Foster Farms** (Fertilizer Division), **Foundation Seed and Plant Materials Service, J.H. Meek & Sons, Lockwood Seeds, Orsetti Seed Company**, and **Pioneer Hi-Bred International**. Thanks to all of our supporters in the agricultural industry!

Our first cash gift, from UCD graduate, **Marilyn E. Miller**, was particularly welcome. She apparently responded to an alumni association fund drive by directing her gift for support of LTRAS. We encourage donations from individuals and foundations, and plan to use them to establish an LTRAS endowment. Without such an endowment, a one-year interruption of funding could potentially terminate our "100-year experiment" at any time. Donations to LTRAS may be made payable to "UC Regents", and sent to R. Ford Denison, Agronomy & Range Science, UCD, Davis, CA 95616.

Cropping System	First Year	Alternate Year
rainfed wheat control	unfertilized rainfed wheat	fallow
rainfed wheat/vetch	unfertilized rainfed wheat	rainfed vetch
rainfed wheat/fallow	fertilized rainfed wheat	fallow
irrigated wheat control	unfertilized irrigated wheat	fallow
irrigated wheat/vetch	unfertilized irrigated wheat	rainfed vetch
irrigated wheat/fallow	fertilized irrigated wheat	fallow
conventional wheat/tomato	fertilized irrigated wheat	fertilized irrigated tomato
conventional corn/tomato	fertilized irrigated corn	fertilized irrigated tomato
vetch/corn/tomato	vetch followed by irrigated corn	fertilized irrigated tomato
organic corn/tomato	vetch followed by corn w/ irrigation and organic fertilizer (compost)	vetch followed by tomato w/ irrigation and compost

Summary of the ten LTRAS cropping systems, including crops, nitrogen sources, and irrigation status. Both starting points of each two-year rotation are represented by three one-acre plots each, for a total of six plots per cropping system.

LTRAS in a Nutshell

The Long Term Research on Agricultural Systems project (LTRAS) is a 300 acre facility dedicated to long term research on the sustainability and environmental impact of agricultural systems. The first experiment is a comparison of ten annual cropping systems that differ in reliance on external inputs of water and nitrogen (see table above). For each cropping system, we will measure and analyze trends in critical soil properties (e.g., organic matter, weed seeds, pH, or salinity), and resulting differences in productivity, resource use efficiency, profitability, and environmental impact (e.g., leaching of nitrate or pesticides).

Previous long term experiments at other locations have shown that important soil parameters often change so slowly that decades are required to directly characterize sustainability from trends in yield or traditional soil analyses. LTRAS therefore has a planned duration of 100 years, to assure unambiguous characterization of sustainability. LTRAS is also expected to make important contributions to agricultural science over a much shorter time period. Information from LTRAS, together with other research at UC Davis and elsewhere, will be used to develop "leading indicators" for sustainability, such as computer models or new methods for soil and plant analysis. These new research tools will facilitate designing new cropping systems with improved performance. LTRAS is primarily a research facility, but it also serves as a resource for teaching and extension.

The LTRAS Staff

- R. Ford Denison, Director; (916)752-9688; FAX 752-4361; rfdenison@ucdavis.edu.
- Dennis Bryant; Assoc. Director; 752-5368.
- Akbar Abshahi; Staff Research Associate; 752-2763.
- David Mata; Farm Manager; 757-3162.
- Sean Eldridge; Agricultural Technician.
- Nora Tamondong, Student Assistant.

Executive Committee

- Graham Fogg; Land, Air & Water Resources, UCD.
- Robert Miller; Land, Air, & Water Resources, UCD.
- Robert Norris; Plant Biology, UCD.
- Richard Plant; Agronomy & Range Science, UCD.
- Carol Shennan; Vegetable Crops, UCD.

The LTRAS Century is an occasional publication of the Long Term Research on Agricultural Systems project at UC Davis. For a free subscription, send your name and address to:
R. Ford Denison/LTRAS
Agronomy & Range Science, UCD
Davis, CA 95616