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Practical lessons for successful long-term cropping systems experiments

William F. Schillinger*

Department of Crop and Soil Sciences, Washington State University, Dryland Research Station, P.O. Box B, Lind, WA 99341, USA.
*Corresponding author: schillw@wsu.edu

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Abstract

Many lessons in long-term cropping systems experiments are learned from practical experience. I have conducted large-scale, long-term, multidisciplinary dryland and irrigated cropping systems experiments with numerous colleagues at university and government research stations and in farmers' fields in the USA and in developing countries for 25 years. Several practical lessons learned through the years are outlined in this short commentary. While some of these lessons learned may be intrinsically obvious, results of many cropping systems experiments have not been published in scientific journals due to fatal flaws in experimental design, improper transitioning between phases of the experiment and many other reasons. Ongoing active support by stakeholders is critical to maintain funding for long-term cropping systems studies. Problems and unexpected challenges will occur, but scientists can often parlay these into opportunities for discovery and testing of new hypotheses. Better understanding and advancement of stable, profitable and sustainable cropping systems will be critical for feeding the world's projected 10 billion people by the mid-21st century.

Key words: long-term cropping systems experiments, crop rotations, world food needs

Introduction

Long-term cropping systems experiments are widely recognized as an ideal mechanism to encourage scientists of different academic disciplines to work toward a common goal[1]. There is a wealth of information on long-term cropping systems experiments related to agronomy, sustainability, environmental concerns, weeds and diseases, soil quality, fertility, economics and other factors[2,3]. There is also a vast quantity of information in the scientific literature and in textbooks on how to design and interpret data from long-term experiments. However, the 'practical' and 'everyday' aspects of successful long-term cropping systems endeavors have received much less attention.

I have spent the majority of my professional career as a cropping systems research agronomist in developing countries and in the Pacific Northwest region of the USA. There are some basic principles or 'lessons learned' from this experience with successful long-term cropping systems experiments that have not been adequately emphasized in the scientific literature and in university classrooms. The principles outlined below apply across diverse cultures and environments, whether: (i) the average farm size is 0.2 or 2000 ha, (ii) implements are pulled by bullocks or 450 hp tractors, or (iii) the grain is threshed by hand or with a fleet of modern combines.

Lessons Learned

1. Form a farmer advisory group of progressive individuals who have a strong vested interest in the research. Allow farmers to play an active role in designing crop rotation treatments. When farmers feel ownership in a project they are likely to remain strong supporters throughout the life of the project[4].
2. Set term limits for farmer advisors (e.g., 3–6 years). Some advisors make numerous valuable contributions and maintain a high level of interest, whereas others do not. The most valuable advisors are likely to agree to serve an additional term. Term limits provide a diplomatic means to end the service of the less energetic advisors and open opportunities for new members.
3. Collaborating scientists will largely determine the success of the study. Put a great deal of thought into what academic disciplines best contribute to the cropping systems team. Look closely at the publication record of experienced scientists. If an individual has an

excellent track record, he or she will be likely to continue to publish regularly. Certainly seek out and mentor enthusiastic new-career scientists and encourage their participation.

4. Involve a statistician from the very first to ensure that the experimental design is valid and the most appropriate for the study[5].
5. Plan to conduct the cropping system experiment for at least 6 years or through two complete cycles of the crop rotations. Each crop in all rotations must appear each year for valid statistical analysis.
6. Ideally, systems experiments should have a staggered start to account for temporal entry into the rotation, but this is seldom imposed because it is not practical.
7. For a valid statistical interpretation of results, all crop rotation treatment combinations must have a common year denominator. For example, with 2-year, 3-year and 4-year crop rotations, the experiment needs to be conducted for 12 years.
8. Obtain and archive baseline soil samples at the beginning of the experiment so that changes over time in carbon, microbial activity and other soil quality indicators can be documented.
9. If possible, conduct long-term experiments at a university or government research station where land and facilities are guaranteed to be available[6]. Mistakes are less likely to occur at a research station than in a cooperating farmer's field. Labor and equipment resources are most efficiently utilized when travel and equipment hauling are kept to a minimum. It generally costs much less to conduct a cropping systems experiment at a research station than in a farmer's field. In addition, personnel at research stations are available to check the experiment daily, if needed.
10. If the long-term experiment is located on a farmer's field, do not expect a cooperating farmer to use and operate his own equipment to conduct field operations (e.g. planting, harvesting and herbicide application). This may be feasible for the first few years when the experiment is new and novel, but the farmer needs to manage his own field operations during the same time period and the experiment is not likely to receive high priority. Plan to provide your own personnel and preferably your own equipment to ensure that field operations are conducted in a timely manner.
11. Become a trusted friend of your cooperating farmer. Do not become a burden. Pay an annual rental fee for the land. List the cooperating farmer as a co-author on all popular and extension publications from the experiment.
12. Consider purchase or fabrication of smaller customized implements, such as no-till drills to facilitate the transport of equipment to and from sites and to reduce tractor size requirements.
13. Equipment may need to be customized for cropping systems experiments. For example, many cropping systems experiments involve conservation-till or no-till management. A small-plot combine is accurate for grain yield determination, but most machines lack proper chaff and residue spreading capability. Residue and chaff spreaders can be fabricated for small-plot combines[7].
14. Many cropping systems experiments do not contain enough treatments and/or replicates to provide adequate degrees of freedom for error to statistically detect treatment differences[8]. Try to maximize the degrees of freedom for error. Remember that the degrees of freedom for error are based on the number of treatments and replications.
15. When field operations or data collection cannot be completed in one day, always stop work for the day at the end of a replicate. This ensures that all treatments within a replicate are exposed to the same environmental factors (e.g., rain, heat and shattering) that may occur from one day to the next.
16. Funding for long-term cropping systems research is often difficult to obtain (and maintain), because answers cannot be obtained within the typical 3-year grant cycle[9]. Even modest set-aside funds from the university experiment station (e.g., Hatch funds) or other sources can go a long way in sustaining long-term experiments.
17. Long-term cropping systems experiments provide critically important data on soil quality[10], soil biology[11], carbon sequestration[12], nitrous oxide emissions[13], nutrient cycling[14] and weed ecology[15]. Such information is of interest to a worldwide audience.
18. If feasible, include a production economist on the team as economic returns of cropping systems are of foremost concern to farmers[16].
19. Be open to new ideas and view problems and surprises as potential opportunities. As an example, Rhizoctonia bare patch (*Rhizoctonia solani* AG-8) appeared in year 3 of a long-term no-till dryland cropping systems experiment in eastern Washington. The fungal root pathogen stunted all cereal and broadleaf crops in the experiment. Rhizoctonia bare patch at these high levels had not previously been encountered in the USA. Scientists decided to map the distribution of bare patches from year to year with a backpack-mounted global positioning system. The severe expression of Rhizoctonia bare patch was unexpected, but led to a unique opportunity to publish journal articles about the epidemiology of this pathogen under long-term no-till management[17].
20. Although scientists need to 'lock in' and stay with the crops and crop rotations throughout each phase of the long-term experiment, there is often an opportunity to superimpose new experiments, especially with wide plots. If the plots are narrow to begin with, options for future additional treatments are limited. Long-term cropping systems experiments continually generate new hypotheses to be tested. Embedding sub-experiments within a long-term study can be a good

way to obtain grant funding to support the long-term effort without comprising the integrity of the treatments already in place.

21. Hold field days at your research site. Scientists, graduate students, farmers and others involved in the experiment will welcome the opportunity to share their data, expertise and insights. Hands-on demonstrations, such as soil quality changes with different management practices, are popular and can carry an excellent take-home message. For field days at off-station cropping systems research sites, always feature the cooperating farmer as a key speaker as he will have important insights into what works and does not work on his farm.
22. Publish results in peer-reviewed journals at regular intervals. Decide beforehand which scientist(s) will take the lead on articles and the time frame when the articles will be written.
23. Do not stop with the publication of your research in a scientific journal article. Publish your research as an Extension Bulletin, Extension Video, or other popular format. Convert units of measurement to those used by farmers. For example, farmers in the USA use English, not metric, units. Delete unneeded verbiage (e.g., scientific names for plants and herbicides) and include interesting and relevant photos. Remember that you must obtain permission from the scientific journal in which the research was published before making the information available to stakeholders in an alternative format. I have never been refused permission by a journal to make information available in an alternative format for stakeholders. Many universities and government agencies have extension publication units that publish Extension Bulletins at no cost to the authors.

Conclusions

Following basic common-sense principles will help scientists achieve success in long-term cropping system experiments. As a research agronomist, I have collaborated most closely with a soil microbiologist, production economist, plant pathologist and soil physicist in cropping systems research endeavors. The specialty areas of scientists needed to address key issues will, of course, vary depending on the experiment. A major goal of the United Nations and other organizations is the widespread adoption of conservation agriculture[18]. To achieve this goal, more long-term systems experiments need to be conducted throughout the world. Long-term experiments provide the best and foremost scientific information for understanding the sustainability and stability of cropping systems.

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