ON-FARM TRIALS AND STATISTICS

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ABSTRACT

New technologies have made on-farm research easier to do. On-farm research networks exist in several states and are also being run by some national programs. These networks are becoming more common. University and/or government agency scientists and educators typically provide statistical expertise. Historical guidance for experimental design has focused on the randomized complete block design (RCBD). Statistical analyses that can be run easily are for an RCBD conducted in one site and one year. In the future, freely-available statistical tools may help transition farmers and agricultural industry professionals to conducting more sophisticated analyses such as multi-site, multi-year studies as well as rate studies.

INTRODUCTION

The process of scientific discovery is conceptualized in Figure 1. The process is a continuous cycle. It starts with defining a problem or question, which relies on agronomic expertise. This question is then formulated in terms of a statistical hypothesis, which can either be accepted or rejected. An experimental design is then created that allows the hypothesis to be tested. An effective design allows any signal in the treatment differences to rise above background noise. Data are collected following some set of protocols and then are statistically analyzed to determine if the variability imposed by the treatments was in fact greater than the natural variability in the conditions studied. The results of statistical analyses are then interpreted using agronomic and economic knowledge. Based on these interpretations, new or revised recommendations are created. To be adopted, these recommendations must prove technically, logistically, and economically advantageous. During or after recommendation adoption, new problems or questions arise, and the cycle starts once again.

In the traditional model of applied research at land-grant universities, Cooperative State Research, Extension, and Education Service (CSREES) soil fertility specialists and educators were responsible for all phases of the discovery cycle; however, the development of new technologies such as variable rate controllers, geo-referencing through the global positioning system, geographic information systems, and yield monitors have facilitated on-farm research. Farmers and members of agribusiness can now participate more easily in the discovery cycle, and partnerships have begun where Extension, industry, government, and farmers divvy the workload but still complete the cycle. These partnerships exist in several states in on-farm research networks.

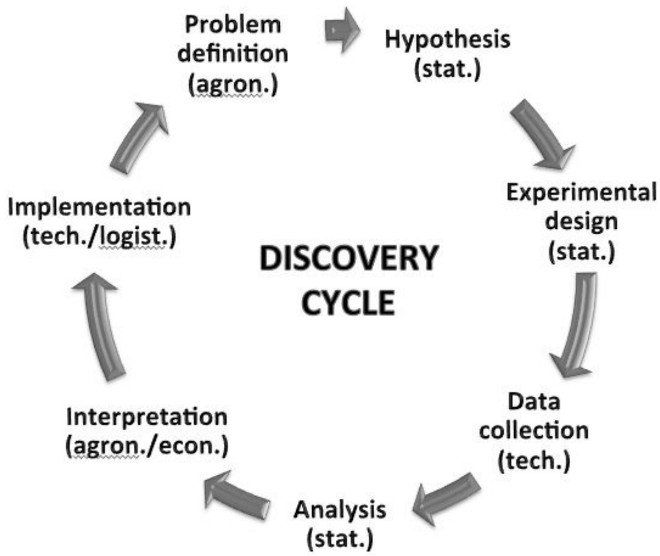

Figure 1. Elements of the discovery cycle with primary expertise in parentheses: agron. = agronomic; econ. = economic; logist. = logistical; stat. = statistical; tech. = technical.

ON-FARM RESEARCH NETWORKS AND REPORTS

On-farm research networks are being used primarily to test the efficacy and/or rates of commercial inputs and changes to cropping systems. As these networks expand in the future, they may be able to assume a greater part of the demand for this type of research, allowing the Extension soil fertility specialists to focus on other hypotheses. Below are some descriptions of existing on-farm networks.

1. Iowa Soybean Association On-Farm Network®

This network is funded by the Iowa Soybean Association and started in 2000. There is a dedicated staff to manage the network. Experiments compare a farmer's current practice to one alternative. Project results are publicly distributed and the organization holds an annual conference, the On-Farm Network® Conference. Trial results are publicly available back to 2008.

(http://www.isafarmnet.com)

2. Kansas Ag Research and Technology Association (KARTA)

The association is governed by a Board of Directors composed of producer, Kansas State University, and agricultural industry representatives. The goals of KARTA are to facilitate on-farm research, find funding through grants, sponsor the annual Precision Ag Conference, communicate results, and adopt information-sharing tools. The organization started in 2000. Study results are publicly available back to 2005.

(http://www.kartaonline.org)

3. Nebraska On-Farm Research Network (NOFRN)

This program is sponsored by the Nebraska Corn Growers Association and the Nebraska Corn Board. The University of Nebraska provides expertise on statistical design, harvest data collection and formatting, statistical analysis, and interpretation, both agronomic and economic.

An annual report of all projects occurring statewide is shared with all farmer participants and released to the public. Reports are available back to the early 1990s.

(http://cropwatch.unl.edu/web/farmresearch/home)

4. Ohio On-Farm Research

Research is conducted by The Ohio State University CSREES professionals and is peer reviewed by two reviewers. Reports are publicly available and extend back to 1997.

(http://agcrops.osu.edu/on-farm-research)

5. Penn State On-Farm Research

The program is facilitated by the Penn State CSREES at the state and county levels. The program has a dedicated coordinator who is a staff member of Penn State University. Reports are publicly available back to 2002.

(http://extension.psu.edu/on-farm)

6. Practical Farmers of Iowa (PFI) Cooperator's Program

The program is supported by a competitive grant from the Leopold Center for Sustainable Agriculture. The PFI was founded in 1985. The program holds an annual brainstorming meeting where project ideas are formulated. To cooperate, one must be a PFI member. Cooperators work with PFI staff in all phases of discovery. One member of the staff is the Research and Policy Director who directs the Cooperator's Program. Research reports are publicly available back to 1987.

(http://practicalfarmers.org)

7. Purdue Collaborative On-Farm Research

The program brings together Indiana Certified Crop Advisers (CCAs), Purdue County Extension Educators, and Purdue Extension specialists. Summary reports using on-farm data are publicly available.

(http://www.agry.purdue.edu/ext/ofr/)

8. Solutions to Environmental and Economic Problems (STEEP) II On-Farm Testing Project

The STEEP II On-Farm Testing (OFT) Project is a research and education program supported by the University of Idaho, Oregon State University, and Washington State University. Funding has been provided through CSREES and through the United States Department of Agriculture – Agricultural Research Service (USDA-ARS). The STEEP II OFT program is managed by three committees: 1) the Technical Coordinating Committee, comprised of scientists from University of Idaho, Oregon State University, and Washington State University, as well as scientists for the USDA-ARS and a representative from the USDA Natural Resources Conservation Service (NRCS); 2) the Industry Advisory Committee composed of two growers from each of the three states who represent farmer organizations; and 3) the Administrative Committee composed of research and Extension sectors in each of the three universities as well as the USDA-ARS and USDA-NRCS. Reports back to 1998 are publicly available.

(http://pnwsteep.wsu.edu/onfarmtesting/)

9. Sustainable Agriculture Research and Education (SARE) Program

The SARE Program is present in all U.S. states and is managed by region. There are four major regions: Northeast, North Central, Southern, and Western. SARE offers competitive grants for research and education. Grants are available, depending on region, to researchers, educators, producers, CSREES, graduate students, and community organizations. Reports are available in a searchable database.

(http://www.sare.org/)

Partitioning the Discovery Cycle in On-Farm Networks

In the nine on-farm networks above, the phases of the discovery cycle that require statistical expertise (hypothesis, design, and analysis) are typically centralized and are managed by scientists or educators with Ph.D. or M.S. degrees. In only one case, 8. STEEP II OFT, is there a publicly available, customized online tool for statistical analysis. Farmer and industry cooperators are generally responsible for data collection and management. Farmers, industry professionals, and university researchers and educators generally work as a team on the interpretation, implementation, and problem definition phases.

EXPERIMENTAL DESIGNS

Some on-farm networks are developing experimental design examples and/or protocols for their cooperators to follow. Table 1 lists various types of comparisons for which such guidance exists. Each comparison is categorized according to the 4R Nutrient Stewardship component: Right Source, Right Rate, Right Time, or Right Place (IPNI, 2012). The focus has been primarily on nitrogen (N).

Table 1. Crop nutrient experimental designs currently available online from on-farm research networks.

4R Component	Comparisons	On-farm research network no.
N source	+/- inhibitor	1
N source	UAN vs. anhydrous ammonia	1
N rate	Farmer practice +/- *X* lb N/acre	1, 3
N rate	Rate based on field average yield vs. rate based on yield map	3
N time	Side-dress vs. pre-plant + side-dress	1
P form	MAP or DAP vs. MESZ vs. check	1
S rate	Check vs. *X* lb S/acre	1

General guidance for on-farm experimental designs also exists both inside and outside each network's website. Table 2 provides information on which designs are discussed in various publications. The randomized complete block design (RCBD) is the most discussed design for on-farm research.

Table 2. Statistical designs discussed in various publications.

Design	References
Completely randomized design (CRD)	Davis et al., 2012; Havlin et al., 1990
Randomized complete block design (RCBD)	Anderson, 1996; Anderson et al., 2004; Baldwin, 2004; Davis et al., 2012; Exner and Thompson, 2008; Ketterings et al., 2012; Rzewnicki , 1992; Sooby, 2012; Sundermeier, 1997; Veseth et al., 1999
Split-plot design	Anderson et al., 2004; Davis et al., 2012; Sooby, 2012

DATA ANALYSIS

Many on-farm research guides do not provide instructions on data analysis. Instead, they suggest that farmers and/or industry professionals consult with university scientists; however there are some publications that show how to perform the calculations needed to conduct certain statistical tests. Table 3 shows that guidance exists for conducting an analysis of variance (ANOVA), a least significant difference, and a Student's t-test. In all cases, the analyses provided are valid for one site in one year.

Table 3. Publications providing guidance on specific statistical tests.

Analysis	References
Analysis of variance (ANOVA)	Anderson, 1996; Baldwin, 2004; Murrell and Moore, 2001; Rzewnicki , 1992
Least significant difference (LSD)	Anderson, 1996; Baldwin, 2004; Exner and Thompson, 2008; Murrell and Moore, 2001; Rzewnicki , 1992
Student's t-test	Exner and Thompson, 2008

There are online resources for conducting certain types of statistical analyses. The most widely cited resource is AGSTATS02, an online tool that allows users without any statistical background to enter data for either a CRD or a RCBD and receive an analysis of variance with an LSD test for mean separation (Sano and Gunadi). AGSTATS02 works for one site-year of data. A resource for fitting a series of regression curves through rate data is the Crop Nutrient Response Tool (Bruulsema, 2013). Finally, R is a very powerful open-source statistical package that is accepted and used by the scientific and statistical communities; however, R is not for those looking for an intuitive, simple tool. It requires knowledge of commands and uses a command line entry format (R Development Core Team, 2008).

THOUGHTS ON FUTURE DIRECTION

Historical efforts have focused on using the RCBD and associated ANOVA and LSD for one site-year. In the future, tools similar to AGSTATS02 may be developed that are freely available, do not require statistical expertise by users, and can pull from the statistical computing power of R. Priorities for future tool development should be on multi-year and multi-site analyses as well as on regression analyses for rate studies.

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