SYMPOSIUM—ANALYSIS OF UNREPLICATED EXPERIMENTS

Introduction

Stephen Machado* and Steven E. Petrie

The following four papers were presented at the symposium entitled "Analysis of Unreplicated Experiments" held during the 2005 ASA–CSSA–SSSA annual meetings in Salt Lake City, UT. The symposium was organized by Dr. Stephen Machado and Dr. Steven Petrie, both based at Oregon State University, Columbia Basin Agricultural Research Station, Pendleton, OR. The symposium was sponsored by Oregon State University. We also gratefully acknowledge those presenters who provided their own transportation and accommodations.

Replication of treatments is a fundamental concept of statistical analysis. It is safe to say that all agricultural scientists are aware of the need to replicate experimental treatments to calculate an estimate of the experimental error variance. Without replication, it is difficult to assess the underlying error against which treatment effects should be judged. Therefore, whenever possible, experimental treatments should be replicated.

Nonetheless, there are a great many situations in which replication is excessively impractical, prohibitively expensive, or simply impossible. Examples of unreplicated experiments include long-term experiments initiated before our current understanding of statistics, various ecological and watershed studies, large field-scale research trials, demonstration plots, geological research, biomedical research, and demographic studies. Long-term agricultural experiments offer us an unequaled opportunity to study the effects of various practices on soil biological, chemical, and physical properties. However, some of the oldest long-term experiments were initiated before the science of statistics was fully developed. Examples include the Rothamsted classical experiments at Rothamsted, U.K. (established in 1843) that are not replicated (Leigh and Johnston, 1994), and the Columbia Basin Agricultural Research Center (CBARC) experiments (Pendleton, OR) (established in 1931) that are replicated but have ordered treatments. Both of these long-term experiments and others are an invaluable resource for studies involving yield trends, soil carbon and nutrient dynamics, and agricultural sustainability. The immense amount of irreplaceable information in the databases from these long-term experiments should not be ignored because of the lack of replication or randomization. Other types of agricultural research may not be replicated. Replication in the large field-scale trials that are common in site-specific farming research is prohibitively expensive; georeferenced locations within the field are instead studied and analyzed using geostatistics (Pierce and Sadler, 1997; Robert et al., 1996, 1999). In some cases, nonreplicated demonstration trials are used by county agricultural agents and agribusiness to show comparisons of tillage practices, varieties, pesticides, fertilizers, or other inputs. In other cases, mistakes in the conduct of an experiment through treatment application may reduce or eliminate replication. Many ecological and hydrologic studies defy replication; how can the particular details of variables such as vegetation, soils, slope, precipitation, and temperature be replicated across a landscape? However, methods to analyze paired watersheds are available (Meek et al., 2000). Geological studies cannot be replicated, so spatial analysis is usually employed in the statistical analysis of geological features (Isaaks and Srivastava, 1989; Chilés and Delfiner, 1999).

The use of nonreplicated experiments is not limited to agriculture or the natural world. Biomedical research does not utilize replication; consider the case of studying the effects of smoking. Either the individual smokes or does not; without cloning the individual, there is only one person to examine. As another example, one cannot impose both surgery and nonsurgery on the same patient. Replication in demographic studies is difficult, if not impossible. Finally, there is no replication in the world of commerce. Apple, Compaq, and Dell; Ford, Toyota, and Hyundai; Bank of America, Wells Fargo, and Citicorp—none of these corporations are replicated, yet there are statistical methods that permit valid comparisons of their financial performance.

Much of the world relies on data generated in nonreplicated experiments. In fact, agricultural examples constitute a small percentage of the examples used in SAS notes and guidelines publications. Most of the programs are derived from real-world situations that cannot be duplicated. There have been many developments in statistics that permit researchers to analyze these types of unreplicated treatments and to collect important information that cannot be gleaned in any other way.

Against the backdrop of these and many other fields that successfully utilize unreplicated experiments, it is rather puzzling that many agricultural scientists are uncomfortable with these methods and consider data from

Oregon State Univ., Columbia Basin Agricultural Research Center, P.O. Box 370, Pendleton, OR 97801. Contribution of Oregon State University, Columbia Basin Agricultural Research Center, P.O. Box 370, Pendleton, OR 97801. Received 16 May 2006. *Corresponding author (Stephen.Machado@oregonstate.edu).

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677 S. Segoe Rd., Madison, WI 53711 USA

unreplicated experiments to be unscientific and therefore not acceptable for publication. Our heavy reliance on ANOVA has limited our ability to work with and interpret the data from experiments that fall outside this norm. Reviewers and editors reject information from unreplicated experiments, yet there is a sea of information in the literature illustrating the various techniques that can be used to analyze unreplicated experiments (Box and Meyer, 1986a, 1986b, 1986c, 1986d; Meyer, 1987; Lenth, 1989; Scheiner and Gurevitch, 1993; Balakrishnan and Hamada, 1994; Ellekjaer et al., 1995; Loughin and Noble, 1997; Hamanda and Balakrishnan, 1998; Loughin, 1998a, 1998b; Barrentine, 1999; Angela and Voss, 1999; Ye et al., 2001; Loeppky and Sitter, 2002; Milliken and Johnson, 1989, 2002; and Perrett, 2004). This symposium was designed for researchers conducting studies with unreplicated treatments and editors and reviewers who are asked to review these types of studies. The objectives of this symposium were to discuss and illustrate some of the statistical methods that permit valid comparisons to be made in studies with unreplicated treatments and to create a springboard for further discussions on this topic.

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