Quantifying Farmer Evaluation of Technologies: The Mother and Baby Trial Design

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Abstract

This paper presents five years of experience in Malawi, experimenting with a novel mother and baby trial design to systematically connect assessment of technologies by farmers with biological performance. This design consists of two types of trials. The "mother" trial is replicated within-site to test a range of technologies and research hypotheses under researcher management. This trial is either located on a research station or on-farm, e.g., at a central location in the village. The "baby" trial comprises a number of satellite trials (each trial is one replicate) of large plots under farmer management and farm resources. Each trial compares one to four technologies (usually a subset of those tested in the mother trial chosen by the farmer or researcher) with farmers' technologies/cropping systems. Researchers indicate the recommended management for each technology, then monitor actual farmer practice, and document farmer perceptions and ranking. Researchers test complex questions (e.g., variety response to inputs) at the central mother trial, while farmers gain experience with the subset of technologies. Farmer perceptions are systematically monitored together with biological performance of the technologies. Farmer participation in the design of baby trials can vary from limited to high, depending on the research objectives. This linked trial process provides quantitative feedback to researchers for improving the design of future technologies. In this study, different analytical tools were used in conjunction with the trial design. Biological performance data included "adaptability analysis", which consists of regressing yield or other data against an environmental index (average yield, soil factor, or others), analysis of variance and marginal rate of returns economic analysis, and evaluating benefits and risk aversion. Survey data included the use of descriptive statistics for different farmer group answers, analysis of the ranking of technologies by farmers, grouping answers from open-ended questions, and expressing each answer as a percentage of all answers.

Introduction

There has been limited adoption of improved seed and farming technologies by smallholder farmers in many regions of the world. According to the participatory research literature, one of the major barriers to uptake has been insufficient attention to understanding farmer priorities and perceptions (Chambers et al. 1989; Ashby and Sperling 1995). Researchers and extension staff are frequently aware that farmers need to be consulted and that indigenous knowledge should be documented, however the time and resources required for participatory research are seen as onerous (Snapp et al. 2002a). Rigorous and practical tools are urgently required to improve the process of participatory variety selection and technology development (Bellon 1998). This workshop was convened to address the need for quantitative methodology and statistical approaches to document farmer criteria and perceptions.

In this paper we discuss five years of experience in Malawi, experimenting with a novel mother and baby trial design to systematically connect farmer assessment of technologies with biological performance (Snapp 1999). Methodical cross-checking of performance evaluation by researchers and farmers provides complementary rather than competing information from conventional research and participatory processes (van Eeuwijk et al. 2001). We investigated the biological performance of intensified legume use within a maize-based system, and invented the mother and baby trial concept to test the potential for widespread adoption of these technologies by smallholder farmers in southern Africa (Snapp et al. 2002b).

The lessons regarding on-farm trial design and documenting farmer perceptions appear to have wider application than Malawi—the mother and baby trial design is meeting acceptance by many researchers in the region. Scientists from the International Maize and Wheat Improvement Center (CIMMYT) have recently adapted the trial design, using an incomplete lattice design for baby trials, to conduct hundreds of linked mother and baby trials in southern and eastern Africa (Bänziger and Diallo 2001). A survey of 30 participatory research scientists conducted in 2001 found that 11 were using the mother and baby trial design or were in the process of adopting it, which frequently included adapting it to local circumstances (Morrone and Snapp 2001). The primary reason cited for interest in the approach was the ability to systematically involve many farmers and to rapidly elicit evaluation of technologies and varieties.

On-Farm Trial Methodology

It is now over 20 years since the farming-system approach was initiated in southern Africa, and now research is primarily conducted on-farm (Heisey and Waddington 1993). Methods to document the biological performance and yield potential of varieties and technologies are widely known. For example, it is highly recommended that on-farm trials be conducted at representative, well characterized sites, so that results can be extrapolated to recommendation domains. In some cases researchers use trial designs on-farm similar to those conducted at research stations, with four or five replicated plots per treatment and a randomized complete block or similar design. Generally farmers are treated in a contractual manner, and this trial design can be an effective means for evaluating technology performance under edaphic conditions typical of a farming community.

Another widely used approach is to conduct a large number of on-farm trials to evaluate technology performance across a spectrum of environments (Fielding and Riley 1998; Mutsaers et al. 1997). This takes into account the variability of the heterogeneous environment that characterizes many smallholder regions. A trial design where each site acts as a replicate is one approach that allows many environments to be sampled (Mutsaers et al. 1997). Adaptability analysis and related statistical tools can use data from the many sites to evaluate technology performance across different environments. This may make it possible to detect which varieties perform best in a weedy environment or on acid soils, for example (Hildebrand and Russell 1996). Another recently developed tool for multi-environment trial data is multiplicative mixed models, which can be used to model genetic variances and covariances. These statistical approaches are illustrated by van Eeuwijk and colleagues (2001) for participatory breeding and variety selection in barley.

Despite the extensive on-farm experience of many research programs, there is still widespread inability to understand or take account of farmers' priorities. Farmers' production priorities are often assumed to focus on maximizing yields or financial returns, while in reality they may be concentrate on gaining the best return from a very small cash investment, or on maximizing food security (Snapp et al. 2002a). Tools to evaluate potential profitability of technologies from trial data are documented, such as partial budgeting to estimate economic returns (CIMMYT 1988).

In contrast to economic budgets, there is limited documentation of methodology that systematically involves farmers in technology evaluation. There are a few outstanding examples, however, such as the use of expert farmer panels to document farmer criteria and improve variety selection in West and East Africa (Sperling et al. 1993; Kitch et al. 1998). Other methods are described in newsletters, working papers, and other publications that are important, but can be difficult to access (Bellon 1998; Kamangira 1997). Here we describe an approach that facilitates and documents the hands on experience of farmers. This provides a relatively rapid and rigorous approach to systematically involving farmers in the development of best bet technologies or varieties. Researchers assess input from farmers through surveys, farmer ranking of technologies, and by monitoring farmer adaptations and spontaneous experimentation (Snapp et al. 2002a). Through the mother and baby trial design we catalyze and improve on the ongoing experimentation by farmers through a systematic process.

Mother and Baby Trial Case Study

The sites

Four agroecosystems for participatory research were chosen in Central and southern Malawi, where about 70% of the country's smallholder agriculture is practiced. The agroecosystems, with the study sites in parentheses, are:

1. Central Malawi: subhumid, mid altitude plain (Chisepo, Mitundu, and Mpingu)

2. Central Malawi: subhumid, high altitude hills (Bembeke)
3. Malawi lakeshore: semi-arid zone (Chitala and Mangochi)
4. Southern Malawi: subhumid, mid altitude plateau (Songani)

Mother and baby trial design

The "mother and baby" trial was named by one of the farmers involved in the trials. The "mother" trials test many different technologies, while the "baby" trials test a subset of three or fewer technologies, plus one control (Snapp 1999). The design makes it possible to collect quantitative data from mother trials managed by researchers, and to systematically crosscheck them with baby trials on a similar theme that are managed by farmers (Figure 1). The design is flexible: the mother trials described here were located on-farm at central locations in villages, but they can be located at nearby research stations (Snapp 1999). The level of farmer participation in baby trial design and implementation can vary from consultative to collaborative. We discuss here a consultative process where researchers lead the implementation of baby trials, however the role of farmer participation in baby trials can be much higher. For example, at the Bembeke site, the nongovernmental organization (NGO) Concern Universal has catalyzed greater farmer involvement, including in baby trial design (Figure 2).

This study started in 1996, when soil scientists and agronomists from the University of Malawi and the Malawian Department of Agriculture and Irrigation met to synthesize published information and results from years of on-farm research (Figure 3a). Reconnaissance surveys and village meetings helped to form the hypotheses that smallholder farmers have limited resources, use small amounts of mineral fertilizer, and experiment with alternative nutrient sources such as legume residues (Kanyama-Phiri et al. 2000). Researchers designed best bet technologies to improve soil productivity that required minimal cash

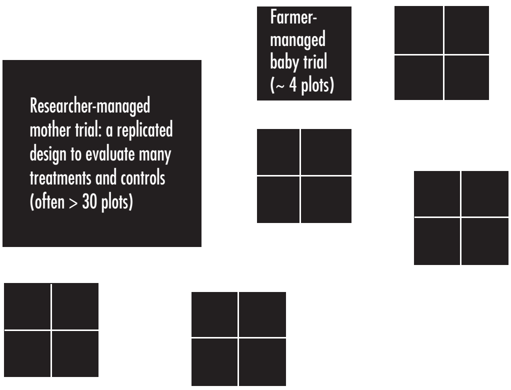

Figure 1. Mother and baby trial design layout. A mother trial is centrally located in a village or at a nearby research station and replicated on-site. Baby trials are located in farmers' fields and compare a subset of technologies or varieties from the mother trial. Each baby trial site is a replicate.

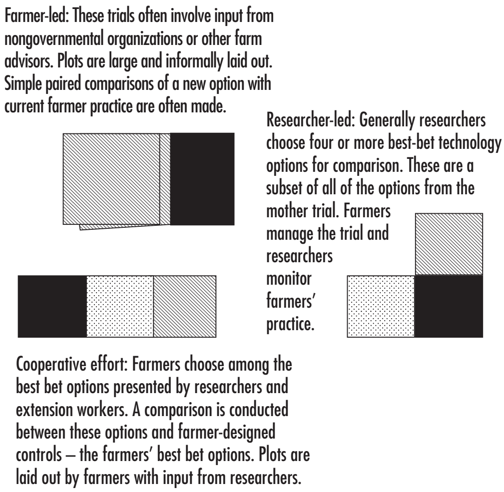

Figure 2. Different levels of farmer and researcher participation in the design and implementation of baby trials.

and labor. Representative villages in key agroecosystems were chosen on the basis of information from community meetings, consultations with extension staff, and government statistics on population density and agroclimatic data (Snapp et al. 2002a). The selected villages had to be representative of four major agroecozones and in terms of population density and access to markets.

The researchers involved in the mother and baby trials selected the "test" farmers in collaboration with community members at a meeting. They asked for volunteers and stressed the need to include both well-off farmers and those with few resources, as well as households headed by women. The trial design was geared to meet both farmers' and researchers' objectives, which by no means are identical. Relatively simple "one-farmer, one-replica" trials were managed by farmers as satellites or baby trials to a central mother trial, which was managed by researchers and had within-site replications (Figure 1). A trial design with a maximum of four plots and no replication within the farmer's field fits a limited field size, simplifies the design, and makes it easier for farmers to evaluate technologies.

Many replicates across sites make it possible to sample wider variations in farm management and environment (Fielding and Riley 1998; Mutsaers et al. 1997). However, replication within a site and intensive, uniform management improve research on biological processes. The mother and baby trial design is the first attempt we are aware of that methodically links "replicated within a site" researcher-led trials with "one site, one replica" farmer-led trials (Figure 1). Van Eeuwijk and colleagues (2001) advocate using both types of trials, but do not explore the deliberate, simultaneous use of the trials in a design that systematically links the two.

Technology evaluation in the mother-baby trial approach

Farmers initially chose their test technologies on the basis of information given in introductory community meetings (Figure 3a). Descriptions of promising technology options were presented, and visits to research station trials were arranged where possible. Researchers and assistants provided supervision and interaction through monthly visits to sites. Enumerators were based at each site to assist with trial setup and measurements, in collaboration with local extension or NGO staff and farmers (Figure 3b). Training in participatory approaches and survey techniques to reduce bias was conducted at annual project meetings.

Plot size for mother and baby trials was approximately 8 m by 8 m. Ridges were prepared by hoe and placed about 0.9 m apart, following conventional practice. A wide range of cropping system technologies was compared to current farmer practice, as described in Snapp et al. (2002a). The mother trials were planted by extension staff with assistance from enumerators within 10 days of the arrival of the rainy season. It was interesting to note that farmers were very timely in planting their baby trials—in many cases they were planted before the mother trials.

Data collected from trials included: plot size measurements, planting date, emergence date, population density at emergence, early weed cover, dates when plot was weeded (plots were weeded twice, approximately 5 and 10 weeks after planting), aboveground biomass of a subsample of legumes measured at flowering, harvest plant population, and grain yield at harvest. Fresh weight measurements were conducted in the field, and subsamples of 5-15 kg were collected to determine grain moisture content and dry weight to fresh weight conversions. Soil samples from the topsoil were collected at all sites, and soil pH, organic carbon, inorganic nitrogen, and texture analyses were conducted (Snapp et al. 2002a).

The farmers provided quantitative feedback on their evaluation of technologies to researchers through surveys, paired matrix ranking, and by rating technologies. Examples of the type of short survey and rating exercises used are presented by Bellon (1998). Qualitative feedback was obtained from meetings between farmers and researchers and comments recorded at field days. The mother trials were evaluated more informally during discussions held at field days. This made it possible to integrate the farmers' assessment and improve research priority setting (Figure 3c). Meetings were also held with senior stakeholders, conducted as part of an iterative process to maintain support and inform priority setting at every level. This included policymakers, supervisors of extension and NGO staff, senior researchers, and industry representatives (Figure 3c).

Statistical analysis

Adaptability analysis was used for an initial review of all the data combined from mother and baby trials (Hildebrand and Russell 1996). This regression

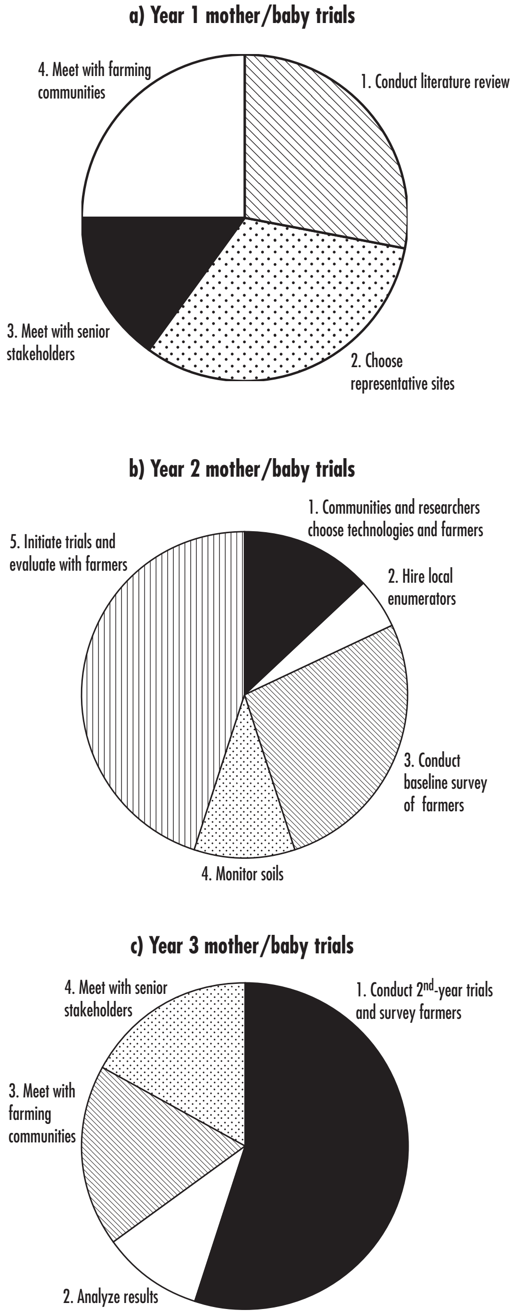

Figure 3. The sequence of steps in designing and implementing mother and baby trial methodology. Approximate time allocation for activities in a) year one, b) year two, and c) year three of the mother and baby trial approach.

approach allows performance of technologies to be compared across a range of environments, where average yield or edaphic factors are used as an environmental index. Yield potential of varieties under stressed conditions can be reviewed through adaptability analysis, providing insight into the risk associated with different technologies. A more rigorous approach is provided by mixed models, such as factor-analytic models for modeling variance and covariance from multi-environment trial data (van Eeuwijk 2001). An incomplete lattice design for the baby trials allows CIMMYT scientists to systematically evaluate new stress-tolerant varieties of maize (Bänziger and Diallo 2001).

Our statistical analyses relied on the analyses of variance module of a statistical package (Statsoft 1995). The response of maize yield gain in year two of mother trials was evaluated through a two-way analysis of variance conducted for technology and location. Where technology effects were significant in the analysis of variance, a planned non-orthogonal comparison was used to evaluate mean technology effects compared to the control (continuous maize without nutrient inputs). A separate analysis of variance was conducted for baby trials, where a one-way analysis of variance was conducted to evaluate the effect of technologies. Descriptive statistics were conducted for farmer rating data, and means compared using paired t-tests (Taplin 1997).

Economic analysis

Economic analysis of net benefits was conducted over two years. This allowed comparison of best bet technologies that involved intercrop systems and rotation treatments requiring a two year evaluation period. The difference was computed between the value of maize and legume grain yields (total price benefits) accruing from fertilizer and legume seed inputs and costs (CIMMYT 1988).

Conclusion

By facilitating hands on experience for farmers, the mother and baby trials provide a relatively rapid approach to developing improved varieties and soil management technologies. In contrast to some approaches which merge objectives, such as research validation of technologies and farmer experimentation, the goal of the mother and baby trial approach is to facilitate communication across different approaches to experimentation and information flow among the partners. The linked trial design provides researchers with tools for quantifying feedback from farmers. Farmer input generated new insights, such as the need to broaden the research focus beyond soil fertility or variety selection to include system-wide benefits such as weed suppression. Some Malawi extension staff and researchers have expressed reservations about the time requirements for participatory approaches; however, the success of the approach is reflected in the uptake of the mother and baby trial design by researchers in ten neighboring countries.

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Discussion Summary

The discussion following the presentation dealt with the use of the mother-baby trial system in the context of participatory plant breeding, and was divided into two themes: (1) the technical advantages and disadvantages of mother-baby trials for selection and breeding, and (2) the role of mother-baby trials in formal research systems.

Discussing the first theme, it was pointed out that one of the main advantages of this system, particularly of the baby trials, is the number of trials that can be evaluated. Selection intensity relates directly to genetic advance, and the objective is to obtain high precision ranking. The choice is to evaluate a small number of plots more intensely or a larger number less intensely. It was pointed out that the use of incomplete multilocation trials may sacrifice some precision, but this is circumvented by having access to the appropriate environments. Furthermore, many environments can be sampled at a lower cost, although it was pointed out that in India, on-farm trials were more precise than station trials, and heritabilities can be higher. Farmers' knowledge of their fields and their heterogeneity can be used to design the baby trial to increase heritabilities. An issue that reappeared throughout the workshop was the appropriateness of having many unreplicated trials in many different locations versus having fewer replicated trials and therefore fewer locations. There appeared to be general agreement that the former option may be better because it may generate more useful information at a lower cost. Replication within a site may yield less information than sampling numerous sites, particularly from a cost-effective viewpoint.

The other point discussed was the use of mother-baby trials in the formal research system in relation to national agricultural research systems (NARS) and variety releases. A challenge is to get NARS to assess the value of these new tools and to incorporate this type of trial system, particularly in conjunction with participatory varietal selection (PVS), especially with PVS for variety release systems. Involving national programs in PVS may be the most straightforward way to link PVS with regulatory systems; PVS by the Centers of the Consultative Group on International Agricultural Research should not be done in isolation. The linking of PVS, innovative trial systems, and regulatory agencies is already underway in Nepal and Kenya. It was pointed out that regulatory agencies are more closely linked to formal seed systems than informal farmer-based systems in which PVS may take place. Regulatory committees may disfavor systems that are perceived as threatening, and hence lobbying is necessary to make the system more active. However, it is necessary that these committees do not perceive these new approaches as substitutes, but more as cost-effective complements to their work. There may be some resistance.