One Animal Per Farm?

A guide to resolving the statistical difficulties encountered by on-farm researchers working with small livestock numbers in the developing world

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Contents

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1. Introduction

In livestock experiments, as with other areas of agricultural experimentation, researchers are well aware of the need to replicate their experimental treatments. In on-station experiments this means having several animals in a study, with treatments randomly allocated to the animals. Furthermore, because of the need to control extraneous variation, the animals are grouped before randomisation in terms of characteristics such as breed, lactation number, anticipated calving date, age or body weight. Designs are often a randomised complete block design (RCBD) or a changeover design. The reader is expected to be familiar with both of these.

The move to on-farm experiments, where frequently there is only one animal (or possibly two) per farm has raised the question "What do I do when I only have one animal per farm?" Clearly the researcher needs to have several farms in the experiment so that the experimental treatments can be replicated. However, the animals at his disposal are now likely to be heterogeneous because of differences in breed, age, stage of lactation etc. and so we can expect large animal to animal variation in milk yield, weight gain etc. Farmers' management practice will also contribute to the between animal variation.

It is this large variation, compared to on-station work, which seems to cause concern about on-farm animal experiments. However, it should not, since it is often this very variation, and its effects on the responses to treatment, which is now of interest in the research. This booklet discusses on-farm experiments when there is only one animal at a farm, and offers advice on the design of such studies.

For a more general discussion of on-farm experiments and experimental design principles the reader is referred to the booklets "On-Farm Trials – Some Biometric Guidelines" and "The Design of Experiments".

2. Types of On-farm Animal Experimentation

On-farm experimentation is often described in terms of the amount of researcher and farmer involvement in the design and management of the trial. In many on-farm livestock experiments the farmer manages the trial, and we assume this here. The extent of the farmer's input to the design of the study and the types of measurements depend on the objectives of the study. Below we illustrate the range of on-farm livestock research.

A typical study might be to compare the effects of a dietary supplement such as Napier grass on milk yield and to examine its relative effects in animals with different lactation numbers. Additional objectives may be to identify whether there are farms at which the supplement was of particular benefit, and to gain some insight into farmer preference. The researcher is therefore interested in both the overall effects of the Napier grass and the effects in different subgroups of animals or farmers. These objectives dictate the need for a range of farm conditions and an intention to explore the farm-to-farm variation.

Some on-farm studies are mainly socio-economic. Yield or growth data are of little interest, and are unlikely to be recorded. Instead what is of interest is the acceptability of the intervention to the farmer. An example might be where farmers are being encouraged to grow Rhodes grass for supplementary feeding in dry seasons. Interest is now in how the farmer adopts the technology and his opinions on its adoption. Again the objectives of the study indicate an interest in the variability between farms and how to explain it - the experimenter therefore needs to cover a range of farm and animal conditions in his study.

These two studies typify those that concern us here. They can be contrasted with an on-farm experiment to investigate the effect of a dietary supplement on milk progesterone profiles of local crossbred cattle. This type of study is only conducted on-farm to have the correct biophysical conditions - since on-station animals are all pure-breds and in prime condition - but otherwise it is similar to an on-station trial. The researcher would want to control the farm to farm variation rather than explore it, and would therefore choose to site the study at a few selected farms, which are similar in terms of their animals, management practices, etc. Conclusions from this type of study cannot be generalised to the population at large.

3. Design Options

3.1 Introduction

With the need for several farms in a trial, there are two options open to the researcher, and these are extensions of the designs which are used on-station – a "between animal" design or a "within animal" design. Note that with only one animal per farm, animal and farm are interchangeable identifiers of the experimenter's material and both are used here.

- ***between animal experiments***

  Here the experimental unit is the animal at a farm. The experimental treatments are randomly allocated to each farm, so that each animal in the study receives only one treatment, and there are several farms where each treatment is given.

- ***within animal experiments***

  In these experiments a sequence of experimental treatments is randomly allocated to each farm-animal, and there are several different treatment sequences. Each animal is given a treatment for a fixed period of time, and then changes over to another treatment. The sequences need not contain all the treatments under investigation.

The advantages and disadvantages of these two approaches are discussed below, and resource implications for both are illustrated in Section 5 using an example of a fodder trial in dairy cows.

3.2 Between Animal (Farm) Experiments

These experiments are relatively easy to set up and run, and there is no real restriction on the duration of treatment - it can be long or short, as appropriate to the circumstances.

There are certain types of animal experiment which naturally lend themselves to a between farm study - for instance an investigation of the efficacy of some veterinary treatment, or an investigation into the prolonged effects of different diets on sustaining lactation yields.

The one potential drawback of the between animal experiment in the on-farm setting is the large animal-to-animal variation. Unless there are very large differences between the treatments under investigation it will be difficult, with only a small number of farms, to demonstrate treatment effects over and above this variation. Consequently, studies will need a large number of farms in order to detect treatment

differences. This in turn means that the number of experimental treatments under investigation will be limited - often to two simple treatments, or possibly a 2x2 factorial treatment set.

Necessary sample size is directly related to the amount of variation amongst the animals. Therefore, when planning a trial the researcher should consider how to deal with this variation so that the number of farms needed is within his resource constraints, while still having an adequate level of precision for the objectives. The actions discussed below can all help to control or explain the farm-to-farm variation.

(a) **Restricting the study population** for instance to one, or perhaps two, breed(s) of animal – or excluding first lactation heifers when animals are a mixture of ages – can reduce animal-to-animal variation. The advantage of restricting the study population, however, is counterbalanced by the disadvantage that the results of the trial now only relate to that particular study population.

(b) **Grouping farms into "blocks" of similar farms** and randomly allocating the study treatments to farms within the groups improves the precision of treatment investigations. Farms can be grouped together using one or more characteristic of the animal itself (e.g. breed, age), the farm (e.g. location), and / or the farmer (e.g. his management practices). If there are only two treatments under investigation the simplest approach is to identify pairs of similar farms, and randomly allocate the treatments to the farms in each pair.

(c) **Using additional information about the farms or animals** that seem responsible for some of the noise in the data. The use of such explanatory - or covariate - information is discussed further in Section 4.

3.3 Within Animal (Farm) Experiments

The major advantage which the within animal experiment has over a between animal one is improved precision. Since the animals each receive more than one experimental treatment, the treatment comparisons are based on the differences observed within an animal. Consequently the treatment comparisons are assessed relative to within animal variation - which is almost always very much less than that between animals.

The increased precision of the within animal investigation means that fewer animals, i.e. farms, are needed to detect a treatment difference. This is an attractive reason for using such a design in on-farm animal experiments. However some potential drawbacks exist with these designs, and we discuss them here so that researchers can consider their importance, if any, for particular studies.

(a) **These experiments have more scope for "going wrong"** than between animal experiments. For instance, if treatment periods are long, or there are too many of them, the whole trial becomes too long and the farmer loses interest and fails to complete the trial. It is advisable therefore to restrict the number of treatments to two or three, depending on the duration of treatment.

There is also the issue that the farmer might be reluctant to keep an animal on a particular treatment once he observes an earlier one to be better. However this is not such a major drawback since, if it happens, it provides important information about farmer preference.

(b) **Conclusions apply to the duration over which the treatments were given**, and should not be extrapolated far beyond that. For instance, a crossover trial with periods of 2-3 weeks duration may be appropriate for comparing diets when the intended use is as additional feed during the dry season, but not if the intended use is over most of the lactation cycle.

(c) **Carryover (or residual) effects.** This is where a treatment given in an earlier period still has some effect in a later period when a different treatment is being given. This can sometimes be handled by incorporating into the experiment "adaptation periods", i.e. periods which are long enough to allow carryover effect to disappear. Alternatively, experimental designs exist whose subsequent analysis helps to deal with the carryover.

It is perhaps worth pointing out here one big difference between on-farm and on-station changeover experiments. In on-station studies the treatment effects are assumed to be consistent across the animals in the study, and so the data analysis is relatively straightforward. However in on-farm work, where the animals may be different ages etc. and the farmers may have different management practices, there is no reason why we should expect, or even want, treatment effects to be the same in all animals. In fact we are now often interested in how the treatments vary across farm types or animals. Such questions can be addressed in the data analysis using the approaches considered in Section 4.

A second point relates to changeover designs in lactation studies. Experimenters are sometimes concerned that, if a trial has several periods covering most of the lactation curve, any treatment effects on milk yield may diminish over the course of the trial. Provided the first treatment period is not too close to calving, any such trend is likely to be of little importance in on-farm experimentation when seen in the context of other between and within farm variation.

4. Explaining variation

As mentioned earlier, on-farm experiments are often interested in exploring the causes of farm-to-farm variation. This means being able to identify characteristics of the farm, farmer or animal which are responsible for patterns in the data. Therefore, irrespective of which design is used, it is important at the planning stage to consider what ancillary data needs to be collected before and during the trial so that such analyses are possible.

These data will be used in the subsequent analysis in three different ways:

(i) to explain some between and/or within animal variation and thus improve precision in respect of important objectives,

(ii) to explore the behaviour of different group of animals or farms, as identified by the objectives of the study, and

(iii) to help to explain unexpected findings which emerge in the analysis.

The data to be collected are features of the animal / farm / farmer which are known, or thought, to influence the response of the animal. They may be characteristics which can be recorded at the outset of the trial such as location, farm size or an indicator of animal performance such as lactation number or previous milk yield. Equally, they could be information that cannot be known at the start of the trial, such as whether the farmer decides to feed additional maize stover to the animal during the trial. This latter example demonstrates not only the need to identify in advance what additional data to collect, but also the importance of collecting information throughout the trial, even if it is not accurately measured or quantified.

5. Number of farms required?

This purpose of this section is to illustrate, by example, the resource implications for between and within animal investigations when there is only one animal per farm. We use the simple situation where there are only two treatments and assume initially that the main objective is to detect whether there is a difference between them.

Example: An on-farm study in dairy cows is to be carried out in one district to compare the effects of two fodder treatments on milk yield:

A = a basal diet (involving crop residues, etc.)

B = the same diet but with a supplement of calliandra (3kg/day)

The average milk yield given by a cow in the district is of the order of 6-8 kg/day. It is expected that the calliandra supplement will improve the milk yield by about 0.5-0.75 kg/day. Some previous work has led us to believe that the between farm standard deviation is about 2.7 kg/day and the within animal standard deviation 0.8 kg/day.

These values of the difference we hope to detect and the expected variation in the data provide the information to calculate the required sample size[1]. The experiment, if carried out as a between animal study, will require at least 200 animals per treatment – i.e. a total of 400 farms. The crossover study would require somewhere in the region of 20 to 40 replicates of each treatment. Since each treatment is to be given to each farm animal this means 20 to 40 farms - but the experimenter would usually want to recruit a few more, just in case some farmers stop the study after one treatment. Even

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[1] Sample Size Determination

The following sample size formula was used here. It is suitable for data which are a continuous measure such as milk yield or weight. It ensures that, if there really is a difference of a certain magnitude between two treatments, the experiment is highly likely (approx. 80% likely) to detect it as being statistically significant at the 5% significance level.

$n = 16*\sigma^2 / d^2$

where n = number of replicates per treatment

σ^2 = estimate of the variance (of the experimental unit)

d = difference one expects to detect between the treatments

Further details can be found in "Statistical Methods in Agriculture and Experimental Biology" by Mead, Curnow and Hasted, Chapman & Hall, 2nd ed. (1993).

Other textbooks dealing with sample size calculations for different types of measurements include "Adequacy of Sample Size in Health Studies" by Lemeshow, Hosmer, Klar and Lwanga, John Wiley and Sons for WHO (1990).

so, this is still considerably less than the between animal study and therefore the crossover seems like the obvious design to choose.

The "text-book" formula is not the whole story, though, particularly for an on-farm trial. As explained in Section 2 the objectives usually involve an investigation of whether the new treatment is particularly beneficial to specific sub-groups of animals or farmers. Perhaps, for instance, the difference in milk yield is only 0.3kg/day for one group, while it is 1kg/day for another. The benefits of the crossover trial, in terms of improved precision, still remain for such investigations.

So when would a between farm investigation be preferable to a within animal one? The answer to this depends on the objectives of the study. Investigations of farmers' opinion and adoption practices, and questions such as "Under what conditions, if any, is the treatment particularly beneficial?", can only be addressed by studying a wide range of farm conditions. Therefore if these are some of the study objectives, a large number of farms is needed and then a between farm study will often be the more appropriate design. With a smaller crossover study, it is possible to address some questions about subgroups and farmer practice, but not to the same extent as in the large between farm study.

What should be done if the resources are limited? Perhaps the researcher would like to do a between-animal study, but has only sufficient resources for 50 animals (25 on each treatment.) We need then to review the objectives, the calculations and the design. Fifty farms might be adequate for a within-animal study. It might also be sufficient if the researcher knew which groups might be expected to benefit from the treatment and could restrict the study to them. Perhaps therefore a survey of 200 farmers (say) followed by this smaller experiment would satisfy some of the objectives. Perhaps, too, instead of using all the resources initially, a baseline survey plus a small pilot experiment would satisfy a new set of objectives and allow more detailed plans to be made for a future experiment.

6. And finally...

This booklet discusses on-farm livestock experimentation when there is exactly one animal at a farm - and the researcher has been offered a choice of two designs, the between animal and the within animal design. There are, however, various "departures" from this framework, and here we briefly mention two examples, just to illustrate that the ideas and principles discussed can still be adapted to other situations.

- Sometimes - in the case of poultry, goats and pigs - there is a small flock or herd.
- Not every farmer has only one animal - some have two.

What do you do in these circumstances?

In both cases the answer depends largely on how the animals are managed, and how the study treatments can be administered to them. For instance if the whole group of animals is managed and treated collectively, as in the first example, the situation is similar to having a single animal at a farm – except now it is a single flock. The researcher's choice of design is still between a between-farm and a within-farm design, and the issues discussed here about advantages and disadvantages of the two designs, sample size considerations, etc. still apply.

When there is more than one animal at a farm, but treatment can be administered to individual animals (or to pens of animals), then the experimental unit is the animal (or pen). Between and within animal (pen) designs are possible, and again the general principles discussed in this booklet can be used to design an experiment to address the researcher's objectives.

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